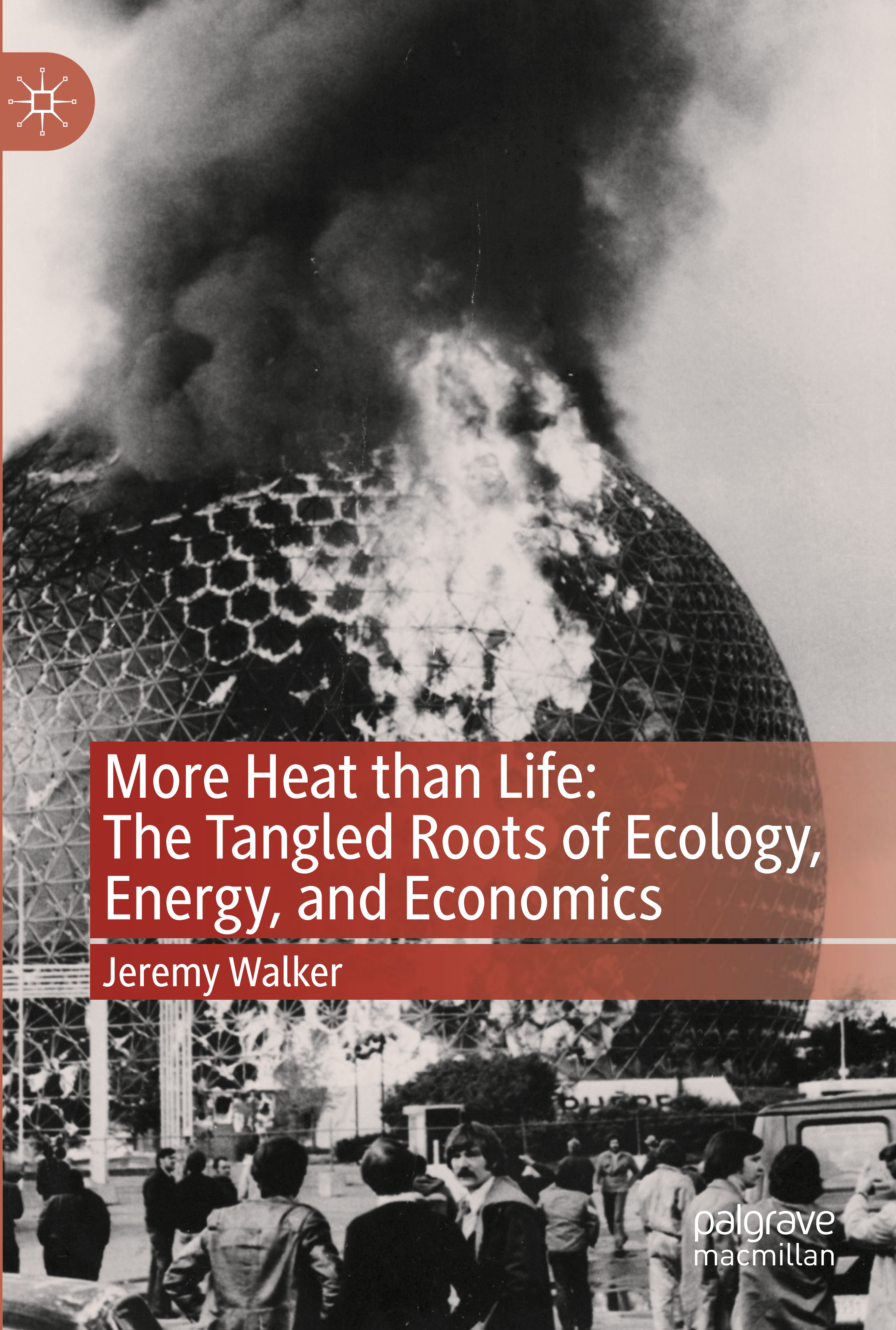

More Heat than Life: The Tangled Roots of Ecology, Energy, and Economics

Jeremy Walker

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"It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us."

—Charles Darwin, *The Origin of Species*, 1859

"One recognizes that there is a first agent in matter by which everything is executed in nature, which moves everything, which is the cause of all generation and all destruction; it is a fire, a matter aetherial or subtle, extremely active, which has the property of all the movement which animates the universe; it is an immense sea which contains all the sensible bodies, which it intimately penetrates and through which it works all the changes which happen."

—François Quesnay, *Essai Physique sur l'Oeconomie Animale*, 1747

"*Machine* n. apparatus in which the action of several parts is combined for the applying of mechanical force to a purpose; person like a machine in regularity or insensibility; controlling organisation in politics."

—Shorter Oxford Dictionary

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Jeremy Walker
Climate Justice Research Centre
Social & Political Sciences, School of Communication
Faculty of Arts & Social Sciences, University of Technology Sydney
Broadway, NSW, Australia

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Cover image: In 1976, the exterior of the Montreal Biosphere caught fire. Designed by Buckminster Fuller for the US pavillion at the 1967 World Fair, the geodesic dome's internal temperature was intended to be controlled by a complex system of transparent acrylic shades. This system had proved faulty, and was not replaced after the fire. © Bettman / Getty Images.

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This book is dedicated to Roswitha, who taught me to see the artistry of life, and without whose unfailing humour, wisdom, and dedication this book would never have been written. This book is dedicated with love to Marlene and Charlie, and to all children, to whom a living future rightfully belongs. It is offered to all who care for Country and community, to all who strive for justice here on the good Earth.

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PART I

Introduction

CHAPTER 1

Neoliberalism, Environmentalism, and the Crisis of the 1970s

The time in which we live is characterised by a set of seemingly intractable political arrangements—a world order designed to foster 'economic freedom' and 'economic growth'—and an ever-deepening planetary crisis of ecological erosion and global heating, a crisis increasingly difficult to normalise in the consciousness of everyday life. The roots of our current condition might be traced to the crisis of American power of the early 1970s, a time when two bodies of knowledge—ecosystems ecology and the economics of the Chicago School—were transforming the institutions of the United States. The new authority accorded these incommensurable and politically charged sciences reflected the coterminous movement of environmentalism from the counter-culture to the conferences of the United Nations, and of neoliberalism from the radical fringes of right-wing economic thought to the commanding heights of governmental power.

As sources of the knowledge claims of counter-posed political cosmologies, ecology and economics, the estranged twin sciences of the *oikos* (both share this Greek root-word meaning 'household' or 'estate') were engaged in the most millenarian of anticipations. Ecologists looked to the future and warned of a coming Apocalypse. Exponential industrialisation meant mounting destruction. Without dramatic social transformation, 'business as usual' would culminate in an Earth so hopelessly polluted, depleted and over-heated that it could no longer sustain civilisation and abundant communities of multi-species life. At stake was nothing less than the regenerative capacity of the biosphere. Meanwhile, economists rallying to the

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banner of 'freedom' foretold a new Heaven and a new Earth. The liberation of individuals and business from the dead hand of government intervention would unshackle 'the invisible hand' of the market, unleashing entrepreneurial techno-innovation and opening an infinite horizon of wealth creation, freeing humanity from the dismal scarcities and servitude of the past. The struggle between these divergent visions of post-natural futures continues into the present, exemplified most dramatically in the agonistic theatre of climate and energy policy. As an offering to the predicaments of our present—which some would gather under the sign of the 'Anthropocene'—this book attempts to unearth a genealogy of the deep contradictions within and between ecology and economics, momentarily brought into sharp relief when they collided in the transformative moment of the 1970s.

There are many critical histories of economics available, less so of ecology. Yet the mutual history of the two disciplines, a topic rarely approached in the burgeoning (though too often unintegrated) literatures on neoliberalism and the climate crisis, is of crucial importance to the grave challenge of restructuring 'the economy' before it destructures 'the ecosystem' beyond all hope of timely regeneration. This task is complicated by the fact that despite their cosmopolitical opposition, the concepts of natural order and (re)production deployed in either discipline share common genealogical roots. This has been noticed by a range of scholars, although mostly with specialist concerns in mind. What remains under-recognised is the significant fact that neoclassical economics and systems ecology, the paradigmatic core disciplines of their respective fields of knowledge, both anchored their claims to the status of science in the energy physics developed by combustion engineers as the thermoindustrial revolution gathered momentum in the mid-nineteenth century. The claims to epistemic authority of both ecology and economics (and thus ultimately of environmentalists and neoliberals) can be traced to a foundational relation to the thermodynamic laws of energy and entropy, and in turn, to older concepts of equilibrium and natural law. However, these claims were made in different ways, at different times and for very different purposes. The ever present possibility for a reconciliation of the estranged twin sciences in the Earthly phenomena of heat and life—for an ecological economics which answers the practical and ethical question of 'how are we to live?'—has been perennially deferred. It is for us, for our children, and all other life to live the consequences.

Focussing on the history of particular concepts—growth and equilibrium—as they appear in each discipline, this book demonstrates the extent of the unacknowledged mutual indebtedness between the two apparently disparate fields. It brings these ideas into focus via an excavation of their histories in political theology, natural history and physics, providing an itinerary of their migration into nineteenth-century 'social physics' and the body of modern systems theories which emerged in the twentieth century. In doing so it addresses the following questions: how do we account for the uncritical commitment to infinite economic growth pursued by almost all nation-states, given the extensive empirical evidence that this is undermining the very habitability of the Earth? How does the constitution of economic knowledge lend itself to this path? How has the ecological world-view gone from a position of critical collision with economists' denial of science and nature to subordinate collusion with neoliberal 'solutions', such as financial markets for carbon and 'ecosystem services', or techno-utopian geoengineering projects to make endangered ecosystems 'resilient' to planetary heating? I pursue such questions via an historical analysis of how economics and ecology came to be constituted as separate, stand-alone sciences, from the 1870s to the 1970s.

The Laws of Nature and the Powers of the Machine

The nineteenth-century triumph of machine technology over nature, and of scientific materialism over theology, had its parallel in political economy, which sought to overcome its history as a moral discourse on wealth and poverty and become a science of statecraft in accordance with natural laws it detected operating in the market economy. Whilst concepts of 'natural law' are deeply rooted in the Western tradition, in the nineteenth century the quest to elaborate them scientifically was profoundly realised in the development of the modern physics of energy—thermodynamics—a science which arose in tandem with the fateful development of the coal-fired steam engine, and which remains foundational to the corpus of scientific materialism.

Now ubiquitous in everyday life, heat engines convert the ancient solar energy stored chemically in hydrocarbon fuels and released as heat during combustion into mechanical force, or 'work'.[1] Histories of thermodynamics

[1] For this reason I use the term 'thermoindustrial society' to characterise modern forms of social organisation in which the heat released by hydrocarbon fuel combustion is the dominant source of energy.

begin by acknowledging the young French engineer Sadi Carnot's *Reflections on the Motive Power of Fire, and on Machines fitted to develop that Power* (1825), a brilliant analysis of the efficiency limits of steam engines in converting the heat of coal combustion into mechanical work. Carnot observed that the machines never gave as good as they got: only some of the heat was converted via the working fluid into the motive force of the driving mechanism. The majority of the heat was inevitably dissipated, flowing into the cooler parts and environment of the engine. Moreover, it was precisely this dissipative flow of heat across a thermal gradient, which in the absence of fresh shovelfuls of coal would grind to a halt as the motor approached thermal equilibrium with its environment, that was the sole source of motive power. Carnot's insights were developed and synthesized with other experimental findings between the 1840s and 1860s by scientists including Julius Mayer, James Joule, William Rankine, Hermann von Helmholtz, James Clerk Maxwell, Rudolf Clausius, and Josiah Willard Gibbs. These inquiries demonstrated that light, heat, mechanical force, chemical affinity, magnetism, electricity, and the atomic structure of matter are all manifestations of a universal phenomenon we now call 'energy'. Formalised in 1847, the law of the conservation of energy (from *energeia*, a Greek term approximating 'work') states that the quantity of energy of a closed system is constant: energy can neither be created nor destroyed in all the transformations we observe, only converted from one form to another.

Revealing a universal invariance underlying all known physical and chemical phenomena, the elaboration of the 1st law of thermodynamics led to a profound confidence in the timeless order and rationality of nature, vindicating the new thermoindustrial society and its scientific achievements. By contrast, the formalisation in 1865 of the 2nd law of thermodynamics—the entropy law (from the Greek *entropia*, meaning 'turning toward', or 'transformation')—implied an irreversible historical trajectory of disorder, depletion, waste, and chaos. Just as we always observe firewood burning to ashes, and never the reverse, the 2nd law states that the entropy of a closed system will always increase, where entropy is a measure of the disorder, dissipation, or unavailability of energy to 'do work'. As it exfoliated into wider scientific and social discourse in the late nineteenth century, the spectre of entropy complicated the optimistic confidence in Progress with *fin-de-siecle* pessimism, declinist fatigue and visions of the heat death of the universe. Accounting for all phenomena involving heat, motion and work, and imposing irreversibility and rigorous limits upon all the transformations of state and material organisation observed in machines, organisms, and inanimate matter from the atomic to the cosmological scale, the laws of thermodynamics are central to the claim of scientific materialism to have identified universal principles at the foundation of all matter and material transformation. Among the most confirmed findings of modern science, contemporary physicists regard them as nothing less than 'the constitution of the universe'.[2]

These apparent paradoxes regarding the fundamental nature of nature were not resolved when economics made its bid to become an exact science on par with physics in the 1870s. When ecology sought to become a 'hard' science in the twentieth century, it similarly strove to bring biology, evolutionary history, and geochemistry into coherence with energy physics. It was not until the 1970s, however, that ecology and economics were brought into direct ontological and political conflict, although most players were unaware—and most remain so now—of the historical origins of the unresolved contradiction between the ecologists' view of the world and that of the economist, a contradiction with increasingly dire consequences for the future of life on Earth.

The neoclassical synthesis of the 1870s consolidated the style and claims of orthodox economics, as its founding authors—including Leon Walras, William Stanley Jevons, Vilfredo Pareto, and John Bates Clark—appropriated the mathematical format of the law of the conservation of energy in their portrayal of 'market forces' operating according to law-like principles of general equilibrium.[3] Modelling the 'subjective utility' sought by hedonistic individual market participants as a universal field of value analogous to 'energy' as described in the 1st law of thermodynamics, the neoclassical economists aimed to excise the 'political' from political economy and develop a pure science of economics on par with physics. This agenda was to be pursued through the construction of mathematical models of the economy as a frictionless, ahistorical market setting in which the 'price mechanism' automatically equilibrates the forces of supply and demand (Fig. 1.1). The equilibrium concept at the core of

[2] Kümmel, R. (2011). *The second law of economics: energy, entropy, and the origins of wealth.* Springer Science & Business Media, p. 113.

[3] Mirowski, P. (1989). *More heat than light: economics as social physics, physics as nature's economics.* Cambridge: Cambridge University Press.

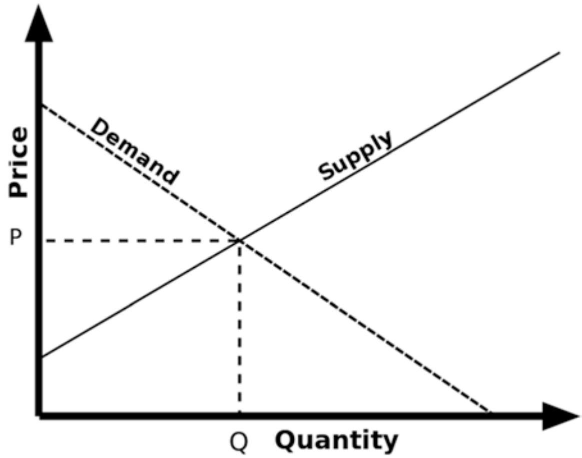

Fig. 1.1 Simple supply and demand graph. The constitutive metaphor of 'economic science': the forces of supply and demand coordinating consumption and production at the equilibrium price (PQ). (Source: Dallas Eperson, 2012. Creative Commons Attribution-Share Alike 3.0 Unported license. https://upload.wikimedia.org/wikipedia/commons/f/f2/Simple_supply_and_demand.svg)

neoclassical economics portrays the market order as universal, natural and optimal, and the economist as a scientist deserving the epistemic authority and prestige accorded to the physicist. However, this simplification of the dynamics of industrial capitalism involved some crucial omissions: the elimination of the question of the dissipation of fossil energy and natural resources in production, and even of 'land' itself from orthodox models of 'the economy'. The 2nd law of thermodynamics, despite being the most directly relevant principle of physics to our economic existence on Earth, has never been integrated into the canon of economic theory.[4]

The term 'ecology' was coined in 1866 by the Darwinian biologist and energeticist Ernst Haeckel, to distinguish as a modern science the study that had outgrown the earlier term for natural histories of multi-species inter-relations: 'oeconomy of nature'. The resemblance is more than nominal. Ecology's trajectory of scientisation mirrors the path taken by economics. Ecology has borrowed directly from the social sciences, and

[4] Georgescu-Roegen, N. (1971). *The entropy law and the economic process*. Cambridge, MA: Harvard University Press.

most heavily from political economy—a theme also treated systematically in an original way in this book. First proposed by Arthur Tansley in 1935, the 'ecosystem' has since become the central organising concept of contemporary ecology.[5] Tansley appealed to the laws of thermodynamics in applying a systems approach to the blooming, buzzing confusion of life, beginning with the proposition that 'all living organisms may be regarded as machines transforming energy from one form to another'. The 'ecosystem' is a system in the sense that communities of biological life cannot but conform to

> The great universal law of equilibrium [that] governs all the processes of which we have any knowledge, from the movements of the planets to those of molecules, atoms and electrons, from the activity of the protoplasm to the vagaries of the human mind. All things which exist are constantly tending towards a position of balance or equilibrium.[6]

In accordance with the 'systems' approach of energy physics, and inspired by Cold War cybernetics, by the mid-twentieth century the concept of the 'ecosystem' promised to unify competing schools of ecological thought around a coherent research object and bring the epistemic status and prestige of a 'hard' science to a field characterised by a past in localised natural histories. Abstracting from communities of organisms to analyse ecosystems driven by the photosynthetic capture of solar energy, ecologists showed how the 'economy of nature' was intimately bound up with the evolutionary trajectory of life's unique biochemistries, which modify geological strata and modulate the oceans and the atmosphere. As the nascent discipline grew in confidence, by the late 1960s systems ecologists offered their science as a full-spectrum framework for rational decision-making regarding human-environment relations.

If both systems ecology and neoclassical economics laid foundational claims to the achievements of energy physicists in identifying laws of nature to which there have been found no exceptions, there are crucial differences. From Vernadsky's epochal account of the photosynthetic transformation of solar energy and the non-living matter of the Earth by *The Biosphere* (1926), through to the confirmatory work of Lovelock and

[5] Tansley, A. (1935). The use and abuse of vegetational concepts and terms. *Ecology*, 16(3), 284–307.

[6] Cited in: Anker, P. (2009). *Imperial ecology: environmental order in the British Empire, 1895–1945*. Cambridge, MA: Harvard University Press, p. 31.

Margulis in the 1970s, and on to contemporary studies in climatology and Earth systems science, systems ecologists have sought to ground their account of life's complex order and planetary unfolding in the phenomena of solar radiation, heat, and energy transformation by fire and photosynthesis.[7] By contrast, orthodox economic theory has systematically excluded from its account of the economic process all the phenomena accounted for by the 2nd law of thermodynamics: the historically irreversible dissipation of energy inherent in all processes of production. This disciplinary exclusion of the physics of fossil-fuel combustion, of the solar ecology of the Earth as 'one physical system',[8] and indeed, of scientific materialism *tout court*—means that economics has no viable theory of 'production', 'growth', or 'development'. The actual physics content of economics is zero. This is of vital importance: since World War II, the period designated 'the Great Acceleration' in the Anthropocene literature, unceasing economic growth has become the goal, measure, and permanent justification of government policy.

Ecology was a term unknown by most until it exploded into public consciousness in the late 1960s. Associated with the environmental movement's apocalyptic warnings of a coming planetary catastrophe, ecology developed a critical reputation as a 'subversive science'.[9] Ecologists took on the public role of the 'sane scientist', warning that the limits to growth were fast approaching and that ecological equilibrium—the 'balance of nature'—was unravelling on a global scale. As the science of life's complex organisation, applicable from the scale of a pond to the geochemical and evolutionary history of the biosphere as whole, systems ecology should thus be recognised as the general science within which the social sciences must be brought into conformity. Since 'the phenomenal domain of ecology is broader than that covered by economics', as the renegade economist Nicholas Georgescu-Roegen put it, it seemed only logical that 'economics will have to merge into ecology.'[10] After all, this merely

[7] Vernadsky, V. ([1926] 1998). *The biosphere*. New York: Copernicus; Lovelock, J., & Margulis, L. (1974). Atmospheric homeostasis by and for the biosphere: the Gaia hypothesis. *Tellus*, 26(1–2), 2–10.

[8] Richter, D. & Billings, S. (2015). 'One physical system': Tansley's ecosystem as Earth's critical zone. *New Phytologist*, (206), 900–912.

[9] Sears, P. (1964). Ecology – a subversive subject. *BioScience*, (14), 11–13.

[10] Georgescu-Roegen, N. (1975). Energy and economic myths. *Southern Economic Journal*, 41(3), 374–381. See p. 374.

recognises (as Elie Ayache has observed in another context) the pertinent fact that

> Contrary to history or life, the market possesses a single metric, the up or down movements of market prices.[11]

As the international post-WWII consensus of 'New Deal' Keynesianism unravelled in the 1970s, along with the control of US-based oil companies over Middle Eastern oil reserves, an international network of economists that had in earlier decades described their project as 'neoliberalism' rose to prominence in the corridors of power, inaugurating what might be described in historical terms as the neoliberal era.[12] The historical and disciplinary scope of the present inquiry is ample enough that an adequate review of the literature on neoliberalism cannot be provided here.[13] What I will rather attempt in the pages that follow is to complement this scholarship in ways which seem to me of crucial importance, given the dawning realisation that the house is quite literally on fire.

Existing traditions of critical theory—institutionalist, Foucauldian, post-Marxist—have engaged with the ideas of neoliberal thinkers and the itinerary of their migration through social institutions, but have rarely (with important exceptions) systematically engaged with the problem of how neoliberalism confronts the biophysical dimensions of the world economy.[14] In much of the literature, the emergence on the political

[11] Ayache, E. (2010). *The blank swan: the end of probability*. Chichester: John Wiley & Sons, p. xvii.

[12] Friedman, M. (1951). Neoliberalism and its prospects. *Formand*, (17), 89–93. Neoliberalism as an historical period might be dated to the radical experiment in violent social engineering conducted by the MPS in collaboration with Pinochet's military dictatorship in Chile following the 1973 coup d'état.

[13] My own reference points here include: Brown, W. (2015). *Undoing the demos: neoliberalism's stealth revolution*. MIT Press; Cooper, M. (2017). *Family values: between neoliberalism and the new social conservatism*. New York: Zone Books; Slobodian, Q. (2018). *Globalists: the end of empire and the birth of neoliberalism*. Cambridge MA: Harvard University Press; Whyte, J. (2019). *The morals of the market: human rights and the rise of neoliberalism*. London: Verso.

[14] See e.g.: Cooper, M. (2008). *Life as surplus: biotechnology and capitalism in the neoliberal era*. Seattle: University of Washington Press; Heynen, N., McCarthy, J., Prudham, S., & Robbins, P. (Eds.). (2007). *Neoliberal environments: false promises and unnatural consequences*. Routledge. Castree, N. (2008). Neoliberalising nature: the logics of deregulation and reregulation. *Environment & Planning A*, 40(1), 131–152; Nelson S. (2015). Beyond the limits to growth: ecology and the neoliberal counterrevolution. *Antipode* 47(2), 461–480.

horizon of planetary ecological crisis remains external to accounts of the neoliberal counter-revolution. At stake in the struggles over knowledge and power of the 1970s, I will argue, was the rising cultural authority of ecology and the Earth system sciences, forms of knowledge now claiming to be indispensable to the urgent reform of political and economic life.

As an evolving and at times contradictory suite of doctrines extending its influence from high finance and international law to the intimate spaces of family life, neoliberalism evades characterisation as a coherent philosophy, and is only loosely captured in calls for privatisation, deregulation, fiscal austerity, and 'limited' government. Rather than attempt to pin down a defining set of propositions from an evolving series of positions, alliances, and strategies, I follow Mirowski and Plehwe's method in *The Road from Mont Pèlerin* (2009) in approaching the 'neoliberal thought collective' as a social network. This they identify with the international membership of the Mont Pèlerin Society (MPS), and with the personnel of the expansive constellation of 'think-tanks' co-ordinated by the Atlas Network, the senior executives of which are usually MPS members.[15]

Founded by Friedrich Hayek in 1947, the MPS sought to clarify the principles and strategies of a 'new liberalism' robust enough to overcome the inexorable slide into socialist unfreedom they feared in the 'unlimited democracy' of the redistributive post-war welfare state and the post-imperial order of nation-state sovereignties constituting the United Nations. Whilst not without internal tensions between the differing schools of thought represented within the MPS, which brought together Austrian economists, German ordoliberals, and American neoclassicals of the Chicago school, what united them was the need for a consistent doctrine. For economic liberalism to revive its prospects at a time when it appeared in terminal decline, it could not afford to adopt the merely negative slogan of nineteenth-century liberalism—'laissez-faire'. What was needed, according to Hayek, was a new, future-oriented liberalism, one which would inspire activism by its courage to be utopian, one robust enough to capture state power and cordon off the social-democratic 'road to serfdom'. Since the 1970s, this new liberalism has succeeded

[15] Mirowski, P., & Plehwe, D. (Eds.) (2009). *The road from Mont Pèlerin: the making of the neoliberal thought collective*. Cambridge MA: Harvard University Press, p. 4. In identifying MPS members I draw on secondary works reporting on the MPS archives, and a more current member list leaked to: DeSmogBlog (n.d.) Mont Pèlerin Society (MPS). https://www.desmogblog.com/montpelerin-society. Accessed 26 June 2019.

spectacularly in reframing economic discourse and policy, in transforming the ethos and practice of law, government, and international relations, and most tragically, in ensuring that hydrocarbon-based industry remains (for the most part) free from mandatory constraints imposed in the name of ecological survival and the maintenance of the Earth's heat balance within the range to which life as we have known it can live.

On the face of it, it's not clear why a political movement claiming to ensure that we are 'free to choose' now functions as an increasingly authoritarian project to defeat democratic attempts to respond to the climate emergency; one adept at deploying the dark arts of 'business propaganda'—to borrow a term from Hayek's mentor Ludwig von Mises[16]—and intent on capturing state power in the service of fossil-fuel corporations. If neoliberals and fossil capitalists first mobilised in the early twentieth century against the labour movement's victories in constitutionalising electoral and then social democracy, the world-historic consolidation of neoliberal technologies of rule from the 1970s cannot be fully grasped, I contend, without recognising that the spectre of a rising environmental movement was a catalyst for the mass-enrolment of transnational corporations in the neoliberal project. Without the long-term consolidated support of big business, and in particular of US-based corporations concentrated in fossil-fuels, petrochemicals, mining and other pollution-intensive industries, the intellectual output of MPS scholars would never have achieved the influence and pre-eminence it now enjoys.

In the remainder of this introduction, I sketch this argument in outline, as a prelude to the history of economic and ecological thought pursued in the book. In the chapters which follow, I offer a pre-history of the present neoliberal era, in terms of the long mutual history of interactions between economic and ecological modes of systems-thinking. This is in turn grounded in a deeper genealogy of Western accounts of social order in the metaphorical mirror of the 'economy of nature'. Offering a critique of biopolitical economy grounded in the vital facts of photosynthesis and fire, the book sets the stage for the contemporary confrontation of neoliberalism with movements for ecological survival and climate justice.

[16] von Mises, L. ([1949] 1996). *Human action*. Irvington, NY: Foundation for Economic Education, p. 272.

Crisis and Contradiction: Life Beyond the Limits of the Earth

All histories involve elective designations of the events to be counted as the critical turning points. In the aftermath of the high modernism of the twentieth century, it became common to express a profound scepticism toward the possibility of understanding 'history as a whole'. Yet any argument must be couched in a narrative, and a history of philosophy can scarcely by disentangled from the philosophy of history. Georg Hegel taught that history was driven by a dialectic of ideological struggle, with periods of complacency punctuated by the irruption of struggle between proponents of antithetical ideologies, with each party driven to distraction by alternative ideologies whose very existence contradicted their own universal ontologies. This occurred at the micro-level of local political and religious discussion and was manifest in the wars of nations—what Hegel referred to as the 'slaughter bench of history'. Through this struggle, in which ideas engaged with contradicting ideas, there was a process of exchange in which a concept or its realisation passed over into its opposite and was preserved and fulfilled by it. Thus the World Soul became conscious and rational, a rationality reflected in the order of the cosmos, and social evolution occurred.[17] Hegel's idealist philosophy of history gave contradiction between opposites in moments of profound crisis a central role in the realisation of Progress. Maintaining that history could always have been otherwise, this book is polemical in relation to Hegelian accounts of state and right which elevate the ideas of the bourgeois state beyond the material conditions of everyday life, promising future progress and bringing actual devastation in the present. Nevertheless, it turns out that a history of interactions between ecology and economics is an exercise in *dialectics*, a term which refers to

> the tension or opposition between two interacting forces or elements […] the logic of appearances and of illusions […] any systematic reasoning, exposition, or argument that juxtaposes opposed or contradictory ideas.[18]

[17] Hegel, G.W. ([1837] 1980). *Lectures on the philosophy of world history*. Cambridge University Press.

[18] Merriam-Webster Online Dictionary. Definition of Dialectic. http://www.m-w.com/dictionary/dialectic. Accessed 4 July 2017.

My understanding of 'contradictions' in the relation between the natural and social sciences is closer to that of Karl Marx. Marx claimed to have 'put Hegel back on his feet', offering a materialist philosophy of history in which moments of social crisis characterised by changes in the material organisation of production drove history into new stages of social organisation. What was specific to the capitalist 'stage', Marx argued, was the subordination of social relations to abstract exchange value, which tends to incorporate all phenomena into its self-referential value system, transcending the embedded times and places of the phenomenal world:

> [A]s representative of the general form of wealth—money—capital is the endless and limitless drive to go beyond its limiting barrier. Every boundary is and has to be a boundary for it.[19]

A new 'crisis of contradictions' emerged in a sharp relief in the early 1970s, transforming abiding Western conceptions of relationships between nature and society. The modern environmental movement was novel in that it re-founded older political and social economy critiques of industrial society upon the models, metaphors and findings of ecology, a previously obscure branch of the life sciences that had recently coalesced around the 'ecosystem' concept. In its orientation to the future, the ecology movement painted a grim vision of the logic of modernisation that radically reversed the growth-oriented techno-optimism of the post-WWII period.

Under the international 'Keynesianism' of the US-sponsored Bretton Woods Treaty (1944), the standardisation of Fordist industry, social insurance and the family wage, and Green revolution agriculture had witnessed the longest period of stable, widely shared increases in material consumption in history—at least amongst the privileged citizens of the West. Whilst political conflict turned on the degree to which economic growth would be best realised by state planning, competitive enterprise, or a managed compromise between them, until the late 1960s, there was an almost universal faith that 'economic growth' or 'the advance of the productive forces' was synonymous with Progress itself. At the time, US and Soviet futurists outbid one another in visions of the triumph of modern technology—and their preferred mode of social organisation—over a nature rendered the malleable servant of technoscience. In *The Year 2000* (1967), the conservative theorists Daniel Bell, Herman Kahn and Anthony Wiener

[19] Cooper (2008, p. 8).

envisioned a shift to a flexible, high-technology, service-oriented consumer economy.[20] Amidst the revolutionary upheavals of the day, Bell discerned *The Coming of Post-industrial Society* (1974): the mass labour of Fordist industry was giving way to a new dynamic of 'science-led growth', testament to the increasing 'centrality of theoretical knowledge'. Bell saw this post-industrial future emerging from the mastery of nature manifest in the harnessing of vast atomic energies and the rapid development of networked digital computers. Presaging a shift from the mass labour of factory production to specialised professional services and the creative consumption of a widening leisure class, these changes demanded a redefinition of promises of the 'end of scarcity' in terms of the new 'economics of information'.[21]

Decades later, the Wall had fallen, and the new millennium was dawning. In a moment of Hegelian euphoria, Francis Fukuyama announced the end of history:

> [...] modern natural science establishes a uniform horizon of economic production possibilities. Technology makes possible the *limitless* accumulation of wealth, and thus the satisfaction of an *ever-expanding* set of human desires. [...] the logic of modern natural science would seem to dictate a universal evolution in the direction of capitalism. [my emphasis][22]

The globalisation of financial markets and the ubiquitous penetration of information technology in the form of the World Wide Web convinced many pundits that we had entered a post-material New Economy, in which the old economy practice of converting resources into goods and services with the labour of bodies and machines had become redundant. The physical world itself appeared to vaporise into the informational ether. Bell's vision seemed to have all but come to pass.

History, as is well known, is written by the victors. Responding in the 1970s to the post-industrial theorists, Soviet academicians outbid the 'bourgeois futurologists' in imagining the future of the 'scientific-technological revolution'. By the turn of the millennium, humanity would control unlimited flows of energy, which would 'unlock the door of

[20] Bell, D., Wiener, A., & Kahn, H. (1967). *The year 2000*. London: Macmillan.

[21] Bell, D. (1974). *The coming of post-industrial society*, Heinemann: London, pp. xciv–xcvi.

[22] Fukuyama, F. (1992). *The end of history and the last man*. Avon Books, p. xv.

nature's treasure house', yielding 'infinite supplies of natural resources'.[23] With this plenitude of energy, hunger would be abolished: the world's deserts converted into gardens, synthetic food produced on an industrial scale and harvested from the seas, and the climate subjected to push-button control. Repetitive work in the Soviet bloc would be automated by 1990, and by the year 2000 citizens would live to 100 through genomic control of the aging process. Abundant leisure time would be absorbed by trips to the moon, which would have an extensive network of railways by 2030. All this would be achieved with new technology that would not degrade the biosphere but actively restore 'ecological equilibrium'.

This last piece of promissory rhetoric recognised the profound influence of one of the most ambitious attempts to anticipate world futures, the 1972 *Limits to Growth* report to the Club of Rome.[24] Like the post-industrial futurists, the Club of Rome warned that the Fordist model of industrial growth had entered a period of irreversible decline, a message brought home vividly to a public shocked by the Arab oil embargos into recognition of their dependence on imported fuel. Yet this was a crisis that went far beyond the conventional terms of productivist thought. It was rather, as Melinda Cooper puts it, 'a wholesale crisis in the realm of reproduction […] what was at stake was no less than the continuing reproduction of the earth's biosphere and hence the future of life on earth'.[25]

Commissioned by a club of industrialists, a team of MIT computer programmers developed a model of the exponential growth trajectory of the global economy, attempting to incorporate the positive and negative feedbacks between industrial expansion and the Earth's resources and ecosystems. The report warned of the dangers of 'thermal pollution', projecting the exponential rise of atmospheric carbon dioxide meticulously recorded by Charles Keeling since 1958.[26] Adapting scenario forecasting methods developed by the US Air Force and the Shell Oil corporation, the authors did not claim to be able to predict the future with precision.[27] Yet through multiple model runs, the finding was clear: exponential growth in

[23] Modhrizinska, Y. & Stephanyan C. (1973). *The future of society*. Moscow: Progress; Kosolopav, V. (1976). *Mankind and the year 2000*. Moscow: Progress.

[24] Meadows, D., Meadows, D., Randers, J. & Behrens, W. (1972). *The limits to growth: a report to the Club of Rome*. New York: Universe.

[25] Cooper (2008, p. 16).

[26] Meadows et al. (1972, pp. 71–73).

[27] Granjou, C., Walker, J., & Salazar, J. (2017). The politics of anticipation: On knowing and governing environmental futures. *Futures*, (92), 5–11.

population and industrial output could not continue without running up against the inherent limits of arable land, fossil energy, mineral resources, and the biosphere's capacity to absorb harvest and pollution, a conclusion resolving to 'the simple fact […] that the earth is finite'.[28]

The Club of Rome forecast that unless there was political agreement on the necessity of shifting from exponential growth to some form of steady-state economy, the limits to growth would be catastrophically transgressed around the mid-twenty-first century, causing drastic declines in human populations. The industrial economy needed to be regulated within the fixed limits set by the geophysical logic of mineral depletion and the fragile equilibria of the global ecosystem. The report called for an urgent, though undefined 'general strategy' to achieve 'global equilibrium', a situation in which 'population and capital are essentially stable, with the forces tending to increase or decrease them kept in a tightly controlled balance'.[29] The authors warned their readers that while

> […] the concept of a society in a steady state of economic and ecological equilibrium may appear easy to grasp […] the reality is so distant from our experience as to require a Copernican revolution of the mind.[30]

From our present fearful orbit, it need hardly be emphasised how remote we are from such a goal. Yet this proposal was widely discussed amongst the delegates to the 1972 United Nations Conference on the Human Environment at Stockholm, the first international environment summit, and the last one at which the explicit critique of economic growth would frame deliberations. Nevertheless, the consensus of the Stockholm Declaration that the 'ecological balance of the biosphere' was threatened by 'major and undesirable disturbances' due to 'dangerous levels of pollution' and the 'destruction and depletion of irreplaceable resources' has only been abundantly confirmed by the Earth systems sciences.[31]

Few American economists were equipped by training or inclination to engage with the scientific basis of such claims. Yet they were troubled by the Club of Rome's pessimistic account of growth, and the consensus of the Stockholm Declaration that '[r]ational planning constitutes an

[28] Meadows et al. (1972, p. 86).

[29] Meadows et al. (1972, p. 189).

[30] Meadows et al. (1972, p. 196).

[31] United Nations (1972). Stockholm Declaration of the UN Conference on the Human Environment. http://www.un-documents.net/unchedec.htm. Accessed 1 Feb 2018.

essential tool for reconciling any conflict between the needs of development and the need to protect and improve the environment.'[32] This was a direct challenge to the standard neoclassical model of permanent growth in 'free market' equilibrium conditions. From Robert Solow's classic 1956 paper down to the Dynamic Stochastic General Equilibrium computer models presently deployed in central banks, neoclassical models promise permanent 'equilibrium-path' growth. Excluding any necessary role for inputs of energy or natural resources to the economic process, the source of this growth is attributed to a 'residual' factor labelled 'technology'.[33] Solow's response to the Club of Rome was to argue that it had undersold the role of the price mechanism in adapting to resource scarcities. Falling supply would increase the marginal utility (and thus the marginal price) of depleted resources, presenting opportunities for entrepreneurs to get rich by innovating beyond the limits with technological substitutes:

> If it is very easy to substitute other factors for natural resources, then there is, in principle, no 'problem'. The world can, in effect, get along without natural resources [...] Exhaustion is just an event, not a catastrophe.[34]

If Solow's enormous 'if' held true, the 'price mechanism' would restore its own conditions of equilibrium, regardless of the wasted condition of the Earth. Responses to the *Limits* thesis in prestigious US economic journals converged on similar themes. Ignoring entirely the accumulation of pollution and loss of ecological abundance, the economists uniformly approached the question of resource depletion in terms of strategic minerals, confining the problem to an 'optimal rate of depletion'.[35] This approach built on a 1931 paper by Howard Hotelling modelling the profit-optimising strategy of a mine owner within the neoclassical mathematics of equilibrium. In it, Hotelling presciently observed that: '[p]roblems of exhaustible assets are peculiarly liable to become entangled

[32] UN (1972, para 16).

[33] Solow, R. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, 70(1): 65–94.

[34] Solow, R. (1974). The economics of resources or the resources of economics. *American Economic Review*, 64(2), 1–14.

[35] Stiglitz, J. (1974). Growth with exhaustible natural resources. *Review of Economic Studies*, 41(128), 139–145.

with the infinite'.[36] Accordingly, concerns about the irreversible depletion of oil were dismissed with confidence in the infinite supplies of nuclear energy promised by the soon-to-be-feasible fusion reactor. Some looked further, anticipating a techno-future centuries hence in which the exhaustion of minerals had instantiated a miraculous age of 'infinite substitutability'.[37] Others claimed the problem was less the scarcity of resources than a scarcity of markets—market failures must be met with more markets. The market prices generated by the exchange of financial futures and derivatives (not the results of natural science) were the relevant data with which to know and decide the future conditions of life on Earth, because

> *Everything* depends upon how traders form their expectations about the future in situations where definite information is lacking [...] Many of the difficulties that are involved in the making of policy recommendations about the rate of depletion of exhaustible resources stem from the fact that crucial aspects of this problem are inherently uncertain, and it is not clear that an adequate class of contingent markets exists. [my emphasis][38]

Such arguments were testament to the rising influence of Chicago School finance theories of rational expectations and efficient markets, which would soon license the radical rollback of New Deal banking and financial regulation. Influenced by Hayek's precocious account of prices as information and markets as distributed computation in the face of a future inherently beyond the capacity of scientific reason to foresee or predict, the 'efficient markets hypothesis' holds that asset prices fully reflect all available 'information.'[39] Therefore any government policy to reign in 'irrational' market activity injurious to the public interest will at best be futile, and at worst, damaging to 'the economy'.

[36] Hotelling, H. (1931). The economics of exhaustible resources. *Journal of Political Economy*, 39(2), 137–175.

[37] Goeller, H., & Weinberg, A. (1978). The age of substitutability. *American Economic Review*, 68(6), 1–11.

[38] Dasgupta, P. & Heal, G. (1974). The optimal depletion of exhaustible resources. *Review of Economic Studies*, 41(128), 3–26. See p. 3.

[39] Hayek, F. (1945). The use of knowledge in society. *American Economic Review*, 35(4), 519–530; Fama, E. (1970). Efficient capital markets: a review of theory and empirical work. *Journal of Finance*, 25(2), 383–417.

Neoliberalism as Anti-environmentalism: Corporations and the Counter-revolution

The analysis of the Club of Rome crystallised into mainstream consciousness the environmental movement's vision of a looming planetary disaster, a sense of impending crisis which had been building among scientists for some time. In 1957, the oceanographer Roger Revelle noted the rising concentrations of carbon dioxide in the oceans and atmosphere, a result of burgeoning fossil-fuel combustion.

> [H]uman beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future. Within a few centuries we are returning to the atmosphere and oceans the concentrated organic carbon stored in sedimentary rocks over hundreds of millions of years.[40]

A talented science organiser, Revelle would be lead author of the first public study to warn of the potentially devastating consequences of this experiment for the future heat balance of the Earth, presented to President Lyndon Johnson in 1965.[41] Revelle was also influential in the International Biological Program (1964–1974), which was tasked with examining the biological basis of the Earth's productivity as it related to human welfare. The IBP project was dominated by American ecologists deploying the 'ecosystems approach' to analyse solar energy flows and nutrient cycles through large-scale bioregions. If ecologists had previously tended to study relatively undisturbed, local ecosystems, the IBP was explicitly global and human-oriented. Ecology would increasingly be proclaimed as a basic science with profound implications for human welfare, carried forward by a new generation of practitioners 'motivated by a sense of responsibility for social action'.[42]

[40] Revelle, R. & Suess, H. (1957). Carbon dioxide exchange between atmosphere and ocean and the question of an increase of atmospheric CO_2 during the past decades. *Tellus*, 9(1), 18–27.

[41] Revelle, R., Broeker, W., Keeling, C., Craig, H. & Smagorinsky, J. (1965). Atmospheric carbon dioxide. In President's Scientific Advisory Committee, Restoring the quality of our environment: report of the environmental pollution panel (pp. 111–133). Washington DC: The White House.

[42] Smith, F. (1968). The International Biological Program and the science of ecology. *Proceedings of the National Academy of Sciences*, 60(1), 5–11. See p. 11.