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Nature Materialities and Economic Valuation
Conceptual Perspectives and their Relevance for
the Study of Social Inequalities

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Nature Materialities and Economic Valuation

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Miriam Boyer

Abstract

The paper discusses the relationship between material qualities of nature and the process of capitalist valuation. While valuation can be defined in a broad sense pertaining to how resources are identified, extracted and integrated into the world market, the focus here is narrower, centering on the specific qualities of nature that are important to the creation of value itself and touching on related questions such as how to evaluate tendencies in which nature materialities are increasingly commodified. The first part of the paper briefly reviews the work of scholars approaching nature as a materiality placing certain 'limits' on valuation. Most of these scholars tend to view valuation at the level of discrete production processes and while offering many examples of how material nature constraints or enables production, the role of these qualities in value generation is not clear. By contrast, a second part of the paper discusses work that directly addresses valuation, proposing that the specific role of nature lies in the fact that nature materialities are not necessarily commodified, offering a view in which nature is not a 'limit' or an 'outside' but a materiality that is a constitutive part of valuation, historically integrated through partial commodification. A final section deals with the specificity of the valuation of living nature. Agricultural biotechnologies in Latin America are briefly discussed, raising various issues that should form part of a future research agenda to evaluate how this particular type of nature valuation will reconfigure social inequalities in the area.

Keywords economic valuation | material qualities of nature | biotechnologies

Biographical Notes

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1. Introduction: The Valuation of Nature¹

The relationship between ‘natural’ resources and economic valuation is an issue on many research agendas due to a number of factors including increasing demand for ‘primary sector’ goods by dominant production centers such as China; the scarcity of resources for various production frameworks; and the high prices and price volatility of many of these commodities. Above and beyond this, the role that nature plays in valuation processes has attracted attention because it has been central to how nature-society relations have been regulated politically since the neoliberal period, as market-based approaches to conservation were developed conceptually in the 1970s and 1980s and consolidated by national and international institutions from the 1990s onward. As concerns Latin America, the debate on nature valuation has additionally been brought to the fore by the salience of a process diagnosed as ‘neo-extractivism’. Neo-extractivism can be seen as an economic and sociopolitical strategy in which the extraction of primary goods (e.g., hydrocarbons as energy sources; minerals; primary agricultural goods) for export has again taken a central stage in the economic strategies of several countries in the region (cf. Brand and Dietz 2014).

In this context the ‘valuation of nature’ signifies a way of regulating nature-society relations in a broad sense, i.e., pertaining to how resources are “defined, identified, extracted and integrated into the world market” (Görg 2004: 1503; cf. also Altvater and Mahnkopf 1999: 376) as part of a wider societal strategy or consensus around a new paradigm in society-nature relations, entailing particular patterns in production and consumption as well as particular cultural understandings of and practices with nature (cf. also Prudham 2009; Castree 2003). From the perspective of the study of social inequalities a broad understanding of valuation can be helpful because it takes into account the reconfiguration of economic, political, cultural and other relations at various levels, from local conflicts related to the privatization of water to transregional projects based on the redistribution of the revenues from resource extraction. This broad definition of valuation is indeed the concept that has indirectly framed most of the work on nature and social inequalities in the *desiguALdades* network until now. At the same time, economic valuation of nature can also be approached from a more ‘narrow’ analytic perspective focusing on the role of specific nature qualities in value creation. This approach highlights the material qualities that play a unique role within the process of valuation (in what sense do we speak of ‘nature’ valuation when we refer to such diverse phenomenon as mining, carbon emission quotas, agricultural crops, etc.), and helps identify the historically-specific role of nature as part of capitalist

¹ I would like to thank Isabella Radhuber, Kristina Dietz, Barbara Göbel and Imme Scholz for comments on an earlier version of this paper.

production in space and time, two dimensions that have been identified as relevant by previous research in the Network (cf. Dietz 2014).

The paper reviews research mainly from the perspective of this ‘narrow’ definition of the economic valuation of nature, focusing on how nature materialities are integrated into the value-generating process. The first part argues why a focus on the role of nature in valuation brings our attention to the materiality of nature and discusses a body of scholarship that has dealt with material qualities as presenting certain ‘limits’ to valuation. Here, a variety of examples shed light on the relationship between the materiality of the resource and the structure of particular industries, access to rents and market power, but given their focus on nature as a ‘natural resource’ and the unclarified relationship between commodification and the valuation process, they do not provide sufficient clarity on the relationship between these material qualities and the creation of value. The second section then discusses scholarship addressing the role played by nature in valuation viewed at the more general level of capital accumulation. The central issue here and in later sections of the paper is the argument that material qualities of nature play a specific role in valuation via partial commodification, providing an argument in which nature materialities are not an outside but are constitutive aspect of capitalist valuation. A final section of the paper deals with valuation via new biotechnologies. Here, the focus is on the specific role that the materiality of living nature can play in valuation. The example of agricultural biotechnologies is used to discuss further aspects of Moore’s (2014a; 2014b) argument and to provide elements of a future research agenda to evaluate the reconfiguration of social inequalities in the context of the new material constellations brought about by this type of production and valuation.

2. Nature understood as a Material ‘Limit’ to Valuation

Economic processes —entailing production and value creation— are structured by social relations that shape the conditions under which production takes place. In addition to these socially specific aspects, nature as a materiality distinct from that of social relations —e.g., the time it takes for a tree to mature; the chemical properties of substances when they react with each other; and the transformative capacities of human labor power— also plays an important role in configuring the economic process. This is more readily apparent when we focus on production as the physical process of material transformation, but also plays an indirect albeit important role in the constitution of value, as explored throughout the paper.

Given the institutional divide between the social and the natural sciences and the fact that a focus on material qualities of nature has been seen as the exclusive prerogative of

the latter, it is not surprising that social science scholars have typically relied on indirect terminology to grasp such qualities of nature in relation to social relations (cf. Boyer 2014). One of these approaches has been the notion that particular nature qualities place certain 'limits', 'obstacles', or other constraints on economic processes, typically focusing on particular industries or productive sectors such as aluminum extraction (cf. Barham et al. 1994), agriculture (cf. Goodman et al. 1987) or forestry (Boyd et al. 2001). Early work in this tradition drew attention to the relative 'rigidity' of extraction whose "production rates and turnover time...are inexorably constrained by geological, hydrological, and biological forces" (Bunker 1989: 592). This type of work and its focus on "raw materials industries" specified particular qualities that presented a constraint or limiting factor to production, such as unmovable location of location and grade of the mineral resource, identifying how this constrained a firm or sector's ability to exert influence in the market, or to capture rents from these resources.

A similar approach was also pursued by scholars working within the rural sociology tradition in the United States. Mann (1990), Mann and Dickinson (1978) and Goodman et al. (1987) identified 'obstacles' and 'structural constraints' to the capitalist restructuring of agriculture, arguing that agriculture presented a "special case or anomaly...arising from singularities of its natural production process" (Goodman 2001: 185). Here, attention turned to temporal discontinuities inherent to seasonal production; the perishability or short shelf life of agricultural products as well as growth and gestation time in animals. Breaking with previous work that only looked at production at the level of the farm, later work by Goodman et al. (1987) built on this perspective by developing on how the material qualities of agricultural plants and animals impacted not only upon farming but also agricultural processing industries, identifying a unique path of agricultural industrialization as a result of the materiality of agricultural plants and animals: "nature as the biological conversion of energy, as biological time in plant growth and animal gestation, and the space and land-based rural activities" (Goodman et al. 1987: 1f.).

Goodman et al.'s study focuses on two strategies deployed by industrial capital in the face of these material constraints. The first, 'appropriationism', is a strategy predicated on increasing the capitalization of agricultural production activities, that are then reincorporated as new production inputs such as synthetic fertilizer and hybrid seeds (Goodman et al. 1987: 10). 'Substitutionism' is a second strategy referring to how industrial substances were developed to replace agricultural products in the form of inputs. This "open[s] the way to the elimination of the rural production process, either by utilizing non-agricultural raw materials or by creating industrial substitutes for food and fibres" (Goodman et al. 1987: 58). A prime example of substitutionism is the 19th century replacement of dyes of vegetable origin with synthetic aniline dyes obtained

from coal tar. In these examples one material quality of nature is replaced with another posing fewer 'constraints' to capital, either because the materiality is more abundant; because there may be new techniques to transform it more cheaply; or because it is reduced to a materiality that can simply be substituted interchangeably, as in the case of the replacement of butter made from cow's milk to margarine made from a variety of interchangeable oils of animal or vegetable origin.

This scholarship provided many such examples of how diverse nature materialities reconfigured the economic process in a broad sense, including not only industry structure and access to markets and rents but also the distribution of economic benefits from extraction. This highlights certain material qualities of nature in production but is also of limited use from the perspective of this paper as it sheds little light on the creation of value as such: On the one hand, value as such is usually only addressed in the sense of how various capitals vie to control where value is created post extraction. On the other, in most cases nature is defined in the traditional sense of a 'natural resource', that is, as nature at the point of 'extraction' but ceasing to be important in affecting how production and valuation unfold once the primary resource is further processed. This is underlined by the literature identifying agriculture as a "special case or anomaly" (Goodman 2001: 185); or in Goodman et al.'s observation that once agricultural production is substituted, "nature, whether as land, space, or biological reproduction...no longer poses a binding constraint to the capitalist transformation of the production process" (1987: 58). An exception in this tradition is work addressing the specificity of "biological production" that is "consciously manipulated (up to a certain point)" and contrasts with "geological production [that] is for all intents and purposes beyond the scope of human control" (Boyd et al. 2001: 561). The paradigmatic illustration for this difference is the transition from extraction to cultivation within the forestry industry, where instead of increasing production through increased logging, tree growth is optimized through "intensive nursery operations for seedling cultivation, mechanical planting of forest trees" as well as breeding (Boyd et al. 2001: 556; cf. also Kloppenburg, 2004, for a similar discussion related to plant breeding). Here, what is identified is that modifying the materiality of living nature can make human labor power more productive, an issue I return to in the third part of the paper.

Without necessarily adopting and developing on the concept of limits or obstacles, more recent work in other research traditions such as political ecology has carried forth a similar focus but has been characterized by focusing on the question of how material qualities may constrain or modify whether and how nature becomes a commodity. The focus on valuation qua commodification of nature in this more recent work is likely a reflection of a market-mediated regulation of nature during a period of increasing neoliberal hegemony accompanied by an upsurge of old and new 'natural resources'

as market commodities: Water, seeds, 'genes', ecosystem services, or carbon dioxide that are sometimes brought into value via new productive processes (e.g., industrial substances produced via microorganisms, as discussed in the last part of this paper) or via property monopolies that create surplus profits (e.g., as a result of patents, or offset credit trading).² For example, Karen Bakker has argued that material qualities of certain resources have sometimes presented some kind of constraint to becoming 'full' market commodities (Bakker 2010: 552). In her study of water supply in England and Wales under neoliberal regimes, water's 'biophysical characteristics' underlie the difficulty in making water a resource available as a market-distributed commodity. On the one hand, this is related to the materiality of water as a "flow resource to which pollution is not easily contained and hence easy to externalize" and on the other to water as a material that is "cheap to store but heavy to transport, requiring expensive sunk infrastructure with a long lifetime" that favors a single supplier and therefore makes it difficult to create an easily traded commodity (Bakker 2010). Bridge (2000) reaches a similar conclusion in his study of the US copper industry. This is related to the physical quality of mineral production where storage or disposal for the waste created by the purification of the copper ore is constrained both by size as well as the "chemical complexity of the waste streams", (2000: 243) creating high costs for industry and eventually constraining the commodification process.

From the perspective of this paper, this work on the commodification of nature can be considered useful if we follow the assumption that commodification of natural resources is a prerequisite for the capitalist generation of value during the present period in which "what we come to know as nature seems ever more tied to commodity circuits" and as capital "seeks new avenues...in and through discrete biophysical processes" (Prudham 2009: 124; cf. also Castree 2003). However, is this necessarily the case? Does commodified nature help us identify a relationship between the materiality of nature and capital valuation? And if so, how do we make sense of valuation in earlier periods in which fewer nature materialities entered production in the form of commodities? The following section of the paper will give one answer to this question. It is an unexpected answer in arguing that a specific role of nature in capitalist valuation lies in providing material qualities that can be appropriated without necessarily being commodified.

3. The Role of Nature in Valuation: Appropriation as a 'Free Gift'

There is a different scholarly tradition that we can turn to which has generally made more specific inquiries into the relationship between valuation and material qualities in nature, albeit typically at the level of capital accumulation rather than particular sectors

² For a literature overview on the 'commodification of nature' literatures, see Castree (2003) and Prudham (2009).

or commodities. One branch of this scholarship also relies on the concept of limits, in this case related to how the term was used in the context of a critique of the 'limits to growth' debate, as declared in the well-known study published by the Club of Rome in 1972 (Meadows et al. 1972). According to the 'limits to growth' argument, economic valuation ('growth') is limited by purportedly objective limitations set by an outer environment, such as food scarcity (cf. Ehrlich 1968). In this context, various scholars reacted by calling attention to the socially-mediated character of such limits (Dietz and Wissen 2009). For example, James O'Connor identified qualities of nature in relation to the historical specificity of capitalist accumulation and development, arguing that these affect how the valuation process unfolded, not because they themselves presented objective or absolute 'limits to growth', but because, as O'Connor formulated it, they "are not produced and reproduced capitalistically" (O'Connor 1988: 21). The fact that they are 'not produced capitalistically' clearly refers to the materiality of nature as distinct from the materiality of capitalist social relations, including human labor power, water, soil, etc. Although scholars like O'Connor did not use the term 'materiality' and did not seek to theorize it but to develop a theory of how those qualities created capitalism as a "crisis-ridden system" (O'Connor 1988: 22),³ their work nevertheless explicitly identified a relationship between various qualities of nature and capitalist valuation. An example of this would be the depletion of agricultural biodiversity through industrial agriculture, limiting valuation by impairing production when monocultures are devastated by a single plague, "increasing the costs and expenses of capital, thereby threatening capitals' ability to produce profits" (O'Connor 1988: 13).

A second branch of this scholarship also views valuation at the level of capital accumulation, based on a notion of nature as a materiality 'outside' of particular social relations, specifically where capitalist relations are not present or not dominant. Typically, this notion of a non-capitalist outside traces back to Karl Marx's analysis of 'original accumulation' describing the process establishing capitalist production relations, including a historically-specific way of producing value via the commodification of labor, the process of constraining other economies/other forms of producing value and the incorporation of (human and non-human) materialities into the process of capital accumulation. Marx's description of 'original accumulation' includes a number of specific processes such as the privatization of common lands and the expulsion of peasants; the suppression of prior forms of production and the extension of commodified labor power; the transformation of collective property rights into private property rights; the monetization of exchange and taxation, especially of land; the

3 The work of O'Connor builds on Karl Polanyi's earlier theories regarding fictitious commodities (cf. O'Connor 1988), following a similar line of thought according to which labor, land (and money) are commodities in a limited sense requiring political-cultural regulation in order to avoid destructive tendencies such as the overuse of land.

slave trade; as well as debt and the credit system (Marx 1867 (1975): Chapter 24). Here, what is described is a type of value production as it relates to the appropriation of resources that lie outside the circuit of surplus value creation: The land of local communities is appropriated, privatized, peasants are expelled, and land and labor are released into the circuit of capital accumulation (Marx 1867 (1975)). As Harvey (2003) describes it, it is a mechanism that “releases a set of assets (including labor power) at very low (and in some instances zero) cost” (2003: 149). Beyond a process through which capitalism ‘originally’ took root, similar processes have been theorized as an ongoing mechanism for the creation of value, from Rosa Luxemburg, who proposed that capitalist accumulation “needs for its existence and further development non-capitalist production forms as its surroundings” (Luxemburg, cited in Görg, 2004: 1502) to Harvey’s proposition of ‘accumulation by dispossession’ as a recurring mechanism to explain recent accumulation crises (2003: 137).

In accounts of accumulation through dispossession nature frequently plays a role, such as the gold and silver mines of the New World from the 16th century onward; classic accounts of enclosure of the commons, from England to India; present accounts of biopiracy and the “escalating depletion of the global environmental Commons (land, air, water) and proliferating habitat degradation that preclude anything but capital-intensive modes of agricultural production” (Harvey 2003: 147f.). But for the sake of specifying the relationship between valuation and natural resources this is unsatisfying because descriptions of original accumulation/accumulation by dispossession frequently include ‘nature’ as one element among a sundry list of other phenomena, telling us little about the role of nature in the process of value creation: In Marx’s own descriptions we find the privatization of land alongside the descriptions of accumulation through the credit system. In Luxemburg’s accounts war plays a key role where “violence, fraud, oppression, plunder appear without concealment” (Luxemburg, cited in Görg 2004: 1502). And alongside Harvey’s accounts involving nature he also describes the commodification of cultural forms, the privatization of public assets, the rolling back of state regulatory frameworks for the protection of labor rights, and massive currency devaluations, among others.

To bring into focus the particular role of nature in valuation, it is necessary to focus on the material qualities of nature beyond identifying them indirectly as an ‘outside’. Here, the work of geographer Jason Moore is particularly helpful. Following in the steps of scholars who depart from the importance of original accumulation/accumulation by dispossession, Moore agrees that the extension of capitalist relations to new spaces or frontiers that were not previously commodified has been essential to ongoing capital accumulation. But in addition, he proposes that just as important has been the integration of natures that are not fully valued within capitalist relations (cf. Moore

2014a; 2014b). This line of thinking has parallels to feminist or dependency theorizing regarding the role of housework and other activities such as subsistence production or slavery, which are important in the larger process of capital accumulation because they are not fully valued within capitalist circuits, i.e., are not commodified, providing a kind of 'subsidy' to capital.

Thus, in contrast to the 'accumulation by dispossession' argument assuming that through a process of dispossession certain assets are released in order for capital to render them profitable by creating new commodities (cf. Harvey 2003: 149), Moore's assumption is that nature's "life-making capacities" (2014a: 291) are actually not being fully brought into the cycle of capital accumulation in the first place because doing so would be too costly from the point of view of surplus value and profitability. To understand what this means concretely, Moore provides various examples that are important from the point of view of how capitalism developed historically. He contrasts the major differences in labor productivity in the 16th century between the long-exploited European silver production in central Europe with the silver mines of the 'new world' such as Potosí; and, similarly, between the production of wheat by family farmers in the un-ploughed North American prairies in the 19th century versus the production of cereal grains in Europe at the time (cf. Moore 2014b: 10f.). Extracting silver in Potosí or wheat from the North American plains depended on a certain degree of capitalization (shipbuilding and cartography; or railroads and rationalization of the new North American territories), but Moore suggests that reproducing 'cheap' nature depended crucially on controlling and channeling but not necessarily capitalizing "the reproduction of life-making capacities for the benefit of accumulation" (2014b: 12). In other words, instead of investing more capital, the 'life-making capacities' of mineral formations or fertile prairie soils were appropriated in a kind of subsidy to production. Because they are appropriated rather than 'paid for' (cf. Moore 2014a: 291) as commodities, Moore speaks of a nature that is 'cheap'.

Moore's analysis, rich in historical detail, provides an insightful perspective for understanding the recurring role played by the materiality of nature in valuation, in particular its transformative capacities/qualities: "Extra-human natures such as forests, soils or rivers" (2014a: 288) but also labor power (cf. Moore 2014a: 291ff). Although he does not underline the role of this nature materiality explicitly, it is clear that how nature "may be taken up into commodity production but not fully capitalized" (2014b: 9) is based on nature's perpetual capacity to transform material substances. Thus, whether over long periods in which minerals and fossilized hydrocarbons were formed, or the relatively faster cycles of living nature and the creation of fertile land and a diversity of living ecosystems, or the even faster cycles of the human lifespan, all of these entail material transformations that are essential not only for the materiality of production,

but also for valuation qua capital accumulation, as “cheap natures” (2014a; 2014b) that lowered production costs and were thus a boon to new accumulation cycles. In other words, these are qualities that not only “are not produced and reproduced capitalistically”, as formulated by O’Connor (1988: 21) and would therefore represent a limit to valuation in the sense of a scarce productive input that would “increase the costs and expenses of capital” (O’Connor 1988:13); but are also an advantage to capital because they provide a quality that need not be ‘produced capitalistically’ but is merely appropriated and not paid for, a process that has historically allowed “accumulation to proceed at acceptable rates of profit” (Moore 2014a: 292). As I discuss later on, this is a process that is conceivable even when the use of nature resources is associated with a high degree of capitalization given the fact that it is not discrete resources as such that are commodified or capitalized but specific ‘capacities’ or transformative qualities of nature.

Moore’s observations might also provide an interesting analytic background for considering processes such as the current cycles of extractivism in Latin America or China from the perspective of cycles of capital accumulation at a global scale, giving another layer of analysis to the ‘global valuation of nature’ perspective developed in the *desiguALdades.net* research network. While a frequent focus has been to draw attention to the high prices of commodities, can these also be seen as a cycle of ‘cheap’ nature from the point of view of valuation? This is a proposition that would have to be evaluated empirically across many areas, but for which there would seem to be examples suggesting that such a boom could also be seen as strongly coupled to processes of partial commodification, including the expansion of previously uncultivated and thus highly fertile lands in the southern cone for the provision of cheap soy for the global meat industry; the state-financed provision of the infrastructure for the extraction of fossil fuels; the continued source of cheap labor power through the informal sector, even when this labor power is commodified in other geographic locations or is partially commodified; the flow of resources, from minerals to water and human organs through non-regulated and criminal economies; or the insertion of entire new resources that are formally commodified but are little capitalized such as the provision of a number of ‘ecosystem services’. While Moore’s interest is in evaluating cheap nature from the perspective of long cycles of capital accumulation and crises, his understanding of the relationship between value creation and nature could also shed light upon the historical role of regions such as Latin America in the provision of resources that are ‘cheap’. To evaluate these tendencies, among others it would be necessary to look more carefully at the trajectory of various sectors at a global level, the role of these resources in the composition of wider value networks as well as the rates of investment across these sectors relative to others.

It should be emphasized that the partial commodification observed by Moore should not be seen in a functional manner. Rather, the degree to which nature is integrated into the market and more or less capitalized/commodified also depends on specific society-nature relations and their regulation, such as how capital-intensive new technologies are for accessing particular nature materialities (how much 'needs' to be capitalized/commodified from the point of view of the productive process in general); but also political and cultural relations that are key to shaping whether and how nature is valued according to capitalist relations such as social movements that hinder or may even revert commodification. An interesting question in the context of Moore's argument and the earlier discussion of recent work focusing on the process of commodification is the extent to which de-commodification of particular natures is in fact a step away from the capitalist valuation of nature. When political ecology has documented myriad political struggles taking place at "the border of the commodity frontier" (Gómez-Baggethun and Ruiz-Pérez 2011: 622) often the focus is on the de-commodification of a particular 'natural resource' (e.g., water, wheat, soil etc.). Without doubt, de-commodification in this sense is significant, as it can have a significant impact on reorganizing nature-society relations in the sense of a non-market mediated use of nature materialities, such as when local communities regain access to water, land, fisheries, etc. and can re-develop other forms of production. But de-commodification of nature cannot, per se, or independently of broader relations, be seen as bringing nature materialities 'outside' of the capitalist valuation of nature. Indeed, this is what Moore would seem to highlight when he pleads for a concept of "capitalism as environment-making processes" (2014a: 287, emphasis in original).

One way of putting Moore's argument is that beyond the question of whether or not capital invests directly in these resources so that the water, wheat, soils, etc. enter the market as commodities, there is another dimension in which non-commodification is key to value creation in the sense that capital has access to natures that are 'cheap': The regenerating capacities of forests and aquifers in providing water; the reproductive capacity of plants like wheat; the microorganisms that provide soil fertility which according to Moore provide a subsidy to capital invested because they are not commodified and must therefore not be paid for. In other words, we may be dealing with both, a constant process of commodification and non-commodification, as discussed further below. This is an insight that we can gain from following Moore's line of thinking pushing us to think of nature materialities beyond the usual schema of 'natural resources' and focusing instead on particular qualities of nature and in particular their transformative *capacities*, a point that underlines the material proximity of human labor power and the transformative capacity of various nature materialities in the context of value creation.

4. Valuation of Living Nature

The first part of the paper discussed the tendency to replace certain nature materialities with others, a process that Goodman et al. (1987) described as ‘substitutionism’. Upon closer look, it seems that such mechanisms often hinge upon attempts to move away from the particular material qualities of *living* nature: The growth and maturation rates of animals; or the quantities of plants required to harvest a given amount of a substance. For instance, acetylsalicylic acid —the substance popularly known as aspirin— was obtained from the bark of the willow tree since antiquity. However, producing the same molecule by chemically transforming hydrocarbons in the 20th century resulted in higher amounts of the substance being derived with considerably less labor and therefore more cheaply than deriving it from the tree. In the examples mentioned earlier, the substitution of butter by margarine was also an attempt to move away from the constraints of perishability or the expenses of feeding and raising cows for dairy products.

By contrast, a recent development traces the opposite trend in which specific material qualities of living nature are sometimes explicitly sought out as transformative qualities in production for some of the most industrially ‘advanced’ processes. This is illustrated by how the anti-malarial drug, artemisinin, is being produced through a new process relying on the living processes of microorganisms. Until recently, the drug was obtained almost exclusively through a labor-intensive process lasting ca. 1.5 years that involves cultivating the sweet wormwood shrub, a process which currently employs ca. 100,000 farmers worldwide, then extracting an oil from its leaves and flowers, a process yielding only 2-3kg of extract per hectare planted (0.01-1.4% of dry leaf mass), which must then undergo a long purification process to yield pharmaceutical artemisinin (Peplow 2013: 160; Novartis n.d.). As an alternative to this labor-intensive production, the same substance is currently being produced by a company that molecularly engineered yeast cells to (re)produce the drug in tanks in a medium of table sugar. In this case, the metabolism the yeast cell itself replaces the labor process both the farmers, as well as some of the labor for further chemical processing of the extracted oil: Once the yeast has been modified through molecular engineering, the increase in labor productivity is very high since the organisms continue to produce the substances as part of their (modified) metabolism. This is reflected in the fact that this type of production is currently generating substantial investment among powerful industries such as those involved in the production of chemicals, petrochemicals and pharmaceuticals (cf. Birch and Tyfeld 2012).

In this context, it is not surprising that scholars in the tradition of agricultural sociology (described in Part I of the paper) have used related terminology to suggest whether

these qualities of nature might also be described as presenting not only “limits”, “barriers” or “constraints”; but also “variability” or “surprise” (cf. Boyd et al. 2001: 557), terms seeking to describe the material qualities of nature in which “biological systems are made to act as actual forces of production” (Boyd et al. 2001: 565). From the perspective of the productive process, the materiality of living organisms is crucial because it is their life processes or reproduction that transforms substances to create a new useful quality, as described in the examples above (cf. also Boyer 2014). However, from the perspective of valuation, their importance is in the fact that the transformations in living nature acting as productive forces play an important role in the valuation process by substantially increasing labor productivity. In other words, complementing Jason Moore’s argument that the valuation of nature is ‘cheap’ because material qualities in nature are not fully capitalized/commodified, we can further specify his argument, at least in the context of the new biotechnologies: Nature materialities and in particular the qualities of living nature can also be advantages to capital in the sense that they are inserted in valuation processes as productive forces that increase labor productivity and therefore ‘cheapen’ production.

Here, we are dealing with a distinctly new process through which human labor is not typically replaced by ‘dead’ capital, as described by Marx, i.e., by machines, but by a living process—in this case the metabolism of the yeast cell—that is in some ways similar to the human labor in its capacity to transform one material quality into another (cf. Boyer 2014; Boyer 2015). Artemisinin is one of the first currently-marketed examples of an industry targeting to produce high-value substances in which the major advantage is that the processed product (or its close chemical precursor) is directly produced by the living organism in question. Examples of high-value agricultural products to be replaced by this type of production include labor-intensive crops such as saffron, anise, vanilla, or palm oil (University of Manchester iGEM Team; Pollack 2013). In addition, substances are targeted whose production currently requires substantial and labor-intensive chemical processing such as fuels for engines, as well as oils and various types of polymers used in industrial production.⁴

Because transforming nature in this manner—e.g., molecularly altering the metabolism of yeast cells to produce a new substance—tends to be very capital-intensive it is interesting to ask whether Moore’s observations that the valuation of

4 Artemisinin is one of the first products of this type to be sold on the market. Often, the products targeted by this type of production may be employed as an input in production rather than as a consumer product. Jet fuels, oils used in the production of detergents or industrial oils such as palm oil are examples. The extent to which these products will become more widespread is by no means only a question of their productivity or economic viability but of course a question to be determined by other social relations that frame valuation in a broader sense, including acceptance of this way of producing.

nature often entails the non-commodification of nature also ‘apply’ here. When a company produces artemisinin in yeast cells, there is a substantial process of capital investment in the transformation of the yeast’s reproductive process, from the many years of basic scientific research, to the global markets for the organisms and the associated knowledge that are all increasingly commodified (cf. Parry 2006). But while the transformation of the cell’s reproduction does entail a substantial degree of capitalization related to creating the novel substance, certain material dimensions of the cell are in fact not commodified, in particular the yeast cell’s *ability to reproduce*, which existed prior to and independently of its ‘optimization’ through the molecular engineering process. In a different context, this point is echoed in a passage observing that “the producer who works with the steam machine also uses nature power which poses no cost to him, but which makes labor more productive... The producer pays the coal *but not the capacity of water to change its aggregate state, to be transformed into steam...*” (Marx 1876 (1975): 656, emphasis added). Indeed, while the tweaking with the cell’s reproduction to metabolize new substances is commodified (and paid for), the key productive force —the cell’s basic living process and its ability to reproduce— is indeed taken as a ‘free gift’ to the process of valuation, corresponding with Moore’s notion of a valuation process characterized by material qualities of nature that create a ‘subsidy’ in terms of production costs that are not paid for.

In this sense, a further analytical precision of Moore’s argument already alluded to at the end of Part II of the paper, is that when approaching the materiality of nature in the context of valuation we must move away from the notion of discrete resources that bolster an understanding of nature as ‘pieces’ of the environment, a term used by Castree (2003: 285) and others; that is, as nature ‘entities’ that are either commodified or not commodified. Rather, to the extent that we gain practical insight into the various qualities of nature’s materialities —the plant, its seeds, particular cells, tissues, molecules, ecosystem processes— some of these material qualities may become commodified while others are not. This is not new to the valuation of living nature processes but is an important part of the capitalist valuation of nature more generally. The materiality of the human body is a good example: While certain dimensions of human nature materialities such as labor power have been a commodity for centuries already, new material qualities or dimensions of human metabolisms are only now being commodified, such as intellectual labor and reproductive abilities via surrogacy and human reproductive cells, as well as the generative capacities of organs. The same can be said about non-living nature such as a *salar* where lithium is extracted. Here, the extracted lithium salts are commodified but not lithium’s capacity to store energy efficiently. To create a full picture of valuation, it may be more precise to specify how distinct material qualities contribute to specific aspects of valuation: the capacity

of water to turn into steam, as a dimension or specific transformative quality rather than a discrete resource, i.e., 'water'; 'steam'.

In addition to rendering labor more productive, an interesting aspect of the valuation of living organisms in the context of molecular biotechnologies is the new spatial reconfigurations of valuation that emerge as a result of the new materialities. On the one hand, nature is not necessarily relied upon to produce a new material quality that did not previously exist, but to produce it according to new material constellations. For example, in the case of artemisinin there is a spatial rearrangement of production and valuation stemming from the fact that the production process is spatially displaced from the wormwood shrub in China to laboratories in Bulgaria and Italy where the entire production process takes place (PATH 2013). This may be advantageous to industry because not only the production process, but also the valuation process is redistributed, potentially affecting large parts of the previous commodity chain such as the farmers growing the wormwood bush (cf. Pollack 2013). Another example is the molecularly engineered agricultural plants that produce a toxin that serves as their 'own' insecticide. In this case, it is advantageous that the insecticidal toxin, frequently produced through a separate process, can now be (re)produced not only in the identical spatial location as the plant, but also throughout its entire lifecycle. The possibility to create these types of changes in the location of production result in a reconfiguration of valuation patterns in space, opening up a terrain in which social inequalities are likely to be reconfigured, as can be illustrated with a preliminary look at how such molecular biotechnologies have developed in Latin America.

Latin America has been an important site for production deploying molecular biotechnologies, albeit not for the production of high-end substances such as artemisinin, but primarily for growing molecularly engineered agricultural crops such as soy, a key materiality in the global production networks for meat and processed foods (cf. Teubal, 2008). From the point of view of the transformation of nature to create new material qualities, the two molecular biotechnologies are similar, i.e., they use living organisms as a productive-transformative force to create new material qualities. However, in the case of the crops, the qualities created and their particular material constellations do not contribute in any significant measure towards transforming production and valuation in a broader sense, much in contrast to processes such as yeast-based artemisinin. Thus, despite the fact that in 2012 a full 12% of total arable land worldwide (i.e., not including land for livestock or forestry) was farmed with such crops (FAO 2010; ISAAA 2012), over 99 percent of these plants have been bred to exhibit two material qualities: Plants producing bacterial enzymes making crops resistant to various herbicidal chemicals; and plants producing a bacterial toxin with insecticidal properties. While these material qualities represent a radically new way of reproducing nature in terms

of the evolutionary history of particular nature materialities (cf. Boyer 2014; 2015), unlike yeast-based artemisinin, they represent neither a truly new productive quality nor a new productive force in agricultural production. Far from this, the new material qualities tend to reinforce productive processes that became dominant during Fordism, in particular the widespread use of chemical inputs as a replacement for labor (Boyer 2014).

Moreover, from the perspective of valuation, these crops also do not represent a transformation in the distribution of value, but would appear to reinforce established and unequal patterns of value creation in space. Thus, if we again compare artemisinin and the crops, we can see that while the development and control of both types of technologies is already in the hands of capital in Europe and North America, the production of high-value substances such as artemisinin possibly associated with advantages in valuation due to increases in labor productivity as described seem to remain in the North, while the engineered crops that do not represent new patterns in production and valuation, are heavily promoted in the South, where land and labor is available at a lesser cost. As a result, the new transformations in the relationship between nature materialities and valuation in the context of the new biotechnologies would seem to tend to keep Latin America in a position of a traditional provider of unprocessed agricultural goods such as soy, a key material input in the global production network for meat and processed foods while the production of high-value substances such as artemisinin is carried out by sectors with the potential for high profits due to increases in labor productivity as described above; but also for surplus profits associated with intellectual property monopolies, stemming from licensing agreements for the seeds (cf. Birch and Tyfeld 2012; Zeller 2008). These are broad tendencies based on preliminary observations and must be followed up with further research in an attempt to characterize the process of valuation in this incipient industry.

In addition to reinforcing established inequalities in terms of spatial distribution of value and of access to and control of these new material qualities as resources, there may also be new sources of inequalities stemming from risks posed by the new material constellations. For example, it is not understood entirely what risks may entail from plants whose every cell produces antibacterial toxin throughout the lifetime of the plant, including when they are eaten along the food chain (cf. Chen et al. 2009). Other examples of these risks are the well-documented contamination of traditional crop varieties which tend to be used overwhelmingly by local or indigenous populations, as is the case of the contamination of native maize and cotton varieties in Mexico (Wegier et al. 2011). Given that this materiality is reproduced according to the patterns of wind and air that spread the pollen of the plants, it is conceivable that new inequalities may not only develop along established patterns but that social effects may also unfold

according to new and unforeseeable configurations. In such instances, new inequalities are likely to appear that may not necessarily follow established social hierarchies within and among social relations, constituting a kind of 'wildcard' as new productive forces may in fact also act as destructive forces in ways that cannot be controlled or predicted and thus creating new patterns in social inequalities. At the same time, as suggested by a number of studies in the field of political ecology on phenomena such as earthquakes or floods, we could also expect that many of these risks will also be distributed unevenly but according to established cleavages along power and other relations. For example, populations with a higher economic status may have access to alternative circuits for the provision of food and may be able to avoid any risks posed by the plants. Given the novelty of the material constellations being configured by the new biotechnologies there is substantial research that remains to be done to evaluate the effects of these materialities across a broad range of social relations, in order to assess whether and how they transform consumption patterns, create new needs and how societies work, live and reproduce. This will entail complementing a 'narrow' definition of valuation with a broader definition that can take into account not only how value is created, as explored throughout this paper, but also how it is inserted into society-nature relations more generally.

5. Conclusion

The paper discussed the relationship between material qualities of nature and the process of valuation. Two definitions of valuation were presented and a 'narrow' definition was pursued in depth throughout the paper. The narrow definition did not address aspects of valuation such as the technological or the symbolic-cultural constitution of the resources, but allowed a more sustained focus on deciphering the role of material qualities of nature in the process of value creation. Various scholarly traditions have indirectly touched on the issue by positing that nature places certain 'limits' on commodification; that nature is a type of 'fictitious commodity'; or that the process of valuation tends to have a type of 'outside' appropriated as part of a process of 'accumulation through dispossession'. In contrast to these, Moore's specification that the role of nature in the process of value creation hinges on the fact that nature is *not* necessarily commodified is particularly useful. Despite the fact that Moore's approach does not theorize on the materiality of nature directly, his arguments show clearly that such qualities of nature are not only an 'outside' but a constitutive part of valuation, historically integrated through partial commodification. This is very vivid in the case of production processes directly relying on living organisms as a material quality such as yeast-based artemisinin, but is also evident in other examples such as the use of water in a steam engine.

In this sense and as a further specification of Moore's argument, the paper suggested that rather than approach nature materialities as discrete entities (seen as 'natural resources' that are either commodified or not), it would be more precise to conceive of various material qualities that constitute a 'free gift' to the process of valuation via their transformative potential. Thus, rather than speak of the commodification (or non-commodification) of water, the paper suggested to focus on the capacity of water molecules to turn into steam in order to run an engine; or the reproductive capacity of a molecularly engineered to reproduce for the creation of yeast-based artemisinin. Furthermore, this focus on nature qualities as transformative qualities with a potential of being appropriated, rather than capitalized, suggested a similarity in the transformative capacity of non-human natures and human labor power as the key materiality in the creation of surplus value.

Furthermore, the paper argued that the notion that 'cheap nature' —i.e., nature materialities that are not capitalized/commodified and are therefore not 'paid for'— need not run counter to other scholarly arguments regarding an increased commodification of nature. On the one hand, we are dealing with two different levels of analysis, one about society-nature relations highly mediated by the market and by myriad new attempts to conceive of, transform and produce with nature in commodity form; and on the other about the role of nature in the process of how value has been created within capitalist relations historically. Furthermore, as the discussion on agricultural biotechnologies showed, it is possible to have a process of high capitalization/ commodification and still identify material qualities of nature that are not commodified and therefore continue to present a source of 'cheap nature' in Moore's sense. By the same token, if we follow Moore's line of argument, it is not possible to argue that processes in which nature is de-commodified would somehow place nature 'outside' the sphere of capitalist value creation. Due to the constitutive role of nature in the process of value creation, transforming the capitalist valuation of nature would entail much larger transformations beyond the de-commodification of particular nature materialities, entailing broader changes to society-nature relations and the expansion of alternative ways of producing. Finally, the paper addressed valuation in the context of new molecular biotechnologies, asking how the new material constellations in this type of production may or may not reconfigure unequal social relations and their distribution in space and across various social relations. As illustrated by a brief comparison of two types of production based on molecular biotechnologies, it was suggested that production and valuation based on microorganisms such as yeast for the production of high-value industrial substances is substantially different than that based on molecularly-modified agricultural plants. This discussion underlined that the different kinds of material constellations in each one of these examples appeared to reinforce established patterns of how production and economic value are distributed, suggesting that the new material qualities associated

with the two types of resources would seem to reinforce established patterns in social relations and their unequal configurations, in particular the role of regions such as Latin America as providers of unprocessed primary goods while the accumulation of surplus value is spatially distributed in other regions, including via surplus profits. These preliminary observations suggested a future research agenda for exploring these valuation processes. In particular, an area of interest should be to study how the new materialities of engineered organisms, distributed through the reproductive patterns of the living organisms in space and time might also reconfigure social relations according to unexpected patterns, providing a possible 'wild card' in the study of social inequalities associated with production in which living organisms take a central stage.

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