# On Nonscalability: The Living World Is Not Amenable to Precision-Nested Scales

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# ON NONSCALABILITY

## The Living World Is Not Amenable to Precision-Nested Scales

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There is something disturbingly beautiful about precision, even when we know it fails us. A century ago, people stood awestruck at the terrible precision of the factory; today it is the precision of the computer. Precision has mesmerized not just engineers but all kinds of designers, scholars, and observers. One arena where precision has gained a malevolent hegemony is the use of scale. As in digital media, with its power to make the great tiny and the tiny great in an effortless zoom, *scale* has become a verb that requires precision; to scale well is to develop the quality called *scalability*, that is, the ability to expand—and expand, and expand—without rethinking basic elements. Scalability is, indeed, a triumph of precision design, not just in computers but in business, development, the "conquest" of nature, and, more generally, world making. It is a form of design that has a long history of dividing winners and losers. Yet it disguises such divisions by blocking our ability to notice the heterogeneity of the world; by its design, scalability allows us to see only uniform blocks, ready for further expansion. This essay recalls attention to the wild diversity of life on earth through the argument that it is time for a theory of *nonscalability*.[1]

1. An earlier version of this essay was presented at the "Conceptualizing the World" conference at the University of Oslo (September 2011). Conversations with colleagues there, as well as at the University of California, Santa Cruz; Aarhus University; Leiden University; and the University of Wisconsin "Globalization and the Humanities" conference (February 2010) have been most instructive.

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Even as technologies of scalability advance, the charm of world-making scalability is unraveling in our times. Scalability spreads—and yet it is constantly abandoned, leaving ruins. We need a nonscalability theory that pays attention to the mounting pile of ruins that scalability leaves behind. Nonscalability theory makes it possible to see how scalability uses articulations with nonscalable forms even as it denies or erases them. Entrepreneurs have already taken great advantage of this feature of the contemporary political economy. So have the plants and animals we call weeds and pests, and indeed the great variety of life that thrives with human disturbance. Yet scholars lag behind, holding on to the aesthetic pleasures of scalable precision even when it projects only our fantasies. It is time for scholars to look out beyond our models to the continuing vitality of life, both terrible and wonderful.

## Scalability and Expansion

Conceptualizing the world and making the world are wrapped up with each other—at least for those with the privilege to turn their dreams into action. The relationship goes both ways: new projects inspire new ways to think, which also inspire new projects. This essay concerns one historically significant link between conceptualizing and making the world: the naturalization of *expansion* as the way for humans to inhabit the earth. Why have people called expansion "growth" as if it were a biological process? I came to this question not only for historical reasons but also to consider contemporary challenges of how to live well with others—both other species and other cultures. European and North American elites have had trouble living with others, and not just because of prejudice. In the twentieth century, we became used to political ecologies of production—the production of stuff, the production of citizenship, and the production of knowledge—in which unauthorized others had no useful place. Others had no useful place because they got in the way of that expansion imagined as necessary for well-being; expansion was progress. Biological and cultural diversity were the enemies of progress. So it seems important to ask: What was that growth? What legacy has it left us with today?

Expansion reflects more than a will to power, although it may reflect that too. Expansion in the sense I am discussing is a technical problem, requiring considerable ingenuity in design. Ordinarily, things that expand change as they take on new materials and relationships. Let us say I expand my scholarly network to include colleagues in another country or another discipline. My scholarly outlook will change as I learn something new. This is not the kind of expansion I am discussing. The expansion that counted as progress did not allow changes in the nature of the expanding project. The whole point was to extend the project without transforming it at all. Otherwise it would not have added to the universal

prowess imagined as progress. This was a technical feat involving scale—that is, the relationship between the small and the large. Somehow, project elements had to be stabilized so that expansion added more elements without changing the program. My title calls this trick the "precision nesting" of scales, and the term works if applied to questions about design: the small is encompassed neatly by the large only when both are crafted for uniform expansion. Precision nesting must avoid the project-distorting effects of transformation. How do you keep project inputs standardized? How do you keep them self-contained, unable to form relationships? Relationships are potential vectors of transformation. Only without the indeterminacy of transformation can you nest scales—that is, move from small to large without redoing the design.

When small projects can become big without changing the nature of the project, we call that design feature "scalability." Scalability is a confusing term because it seems to mean something broader, the ability to use scale; but that is not the technical meaning of the term. Scalable projects are those that can expand without changing. My interest is in the exclusion of biological and cultural diversity from scalable designs. Scalability is possible only if project elements do not form transformative relationships that might change the project as elements are added. But transformative relationships are the medium for the emergence of diversity. Scalability projects banish meaningful diversity, which is to say, diversity that might change things.

Scalability is not an ordinary feature of nature. Making projects scalable takes a lot of work. Yet we take scalability so much for granted that scholars often imagine that, without scalable research designs, we would be stuck in tiny microworlds, unable to scale up. To "scale up," indeed, is to rely on scalability—to change the scale without changing the framework of knowledge or action. There are alternatives for changing world history locally and for telling big stories alongside small ones, and "nonscalability theory" is an alternative for conceptualizing the world. But before considering these alternatives, let me return to that familiar domain for experience with scalability: digital technology.

The digital technologies of the last fifty years have shown us the pleasures of the pixelated zoom: we move from tiny details to wide views with a few clicks. On our computers, we enlarge text and the alphabet looks just the same. Our digital photographs lend themselves to looking for details or panning for overviews. On the website "Paris 26 Gigapixels," we see all of Paris, or one room inside a window.[2] This wizard-like skill is scalability. In digital files, scalability is the ability to move across scales without changing the shapes of images, which is made possible by the stability of the pixel, the picture element. The digital image is made bigger or smaller by resizing the pixels. Of course, pixels must therefore

2. www.paris-26–gigapixels.com/index-en.html.

remain uniform, separate, and autonomous; they cannot bleed into each other or transform each other. Artists complain about pixelation, which fragments our vision of the world. Most of us do not care. But what made this technology so easy to imagine, I would argue, is the pixelated quality of the expansion-oriented world, which *is* something we ought to care about. To capture the vividness of the pixel, I will coin a parallel term. *Pixel* is an abbreviation of picture, "pix," and element, "el." Elements of the social landscape removed from formative social relations might be termed "nonsocial landscape elements" or, using the pixel formula, "nonso" plus "el" or *nonsoels*. How did we come to inhabit an expansionist world of nonsoels?

The term "scalability" had its original home not in technology but in business. Scalability in business is the ability of a firm to expand without changing the nature of what it does. "Economies of scale"—organizational practices that make goods cheaper because more are being produced—comprise one kind of business scalability. In contrast to digital technology, the point is not to zoom in; only expansion counts. Business scalability is about expansion for growth and profits: this was a tenet of twentieth-century progress. Under American hegemony, bigger was always better. Like business, development was supposed to scale up. The World Bank only funded village projects if they were already scalable; that is, if they could be spread to other villages without changing project elements. Indeed, the way you could tell if an institution was modern and developed, as opposed to backward, was if it was big. Bigness was progress.

Clifford Geertz went to study markets in Java at the height of this program, in the mid-twentieth century.[3] He was worried about what he saw: instead of scalable firms, Javanese traders based their businesses on *relationships* with buyers and other traders. Every time they expanded their networks, the business changed. Without scalable firms for expansion, Geertz argued, there could be no development. Javanese markets were hopelessly caught beyond the reach of progress. From our current perspective, Geertz's assessment tells us as much about the program of progress as it does about the Javanese.

Today, it is easy to look back with a critical eye on this twentieth-century program, because it has been challenged by changes in the global political economy. In the twenty-first century, the hegemony of economies of scale has crumbled before the advance of global supply chains in which economic activities are spread across many firms, in many places. Many powerful firms no longer strive just to be big; instead they use their "competencies" strategically. Competency here is one way of talking about privilege. Firms in powerful countries use their position to contract with firms in poor countries; and national elites, to contract

3. Clifford Geertz, *Peddlers and Princes: Social Development and Economic Change in Two Indonesian Towns* (Chicago: University of Chicago Press, 1968).

with their countries' disadvantaged. Competency is also a way of talking about cultural mobilization. Firms at every level save costs by getting workers to do their jobs for cultural reasons, rather than for wage-and-benefit packets. The turn to cultural niche making in the global economy is surprising from the perspective of twentieth-century ideals of scalability, which depended on the regularization and discipline of labor to drive expansion. Today, inventory is scalable, but both labor and natural-resource management are in retreat from scalability. Meanwhile, supply chains require attention to relationships among firms, rather than just expanding inputs; there is something here reminiscent of the progress-resisting practices of the Javanese traders Geertz described. All these developments allow us to look back at twentieth-century projects of scalability with an awareness of their limitations and failings, including their aversion to diversity and its consequence—imprecision.[4]

As for nonscalability theory: nonscalability is by no means better than scalability just by being nonscalable. The nonscalable aspects of the twenty-first century political economy do not represent an improvement over those of the twentieth century; indeed, they stimulate nostalgia for a moment when one could say "regulation" without politicians looking horrified. Both good and bad things can be nonscalable. Feudal service was a nonscalable form of labor but not commendable because of it. Cutting down a forest may be nonscalable but not, as a result, better than scientific forestry. At the same time, ecological complexity is nonscalable, and so is love; and we value these things. The difference between scalable and nonscalable designs cannot be placed a priori on a normative scale. The definition of nonscalability is in the negative: scalability is a distinctive design feature; nonscalability refers to everything that is without that feature, whether good or bad. But our not wanting something is no reason to ignore it. Nonscalability theory is an analytic apparatus that helps us notice nonscalable phenomena.[5]

Nonscalability theory allows scales to arise from the relationships that inform particular projects, scenes, or events. Many scale-making projects compete for the scholar or world-builder's attention; the trick is to trace or make relationships between projects. In that work, there are big stories as well as small ones to tell. There is no requirement that the scales nest or that one perform the

4. For additional discussion of supply-chain capitalism, see Anna Lowenhaupt Tsing, "Supply Chains and the Human Condition," *Rethinking Marxism* 21.2 (2009): 148–76.

5. In contrast, scalability theory asks how to make systems more scalable and takes the desirability of doing so for granted. Scalability theory is like nonscalability theory in tracking design problems that arise in making things scalable. (See, e.g., Martin Abbott and Michael Fisher, *The Art of Scalability* [Upper Saddle River, NJ: Addison-Wesley, 2010].) However, the point of scalability theory is not only to improve but also to *naturalize* scalability. In this framework, a system that works ought to be scalable, and nonscalable systems are understood to be flawed. The first step in building nonscalability theory is to denaturalize scalability, revealing its historicity and specifying alternatives.

wizardry of conversion from one to the other without distortion. Project scales jostle and contest each other. Because relationships are encounters across difference, they have a quality of indeterminacy. Relationships are transformative, and one is not sure of the outcome. Thus diversity-in-the-making is always part of the mix. Nonscalability theory requires attention to historical contingency, unexpected conjuncture, and the ways that contact across difference can produce new agendas. In earlier work, I have called these processes "friction."[6] This kind of friction is an important feature of nonscalability theory.

To demonstrate how scalability works through friction, let me begin to tell a nonscalable version of the history of scalability. One important model of scalability design was the plantation and, particularly, the European sugarcane plantations of the New World. These plantations developed the standardized and segregated nonsocial landscape elements, the "nonsoels," that showed how scalability might work to produce profit (and progress). Plantations gave us the equivalent of pixels for the land. But unlike pixels these plantations did not come into being through an already developed aesthetics of scalability. Instead they stumbled into history and only afterward became a model for further scalable designs. Attention to their stumbling—that is, the contingencies and conjunctures that informed their design—is the "nonscalable" approach I take to seeing where their plans failed to meet their own expectations. Scalability is never complete. If the world is still diverse and dynamic, it is because scalability never fulfills its own promises.

Nonscalability theory is of use even in recounting the highlights of scalability. Instead of taking scalability for granted as a necessary tool of progress, nonscalability theory attends to the work of contingency and failure. Nonscalability theory shows us scalability in action.

## Plantations as Models for Scalability

Scalability, one might argue, came into being with the European colonial plantation, as it emerged between the fifteenth and seventeenth centuries. Sugarcane plantations can show us how.[7] Early plantations were not designed with modern blueprints, and there were many dead ends. When the Spanish first tried planting cane in the Caribbean, for example, they employed Native Americans and used their mound-planting methods.[8] The cane grew, but the results were ordinary; in

6. Anna Lowenhaupt Tsing, *Friction: An Ethnography of Global Connections* (Princeton, NJ: Princeton University Press, 2005).

7. A rich interdisciplinary literature—comprising anthropology, geography, art history, and historical agronomy, among other fields—has gathered around the history of the sugarcane plantation. See especially Sidney Mintz, *Sweetness and Power: The Place of Sugar in Modern History* (Harmondsworth, UK: Penguin, 1986) and *Worker in the Cane* (New Haven, CT: Yale University Press, 1960); J. H. Galloway, *The Sugar Cane Industry* (Cambridge: Cambridge University Press, 1991); Jill Casid, *Sowing Empire* (Minneapolis: University of Minnesota Press, 2005); and Jonathan Sauer, *A Historical Geography of Crop Plants* (Boca Raton, FL: CRC Press, 1993).

8. Eric Wolf, *Europe and the People without History* (Berkeley: University of California Press, 1982).

other words, nonscalable. When the Spanish saw what the Portuguese were doing in Brazil, they gave up mounds and native peoples and copied the Portuguese. So it is to Portuguese experiments we might look to see how stable landscape elements were formed by contingency and friction.

Consider the nature of the cane itself, as Europeans knew it then: domestic sugarcane is not a proper species, not an interbreeding group of organisms. What Linneas called *Saccharum officinarum*, domestic sugarcane, is a group of vegetatively propagated clones.[9] Sugarcane was planted by sticking a cane in the ground and waiting for it to sprout. All plants were clones, and Europeans had no knowledge of how to breed this tropical species group. The interchangeability of planting stock was not a result of European intent but a characteristic of the cane. If Europeans had known how to choose new varieties, as Southeast Asians did, they would not have had to work so hard to grow the ones they had. But doing so forced them to experiment with new forms of land preparation, which led by chance to further forms of cane containment. In the New World, too, the cane had no history of either companion species or disease relations; it was isolated. Genetic isolates without interspecies ties: New World cane clones were the original nonsoels, landscape elements without transformative relationships. They made fields ready for expansion.

The original impetus for European sugarcane plantations was to obtain sugar not controlled by Muslims, but Europe was generally too cold to grow cane. When European voyages of discovery revealed warm new lands, investors raced to sponsor cane planting. By chance, one of the first Portuguese experiments was on the Atlantic island of Madeira, where a dry climate made the building of extensive irrigation works necessary, in the process remaking the landscape entirely.[10] The success of this experiment directed subsequent Portuguese efforts toward terraforming and irrigation, though neither was necessary to grow cane in the tropical New World, where flat and moist country was easily available. But it turned out that these technologies made a tighter *control* of cane growth possible, facilitating the interchangeability of elements and, thus, scalability. Irrigation helped to coordinate synchronized growth, facilitating the scalability of both resource management and labor. Meanwhile, colonial planters took control of native lands. Through doing away with native peoples and seizing their land, a

9. Many domestic sugarcane clones cannot reproduce sexually; breeders cannot develop new varieties with them. In the homeland of sugarcane in New Guinea and Southeast Asia, however, people have long produced new varieties through choosing useful hybrids of *Saccharum robustum* and *S. spontaneum*. Europeans came into this knowledge very late, only after they had finished conquering the world for sugar. Before the twentieth century, Europeans obtained new varieties only by getting samples from people who grew them. See Sauer, *Historical Geography of Crop Plants*, 236–50.

10. War captives were hung over cliffs to carve channels into the rock; many lost their lives in the process. Madeira's cane-preparation experiments thus also prefigured the use of unfree labor for scalable agribusiness. See Sidney Greenfield, "Madeira and the Beginnings of New World Sugar Cane Cultivation and Plantation Slavery: A Study in Institution Building," *Annals of the New York Academy of Sciences* 292 (1977): 536–52. Christopher Columbus went to check out Madeiran sugar and took Madeiran cane with him on his travels to the New World, where landscape reengineering for cane soon became the norm.

vast terrain for experimentation with nonsoels spread out before the European planters. As the geographer J. H. Galloway writes: "The vast plantations of Brazil presented a picture of abundant resources and profligate use that must have astonished anyone familiar with the careful husbandry of the tiny terraced fields of Madeira."[11] Despite the new terrain, planters followed the precedent established in Madeira by terraforming artificial cane-field modules. Brazil showed the potential of the Madeira experiment to create an expansion-oriented world through the replication of controlled field practices.

Portuguese cane growing came together with their newly gained power to extract enslaved people from Africa. As cane workers in the New World, enslaved Africans had great advantages from the growers' perspective: slaves had no local social relations and thus no easy place to run. Like the cane itself, they had been transplanted; and now they were isolated. They were on their way to becoming self-contained. Furthermore, the plantations were organized to foster alienation and thus enhance control. Once central milling operations were started, all operations had to run on the time frame of the mill. Workers had to cut cane as fast as they could, and with full attention, just to avoid injury. Under these conditions, workers became autonomous units.[12] Already considered commodities, they were given jobs made interchangeable by the monotonous regularity and coordinated timing engineered into the cane. Slaves were the next nonsoel, design elements engineered for expansion without change.

The success of the Brazilian experiment prompted Spanish, English, French, and Dutch versions in the Caribbean. Landscapes were transformed for the new, disciplined cane and its enslaved workforce. The art historian Jill Casid calls what they made "a hybrid agro-industrial landscape, a landscape machine," overseen by colonial grafting and drafting.[13] The Caribbean was just the start for this machine. When the abolition of the slave trade reduced the profits of the Atlantic exchange, growers took their terraforming machine to the Pacific. Coerced Asian labor took the place of Africans. Capital intensification resulted in fewer firms with more expensive milling technologies. Sugarcane production became increasingly tied to concentrated foreign capital. In Puerto Rico, the US occupation in 1901 signaled a new American sugar industry, controlled by a few giants that offered piecework and day wages. This is the industry that Sidney

11. Galloway, *Sugar Cane Industry*, 72.

12. Mintz described cane labor in the 1950s in Puerto Rico. Synchronized planting and harvesting of a single variety made attention to the growth of the plants unnecessary. Instead, discipline of humans and nonhumans was key. When harvest time was announced, the cane had to be cut and transferred to the factory in twenty-four hours, before any sugar was lost to fermentation. The coordination of time was of the essence. Workers were forced to use their full energy and attention to cut in synchrony and avoid injury. As Mintz's key informant put it, "I am really afraid of it. Especially when they are cutting cane heavy with trash [cane leaves], a machete can easily get entangled in the straw and incapacitate a man, what with so many people cutting at the same time." Mintz, *Worker in the Cane*, 202.

13. Casid, *Sowing Empire*, 44.

Mintz later described as producing a rural proletariat "doing battle" with the cane.[14] Replacing relations of care between farmers and crops, plantation designs led to alienation between workers and cane; cane was the enemy. At least in theory, such labor avoided transformative relationships and thus could not disturb system design. Human work and plant commodities each emerged as modules composed of stable and regularized units.

The experiment was a success: great profits were made in Europe, and most Europeans were too far away to see the effects. The project seemed, for the first time, scalable. Sugarcane plantations expanded and spread across the warm regions of the world. Their contingent components—cloned planting stock, unfree labor, and conquered, thus open, land to put them on—showed how making nonsoels could lead to unprecedented profits. This formula shaped a dream we have come to call modernity. Even now, we see a trace of the plantation in conditions we think of as modern. Modernity is, among other things, the triumph of technical prowess over nature. This triumph requires that nature be cleansed of transformative social relations; otherwise it cannot be the raw material of techne.[15] The plantation shows how: one must create *terra nullius*, nature without entangling claims. Native entanglements, human and not human, must be extinguished; remaking the landscape is a way to get rid of them. Then exotic workers and plants (or other project elements) can be brought in, engineered for alienation and control: nonsoels. Both work and nature are close to self-contained and interchangeable in relation to the project frame under these conditions, and thus the project is ready for expansion.

Expand it did. By the eighteenth century, Europeans thought that remaking the world as a plantation might be necessary to progress. They devised governance systems in which potential workers and natural resources were prepared for within-project interchangeability through administrative decree. They invented machines through which the interface between work and nature could be ever more tightly managed, facilitating scalable economic projects. Factories modeled themselves on plantations, building the segregation of work and nature, and the alienation of each, into their plans.[16] Meanwhile, with the enclosure of the peasant commons, a new kind of "free labor" appeared in cities. This displaced and already alienated labor could be set to work in factories with some of the same nonsoel control as enslaved labor. When Marx adapted the labor theory of value to talk about the factory, he proposed a history of the scalability of work. The commodification of "labor power" means that workers become interchangeable and self-contained elements of the factory, since only then are they able to sell

14. Mintz, *Worker in the Cane*, 16.

15. For a related analysis, see Bruno Latour, *We Have Never Been Modern*, trans. Catherine Porter (Cambridge, MA: Harvard University Press, 1993).

16. For discussion of sugar cane plantations as a model for factory discipline, see Mintz, *Sweetness and Power*, 47; also, Wolf, *Europe and the People without History*.

their abstract labor—that is, their ability to work in standardized conditions. The scalability of labor thus lies at the foundation of capitalism.[17] This point seemed so important that Marx hesitated to posit any constitutive "outside" within capitalism—any joints where scalability required articulations with nonscalable relations. Most Marxists have continued to treat the scalability of labor as limited only by the progress of the expansion of capitalism, itself a scalable project. As capitalism spreads, they argue, so too does scalability.

Investors have agreed. Thinking through scalability has allowed them to expand capitalism. By envisioning more and more of the world as the nonsoels of the plantation, they devised all kinds of new commodities, both material and virtual. Eventually, they posited that everything on earth—and beyond—might be scalable and thus exchangeable at market values. This was utilitarianism, which eventually congealed as neoclassical economics and contributed to forging more scalability. In contrast to Marxism, which considered the potential for radical change offered by scalability, neoclassical economics theorized the potential for scalability offered by even the most radical change.

What happened to diversity in the shadow of scalable projects? The free play of diversity was banished from the plantation and the factory. However, until the end of the nineteenth century, plantations and factories were islands of scalability in an ocean of nonscalable diversity. Only in the twentieth century did modernization and development spread scalability projects across the earth, shrinking what had been a diversity ocean into residual puddles. The twentieth-century advance of modernization succeeded, in part, through a chain of related projects in which government and industry formed joint-scalability pacts. In the beginning of the century, it was still colonial enterprise that formed the model. But as the century advanced, populist endorsements of scalability arose in the metropole. Both socialism and social democracy mobilized popular excitement about scalability: scalability was progress. For example, the New Deal in the United States enrolled unions and ignited popular sentiment in support of scalable business. By the mid-twentieth century, one role of government in the United States was to educate citizens for a role as interchangeable units of labor in industry. Another was to regulate natural resources, such as water and forests, to facilitate their use as scalable raw materials. Such arts of governance were supposed to build wealth and well-being by allowing economies of scale. Thus projects of training and regulation were spread around the world in the twentieth-century enthusiasm for global development. The new nations of the global south all wanted to remake their citizens and resources for scalability projects. Expansion was advancement.[18]

17. Karl Marx, *Capital: A Critique of Political Economy*, vol. 1, trans. Ben Fowkes (1976; Harmondsworth, UK: Penguin, 1992).

18. For a related analysis, see James Scott, *Seeing like a State* (New Haven, CT: Yale University Press, 1999).

In the last third of the century, critical social movements gathered steam. Minorities demanded rights. Environmentalists raged at nature's desecration. Indigenous people mobilized. By the 1990s, "diversity" as an issue had enough clout to acquire both lip service and co-optation from government and industry around the world. Yet by that time scalability seemed unstoppable. Many critics pointed to its problems: it did not stop for human needs. It did not stop at the destruction of nature. It knew no limits—only expansion. Widespread public realization of its horrors has not slowed it down. Perhaps, however, public notice has contributed to awareness of a different issue: scalability is always incomplete. Project elements are never fully under control. Even on the sugar plantation, enslaved workers slipped away to form maroon communities, and planting stock arrived with stowaway fungal rots that spread to the whole field. At best, scalable projects are articulations between scalable and nonscalable elements, in which nonscalable effects can be hidden from project investors. In the wake of nineteenth- and twentieth-century enthusiasms for scalability, the world today is crisscrossed by such articulations between the scalable and the nonscalable. Many projects for life—both human and otherwise—take place in the ruins of scalability designs.

## From Sugar to Mushrooms

To illustrate the uses of nonscalability theory, it may be helpful to turn to a completely different example, drawn from my collaborative research on the global ecologies and commodity chains of matsutake.[19] Found in forests across the northern hemisphere, matsutake are expensive wild mushrooms of especially high value in Japan, and so a transcontinental trade in them has emerged.[20] As icons for scalability, matsutake and sugarcane occupy opposite ends of the spectrum. Sugarcane is grown as self-contained clones, nonsoels ready for expansion. Matsutake, in contrast, cannot live without transformative relations with other species; they refuse to become nonsoels. Matsutake mushrooms are the fruiting bodies of an underground fungus associated with certain forest trees. The fungus gets its carbohydrates from mutualistic relations with the roots of its host trees, for which it also forages. Matsutake make it possible for host trees to live in poor soils, without fertile humus. In turn, the fungi are nourished by the trees. This transformative mutualism has made it impossible for humans to cultivate matsutake. Japanese research institutions have thrown millions of yen into making

19. The Matsutake Worlds Research Group consists of Tim Choy, Lieba Faier, Michael Hathaway, Miyako Inoue, and Shiho Satsuka, as well as myself. Parts of our research were supported by grants from the Toyota Foundation and the UC Pacific Rim research initiative.

20. The term *matsutake* refers to mushrooms acceptable in the transnational trade, including *Tricholoma matsutake* from Eurasia, *T. magnivelera* from North America, and *T. caligatum* from North Africa.

matsutake cultivation possible, but so far without success. Matsutake resist the conditions of the plantation. They require the dynamic multispecies diversity of the forest.[21]

Just as sugarcane allowed me to tell a story about the advance of scalability projects through the reordering of the social-natural landscape, matsutake provoke a story about life in the ruins of scalability. In the United States, matsutake grow in the ruins of industrial forests—a scalability project gone awry. They allow us to consider the diversity of life in such ruins. They show us how human livelihoods are eked from nonscalable resource patches without the fanfare—or planning, or work—of making things scalable. And because matsutake pickers are something like the opposite of scalable labor, they allow us to consider the possibilities of forms of capitalism that wind in and out of scalability. Much of the world's economy looks more like this, I would argue, than conventional economic models (whether liberal or Marxist) show us. Expectations about scalability have blinded observers to the vitality of nonscalable worlds—and to the links between the scalable and nonscalable.

Consider the Pacific Northwest, the most concentrated area for twentieth-century scientific-industrial forestry in the United States. The Pacific Northwest attracted the timber industry after it had already destroyed midwestern forests and just as scientific forestry became a power in US administration. More recently, big timber moved on. The region's centrality as the crucible of timber policy and practice in the United States thus neatly spans the twentieth century. Private and public (and, later, environmentalist) forest interests battled it out in the Pacific Northwest; the scientific-industrial forestry on which they tenuously agreed was a creature of many compromises. Still, here is a place to see forests treated as much like scalable plantations as they might ever be. During the heyday of joint public-private industrial forestry in the 1960s and 1970s, model forests were monocrop, even-aged timber stands. Such management took a huge amount of work. Unwanted tree species, and indeed all other species, were sprayed with poison. Fires were absolutely excluded. "Superior" trees were planted by alienated work crews, sometimes prisoners. Thinning was brutal, regular, and essential. Proper spacing allowed maximum rates of growth as well as mechanical harvesting. Timber trees were a new kind of sugarcane: managed for uniform growth, without multispecies interference, thinned and

21. For matsutake biology, see Ogawa Makoto, *Matsutake no seibutsugaku* (*Biology of matsutake mushrooms*) (Tokyo: Tsukiji Shokan, 1991); David Hosford, David Pilz, Randy Molina, and Michael Amaranthus, "Ecology and Management of the Commercially Harvested American Matsutake Mushroom," USDA Forest Service General Technical Report PNW–412 (1997). For matsutake social worlds, see Matsutake Worlds Research Group, "A New Form of Collaboration in Cultural Anthropology: Matsutake Worlds," *American Ethnologist* 36.2 (2009): 380–403; Anna Lowenhaupt Tsing, "Beyond Economic and Ecological Standardization," *Australian Journal of Anthropology* 20.3 (2009): 347–68.

harvested by machines and anonymous work crews. They were nonsoels, units of controlled expansion.[22]

Despite its technological prowess, the project of turning forests into plantations worked out unevenly, at best. Earlier, timber companies had made a killing just by harvesting the most expensive trees; when US national forests were opened after World War II, they continued this policy of "high grading," dignified under standards that said mature trees were better replaced by fast-growing youngsters. Clear cutting, or "even-aged management," was introduced to move beyond the inefficiencies of such pick-and-choose harvesting. But the regrowing trees of scientific-industrial management were not so inviting, in terms of profit. In places where the great timber species had earlier been maintained by fire regimes, including Native American burning, it was difficult to reproduce the "right" species. Firs and spindly lodgepole pines grew up where great ponderosas had once held dominance. Meanwhile, the price of Pacific Northwest timber plummeted as Japan found cheaper Southeast Asian trees to import. Without the easy pickings of high grading, timber companies began to search elsewhere for cheaper trees. Without the political clout and funds of big timber, the regional Forest Service lost funding, and maintaining plantation-like forests became cost prohibitive. At this same time, environmentalists started going to the courts, asking for stricter conservation protections. The environmentalists were easily blamed for the crashing timber economy, but the timber companies—and most of the big trees—had already left.[23]

By the time I first wandered into the eastern Cascades, in 2004, fir and lodgepole had made great advances across what once were almost pure stands of ponderosa pine. The Forest Service had no funds for forest management except those generated by offering timber contracts; thus they had to give away their best timber just to thin the dense and fire-prone brush of regrowing lodgepole. Although signs along the highways still said "Industrial Timber," it was hard to imagine money rolling in. The landscape was covered with thickets of lodgepole and fir: too small for most timber users, not scenic enough for recreation. But something else had emerged in the regional economy: matsutake mushrooms. Although Japanese Americans began harvesting matsutake from the Cascades in the early twentieth century, most foresters and regional planners never noticed

22. My discussion of Pacific Northwest forestry draws particularly on William Robbins, *Landscapes of Conflict* (Seattle: University of Washington Press, 2004); Paul Hirt, *A Conspiracy of Optimism* (Lincoln: University of Nebraska Press, 1994); Richard Rajala, *Clearcutting the Pacific Rain Forest: Production, Science, and Regulation* (Vancouver: UBC Press, 1998).

23. For what went wrong, see Nancy Langston, *Forest Dreams, Forest Nightmares* (Seattle: University of Washington Press, 1996). For the eastern Cascades, see Mike Znerold, "A New Integrated Forest Resource Plan for Ponderosa Pine Forests on the Deschutes National Forest" (paper presented at the Ontario Ministry of Natural Resources workshop, "Tools for Site Specific Silviculture in Northwestern Ontario," Thunder Bay, Ontario, April 19–20, 1989).

matsutake: this was timber country.[24] Still, beneath official notice, matsutake nurtured timber. Some matsutake grow with ponderosa pine, the prime timber species. Shasta red fir is such a good host for matsutake that some pickers call it the "mushroom tree." Most strikingly, matsutake produce mushrooms especially well under mature lodgepoles, But these exist in prodigious numbers in the eastern Cascades only because of fire exclusion, the starting point of industrial forestry. Fire exclusion has made it more difficult for the ponderosas to reestablish their dominance after logging, and lodgepoles have spread. Despite their flammability, they are allowed a long maturity. Matsutake flourish only after forty to fifty years.[25] The abundance of matsutake may derive in part from the conditions of both making and abandoning industrial forests in the Pacific Northwest.

In this combination of changing ecologies and changing perspectival frames, the matsutake economy blossomed in the late 1980s. Japan's own changing ecology had made matsutake rare there by the 1970s; at the same time, its boom economy of the 1970s and 1980s made expensive imports possible. There was also ready labor—not only the discards of the logging industry in the Pacific Northwest, who were already familiar with the forest, but also a new migration of Southeast Asian refugees, fresh from experience with precarious survival. But this labor was totally different from that of the tree-planting and -thinning crews; it was impossible to recruit and impossible to discipline. It was unresponsive to authority. It self-mobilized.

Matsutake foragers in the Pacific Northwest work only for themselves. Most are there because they love mushroom picking—for the freedom of the forest, for the independent searching, and for the money, which they use to support themselves. Many are war survivors whose priority is living through their trauma in the forest, with its openness to both forgetting and remembering war.[26] Even though they work, matsutake foragers do not fit the requirements for capitalist labor: they receive no wages; they do not have standardized work practices that can be accounted for as "abstract labor"; they do not feel alienated from the work process. They are nothing like nonsoels. Since they come for their own reasons, it would be impossible to expand the work unit without transforming it. Anyone can join, for his or her own reasons. Workers from Mexico and Guatemala do not share ideals of forest work as war survival. Native Americans pick to revive their connections to the land. But whites and Southeast Asians looking for something they call "freedom" dominate the scene.[27]

24. In 2005, an impressive celebration of the Japanese American matsutake legacy was held at the Oregon Nikkei Legacy Center in Portland.

25. Forester Phil Cruz, personal communication, October 2004.

26. See Anna Lowenhaupt Tsing, "Free in the Forest: Popular Neoliberalism and the Aftermath of War in the US Pacific Northwest," in *States of (In)security*, ed. Zeynep Gambetti and Marcial Godoy-Anatiria, forthcoming.

27. This concept of "freedom" touches neoliberal economic ideologies but is too much shaped by cultures of war survival to be synonymous. Matsutake pickers do not believe that they must become autonomous units of choice to be "free." Instead, "freedom" furthers communal cultural agendas of war survival. See Tsing, "Free in the Forest."

Mushrooms are foraged during the day and sold to independent buyers in the evening. Buyers sell to bulkers who sell to exporters who send the mushrooms on their way to Japan by early the next morning. Amazingly, by the time the mushrooms are in the belly of the plane, they have taken the form of scalable inventory: a capitalist commodity sorted by its maturity, size, and weight.[28] Expansion is suddenly easy for these packaged mushrooms; dissociated from the forest and the foragers, they are workable nonsoels. Here we have stumbled on another kind of articulation between the nonscalable and the scalable—not the ruins of scalability, but the recuperation of nonscalable forest resources for scalable inventory. Transformation from unscalable process to scalable inventory is what the contemporary capitalism of supply chains does best. Perhaps this return to scalability is a good place to turn back to general issues.

### Pirates, or Nonscalability for Old Hands

Scalable projects are everywhere linked with nonscalable worlds. In one kind of link, scalability becomes riddled with nonscalability, just as weeds take over plantations every time the poison lets up. One might see the weeds as taking advantage of the hard work of making the plantation, from eradicating the original flora to providing water and fertilizers. Weeds here are "pirates" of scalability, reaping the rewards of plantation work. Matsutake in industrial forests are one kind of weed. Meanwhile, there is another kind of linking: scalable projects can reap the rewards of nonscalability. The pirates here are the sponsors of scalability, stealing from the work of transformative relations. For example, most grasses, including sugarcane, benefit from transformative associations with fungi. The fungi aid the plants' search for nutrients, while also protecting the plants from harmful bacteria.[29] But these are endomycorrhizal fungi, which are found entirely inside the plants. Until recently, European cane producers were entirely unaware that their sugarcane clones contained another species, a species that helped the sugarcane to grow. Plantations were designed with the idea that only one crop was relevant: the sugarcane. Yet plantation owners were pirates, reaping the rewards of the transformative work of sugarcane-fungal relations.

This kind of piracy is illustrative of an emergent form of global capitalism that I have called "supply-chain capitalism."[30] The name is supposed to be

28. See Anna Lowenhaupt Tsing, "Sorting Out Commodities," in *The Paradox of Value*, ed. Ton Otto and Rane Willerslev, forthcoming.

29. See, e.g., S. F. Jamal, Patrice Cadet, R. S. Rutherford, and C. J. Straker, "Effect of Mycorrhiza on the Nutrient Uptake of Sugarcane," *Proceedings of the South African Sugar Technology Association* 78 (2004): 343–47, www.sasta.co.za/wp-content/uploads/Proceedings/2000s/2004_jamal_EFFECT%20OF%20MYCORRHIZA%20ON%20THE.pdf.

30. See Tsing, "Supply Chains and the Human Condition." Making use of links between scalable projects and unscalable relations is not limited to supply-chain capitalism, though the process is especially clear in that context.

jarring: "supply chain" is the term used by enthusiasts, while "capitalism" is the term used by critics. I use it to describe the supply-chain-based political economy that, since the 1970s, has emerged with the rise of finance capital. At the heart of this system are links between scalable and nonscalable projects, which is why conventional social analysts have not been able to see it very clearly. The uneasiness of the name is intended to stimulate awareness. Japanese supply chains are a good place to start. In the 1960s and 1970s, general trading companies in Japan perfected the art of forging global supply chains. Since the nineteenth-century Meiji Restoration, Japanese have characterized their country as dependent on foreign resources, making international trade a key sector for national development. General trading companies were a post–World War II version of how to craft such ties.[31] Unlike American companies of that time, they had no interest (despite their vast wealth) in taking over production in the various countries from which they bought supplies. Japanese companies were traders: their goal was to turn products created in strange places and processes into inventory. Their secret of success was to imagine this practice as the work of sorting and translation; they dictated standards but allowed producers to obtain the products through any crazy means producers wanted. Thus, for example, to obtain cheap timber, the trading companies made deals with corrupt officials and vicious generals in Southeast Asia, who, in turn, bulldozed the forest territories of villagers. The traders were not responsible, and the wood was cheap.[32] (Hence the drop in prices that helped drive timber companies from the US Pacific Northwest, giving birth to that region's matsutake economy.)

In this model, production need not be scalable. In Southeast Asian forests, for instance, timber was obtained by merely cutting without replenishing: this is not scalability. But the same timber became scalable when it entered the inventory of Japanese traders. Its origins and the process of harvesting were erased; it was sorted and translated into size, wood quality, and weight. In transport, it became a nonsoel, ready for expansion. Inventory making, a project of scalability, reaped the benefits of a nonscalable process of forest destruction and indigenous displacement. Piracy of this sort makes supply-chain capitalism work.

The success of Japanese trading companies was one factor promoting the US "stockholders revolution" of the 1980s and 1990s, in which big companies were dismantled and replaced with supply chains. US investors were worried that the United States was losing its global power, and they thought it might be

31. See Alexander Young, *The Sogo Shosha: Japan's Multinational Trading Companies* (Boulder, CO: Westview, 1979); Michael Yoshino and Thomas Lifson, *The Invisible Link: Japan's Sogo Shosha and the Organization of Trade* (Cambridge: MA: MIT Press, 1986).

32. See Peter Dauvergne, *Shadows in the Forest: Japan and the Politics of Timber in Southeast Asia* (Cambridge, MA: MIT Press, 1997); Michael L. Ross, *Timber Booms and Institutional Breakdowns in Southeast Asia* (Cambridge: Cambridge University Press, 2001).

renewed by taking advantage of the leverage of American money.[33] The result was a cross continental supply-chain network that quickly dwarfed the Japanese experiment. The goals were, however, similar: to outsource costs and responsibility in order to reap inventory and profits. The key, again, is to allow producers to use any methods they want. Later the goods can be converted to inventory.

Much of the nonscalability exploited in this system is shocking. Instead of using alienated and disciplined labor, violence and intimidation can be used to recruit workers. Instead of even pretending to maintain resources, raw materials can be stolen, salvaged, or adulterated with cheap poisons. As I have been arguing, just because something is nonscalable does not mean it is good. US inventory behemoths, such as Walmart and Amazon, show the economics of pushing costs back to producers so that products can be sold at "everyday low prices." Producers must find a way to please such harsh masters, which usually means eliminating labor and environmental standards while churning out more junk.[34]

But the nonscalability exploited by supply-chain capitalism is not *necessarily* terrible. The point is to save costs, and cost saving is variable. The United States-to-Japan matsutake commodity chain is an example of a relatively benign form of supply-chain capitalism. There are no costs of labor recruitment and discipline, and no benefits. Matsutake pickers work for their own reasons. There are no costs of raw-material renewal. The mushrooms are foraged on national land. Traders do not try to control production; they merely turn these nonscalable production relations into scalable inventory. As pirates, they enjoy the assets of this conversion. And while the matsutake commodity chain is an unusually benign case, it also exemplifies two key principles of supply-chain capitalism: independent contracting as labor; and stealing, foraging, or salvaging as resource procurement. Independent contracting is supply-chain capitalism's signature form of labor; independent contractors recruit and discipline themselves with no cost or responsibilities for lead firms. And why do all the work of starting a plantation if you can take raw materials for free from public or common sources? These forms of nonscalability have become the lifeblood of supply-chain capitalism, from software to mining. Here scalable commodities are made through the exploitation (in the natural-resource sense) of nonscalable labor and environmental relations. Grab—and convert to inventory.

Why have scholars and pundits not described these features of supply chains? Why might knowledge workers be slow to notice what entrepreneurs—not to speak of weeds and fungi—have made use of for so long?

33. See Chris Gregory, *Savage Money* (Amsterdam: Harwood, 1997); Karen Ho, *Liquidated* (Durham, NC: Duke University Press, 2009).

34. Walmart's supply-chain practices are increasingly well documented; see, e.g., Nelson Lichtenstein, ed., *Walmart: The Face of Twenty-First-Century Capitalism* (New York: New Press, 2006).

**Nonscalability for Beginners**

To pay attention to articulations between the scalable and the nonscalable requires rethinking our knowledge practices, which have been shaped within the history of remaking the world for scalability. To explain how requires returning to the design features of scalability.

Most modern science demands scalability, the ability to make one's research framework apply to greater scales without budging the frame. This kind of expansion is only possible when the research framework parses stable data elements—the nonsoels of science. Only data of the same sort can be added to the research without messing up the frame. Thus an economics research project that studies household income can expand to engulf data from many households, but if a data gatherer shows that households are not a unit of income in the place she is recording data, her data can only be discarded. It would destroy the frame of the research to include it. Only data that have been gathered to fit a particular standard allow the research to be expandable. The units of analysis must be stably defined across instances and interchangeable in their relationship to the research frame. Everything outside the nonsoels made by scalability projects is banished here and, with it, the free play of kinds from which diversity emerges. This kind of knowledge cannot see nonscalability, because of the constitutive scalability of its own practices.

The problems of diversity, and of living together with others, require other modes of knowledge. Nonsoels are not enough, whether for knowledge about humans or other species. Consider the global political economy. It seems to me a striking fact that scholars and journalists have conducted many, many studies of the diverse niches that are drawn into global capitalism today. We know about rug-making children and indigenous suppliers of supermarkets and stinking computer graveyards. But most scholars of the global economy as a whole, whether qualitative or quantitative, Marxist or liberal, angry or self-satisfied, are still stuck on scalability assumptions and thus rarely make use of this wealth of ethnographic data. Its anecdotes are isolated, kept outside their big stories. These stories are continuations of twentieth-century scalability stories; the transformative diversity of economic niches is missing. We need nonscalability theory to tell a different story, a story alert to the awkward, fuzzy translations and disjunctures inherent in global supply chains. There are many scale-making projects here, and they do not nest neatly. Nonscalability theory shows us the architecture of nonnesting, which is key to the (re)making of cultural diversity, capitalist and otherwise.

The problem is equally severe in thinking about biological diversity. Classic twentieth-century population genetics blocked attention to diversity-making processes, because it was a science of expansion. By taking scalability for granted, it asked how populations expand. Expansion was possible because each organism

was thought to be autonomous, a nonsoel. Collaboration was not necessary for survival. Diversity was the current scoreboard of varied but similarly autonomous strategies of conquest. To see the *making* of diversity, we need something different. In recent years, the spark has come from a new combination of evolutionary, ecological, and developmental biology, which has studied interactions across species in the generation of multispecies life.[35] For humans, this field shows how much we need the bacteria in our guts and in our skin to become who we are. Note how this knowledge changes the scale-making project. Our units are transformative relations, not self-contained nonsoels. The question of emergence takes precedence over expansion and is, thus, an application of nonscalability theory.

Matsutake show us this kind of biological diversity. Matsutake are creatures of disturbed forests, where they live in relations with tree roots. They do not grow where soils are rich and full of nutrients, but rather where glaciers, volcanoes, drifting sand—or human activities—have deprived the land of nourishing humus. Most commercially collected matsutake grow in industrial forests or peasant forests. In these human-disturbed places, matsutake show us the forms of collaborative survival—the transformative social relations—that make life possible. The forests inhabited by matsutake are collaborations among many species, including humans. We need nonscalability theory to understand how such multispecies landscapes work. Rather than scalable science, the place to start is *critical description* of relational encounters across difference. But that topic is for another article. Here, it is time to rehearse my main points: the ease with which our computers zoom across magnifications lulls us into the false belief that both knowledge and things exist by nature in precision-nested scales. Scalability, again, is this ability to expand without distorting the framework. But it takes hard work to make knowledge, landscapes, and projects scalable. What I have tried to show is how that work, by its design, covers up and attempts to block the transformative diversity of social relations. From this perspective, the history of scalability must be considered in relation to both its moments of success and its sometimes-happy failures.

Projects that could expand through scalability were the poster children of modernization and development. Agribusiness expanded. Biological populations expanded. Scalable approaches to knowledge expanded. We learned to know the modern by its ability to scale up. Scalable expansion reduced a once surrounding ocean of diversity into a few remaining puddles. Project advocates thought that they had grasped the world. But they have been confronted with two problems: first, expandability has gotten out of control. Second, scalability has left ruins in its wake. Nonscalable effects that once could be swept under the rug have come to haunt us all.

35. See, e.g., Scott Gilbert and David Epel, *Ecological Developmental Biology* (Sunderland, MA: Sinauer, 2008).

How is scalability created? It is not a necessary feature of the world. People stumbled on scalable projects through historical contingencies. They cobbled together ways to make raw materials (for both goods and knowledge) self-contained and static, and thus amenable to expansion. In European sugarcane plantations, the natives were wiped out; exotic, coerced, and alienated plants and workers came to substitute for them. Profits were made because the general mess of extermination and slavery could be discounted from the books. Such historically indeterminate encounters formed models for later projects of scalability.

Do we live in a world of scalable nonsocial landscape elements—nonsoels? Yes and no. The great "progress" projects of the last several centuries have built on the legacy of the colonial plantation to make scalability work in business, government, and technology. But scalability has never been complete. In recent years, changes in global capitalism have challenged the assumption of scalability for labor and natural-resource management, and at least some theorists in the social sciences have pointed out the malevolent hegemony of precision. Meanwhile, critics of scalability have raised distress signals about the fate of biological and cultural diversity on earth. It is an important time to develop nonscalability theory as a way to reconceptualize the world—and perhaps rebuild it.