

Chapter 5

Basins of Attraction for Generative Justice

Ron Eglash and Colin Garvey

Abstract It has long been known that dynamic systems typically tend towards some state – an “attractor” – into which they finally settle. The introduction of chaos theory has modified our understanding of these attractors: we no longer think of the final “resting state” as necessarily being at rest. In this essay we consider the attractors of social ecologies: the networks of people, technologies and natural resources that makeup our built environments. Following the work of “communitarians” we posit that basins of attraction could be created for social ecologies that foster both environmental sustainability and social justice. We refer to this confluence as “generative justice”; a phrase which references both the “bottom-up”, self-generating source of its adaptive meta stability, as well as its grounding in the ethics of egalitarian political theory.

Keywords Chaos theory • Attractor • Generative justice • Industrial ecology • Open source

It has long been known that dynamic systems typically tend towards some state – an “attractor” – into which they finally settle: a driven pendulum like a metronome will settle into a repetitive cycle; a racing heart will return to its normal rate after a sprint; an ecosystem will eventually find a stable re-configuration given a newly introduced species. The introduction of chaos theory has modified our understanding of these attractors. We no longer think of the final “resting state” as necessarily being at rest. We now know that a driven double pendulum can settle into a chaotic attractor that never repeats its motion [7]. The beating heart, which seems to be a simple cycle, is actually a subtle chaotic attractor whose variation is key to cardiac health [13].

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And ecosystems which were once seen to settle into a static climax community are now regarded as the ever-changing results of chaotic attractors [22]; what is sometimes referred to as the “metastability” of complex adaptive systems. In this essay we consider the attractors of social ecologies: the networks of people, technologies and natural resources that make up our built environments. Following the work of “communitarians” such as Kropotkin [16], Ostrom [23], Benkler [2] and others, we posit that basins of attraction could be created for social ecologies that foster both environmental sustainability and social justice. We refer to this confluence as “generative justice” [9, 10]; a phrase which references both the “bottom-up”, self-generating source of its adaptive metastability, as well as its grounding in the ethics of egalitarian political theory.

5.1 Generative Justice: Bottom-Up Flows of Value in Social Ecologies

The theory of generative justice posits that both environmental sustainability and social justice can be improved by self-organized flows of value through social ecologies. Adam Smith noted that a commodity such a precious gem may have “exchange value” – you can trade it for other goods or currency – without having “use-value.” Marx made use of this distinction in defining exploitation: by paying only a small wage to the laborers in a factory or farm, the owners of that “means of production” can essentially extract much of the value they produce. In the early 1990s, a new “ecological Marxism” brought this conception of value to bear on the ways that the means of production extracted value from Nature (e.g. [25]). Just as value is extracted from labor, it is also extracted from nature: in the form of either a source for materials, a sink for pollution, or even the useful work performed by a dammed river.

At the same time that Marxist theory was finding more success in ecological views, Marxist practice was finding defeat in the dissolution of the USSR. If it was not obvious before, it became increasingly clear that the extraction of value from labor and nature in the former USSR was at least as exploitative, destructive and unjust under Russian communism than it was under American capitalism [1]. But why?

Both labor and nature are “generators” of value, and they can regenerate if allowed the resources to do so. But externalizing those costs – making workers pay for their own health insurance, or making nature plant trees for reforestation – will increase profits. Figure 5.1 shows the system of value flows under capitalist or communist governance. Note that some small flows loop from labor back to labor: workers continue to take care of their health and households as best they can. Similarly, nature regenerates from its exploitation to the extent it is able. But most of the value is extracted. Under liberal capitalism some of this value is returned because of taxes: as social services to labor or environmental services to nature.

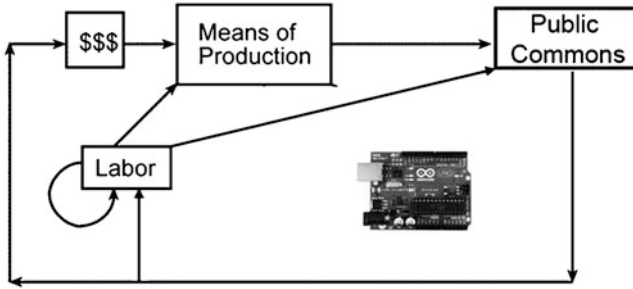


Fig. 5.3 Flow of value in the Arduino open source community

created a “tragedy of the commons,” and voluntary community associations prevented one. Most indigenous economic traditions do not depend on an “alienated” route for returning value to the value-generators. Rather than extracting value through socialist national ownership or capitalist state taxes which might, some day, be eventually returned via some government payment or service, the indigenous tradition allows labor’s herders to integrate local social networks directly with the value produced by their herds. Rather than deplete soil by monocropping and use the income to purchase commercial chemical amendments that might eventually ameliorate the imbalance, the indigenous agroecology allows the soil ecosystem to directly integrate its networks with the fertilization of the animals they support.

One critique of such portraits is that they can only work for people who live “simple,” pre-industrial lives. This is wrong on two counts. First, the model of “generative justice” also fits communities based on Open Source sharing. Arduino, for example, is an Open Source microprocessor that has spawned a surprisingly large community of lay and professional users across the world. Figure 5.3 visualizes some of the flows of value. Unlike the case of proprietary hardware in which users merely carry out consumption, delivering profits to a corporation, the “public commons” in which the Arduino circuits, code and applications are legally owned is both consumer and producer, and thus supplies profits to keep the enterprise financially solvent and yet significant value returns to the source of value generation: the DIY “maker” community.

The second reason that this critique of “simple lives” is incorrect is that even in the case of indigenous traditions, the fact that value is returned in less alienated forms does not mean the paths of flow are simple. Phrases such as “directly integrate” are just shorthand for what are actually highly intricate networks. Lansing and Kremer [17] for example describe how Balinese rice farmers combine spiritual beliefs, ecological knowledge, and representational forms such as the wooden “tika” calendar to collaboratively schedule interlocking irrigation patterns. Despite the potential for conflict over water, this adaptive synthesis of virtual and material aspects allows them to do so without any centralized authority.

We will shortly compare these two cases of generative justice – indigenous irrigation and open source information technology – and show that both can be described using the framework of basins of attraction from nonlinear dynamics. We first offer an introduction to the concept of basins of attraction for those unfamiliar with this model.

5.2 Basics of Basins of Attraction

One of the best ways of obtaining an intuitive understanding for a basin of attraction is to consider a simple pendulum. We know that a pendulum with friction will swing in smaller and smaller angles, eventually coming to a halt. Figure 5.4 shows how plotting the angle and velocity of the pendulum will form a spiral, because these quantities are 180° out of phase. Hence the term “phase space”. The point at the center is a “point attractor.” In Fig. 5.5 we try this same plot for many different starting points. No matter what the starting positions, we end up in the same point attractor. Thus we are always in its “basin of attraction.” One way to gain better intuition about basins of attraction is to add a third dimension such as potential energy. This helps us see that a basin of attraction is similar to the role that gravitational attraction would play in a physical 3D surface, as shown on the right.

Figure 5.6 shows the phase space plot for an inverted pendulum, such as a flexible rod with a weight on the end. Here there are two basins of attraction. Unlike the case of the single pendulum, in which all initial conditions land us in the same attractor, the initial conditions matter greatly. Keeping a system within the basin of attraction characterized by generative justice is the primary goal for our analytic framework.

Finally, Fig. 5.7 shows a phase space plot for a driven pendulum, in which there is a vertical motion in addition to the horizontal swing. Unlike the repetitive cycles of the simple pendulum, the driven pendulum has a chaotic attractor: the behavior will remain bounded but never precisely repeat the same values. As noted in the

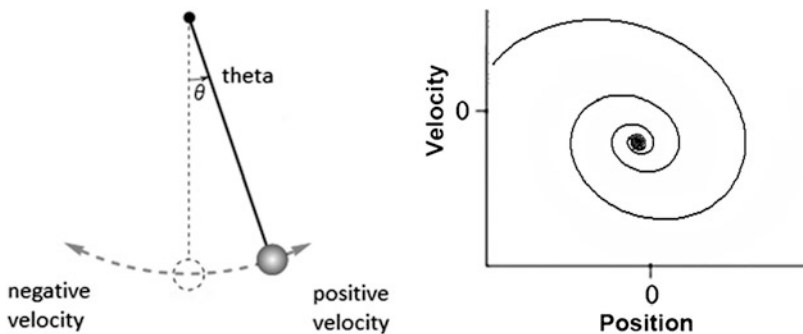


Fig. 5.4 Phase space plot of angle and velocity for a pendulum

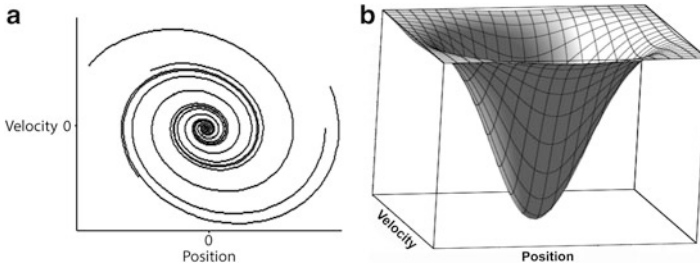


Fig. 5.5 (a) Phase space plot for many different starting positions, showing the basin of attraction. (b) The same basin of attraction as in (a), with a 3rd dimension showing potential energy

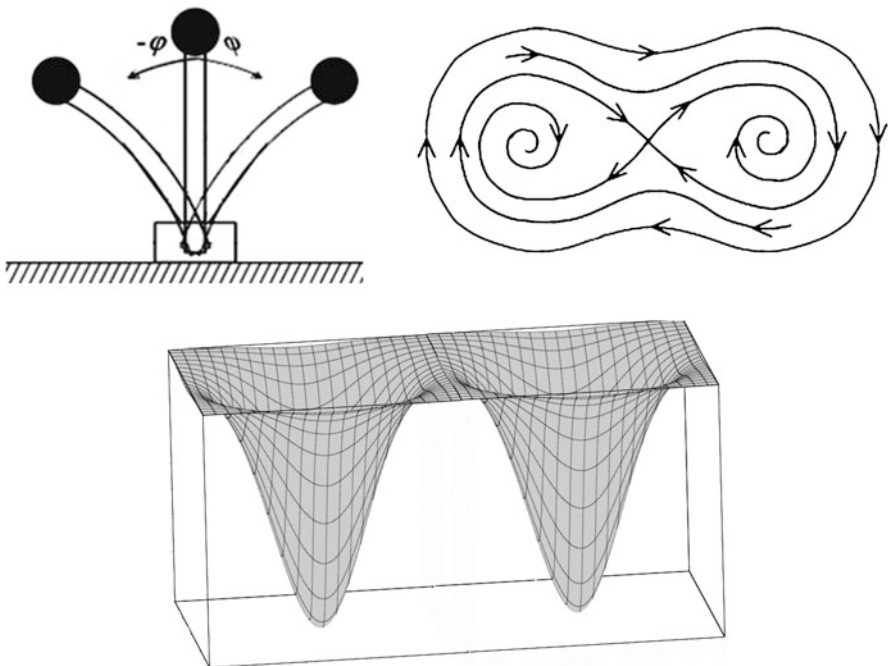


Fig. 5.6 Basins of attraction in 2D and 3D for the inverted pendulum

introduction, research now supports the idea that such mechanisms for internal variation in biological systems – even in something as seemingly repetitive as a heart beat – are an important means by which complex adaptive systems are able to maintain both flexibility in the face of external perturbations and resilience that prevents the system from moving to the “wrong” basin (in our case, that of social injustice and environmental instability).

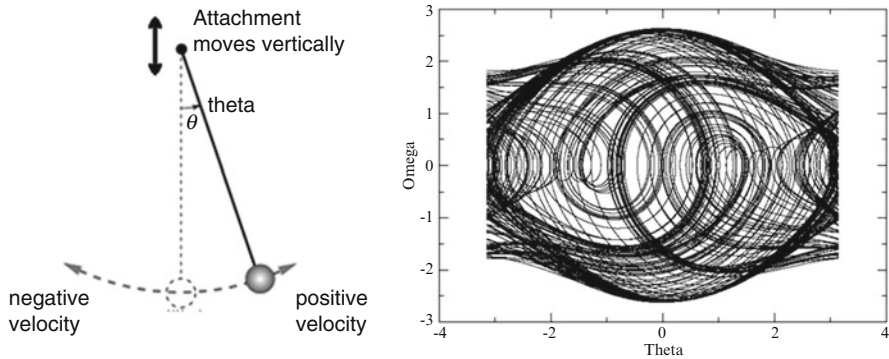


Fig. 5.7 Chaotic attractor of the driven pendulum

5.3 Basins of Attraction in Generative Justice: Comparing Balinese Rice Irrigation and Open Source Software Production

As noted previously, Lansing’s analysis of rice irrigation in Bali offers a well-studied model for how a social ecology can form a basin of attraction around the immediate return of value to its generative sources in labor and nature. Rice farmers on the island of Bali create terraces on its volcanic slope that require an extensive network of irrigation canals, governed by “water temples” which divert and regulate flow. Because water is a precious and well-regulated resource in this context, previous scholars assumed that there must be a hierarchy in which higher social power resides higher up the gravitational aquifer. But Lansing’s careful analysis showed that in fact the schedules for water irrigation are created in an egalitarian, self-organized consensus process. One explanation he provides for this cooperative basin of attraction – an excellent illustration of generative justice – is that pest populations are kept to a minimum by simultaneously flooding or draining nearby fields. If they are not synchronized in their irrigation patterns, pest explosions result, because the pests fleeing a newly flooded field can just hop over to a dry patch next door (and the converse for pests that require an all-wet environment). The results of Lansing’s survey matches the prediction of his model: farmers at the level of a water temple say they fear pests the most, and farmers downhill from the water temple say they fear droughts the most.

Lansing and Miller [18] formalize these observations using game theory, first with a simple model using 2 farmers, upstream (u) and downstream (d), and two dates for irrigation, A and B. If both farmers plant on date A (represented by “Au” and “Ad”) then the upstream farmer has a normal, unencumbered harvest (normalized as $A_u = 1$), and the downstream farmer has his harvest reduced by some

factor “w” (normalized to the range $0 < w < 1$) due to lack of water ($A_d = 1 - w$). If they irrigate on different days, then both will suffer a loss from the increased pest populations (for example $A_u = 1 - p$ and $B_d = 1 - p$). Summarizing this in the payoff matrix typically used for such game theory analysis, we have

	Ad	Bd
Au	1, 1 - w	1 - p, 1 - p
Bu	1 - p, 1 - p	1, 1 - w

As long as $p > w/2$, the aggregate yield will be greater for coordinated irrigation than uncoordinated.

Readers will likely be familiar with the Prisoner’s Dilemma form of such cooperative games, and indeed if the harvest decrease due to pests were made artificially low, the “rational” choice would be a lower aggregate yield, since the upstream farmers would no longer have a logical incentive to cooperate [15]. However Lansing points out that in reality the water damage due to droughts is not a binary choice: upstream farmers can allow a partial release of water that slightly decreases their yield and still provides positive feedback for synchronization from downstream farmers, and he shows that the resulting basin of attraction is towards egalitarian sharing of water. As noted above, Lansing does not attribute the existence of this cooperative basin of attraction purely to such rational calculation – he notes that there is a wealth of very long-term interactions networking religion, marriage, harvest rituals, gossip, comradere, and other social and economic realms. At the same time, the game theoretic model shows that even the logic of pure self-interest can move us toward this attractor.

Basins of attraction for such collective prisoner’s dilemmas and related game scenarios investigated by other researchers show that chaotic attractors may play an important role in the metastability of cooperative solutions [20, 21, 27]. In general, chaotic dynamics are the result of combining negative and positive feedback: the positive feedback moves the system towards the boundary of the basin of attraction, but negative feedback is always simultaneously at work, and recovers it, so to speak, before it can escape to another basin ([8]: p.168). Because this recovery never lands back on the exact values of a previous trajectory, deterministic chaos results. But whether chaotic or periodic, the social ecology of Balinese rice irrigation clearly makes cooperative behavior a basin of attraction by this kind of balance between “upstream” and “downstream” feedback.

A similar model can be used to understand the cooperative basin of Open Source software production, in which a generative capacity is similarly maintained by a balance of upstream/downstream interests. The founders of an Open Source project are typically in a position to accept or reject code contributions (“pull requests” in the language of Github, the most popular open source repository). Like the upstream farmers, they control access to a critical resource. But contributing software developers can create the equivalent of the downstream rice farmer’s pest

problem: a contributor who is disappointed by the lack of code adoption can “fork”¹ the code into another version of the same project, splitting the community and dissipating its human resources.

Establishing an entirely new project would be an extreme option, but it does not actually have to be exercised any more than an actual pest explosion needs to be deployed; merely knowing that the possibility of splitting the community exists could be enough to exert a counter-force. And there are less extreme measures than project forking: for example exercising “soft power” in the form of jokes: “those vested with authority on [Open Source] software projects, because of their success, are usually met with some degree of suspicion, and thus jokes and sometimes accusations of cabals run rampant among hackers” ([6]: p. 122). Stronger forms that still avoid the “nuclear option” of forking the entire project include behaviors such as “going dark,” in which coders suddenly go incommunicado for extended periods of time (<http://www.codinghorror.com/blog/2008/06/dont-go-dark.html>). These can also give be the software equivalent of “downstream pests.”

Our description here, even in the soft power case, models the relationship in antagonistic terms that are perhaps more the result of game theory frameworks than actual lived experience of either rice farmers or OS coders. The option of creating a new version of the same project does not have to be interpreted as a threat; it can simply be seen as a legitimate and reasonable possibility, and thus a good reason for respecting the voice of contributors in pull requests. Lansing makes a similar distinction between the “calculus of self-interest” in game theory and the pragmatic experience of living in a culture that values a deeply cultural commitment to cooperative perspectives and articulations.

Thus the concept of a basin of attraction for generative justice is not merely a utopian dream: it is an empirically testable model for both tradition social ecologies and what we might call the “techno-social” ecosystem for Open Source specifically and Benkler’s “Commons Based Peer Production” more generally. Indigenous communities and online peer production may seem like exotic exceptions to the mainstream global workforce, but in the next section we examine the analytic utility of basins of attraction in the case of environmental sustainability in the mainstream industrial sector.

5.4 Basins of Attraction as a Model for Industrial Symbiosis

Industrial Ecology (IE) is a discipline that takes evolutionary and ecological solutions as inspiration for industrial development. The idea is simple: in biological ecosystems, there is no “waste” per se, only material exchange between entities.

¹There is some confusion over the term “fork”. Originally this referred to a new version of the project, but the source code repository Github now uses the term for any pull request, including those adopted.

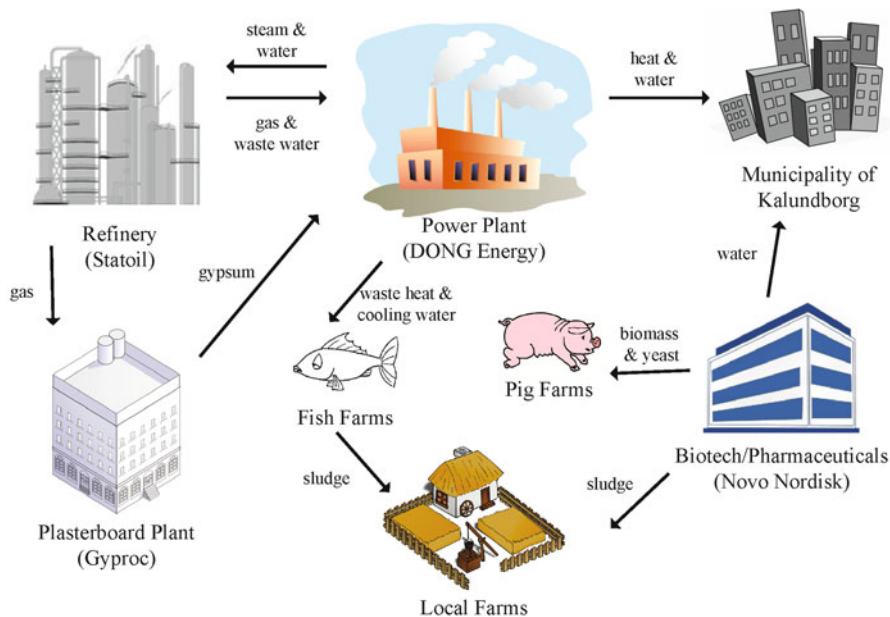


Fig. 5.8 Flow of materials and energy in an EIP, based on the industrial symbiosis in Kalundborg, Denmark

In an industrial ecosystem, waste would not be externalized through disposal into environment but instead “serve as the raw material for another process” and so on, until the “loop is closed” on that particular material flow [12]. As the applied branch of IE, Industrial Symbiosis (IS) focuses on the creation of such industrial ecosystems through the implementation of the eco-industrial park (EIP) model [4]. An EIP is an interdependent network of co-located firms wherein one firm’s wastes are the feedstock of another, transforming what would otherwise be a disposal cost into a profitable byproduct exchange. Therefore, just as the material exchanges between organisms within a biological ecosystem result in optimal resource utilization at the level of the whole system, the EIP model offers the possibility of profitably achieving “zero emissions” at the system level without requiring individual firms to reduce waste. Yet despite its advantages, widespread adoption in the West, especially the US, remains elusive. In the current sociopolitical climate, EIPs are not yet basins of attraction. Why not? (Fig. 5.8).

One reason is the choice of evolutionary/economic analogy. Much of IE currently draws on increasingly obsolete evolutionary theory in which natural selection is conceived exclusively in terms of competition between self-interested individuals. Groups and alliances play little if any role. This is a poor model for sustainable development because IS requires interdependence and coordination between firms, not merely competition. In other words, a solution for building successful EIPs in the US (and perhaps elsewhere) can be approached by asking, “Under what

conditions does cooperative industrial ecology become a basin of attraction”? Such a model could help governments implement “top-down” regulations that, rather than restricting the activities of individual firms, set the conditions for “bottom-up” EIP growth as an adaptive strategy.

Such innovative “win-win-win” solutions to the dilemma posed by sustainable industrial development are not too good to be true: several flexible, stable, and profitable EIPs have been documented around the world [5], though first and most prominently in Kalundborg, Denmark [11]. However, the EIP model has so far failed to catch on in the West for at least two reasons. First, the success of a few examples narrowed the field’s vision, with the result that driving question mutated from “How to facilitate EIP growth?” to “How to replicate Kalundborg?” Second, case studies consistently emphasize the bottom-up, unplanned quality of EIP emergence [14]. This insistence has led to a systematic position in the literature that in order to be successful, EIPs must evolve “spontaneously.” In describing the movements of flocks of birds and other natural phenomena, such language is apropos. But in the creation of an artificial ecosystem – whether in a petri dish, aquarium, or even a simulation – it is carefully planned conditions that allow self-organization to take place. Similarly, the coherence of multiple micro-decisions behind the creation of symbiotic linkages between firms is not a matter of waiting for a lucky convergence, but carefully planning the technosocial conditions that allow an EIP to stabilize and thrive. The insistence on spontaneity implies EIP simply cannot be deliberately developed.

This contradiction has not only undermined efforts to replicate the success of extant EIPs such as Kalundborg, it also confounds EIP development in Asia, where several countries have adopted IS as national policy. China is implementing IS concepts on a massive scale through the Circular Economy Initiative, made law in 2008 [19]. South Korea has instituted a 3-phase, 15 year project transitioning some of the country’s largest industrial parks into EIPs [24]. Japan has incorporated IE principles into official policy since the 1960s, most recently as part of the 1997 Eco-Town Program, designed to foster symbiotic linkages in 26 major urban areas [28]. Despite the fact that these projects have produced empirically verified, successful EIPs and other symbiotic exchanges, because they have been ostensibly planned from the top-down rather than having emerged spontaneously, these examples are perceived as outliers. Clearly a more robust framework for EIP development is needed.

Thus our current research examines the possibilities for applying agent-based modeling to simulate EIPs, with the aim of defining the properties that would make the EIP a basin of attraction. Recent work on “Organizing Self-Organizing Systems” [5] suggests the field of IS is moving in a similar direction. One challenge is that the constant turn-over from manufacturing innovation will change the material flows in ways that destabilize this exchange. However the symbiosis at Kalundborg has proven resilient despite significant changes within and between member firms [3], and there is no reason to think it must remain the exception. As noted above, the metastability offered by chaotic attractors may be an important mechanism by which cooperative basins of attraction achieve resilience in the face of such perturbations.

Another challenge is that unlike idealized agents of simple game theoretic models, real humans live in a rich cultural milieu. It may be that the success of EIPs such as Kalundborg owe as much to the influence of Danish culture as they do to insightful industrial planning or government regulation. Nevertheless, as we note in the comparison of Balinese rice irrigation and Open Source software production, contemporary techno-social ecologies can achieve similar cooperative basins of attraction in the absence of ancient cultural traditions, simply by creating conditions in which “upstream” and “downstream” forces are in balance.

5.5 Conclusion

The concept of “basin of attraction” offers a helpful means for bringing together the disparate scholarly disciplines that can contribute to a future animated by generative justice. Even in the case of industrial systems which are far from egalitarian, better arrangements of generative capacity through industrial symbiosis would at the very least mitigate the environmental devastation that will otherwise continue to grow at an accelerating pace. It is our hope that analyzing the question of IS in terms of basins of attraction – in particular their ability to remain in a closed-loop, byproduct-to-feedstock ecosystem and yet adapt to technological innovation and other perturbations – will offer better chances for creating the regulatory changes and other conditions by which EIPs could have a future in the US. Furthermore, it is our belief that still more significant, far-reaching changes could be broached by considering arrangements for these eco-industrial basins of attraction not simply in terms of industrial loop-closing, but by fully embracing the model of generative justice as a goal. There is no reason why the bottom-up return of value to its generative sources in both Nature *and* labor cannot be elevated as a national priority. In Spain, for example, the worker-owned cooperative system Mondragon, which primarily manufactures large-scale light industry products such as cooking stoves, utilizes a system of wage ratios which limit the distance between executive work and field or factory work to an average of 5:1. It may be that such simple mechanisms can move us towards the “upstream/downstream” balance that is crucial to establishing generative justice as a basin of attraction.

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Colin Garvey (garvec@rpi.edu) received his BA in both Japanese and Media Studies from Vassar College, followed by several years of training in Japan at a Zen Buddhist monastery. He began his PhD in the STS program at Rensselaer under the Triple Helix program. His doctoral dissertation uses evolutionary frameworks to examine symbiotic behavior at community-based and industrial scales, while at the same time reflexively analyzing the use and application of ecological and evolutionary analogies, the power of evolution as a unifying narrative, and the pernicious myth of genetic determinism.