Renting Valuable Assets: Knowledge and Value Production in Academic Science

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Abstract

This paper explores what it takes for research laboratories to produce valuable knowledge in academic institutions marked by the coexistence of multiple evaluative frameworks. Drawing upon ethnographic fieldwork carried out in two UK-based epigenetics research laboratories, I examine the set of practices through which research groups intertwine knowledge production with the making of scientific, health and wealth value. This includes building and maintaining a portfolio of valuable resources, such as expertise, scientific credibility or data and turning these resources into assets by carefully organising and managing their value. Laboratories then put these assets to productive use within and outside their labs towards the creation or extraction of value. I identify two models for producing value within academic science: a commodity-based model whereby laboratories mobilise their assets to produce results, which can be converted into publications for the accumulation of credibility capital; and a rentier model of accumulation, whereby laboratories own valuable assets, which they rent out to others outside their lab against a revenue. Following recent developments in STS on value production in the bioeconomy, I argue that the concepts of asset and rent are essential analytical tools to get to grips with the origins of value within academic science.

Introduction

> I think it's very difficult to define the environment. And in order to get something that is publishable, or worthy of funding, we just stick to very clearly defined factors, environmental factors that have been previously studied. (Mark, Twinomics)

Mark is the Principal Investigator (PI) of the epigenetics team at Twinomics, a research laboratory based in the UK carrying out genetics research on twins. I sit with him in his office as we discuss the work of his team. Epigenetics research refers to the study of the processes that control gene expression but do not entail a change in DNA sequence (Armstrong 2014). More specifically, research in epigenetics investigates the ways the 'environment' impacts gene regulation by leaving marks on the epigenome. Researchers at Twinomics explore associations between epigenetics markers and environmental factors. For Mark, this represents an exciting research area where discoveries could be made that could further "our understanding" of the interplay between environment and genes, thus contributing to the knowledge base in genetics and molecular biology. While there are a myriad of ways of defining the environment in epigenetics (Pinel, Prainsack, and McKevitt 2018), at Twinomics, they focus on specific environmental factors that can be "defined and measured well", such as smoking or diet. They do so to ensure their research will lead to the production of results, which could be converted into publications in high impact-factor journals. Such publications are essential for research teams to accumulate credibility capital, which can help them demonstrate their "productivity" in university research audits (Müller 2014). They also do so because it could help them gain financial resources from funding bodies. As Mark later explained, the focus on specific environmental factors is also driven by the hope that their research will lead to therapeutic applications, with for example "a capsule that you could give to patients" in order to change their diet, and thus modify their epigenome. This point resonates with the translational research agenda, which is central to health policy, research and funding initiatives in the UK (Fudge et al. 2016, and in other contexts too, see for example Dam and Svendsen 2018). Under the translational research agenda, basic research discoveries are fostered to develop new diagnostic tests, drugs, devices and treatment options, which could make a difference for patients (i.e. lead to the production of health value[1]), while it could also be commercialised and rendered economically profitable (i.e. economic value).

[1] Rose and Novas (2004) identified three forms of biovalue: economic value, which entails the production of wealth; health value through the enhancement of health; and ethical value.

I begin with this scene from Twinomics because it points out that there are multiple evaluative frameworks folded into epigenetics research, while it shows how scientists construct their research to make it fit within these simultaneous evaluative frameworks. By evaluative framework I mean a set of evaluative principles, which are operationalised by a series of metrics, and within which "worth can legitimately be claimed." (Fochler, Felt, and Müller 2016: 179). This observation from the field of epigenetics echoes a line of literature within STS and valuation studies that discusses the numerous standards through which academic performance is evaluated (Helgesson and Muniesa 2013, Rushforth, Franssen, and de Rijcke 2019). For example, many discuss the increasing reliance on audits within Higher Education and research institutions, shedding light on the effects of practices for evaluating performance over the type of knowledge produced, disciplines or academic selves (Hammarfelt, de Rijcke, and Rushforth 2016, Rijcke et al. 2015, Sigl 2016, Felt 2009). Coining terms such as 'academic capitalism' (Slaughter and Leslie 1997) or 'entrepreneurial universities' (Etzkowitz 2011), authors have also analysed the growing involvement of higher education and research institutions in the market economy, exploring how the evaluative framework that treats research as a business that ought to be profitable is embedded with academic practices (D'Este and Perkmann 2011, Hackett 2014). To discuss organisational settings in which multiple, and sometimes conflicting, evaluative frameworks are maintained and analyse how these are drawn upon by actors to inform their actions, Stark (2009) coined the term heterarchy[2]. He argued that such organisations are entrepreneurial in the ways they exploit this multiplicity and generate new ways of thinking by "fostering productive frictions" (ibid.: 14) between different modes of valuation.

Building upon this body of literature, in this paper, I attend to knowledge production and value making practices within academic institutions marked by the coexistence of multiple evaluative frameworks. I

[2] Stark draws on Boltanski and Thévenot's (2006 [1991]) sociological theory of value, in which they point to six "orders of worth" actors refer to when justifying their actions.

draw upon 12 months of ethnographic fieldwork carried out in two UK-based research groups conducting epigenetics research to explore how researchers in this field integrate these multiple evaluative frameworks to produce knowledge that can be valuable in different respects. Using the concept of asset, I suggest that this involves a social process that takes different forms of labour and knowledge, and is aimed at organising and managing value. It first entails constructing a diverse portfolio of resources and turning these resources into assets. It then involves mobilising these assets as part of the productive system that is the laboratory. I identify two main ways in which assets are used to produce value: either through a commodity-based model of accumulation whereby assets are used by members of the laboratory to create value, or through a rentier model of accumulation whereby assets are rented out to others outside of the lab in exchange of a fee.

In this article, epigenetics research is a case study to explore valuation and knowledge production practices in 21st century universities. It represents an interesting case because it is a thriving field in the world of bioscience, with high levels of public and private funding. Its translational potential also makes epigenetics a good case study: it is seen as having a revolutionary potential for healthcare (Carey 2012), with the hope that it will provide more precise diagnostic tools and more effective therapies for many chronic and age-associated diseases. While this case study is concerned with epigenetics, the observations I make in this field, however, are relevant to other research contexts.

Knowledge production, value and assets

Within STS, a number of scholars have drawn upon the concept of capitalism as an analytical frame to explore how knowledge and value production are intertwined within academic science (Bourdieu 1975, Hackett 1990, Latour and Woolgar 1979). Fochler (2016: 924), in this journal, unpacked strategies of accumulation within academic research using the concept of 'epistemic capitalism' as denoting "the accumulation of capital, as worth made durable, through the act of doing research, both in and beyond academia." Pointing out that academic researchers strive to accumulate different forms of capital (i.e. academic credibility or economic), he described a capitalist cycle whereby group leaders are concerned

with converting research results into publications, which can serve as assets in the competition for grant funding, a form of economic capital, which could then be reinvested in the laboratory. Analytically, this cycle of accumulation represents a useful framework to understand how different forms of value are fostered through academic work, at the same time that it restricts our view of value production to one main model, that of capital accumulation and commodification. This is because Fochler takes capitalisation as the starting point of his analysis of knowledge making practices and then applies it to the laboratory. Instead, in this paper, my analysis is first and foremost empirically grounded, and seeks to understand the ways value is produced within the laboratory by examining in detail the productive activities of the system, that is, paying attention to the different forms of labour, resources and assets that are mobilised to produce value (Marx 1983 [1872]). For example, what tools do researchers use and how? What data do they mobilise and who produces it? In other words, my analysis starts at the bench, exploring the resources mobilised to produce knowledge, unpacking what these resources are, how these are used, by whom, and how they come together in the productive system that is the laboratory towards the production of value.

To help me unpack the productive system that constitutes the laboratory, I borrow analytical tools from STS scholarship on value production and assetization in the bioeconomy[3] (Birch 2017, Birch and Tyfield 2013, Martin 2015, Geiger and Gross 2019). Authors observe that most life sciences firms fail to deliver on the promises of new marketed products or services, but are still highly valued. Birch (2017) argues that to get to grips with the origins of value in the bioeconomy, one should take into consideration assets and their valuation. An asset is a tradable resource that an actor owns or controls with the expectation that it will provide a future benefit. There are two main ways in which assets can be mobilised to produce value. Let's take the example of a biotechnology firm whose main assets are a sequencing technology and expertise in bioinformatics. First, these assets can be used by the firm to

[3] The term bioeconomy is used here to refer to the set of economic activities derived from biotechnology and biosciences (see Pavone and Goven 2017 for the different understandings of the term bioeconomy).

produce commodities, such as a software to analyse sequencing data, which can be sold on the market to create value. Second, these assets have value as properties and can be rented out to others in exchange of a fee, by for example the firm turning its bioinformatics knowledge into Intellectual Property Rights (IPRs) from which it can earn royalties. For Birch, value in the bioeconomy results to a large extent from processes of assetization by which knowledge is reified and turned into a property that yields an income stream (for a theory of rentiership in technoscience, see Birch 2020b). Authors thus note that the production of value in the bioeconomy is asset-based, rather than commodity-based: value is constituted predominantly by ownership and control of valuable assets, rather than by the production of new commodities that are sold on the market. These observations lead Birch and Tyfield (2013) to argue that the bioeconomy is based on a "rentier regime of accumulation" whereby knowledge is made into valuable assets from which actors extract rents to produce value.

The distinction between value creation and value extraction is relevant to this discussion. Mazzucato (2018: 6) defines value creation as "the ways in which different types of resources (human, physical and intangible) are established and interact to produce new goods and services", which is different from value extraction, understood as "activities focused on moving around existing resources and outputs, and gaining disproportionately from the ensuing trade." In the value creation case, assets are used as resources to produce commodities, while in the value extraction case, actors have control of assets, which can grant them a rent. This distinction between value creation and value extraction will prove useful to unpack the ways laboratories mobilise their assets to produce value: as I will show, the two laboratories studied mobilise some of their assets to *extract* value from rent, while in other instances they use their assets to *create* value.

In short, to explore how academic research teams produce valuable knowledge, I first look into the resources they mobilise at the bench. I examine in detail how they construct their resources and make them valuable, paying attention to the set of practices they enact to turn these resources into assets, while I study the different ways in which they mobilise their assets to produce value.

Methods and the laboratories

Ethnographic fieldwork was carried out between January 2016 and May 2017 in two research groups conducting epigenetics research. The first laboratory, which I term the 'Cancer Lab', conducts research into the biology of breast cancer. During the time of fieldwork, the work of the group was organised in two main research areas: glycobiology[4] and epigenetics. Work at the Cancer Lab revolved around the study of two genes, which I term Gene 1 and Gene 2. Discovered and cloned by researchers in the group in the 1980s and 1990s, the two genes represented the common thread between the different areas of research the lab was involved in: while work on glycobiology focused on understanding the mechanisms of Gene 1, epigenetics research focused on the study of Gene 2. The lab carried out its research in a so-called 'wet lab', that is, work was based on the conduct of experiments at the bench. Benchwork was a skilled craft that entailed a multitude of small tools, fragile materials, samples and machines. Researchers relied on these objects to produce data and construct a series of signs to represent the biological phenomenon investigated and stand for the invisible of molecular biology.

The second laboratory studied, which I call 'Twinomics', carries out genetics research on twins based on a large database of clinical and research data. During fieldwork, research at Twinomics was primarily focused on the study of epigenetics, microbiome and transcriptomics, and explored complex diseases with a particular interest in age-related diseases. Work at Twinomics was centred around a twin data registry gathered over several decades, with clinical, physiological and lifestyle data, as well as hundreds of phenotypes related to common diseases. Scientists outside the lab could access and use the data for their own (academic or commercial) research. As a 'dry-lab', scientists within Twinomics conducted computational or applied mathematical analyses of their data. This means that researchers' work did not involve standing at the bench and dealing with biological materials, but instead they

[4] Research in glycobiology is concerned with the study of the structure, biology and evolution of saccharides, sometimes also termed carbohydrates, sugar chains or glycans (Dwek 1996).

worked on their computers to perform experiments on datasets using statistical analysis and computer-generated models.

I spent time with researchers at the bench as they prepared and conducted experimental work, sat with them at their desks as they 'ran' computational simulations, or shared lunch and coffee breaks with members of the teams. Ethnographic fieldwork also involved attending the weekly team meetings during which researchers discussed their 'progress' over the past week with their PI and colleagues. I also accompanied the teams to conferences and seminars, observing who was present and what was being talked about. In addition, I conducted semi-structured interviews across the two research groups with laboratory leads through to junior researchers (25 in total).

Making valuable assets

In the two laboratories studied, a set of resources are drawn upon for the production of knowledge. Resources are sources of supply or support that can readily be mobilised for production. These include the laboratories' facilities and machineries, with for example lab space and benches at the Cancer Lab. It also involves human resources, with Twinomics staff collecting samples from twins and producing datasets, or researchers conducting experiments, analysing and writing up results for publications.

Some of these resources are also turned into assets. While resources can be 'raw' such as electricity or personnel, assets require labour and imply a social process: they are cultivated, rendered valuable, organised and managed by those who own or control them. It is also as part of this assetization process that resources are turned into identifiable and alienable properties ready to be mobilised as part of productive systems (Birch 2020b). Expertise and credibility are some of these resources turned into assets: the two laboratories have expertise in cancer biology and bioinformatics respectively, and through collaborations, conferences or publications, they continually look to enhance their reputation in their respective fields. For example, the Cancer Lab benefits from high credibility and expertise in

glycobiology. This is linked to the lab's involvement in the discovery of Gene 1 and its role as a mucin[5]. Diana and Susan, the two senior members of the lab, who were involved in the discovery, are recognised as founding members of this research area. Their extensive expertise in the biology of Gene 1 and high scientific credibility in this field constitutes one of the Cancer Lab's key assets. Members of the laboratory work towards constituting the value of this intangible asset, and in particular, this is achieved through relational labour, with, for instance, the organisation of a biennial conference on mucins. As part of fieldwork, I travelled with the group to the conference. It brought together long-term collaborators and new starters in glycobiology to network, discuss developments in the field, and foster new ideas. Throughout the three days of the conference, I observed dozens of presentations and noticed that most speakers referred to Gene 1 in their talk. Diana chaired two sessions during the conference, and speakers respectfully acknowledged her contributions by mentioning papers she published on the topic. Conferences like these were opportunities for the Cancer Lab to reaffirm its status as leading expert and assert its scientific expertise, credibility and reputation in the field of glycobiology. By organising such a conference, deciding on speakers, organising discussion panels, identifying the posters to be presented, the Cancer Lab makes and maintains the glycobiology community and places itself at its centre. It is through this relational labour that the laboratory converts its expertise and credibility into a valuable asset.

The Cancer Lab also discovered Gene 2, a histone demethylase involved in epigenetics. However, work around Gene 2, and in epigenetics more generally, does not confer the lab as much credibility and reputation than research on Gene 1. They are relatively unknown in epigenetics, or as Susan put it in an interview, "we're known as glycobiologists, we're not known as epigeneticists." One of the challenges for the Cancer Lab is to rebrand themselves as epigeneticists and show the importance of Gene 2 in this research field. One way in which they do so is by turning their Gene 2 expertise into a number of Gene 2-based technologies, which can be used by researchers in and out of the laboratory. These include a

[5] Mucins are the main constituents of mucus. They are understood to be involved in inflammation and cancer (Kufe 2009).

Gene 2 knock-out mice strand and a Gene 2 knock-out cell line. For example, Melissa, a PhD student in the lab, mobilised her skills and know-how at the bench, as well as her expertise in Gene 2 and CRISPR-Cas9 – the latest genome editing technique – to produce the Gene 2 knock-out cell line. The production of this asset also required continued 'care' (Friese 2013) to ensure the cell line was functional when needed for the conduct of experiments. In the cell-culture room in the laboratory, cells were nursed along in flasks and plated under special environmental conditions. On a daily basis, Melissa came to check on her cells, watching them develop, to then periodically dividing and propagating them into new flasks for them to grow. With this set of practices, the Cancer Lab turns its expertise of Gene 2 into tangible and unique assets, which can be used in and out of the laboratory for a variety of projects in order to explore the role of Gene 2 in cancer biology and epigenetics.

Data represents another type of asset. Members of the labs enact a series of practices to make their data into valuable assets for the production of value within and outside the lab. This is particularly salient at Twinomics. The lab is well-known across the research community for its database of twins. It is continually being worked on, improved or added to, or as I argued elsewhere (Pinel, Prainsack, and McKevitt In Press), data is 'cared for' in a myriad of ways. This work is essential for Twinomics to keep the database unique and interesting for others to use. One way in which the laboratory cares for its data is by making the database grow through the addition of new data. This entails forging relationships with actors who can provide funds towards the building up of the database, including traditional funding bodies, pharmaceutical or biotechnology companies. In the quote below, Thor, the head of Twinomics, describes how he approached commercial companies to fund some of the datasets:

> Companies will give you money to [fund a new dataset]. It's the way I funded a lot of the 'omics'. It's getting a company and say: "there's great technology, we combine that with great clinical data, this will be a great dataset for your guys to work on and our guys to work on". (Thor, Twinomics)

Expectations about what one might do with new data are mobilised to enrol partners. More specifically, in talks with commercial companies, Thor rebrands the twins' data as a clinically relevant asset that holds promises in terms of health and wealth benefits. As such, Thor renders the twins' data valuable by capitalising on hope (Martin, Brown, and Turner 2008) and turning the data into a 'promissory asset' (Martin 2015). This is another sort of practice scientists at Twinomics enact to constitute the value of their key asset. Twinomics thus makes its data valuable not only within the evaluative framework that sees research as an intellectual endeavour in search of truth, but also within the translational research agenda that fosters research for health and wealth benefits.

The value of the database not only increases with growing numbers, but also with quality, and the range of datapoints included. This entails a set of practices, with, for example, staff turning the "raw" data produced by sequencing arrays into numbers that can be analysed computationally. Researchers mobilise their bioinformatics expertise and experience with large-scale datasets to format and 'clean' the laboratory's data (Pinel 2020). Staff also make sure that every set of data is accompanied by detailed metadata to enable later data users to understand the context in which the data was produced. These data practices are enacted to turn the twins' data into a versatile asset that can travel to other research teams and be used in different research projects, thus echoing Leonelli (2016) and her concept of 'data curation'. But more importantly, I suggest analysing these curating practices, together with the whole set of data practices at Twinomics, as forming part of a process of assetization, through which the value of the database is made and organised.

Twinomics also looks to manage the value of its database by regulating how and by whom it can be used. Specifically, the lab enacts limits and exclusions over the use of the data. The PIs who bring in new data to the lab (for example, thanks to a successful funding application) are in charge of overseeing its use. For example, Mark, the PI of the epigenetics team, oversees the use of the DNA methylation data at Twinomics. He grants access to researchers in and out of the lab who wish to use the data. When considering 'data access requests' from collaborators, he evaluates whether the proposed projects "clash" with any of his existing research: "If it clashes, then we ask them to alter it [the proposed project]

and tell them that this clashes, so we can approve this and not that." Access to the data therefore also comes with forms of exclusion, as the lab encloses its data within its walls to then distribute access rights under specific conditions. As part of the assetization process at Twinomics, the lab therefore constructs its data as an alienable, yet exclusive, asset.

For the two laboratories studied, the production of value starts by turning some their resources into assets that can be used within and outside their laboratories as part of productive systems. Members of the labs mobilise their skills, expertise and networks to make these assets valuable, while they implement a set of practices to manage them as unique and exclusive assets. Next, I unpack the different ways in which these assets are mobilised to produce value.

In-house value production

In the two laboratories studied, there are two main ways in which assets are mobilised towards the production of value. In the first model, a number of assets are used and combined to produce commodities, which are then sold on a market to create value. At Twinomics, this model entails researchers using the twins' data together with their expertise and computational tools to produce research results that can be written up for publication towards the production of epistemic value, which can then be mobilised as tokens of credibility in the competition for grant funding (economic value). Specifically, epigenetics research projects are based on the use of DNA methylation data. While these projects differ in their aims, they have two things in common: every project is overseen by Mark, the PI of the epigenetics team, and they all borrow the "epigenetics pipeline" to conduct the analysis.

This model of knowledge and value production was particularly apparent in a project undertaken by Olivia and Maria, two post-docs at Twinomics. During fieldwork, they were starting a research project together exploring environmental influences over DNA methylation. I followed their progress, joining them in meetings, observing them at their desks, or being copied in email conversations. One afternoon, I joined Olivia and Maria as they met to discuss the project. They were considering what environmental

factor to study in association with DNA methylation. Smoking is the first one they considered and agreed on. Olivia argued that smoking is "a very strong environmental factor", meaning that it could lead to the production of results that could easily be interpreted and converted into publications. She added that it made sense to choose this environmental factor because the data was "clean" and discordant analysis was possible. Put differently, the availability of data and the likelihood of producing epistemic value drove the choice of research question. Then Olivia said, "we should talk to Mark about our plans." At Twinomics, Mark acts as the 'guardian' to the DNA methylation datasets. This means deciding on the projects that can use the datasets, as well as overseeing the way they are used by providing feedback on the analysis and the writing up of results. By helping develop the twins' data over the years, Mark 'knows' his data, that is, he has contextual and practical knowledge about what a dataset seeks to represent, its strengths and limitations. When Olivia and Maria discuss their project with Mark, they are not only granted access to the DNA methylation data, but they also receive input about how to 'deal' with the data in their work so as to make the most of it towards the production of valuable research. In particular, they are reminded by Mark that to conduct the analysis on the DNA methylation data, they should apply "the analysis pipeline", which was developed by Katherine, another post-doc on the epigenetics team, together with Mark. It consists of a detailed plan indicating how to go about analysing the DNA methylation data computationally using a 'twin model', with steps and sub-steps and the necessary "scripts" to use in each step. This pipeline functions like a 'standardised package' (Fujimura 1996) providing researchers on the epigenetics team with an established route to produce results based on the twins' data. This is what Maria suggests in the quote below:

> Now we are starting something completely new, but every time that we are doing an association study, you take the "Katherine data", the "Katherine covariate", the "Katherine formula" and you run. (Maria, Twinomics)

Through this analysis pipeline, Mark imposes limits on how the twins' data can be used. In addition, as Mark selectively grants access to 'his' datasets, he gains authorship on future publications, therefore *extracting* epistemic value from the productive endeavour. Mark's authorship thus constitutes value that

is derived from the ownership of exclusive assets (see next section for more detail about the process of value extraction).

In this project, value is produced using only the laboratory's resources and assets – i.e. the lab's facilities and machines, the twins' data, the analysis pipeline, the laboratory's staff. These assets are mobilised within the lab to create something valuable, that is, research results, which are written up for publication for academic peer-reviewed journals. In other words, research results function like commodities, which are mobilised and sold on a market – academic peer reviewed journals – against epistemic value. The epistemic value accumulated can then serve as tokens of credibility for members of the lab, which they can mobilise in competition for grant funding, another market, to accumulate economic value, which in turn can be reinvested in the laboratory. This represents an 'in-house' model of value production, whereby something of value is *created* within the walls of Twinomics, by members of the lab and using only the laboratory's resources and assets. The value of the commodity produced 'in house' is then negotiated and ascribed in interaction with actors outside the lab, such as academic peer-reviewed journals. However, as the granting of authorship to PIs like Mark suggests, 'in-house' value creation at Twinomics also comes with forms of value extraction, whereby value is also produced from the ownership and control of exclusive assets.

The dissemination of results produced at Twinomics through publications or conferences, apart from fostering epistemic value for members of the lab, is also aimed at enhancing the value of the twins' database. During fieldwork, I was invited to observe a post-doc rehearsing a conference presentation. After introducing the project's aims in the first slide, he spent the next two slides discussing the data used: the first slide showed the database's logo with a broad description of the twins' database, while also discussing the dataset used in this project; the second slide contained a detailed table showing the different phenotypes and variables used. He then spent the next five slides discussing the results of the study, and concluded by giving a brief summary of what the project achieved and linked this to the data used, its strengths and limitations. Such dissemination exercise enables Twinomics to do two things: foster its credibility within the research community on the one hand, and build the name of its database

on the other. Describing research results in close relation to the data used helps Twinomics show others what the twins' data can achieve. This may lead to collaborations with teams outside the lab interested in accessing portions of datasets for their own projects (see next section).

In sum, the production of valuable research in the epigenetics team at Twinomics first and foremost entails paying attention to their core asset, the DNA methylation data: the questions researched are driven by what the data enables them to do, how they study the research problem is standardised around an analysis pipeline developed to fit the data, they disseminate results by heavily acknowledging the twins' database, while the overall process is overseen by the PI of the epigenetics team, who 'guards' the data. In conducting research on the DNA methylation data, researchers *create* value fostering their scientific credibility, while enhancing and managing the value of their database.

Renting out valuable assets

In the concurrent model of value production, actors own valuable assets, which they rent out to others in exchange of a revenue. Across the two laboratories studied, this model entails different sorts of assets, practices and relationships between actors. For the Cancer Lab, growth is about maintaining or enhancing their credibility and expertise around their two genes. While the Cancer Lab is widely known in glycobiology, this is not the case in epigenetics. As Susan explained to me in an interview, "being relatively unknown in epigenetics", they have been struggling to secure funding for their epigenetics research. To tackle this challenge, the Cancer Lab connects with other laboratories conducting epigenetics research and trades some of its assets, namely their Gene 1 credibility and Gene 2 knock-out mice strand. The vignette below illustrates well the trading of assets.

"Come in" says Diana as I knock on her door. We have scheduled to meet for an interview. I sit down on the chair across her desk, while she types on her computer. After a minute, Diana looks up and apologies for keeping me waiting. She explains that the lab is applying for funding with another research team with expertise and credibility in epigenetics to conduct a study of the role of Gene 2 in intellectual

disability. Diana is a co-applicant on the grant and she is completing a section in the application about herself. She was specifically asked by the lead applicant, a more junior scientist, to write in her H index. It is a common indicator of research impact, which is calculated based on a scientist's most cited papers and the number of citations these papers have received. She says, "the Gene 1, it's right up there", meaning that papers discussing the Gene 1 discovery are on the top of her H index. The Cancer Lab provides its credibility and reputation from Gene 1 research to add strength to the grant application and enhance their chances of securing financial capital. The Cancer Lab also provides its Gene 2 knock-out mice strand for the conduct of experiments. This gives rise to a specific trade deal, as Diana suggests, "[our co-applicant] wants to use our mice. … We offer him the mice and he will do the experiments." While the Cancer Lab makes these two assets available, it is their partner who is involved in the actual doing of research and the production of results. That is, it is their collaborator who *creates* value from the available assets. However, by providing its assets for the conduct of the project, the Cancer Lab gains a revenue, in terms of grant money and authorship on publications. Put differently, in this scenario, the Cancer Lab *extracts* value from its assets.

At Twinomics, a similar model of value production exists, but it is primarily based on a different sort of asset, namely the laboratory's data. With its unique database, a series of actors, including academic research groups, biotechnology and pharmaceutical companies reach out to Twinomics to gain access to portions of datasets. The laboratory turns data into a tradable and mobile asset, at the same time that it imposes limits and conditions around its use. As I pointed out earlier, not every 'data access request' is granted, with some portions of the database remaining inaccessible to outsiders. Twinomics may demand that changes be made to project proposals, while they also request that new variables derived from the data be returned to the lab. Once access is granted, collaborators use Twinomics' data together with other assets to produce results for the creation of value. In this configuration, Twinomics receives a revenue from the trade: in exchange for using Twinomics' data, collaborators pay a financial contribution and grant authorship or acknowledgements to the lab on publications. Twinomics uses this financial capital to 'buy' human and material resources towards the maintenance of its database. The

publications earned from the trade are tokens of credibility, which Twinomics mobilises in the competition for grant funding.

This constitutes a rentier model of value production and accumulation, whereby the two laboratories own a number of valuable assets, from which it yields rents to produce value. This model first entails laboratories turning their assets into tradable assets that can be rented out to others against a revenue. They make their assets available to collaborators, who use them to produce results and create value. The laboratories then receive a revenue from the trade, as financial capital, credibility and authorship on publications: it is a form of rent, in that it is an income derived from the ownership of valuable assets. As such, in these collaborations, the laboratories mobilise its assets to *extract* value, rather than create it itself.

Discussion

Across the two laboratories studied, the production of value first starts by building and maintaining a portfolio of valuable resources, and turning these resources into assets. The laboratories mobilise these assets to produce knowledge and value. I identified two main ways in which they do so. First, the laboratories *create* value by mobilising their assets and producing results, which they convert into epistemic credit that can be mobilised in the competition for grant funding towards the accumulation of economic capital. Second, the laboratories trade with other research teams some of their assets against a revenue, in the form of authorship or acknowledgements on publications, or financial capital – as such, they *extract* value from their assets.

The two models of value creation and value extraction, while functioning on different bases, share some common grounds, and in particular they both rest on the active and ongoing management of assets. The two laboratories carefully construct, organise and manage a number of assets in order to derive value from productive endeavours. Laboratories are particularly concerned with asserting ownership and control over its assets, as they impose limits over the use of their assets. They do so in order to render

their assets exclusive, which enables them to selectively distribute access rights to others, to then yield a revenue. As such, the creation and extraction of value are deeply intertwined with assetization processes. In addition, such assetization and value making practices are linked to specific labour relations within the two laboratories: while PIs are usually involved in making decisions about which assets to invest in, while they also negotiate and control how value is extracted from the assets, it is junior staff who makes and maintains such assets. At the Cancer Lab for example, Susan the PI decided to mobilise the lab's expertise to develop the Gene 2 knock-out mice strand, while it is through her networks that she forged a collaboration based on the trading of this technology. However, it was post-docs and PhD students who used their skills at the bench to produce this asset, rendering it operational for the production of valuable research. Once this technology was rented out to collaborators, Susan extracted value from the process by being granted authorship on publications. Resonating with critical labour studies (Gill 2014), one could argue that the production of value in such cases rests on the exploitation of junior staff who are alienated from their work, while senior staff extract surplus value that workers produce.

The rentier model of value production and accumulation is essential to understanding the ways in which academic research laboratories integrate different evaluative frameworks into their work. Instead of acquiring all the necessary assets to produce knowledge that can be valuable within the different evaluative frameworks at play in academic institutions, research teams concentrate on building a number of key assets. They make their assets available for productive use within the research community, renting them out to their networks, while gaining a revenue from the trade. By doing so, the teams move in and out of projects, fields and evaluative frameworks, extracting value as they go. It is around their key assets – expertise and credibility in glycobiology at the Cancer Lab, and twins' data at Twinomics – that the two labs can most easily relate to the different evaluative frameworks at play in academic science. They are well-known for having developed such assets, which means that a broad range of actors, from research teams to commercial firms, regularly approach them to rent these assets against payment.

The observations I make in this paper, while based on the field of epigenetics, are relevant to other research fields. The production of value is a social process that entails a set of actors, knowledge and practices. And in particular, it involves making, maintaining and mobilising assets as part of productive systems. One could argue, however, that what may differ across fields are the sort of assets these value making processes depend on. While in the two labs discussed here, value is intimately linked to model organisms or databases, these assets would not be as central in other academic fields such as in the humanities or social sciences, where credibility or expertise might have more of a dominant role. Further empirical work is needed to test and unpack such assetization and value making practices across fields, while it would also be interesting to explore how assets which differ in their materialities and qualities relate to particular models of value production.

Conclusion

In this conclusion, I discuss what these findings teach us about contemporary knowledge production, valuation and theory. I identify three main lessons. First, findings underline how knowledge production is intertwined with valuation processes. Research laboratories are concerned with producing knowledge that can be valuable in different respects. I underlined that processes of assetization, whereby value production rests on the ownership, maintenance and renting of assets, are central to these knowledge production and valuation practices. Contributing to discussions on valuation, this work provides further empirical and analytical grounding to the question of what gets valued and how in the knowledge economy (Birch 2017, Geiger and Gross 2019). This article also makes theoretical contributions to the body of work on (e)valuation in academic science and heterarchical organisations. Considering the laboratory as a productive system made of resources and assets invites us to look beyond the seeming conflict between evaluative frameworks, and get to grips with the origins of value. Furthermore, this article invites discussions on assetization and rentiership to the domain of academic science, demonstrating that they do not just constitute a growing phenomena in innovation strategies within high tech for example (Birch 2020a, Mazzucato 2018). The expansion of rentiership and assetization practices to academic science is grounded on a set of assets, such as model organisms or databases, as

well ‘traditional’ resources within science such as credibility and reputation. This observation comes in complement of existing work on assetization (Birch 2017, 2020b), which has mostly discussed one sort of asset, that is, technoscientific knowledge turned into IPRs. I thus broaden the conceptual applicability of the concept of rent, by pointing out that credibility and reputation in academic science also make intangible assets that form the basis of a rentier model of value production and accumulation.

Second, the rentier model of value production and accumulation I presented here sheds new light on the collaborative nature of academic work. What is at stake in the research collaborations discussed is the trading of valuable assets. While laboratories own a few key assets, through their network of collaborators, they build extended portfolios of assets. Laboratories make their assets available to others in the scientific community, trading them against other assets or a revenue. As such, research networks rest on trading relationships, with valuable assets at its core. These are different trading relationships than the ones discussed by Collins and colleagues (Collins, Evans, and Gorman 2007: 665), which are based on expertise and where trading zones function “as places where cultures meet, languages are learned and tacit knowledge shared.” Instead here, I look at research collaborations through its material dimension and suggest that what brings collaborators together are assets (which can take the shape of expertise). Value production through research collaborations is only possible if laboratories are well connected and well-known for their assets. The bigger their network, the more opportunities a lab has to trade its assets and accumulate value. Laboratories continually look to build their networks, for example by regularly attending and presenting at conferences. In such instances, staff connect with former and new collaborators, become familiar with ongoing research based on others’ assets, while they also promote the value of their own assets by showing the type of results it can produce. In other words, in these events, laboratories scrutinise the supply and demand for assets, and position themselves and their assets in this market.

Third, the knowledge and value making practices discussed have important implications, starting for the type of knowledge produced. In the two laboratories studied, new research projects were not just considered in terms of their potential epistemic value, but also for the ways they could help them

enhance the value of their assets, while the process of producing results and disseminating them was also deeply concerned with constituting and managing the value of their assets. In other words, what and how knowledge was produced was tightly linked to assetization processes. This suggests that entrepreneurial science, marked by the imperative to produce knowledge that can be valuable in different respects, not only matters for researchers and their practices at the bench, but it matters for patients and citizens alike in that it shapes what we know about the world and our health. Building on that observation, further empirical work is needed to demonstrate and unpack how such assetization processes influence the content of science.

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