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MACROÉCONOMIE ÉCOLOGIQUE POUR UNE PLANÈTE PARTAGÉE:

VERS UNE ÉCOLOGIE POLITIQUE GLOBALE DE LA MONNAIE, LA FINANCE ET DE LA PRODUCTION

Ecological Macroeconomics For a Shared Planet: Towards a Political Ecology of Money, Finance and Production

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...everybody does not see alike.
To the eyes of a miser a guinea is far more beautiful than the Sun,
and a bag worn with the use of money has more beautiful proportions
than a vine filled with grapes.
The tree which moves some to tears of joy is
in the eyes of others only a green thing which stands in the way.
Some see nature all ridicule and deformity...
and some scarce see nature at all.
But to the eyes of the man of imagination,
nature is imagination itself.
As a man is, so he sees.

— William Blake

...again we are reminded that in nature nothing exists alone.

— Rachel Carson, *Silent Spring, 1964*

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ABSTRACT

This thesis builds upon the emerging field of "ecological macroeconomics" to study how dominant development patterns are constituted by and reproduce global inequalities and environmental degradation. Chapter 2 reviews and categorizes the available literature in ecological macroeconomics, noting its contributions to studying economy-environment dynamics. Chapter 3 critically assesses the ecological macroeconomics framework. It is argued that the field can better analyze environmental challenges by considering nature as inherently *political*: human-nature relations are regulated through social conflicts in ways that benefit some groups over others. This approach is applied in chapter 4, which uses a "Core-Periphery" (balance-of-payments constrained growth) model to explore how global environmental inequalities are produced by 'green' sustainability initiatives. The increasing efficiency within a high-income Core region is shown to depend on displacing carbon-intensive activities to the low-income Periphery. Chapter 5 then extends the analysis to understand financialization, presented here as a global dynamic of environmental (re-)organization that supports accumulation in the Core at the expense of social and environmental stability in the Periphery. This dynamic is permitted by the subordination of Peripheral countries within the organization of global monetary, productive and environmental relations. Chapter 6 summarizes and concludes. The evidence presented throughout the thesis signal that for ecological macroeconomics to address contemporary challenges, it must adopt a political view of nature.

Key words: ecological macroeconomics, political ecology, decoupling, ecologically unequal exchange, green growth, uneven development, international monetary system, degrowth, Core-Periphery

RÉSUMÉ

Cette thèse s'appuie sur le domaine émergent de la « macroéconomie écologique » pour étudier la manière dont les modèles dominants de développement sont la source d'inégalités mondiales et de dégradation de l'environnement tout autant qu'ils en résultent. Le chapitre 2 propose une revue de la littérature sur la macroéconomie écologique, et répertorie cinq thématiques à travers lesquelles elle contribue à la compréhension des dynamiques économie-environnement. Le chapitre 3 procède ensuite à une évaluation critique du cadre de la macroéconomie écologique, fondée sur l'idée qu'une analyse rigoureuse des défis environnementaux requiert d'appréhender la nature comme intrinsèquement *politique* et organisée par des conflits sociaux. Cette approche est mise en pratique dans le chapitre 4, qui utilise un modèle « Centre-Périphérie » (croissance contrainte par la balance des paiements) pour étudier la manière dont les inégalités environnementales mondiales peuvent être renforcées par la transition vers une économie « verte ». En particulier, l'augmentation de l'efficacité énergétique et environnementale au « Centre » (pays à revenu élevé) dépend de la délocalisation des activités à forte intensité de carbone dans la Périphérie (pays à revenu faible). Le chapitre 5 élargit l'analyse en abordant la thématique de la financiarisation via le cadre théorique de cette thèse. La financiarisation peut alors être comprise comme une dynamique mondiale de (ré)organisation environnementale, soutenant l'accumulation dans le Centre au détriment de la stabilité sociale et environnementale dans la Périphérie. Cette dynamique est permise par la subordination des pays de la Périphérie dans l'organisation des relations monétaires, productives et environnementales mondiales. Le chapitre 6 résume et conclut. Les éléments présentés tout au long de la thèse signalent que pour être en mesure de relever les défis actuels, la macroéconomie écologique se doit de développer une vision politique de la nature.

Key words: macroéconomie écologique, écologie politique, découplage, échange écologiquement inégal, croissance verte, développement inégal, système monétaire international, décroissance, Centre-Périphérie

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ACRONYMS

BOP	Balance-of-Payments
BOPCG	Balance-of-Payments-Constrained-Growth
CO_2	Carbon Dioxide
CPEF	Core-Periphery Environmental Frontier
CRC	Commodity Reserve Currency
ELR	Employer-of-last-resort
EUE	Ecologically Unequal Exchange
FDI	Foreign Direct Investment
GVC	Global Value Chains
IAM	Integrated Assessment Model
ICU	International Clearing Union
ICB	International Commodities Board
IMS	International Monetary System
IO	Input-Output
IPCC	Intergovernmental Panel on Climate Change
pSEM	piecewise Structural Equation Model
QE	Quantitative Easing
SFC	Stock-Flow Consistent

1

INTRODUCTION

If we can really understand the problem, the answer will come out of it, because the answer is not separate from the problem.

— Jiddu Krishnamurti

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Over the last two hundred years, consumption of both renewable and non-renewable resources has grown at a feverish pace. Despite increasing alarm from scientists, international organizations, NGOs and activists, resource- and pollution-intensity of global economic systems has only accelerated in recent years (Schandl et al., 2018). Indeed, more than half of all carbon dioxide emissions since the beginning of the industrial revolution were produced in just the last thirty years (IRP et al., 2019).

The rapid drawdown of finite resources, alongside the increasing toxicification of environments, is undermining many of the basic functions of the biosphere upon which human and non-human livelihoods depend (Persson et al., 2022). Scientists now regularly caution that humanity is likely to face a future of "vast human misery" (Ripple et al., 2017, p. 1026) and "untold suffering" (Ripple et al., 2020, p. 8) without major systemic changes. A recent report by concerned scientists warns of a "ghastly" future wherein this systematic ecosystem destruction by humanity renders the Earth utterly unable to support complex life (Bradshaw et al., 2021). From air: air pollution and carbon emissions; to land: soil loss, biodiversity decline, and deforestation; to sea: overfishing, plastic pollution, sea-level rise, and ocean acidification, it would appear that humanity itself is on a collision course with the Earth system.

Yet if 'humanity' is driving fast into a wall, it is important to ask a few questions: *Who has control of the steering wheel? Why are we driving so fast? Why are we accelerating, despite obvious alarm? Who benefits from driving in this way? Who gets to wear a seatbelt?* And perhaps most importantly, *what's stopping us from slowing down, turning in a different direction, or getting out of the car, altogether?*

Indeed, upon closer inspection, it is clear that it would be misguided to attribute the environmental crisis to all of humanity (Malm and Hornborg, 2014), as if risks and responsibility were equally shared. While climate change and other forms of ecological degradation are global phenomena, both their causes and consequences are unevenly distributed (Frey, 2019): Those regions and groups that have historically accumulated great material and financial benefit by extracting, transforming, and disposing of the Earth's resources are also the most capable of displacing or adapting to environmental harms. Conversely, those regions and groups that have historically been the most financially and materially marginalized are also the most vulnerable to suffer adverse environmental transformations (Ciplet, Roberts, and Khan, 2015; Thomas et al., 2018); and face serious institutional constraints to avoid or adapt to them (Leichenko and O'Brien, 2008).

In short, a small number of high-income countries (Dorninger et al., 2021), wealthy individuals (Chancel, 2021), and a mere handful of exceedingly profitable corporations (Griffin, 2017) have disproportionate control over the steering-wheel, are systematically rewarded

for pressing down on the gas pedal, and are the only ones with a seatbelt on.

The seeming paradox between environmental benefits and burdens, responsibility and risk, and power and vulnerability reveals important characteristics about the nature of our shared predicament and the limits of current frameworks to adequately assess the situation. In order to properly address the central issue of our time, theory must therefore be able to account for how global environments are accessed, valued and organized to support the world-views and development patterns of a small portion of humanity. This requires a framework capable of assessing how social institutions condition our collective relationships with nature, and organize environments in uneven ways.

Interestingly, however, the vast majority of economists have tended to view the environmental crisis as a problem of technique and financial management, rather than one of conflict, distribution and power. Macroeconomic research and policy is therefore biased towards facilitating 'green' investment and 'green' technology to render economies more efficient, without adequately tackling the social roots and global scope of environmental degradation (Commission, 2019; OECD, 2011; UNCTAD, 2019; UNEP, 2011).

Even scholars that are generally critical of the mainstream have been optimistic about the prospect of 'green' pricing and regulatory shifts, 'green' fiscal interventions and 'green' monetary policy to unleash a wave of investment meant to reorient the economy around sustainability goals. Ecological macroeconomics, for example, is an emerging paradigm of heterodox economics that has called attention to interdependent social, ecological and economic crises and strict biophysical limits to economic growth (Hardt and O'Neill, 2017). Despite having developed as a clear alternative to mainstream research, ecological macroeconomists have overwhelmingly supported similar objectives. Scholars in ecological macroeconomics contend that investment in new and efficient technologies and renewable energy sources will bring greater environmental harmony all while raising employment, securing greater incomes and equity (Fontana and Sawyer, 2016; Pollin, 2015; Rezai and Stagl, 2016).

Yet empirical research now consistently confirms that 'green' investments and technologies have been unable to meaningfully dissociate dominant development patterns from environmental impacts (Haberl et al., 2020; Hickel and Kallis, 2019; Parrique et al., 2019). In large part, this seems to be due to the ways that powerful groups in high-income 'Core' countries have been able to displace resource- and pollution-intensive industries to low-income 'Peripheral' regions (Dorninger et al., 2021). Moreover, the introduction of seemingly 'green' production methods and 'renewable' energy sources (Bonds and Downey, 2012; Sovacool, 2021) are increasingly shown to heighten social and envi-

ronmental vulnerabilities of marginalized groups, perpetuating many of the very patterns they set out to undermine. On a shared planet with vast material and institutional inequalities, policies that fail to account for the global asymmetries and structural imbalances are likely to participate in, rather than undermine, unsustainable structures.

This thesis attempts to develop a more coherent macroeconomic framework to better account for the global and uneven dimensions of socio-ecological change. The present work explores how the ecological macroeconomics framework can be served by taking on a *political* understanding of socio-ecological dynamics. It expands upon ecological macroeconomics by integrating insights from alternative frameworks, including political ecology and world-systems theory. This combination allows for a critical assessment of previous research in ecological macroeconomics, as well as the development of promising new avenues to investigate economy-environment dynamics at the global level.

I argue that the ecological macroeconomics framework has so far been held back by a predominantly instrumental and *apolitical* view of nature. By viewing nature as an instrument of production and a collection of physical aggregates, scholars unwittingly de-historicize and de-politicize human-nature relations. Such a perspective leaves ecological macroeconomics in a theoretical cul-de-sac: Research then privileges top-down engineering solutions to achieve sustainable outcomes via calculable efficiency metrics. Understandably, researchers in ecological macroeconomics are then pushed to develop new ways to channel 'green' investments to reduce economic impacts on the environment, and to reduce environmental impacts on the economy, rather than to imagine new patterns of human-nature relations and how they might be made possible.

This thesis promotes an alternative vision: nature is not an instrument, but a battleground. Nature is organized, accessed and distributed through competitive struggles between differently positioned groups. As such, the material and economic capacities of some groups tend to come at the expense of others. In other words, one person's degradation turns quickly into another's accumulation (Blaikie and Brookfield, 1987, p. 14). Following this alternative perspective, the focus of investigation shifts away from the management of environmental impacts, and towards an attempt to grapple with the structure and regulation of human-environment relations. Sustainability is less an issue of technique, financial capacity and 'green' policy adjustment than a question of social conflict, class power, institutional regulation and (global) inequality.

I apply this framework at the level of the "world-ecological system" (Hornborg, 2006a; Moore, 2015), in order to re-contextualize the environmental crisis within global asymmetric patterns of material and social development. In particular, I explore how Core-Periphery rela-

tions are structured to support the material and financial benefit of the Core, largely at the expense of the material and financial security of the Periphery. In doing so, it becomes possible to understand why moving towards more sustainable social patterns has remained out-of-reach, and why even bold plans - whether towards a 'green' global economy or a smaller, 'degrowing' economy - are likely to be insufficient without significant changes in the global institutional setting.

1.1 RESEARCH METHODS AND THEORETICAL BACKGROUND

The main hypothesis of this work is three-fold:

First, in order to 'embed' macroeconomic theory within the Earth system, scholars must first understand that nature is a political terrain. Human-nature relations evolve through conflicts over how to define, access and organize nature. Structural inequalities then become reflected and reinforced in the ways that nature is valued, transformed and distributed.

Second, following from the above, the global 'environmental crisis' can be more effectively understood as a symptom of the uneven structures that generate it, and a 'functional' component of dominant modes of material and social development.

Third, by integrating this insight, it is possible to more critically evaluate the ethical and practical implications of diverse policy proposals (e.g., 'green' growth or 'degrowth'), and achieve greater explanatory power with a more robust theoretical framework.

This thesis is guided by two broadly-conceived fields of research that provide a potential platform for a holistic and integrative study of global socio-ecological change: (i) Ecological Macro-economics and (ii) World-Ecology.

Ecological macroeconomics is a nascent field of macroeconomics that views economic systems as materially embedded, and therefore dependent upon, the Earth system. Ecological macroeconomics emerged from the combination of two schools of heterodox economic thought: (a) post-Keynesian and (b) ecological economics. Ecological macroeconomics serves as the primary *subject* of inquiry in Chapters 2 and criticism in Chapter 3. These chapters establish ecological macroeconomics as an important, though perhaps incomplete field of economics dedicated to understanding environmental issues. In particular, the field has conceived of 'nature' as an instrument of production, rather than a terrain of political contest. Moreover, it has not been able to sufficiently associate unsustainable patterns with the structural unevenness of global capitalism. This has led to overly technical and top-down strategies for adapting to and mitigating climate change, overlooking how these may worsen global outcomes.

From the perspective of this work, the ways that we think about and frame the unfolding crises can prevent us from fully grasping, or

at least meaningfully questioning the mechanisms propelling them forward. Our frameworks for analysis dictate how and what we see, how and what we measure, and what kinds of propositions are considered valid, ethical, and effective. Failure to grasp the global and uneven structure of the present crisis can therefore lead scholars towards half-measures and maladaptive solutions which participate in, rather than undermine, the present make-up of unsustainable relations.

As such, this thesis also integrates the perspective of 'world-ecology'. World-ecology is a branch of research based in (c) world-systems and dependency theory and (d) political ecology that understands environmental degradation as a 'functional' element within globally uneven structures. Borrowing from the 'world ecology' perspective, I both critically appraise some of the theoretical and methodological grounds of the ecological macroeconomics paradigm (Chapter 3) and use this alternative framework to push the research forward (Chapters 4 and 5)

The 'world-ecology' perspective adds two important attributes that are missing in ecological macroeconomics:

First and foremost, it provides a much-needed *political* interpretation of human-nature relations. This is most clearly articulated in the field of political ecology. As will be described in greater detail in Chapter 3, political ecologists recognize that environments are shaped through social conflict. Different groups attempt to access and organize nature according to their own institutions and values. Political ecologists therefore see nature as a political battleground of competing visions and practices. Moreover, as groups have different capacities to effect change, environmental transformations tend to occur at the expense of less powerful groups and heighten social vulnerabilities.

The political ecology (and hence world-ecology) perspective therefore sees 'environmental problems' as fundamentally problems of relationship. Focus then turns away from investment and technological efficiency, as sustainability then depends primarily on institutional regulation, distribution, and class struggle.

Second, the world-ecology perspective adds a global dimension. World-ecologists describe a world where relations between nation-states are unevenly structured and vying for institutional power and material control (Andersson and Lindroth, 2001). This can be contrasted with the majority of existing work within ecological macroeconomics, which has remained relatively isolated at the level of the nation-state.

Integrating key insights from both ecological macroeconomics and world-ecology (Chapters 4 and 5) creates an alternative lens through which the rapidly worsening environmental crisis can be perceived. Through this paradigm, the increasing intensity and extent of eco-

logical degradation can be conceived as a constituting factor of the present mode of growth and development, and a logical expression of global Core-Periphery asymmetries within finance-dominated capitalism. Policy proposals to resolve the environmental crisis - particularly those looking to rapidly increase investment by 'greening' growth or those looking to rapidly decrease investment by 'degrowing' - must therefore be reappraised in light of the hierarchical and uneven structure of the 'world-ecological system'. In particular, attention must be paid to the interdependent hierarchies of global finance, money and production, which appear to express and rely on uneven environmental transformations.

The following subsections will delve deeper into the fundamentals of 'ecological macroeconomics' and 'world ecology' research, as well as their constituent schools of thought. As shown in Figure 1 each of these fields provides important, and often overlapping, insights that inform this work.

First, I cover some of the foundational elements of 'ecological macroeconomics' used in this thesis, focusing in particular on how they are expressed in (a) post-Keynesian economics and (b) ecological economics.

Second, I discuss the core elements of the 'world-ecology' paradigm, and identify the key elements of its framework as found in (c) world-systems and dependency theories and (d) political ecology.

1.1.1 *Ecological macroeconomics: Integrating post-Keynesian economics and ecological economics*

Ecological macroeconomics is a field of economics which explicitly recognizes the economy as a sub-system of the larger social and biophysical systems of which it is a part. Over more than a decade, ecological macroeconomics has shown itself to be a highly integrative field which attempts to understand the real economy and the financial economy as dependent on materials and energy obtained from the planet. Ecological Macroeconomics has developed an impressive new set of modeling tools and concepts for inquiring into the possibilities and limits of a sustainable transition - with and without growth - in particular by focusing on monetary and financial institutions, effective demand, and income distribution. In doing so, the field bridges a divide between multiple strands of research to highlight the relationships between the human social economy to the natural world in which it is embedded.

Ecological macroeconomics has come to represent a key heterodox voice in the field of economics which offers a clear alternative to neoclassical 'environmental' economics research. Mainstream economists have tended to view the environment as simply another factor of production which can be infinitely and unproblematically substituted by

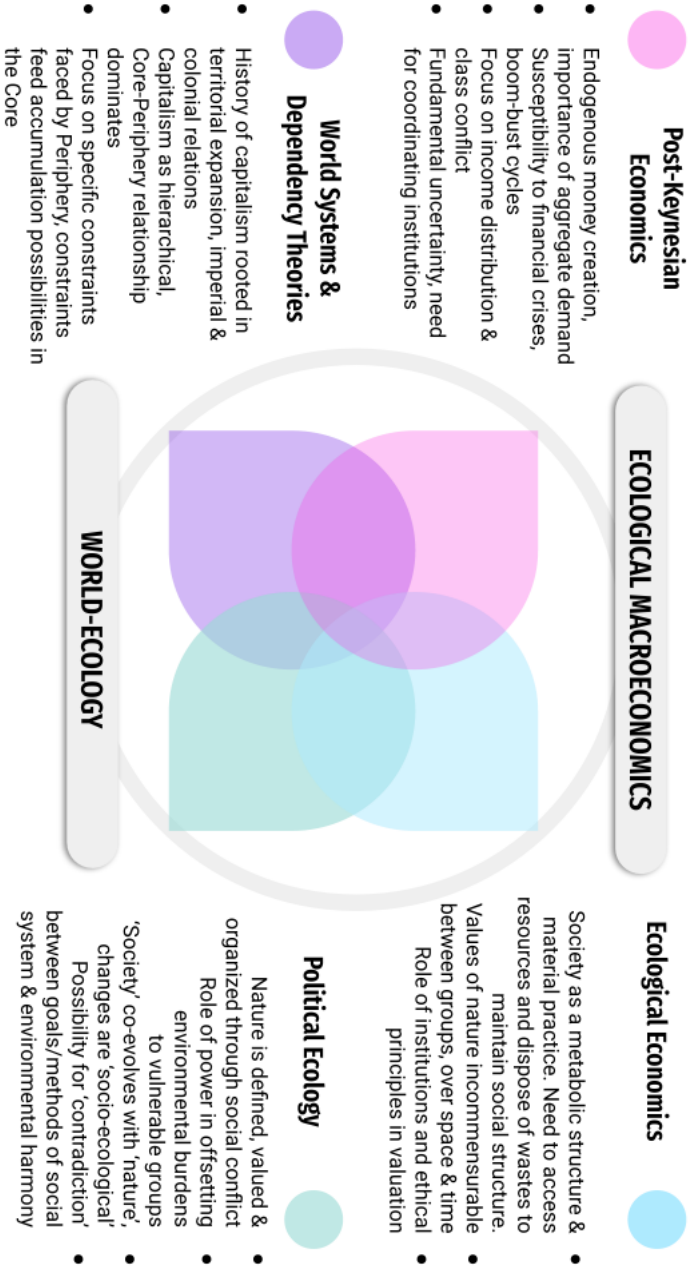

Figure 1: Theoretical Framework: Towards an Ecological Macroeconomics for a Shared Planet

the addition of any other factor (capital, labor, land).[1] In contrast, eco-

1 In the words of Keen (2020)), the logic informing mainstream climate models is not just bad, but "appallingly bad". Briefly, neoclassical economists consider that economic life is built upon frictionless exchanges between perfectly rational individuals. Money values and prices are merely an accounting mechanism which facilitates optimizing buyers to pay what sellers will accept. Markets function, therefore, in the absence of uncertainty, institutions and relations of power (Palermo, 2007). Achieving more sustainable outcomes in this framework then requires supply-side fixes to correct any apparent market rigidities (e.g., misinformation, monopoly power, government intervention), particularly by fixing prices to reflect their "true" underlying

logical macroeconomists have developed a far-more nuanced vision of socio-ecological change. In particular, one of the primary features of ecological macroeconomics is that there is no direct substitutability between the resources used in the production function (Kronenberg, 2010). Ecological macroeconomists therefore take on a "strong sustainability" approach: resources are seen as complements, rather than perfect substitutes. Capital and labor can only stand in for "nature" in limited circumstances, and never completely. The ecological macroeconomics platform is therefore built around the notion that while the economy is propelled by investment demand, it is necessarily constrained by its material dependencies.

The ecological macroeconomics paradigm is primarily informed by two schools of thought: post-Keynesian economics and ecological economics. Here I focus on some of the key insights from each field that inform the rest of this thesis.

1.1.1.1 *Post-Keynesian economics: The importance of money, finance, distribution, and uncertainty*

Post-Keynesian analysis recognizes that capitalist economies are inherently unstable, conflictual, and constantly evolving in historical time.[2] This vision is typically placed in opposition to neoclassical theory, which tends to view market economies as automatically self-equilibrating and frictionless. Post-Keynesian economics ties in three fundamental criteria that are critical for characterizing environmental dynamics of capitalist economies within a shared planet: (i) the role of money and finance in economic developments, (ii) the focus on distribution, and (iii) the presence of fundamental uncertainty and the need for coordinating institutions.

First, post-Keynesians have a deep understanding of the financial and monetary institutions that direct capitalist economies. They recognize, in particular, that economic growth - and the money creation process - is driven endogenously by changes in aggregate demand (Lavoie, 2014)).[3] Aggregate demand depends largely on investment decisions by firms and households, and these are a function of uncertainties, future (adaptive) expectations, and functional income distribution. As such, post-Keynesians place income distribution (class conflict), industrial production (value capture), and institutions (regulatory institutions, norms, conventions) front-and-center to understand financial processes and the periodic booms and busts that character-

market values. If agents are utility-maximizing, and prices are accurate, then they can find an optimal pollution mitigation pathway. In essence, pollution can only be explained in one way: because people prefer it.

2 Post-Keynesian economics can indeed be distinguished by its distinct set of methodological foundations, including realism, historical time, distribution, uncertainty, path dependency and the importance of institutions (Holt, 2005; Lavoie, 2014)

3 According to King (2003, p. xiv) "stripped down to the bare essentials, Post Keynesian economics rests on the principle of effective demand."

ize capitalist economies. This is a particularly important perspective in the age of finance-dominated capitalism, which is constituted by worsening inequalities, new methods of production, increased financial and economic instability, and a number of institutional shifts (e.g., regulatory changes, share-holder value orientation of firms) (Zwan, 2014).

Another distinguishing characteristic of post Keynesian economics is its focus on the role of inequality in the economic process. Post-Keynesians recognize that incomes are distributed unevenly, market competition is dominated by few powerful players, and that differential consumption and investment patterns are determined by class conflict (Hein, 2017, p. 7). Whereas prices are the result of market forces in the neoclassical perspective, they are the result of market power amongst post-Keynesians. Struggles over market power and income distribution shape economic pathways that do not necessarily bring greater social welfare or economic stability. The focus on inequality takes on particular importance at the international scale, where uneven production structures between Core and Peripheral nations can also potentially lead to self-fulfilling cycles of increasing income dispersion (Thirlwall, 2011).

Finally is the presence of uncertainty. Under conditions of uncertainty, social organizations and institutions are necessary tools to resolve tensions between conflicting groups and to guide behavior towards socially desirable outcomes. As opposed to neoclassical economists, which see prices as the 'natural' outcome of market forces and the economy as self-equilibrating, post-Keynesians recognize the importance of the regulatory environment to reduce uncertainty, redistribute income, and redirect economic institutions. For example, post-Keynesians recognize that without contending with uncertainty, firms are unlikely to undertake investments in risky or unproven new technologies. Given uncertainty, post-Keynesians contend that there are no *automatic* forces in a capitalist market economy that can guarantee that the level of output will correspond to the full employment equilibrium, much less an equilibrium that ensures a 'sustainable' economic pathway.

Using post-Keynesian insights on the importance of money, finance, distribution and uncertainty, this thesis follows much of the existing work that has already shown itself useful in the field of ecological macroeconomics (Holt, Pressman, and Spash, 2009)

1.1.1.2 *Ecological Economics: Society as a metabolic process, and nature's values as incommensurable*

Ecological economics is a heterodox field of economics that views the economy as a subset of the society, and biophysical systems. Since its inception, ecological economics has been a heavily divided field (Røpke, 2005): On the one side are more mainstream approaches that

attempt to price the 'value' of ecosystem services and optimize pollution reductions, whereas on the other side are approaches that evaluate the material limits and ethical implications of present patterns of economic growth. Here I describe two key findings - generally from this latter, more 'radical' branch of ecological economics - that are particularly important for informing this thesis: (i) social metabolism, (ii) incommensurability of values. While these have not played a particularly important role in ecological macroeconomics as yet, they are important concepts for this work, as they help to move towards a more conflict-based approach to understanding socio-ecological change.

The first insight from ecological economics that informs this work is that social metabolism. Social metabolism refers to the fact that human social systems develop through their capacity to capture external sources of energy for meeting individual biological, psychological, and social needs and desires. Societies are composed of individuals who, by virtue of the fact that they are alive, expend energy and utilize Earthly matter to maintain themselves and the given social-environmental context. All social functions, structures, and symbolic relations are therefore constituted through the physical material relations that sustain them. As Spash (2012, p. 44) writes, "society can only exist on the basis of human agents acting, reproducing and transforming social structure" embedded within a biophysical context.

Secondly, ecological economics recognizes that 'values' of nature are ultimately incommensurable. Economies are generally measured by aggregating monetary exchanges. Yet economic values cannot be directly ascribed to quantifiable biophysical correlates (Hornborg and Martinez-Alier, 2016). There is no clear way to establish monetary or physical commensurability between different goods: (1) no two goods share the same biophysical qualities (e.g. $1 million of iron ore vs. $1 million of rainforest); (2) even two goods with similar chemical and molecular structures have different meanings, potential and biophysical importance for the structure of local social-ecosystems in space (e.g. the value of a liter of water in the Sahara vs. in British Columbia) and time (e.g. the value of a liter of water in the rainy season vs. dry season); and (3) the apparent value of any good is influenced by divergent tastes, historical developments, cultural desires, habits, institutions, and power structures.

Economy-environment dynamics therefore "elude(s) arithmomorphic schematization" (Georgescu-Roegen, 1971, p. 63). Accurately representing the economy as a subsystem of the environment is therefore fraught with difficulty.[4] As Martinez-Alier Martinez-Alier (1987, p. x)

4 Aggregate measurements, in general, present significant problems when accounting for the environment (Gerber and Raina, 2018; Sullivan and Hannis, 2017). Accounts of aggregate environmental flows and stocks tend to divorce resources from their specific environmental functions and the health and well-being of different social groups. Stock and flow characteristics of mineral ores cannot effectively communicate the deforestation and chemical runoff used to establish and expand a mine. Nor

argues in an early contribution to ecological economics, without a clear method of calculation, "ecological economists are left without a theory of value". Indeed, the ecological economics approach is said to "destroy theories of value" (M'gonigle, 1999, p. 21).

These two perspectives from ecological economics are key principles for the present work. If society has an inherent *metabolic* relation to its biophysical context, and the 'value' of that context is incommensurable or uncertain, then understanding human-nature relations therefore requires going beyond seeing the economy as an aggregation of monetized exchanges or quantified biophysical flows. The physical transformations of the Earth must then be understood within the overarching institutional framework which guide human behavior and, by extension, environmental changes. This requires insight into the "structure of the relationship between qualitative and quantitative elements," an effort which requires connecting "the relationship between time, space and human intentionality" (Farrel, 2019, p. 26).

Moreover, since humans are guided by values, meanings and subjective identities created through relations between self, other and world, accounting for social structure turns on the power to contest and mobilize particular visions, and ensure that they are embodied and carried out (Douai and Montalban, 2012).[5] An ecological macroeconomics approach capable of interpreting present ecological crises therefore requires an understanding of how social structure, biophysical structure, and power intersect.

1.1.2 *World-Ecology: Integrating world-systems theory and political ecology*

While the ecological macroeconomics paradigm forms a core component of this thesis, the field is not without its critics. As will be described in Chapter 3, doubt has been raised as to whether ecological macroeconomics, as it currently exists, presents a sufficiently coherent paradigm to comprehend (or help to transcend) interdependent social, economic and ecological crises. Some scholars, for example, have argued that the field suffers from a "shallow" ecological stance

do they mention the disadvantaged groups who have been relocated by the project or effectively dispossessed of their lands. A mangrove forest, for example, is not simply an aggregate of trees, but a web of complex relationships supporting ecosystem and community health. The destruction of the forest not only disturbs wider ecological processes (e.g., biodiversity decline, soil erosion, etc.), but reinforces inequality, introduces new consumption needs, reduces community resilience (e.g. to tropical storms and flooding) and undermines local sovereignty.

5 Douai and Montalban (2012, p. 1213) explain, "....moral values are always embedded in material realities and practices... they cannot be separated from the social context in which they originate. Values are also a 'function of social structures'. Interests and values can thus be distinguished but not strictly... the common good is always a *disputed* social construct" .

(Spash, 2013) which presents an overly instrumental vision of nature that fails to grasp the institutional and conflictual processes at the heart of environmental change (Chester and Paton, 2013; Svartzman, Dron, and Espagne, 2019). Others have claimed that current scholarship has not sufficiently contended with the way environments are shaped unevenly through global relations of production (Røpke, 2013), and that the field needs to do a better job of incorporating distributional issues and a broader systems analysis (Røpke, 2016).

From the perspective of this thesis, the ecological macroeconomics paradigm is not only salvageable, but can be reinvigorated with the addition of the "world-ecology" perspective.[6] Scholars in the world-ecology tradition uphold that the process of capital accumulation is constituted by structurally uneven patterns of material access and appropriation. World-Ecology is an approach that includes views from political ecology (Buscher and Fletcher, 2020; Castree, 2008; Robbins, 2012), and world-systems theory (Frey, 2019; Hornborg, 2020; Moore, 2003)

As yet, much of the existing research in ecological macroeconomics has been contained within national boundaries, and has ignored the uneven global consequences and geopolitical drivers of environmental change (see Chapter 3). The world-ecology framework, in contrast, provides a convincing macro-narrative of global developments, informed by the recognition that "histories of human communities and their natural environments are interconnected in complex spatial and hierarchical relations of power." (Di Muzio and Robbins, 2015, p. 9)). In particular, this perspective can be used to understand the link between capital accumulation, asymmetric pollution and resource flows, and structural constraints, and geographic vulnerabilities. The global environmental crisis can then be understood within the context of an ever-evolving thought highly uneven "world-ecological system" (Hornborg, 2006b).

Such a framework can shed better light on emergent properties that are not presently captured by mainstream or even many heterodox frameworks, like ecological macroeconomics. As (Guttmann, 2016, p. 48) argues, today's complex issues require moving beyond the macro-economic revolution that began under Keynes at the beginning of the 20th century, towards "a meta-economic revolution" that would allow for rethinking the global economy as a complex adaptive system. The global economy is far more than a sum of national balance of payments, exchange rates, and material balances. Cross border flows of capital, physical materials, income and ownership are expressions of a "supra-national growth dynamic integrating national economies into a new web" (Guttmann, 2015, p. 208). As will

6 Despite many internal debates, for the purposes of this section, for the purposes of this section there is sufficient complementarity to consider these as broadly-aligned (Foster and Clark, 2020; Hornborg, 2019b; Hornborg and Martinez-Alier, 2016). I find it more important to highlight their similarities than contradictions in this part.

be studied in Chapter 5, this vision is imperative for understanding finance-dominated capitalism today.

From the world-ecology perspective, national containers are constituent parts of a larger totality. Socio-ecological changes are understood to occur at the intersection of "historical-geographical struggles and social power geometries" (Swyngedouw, 1999, p. 461) which shape the way human and non-human natures are imagined, valued and distributed and transformed. At the level of the world as a whole, national economies are interdependent social metabolic structures that expand to absorb and transform resources, and dispose of wastes in a process of constant co-evolution (Norgaard and Kallis, 2011). Core centers of accumulation and Peripheries of extraction then form a unified complex dynamic system of metabolic relations. These dynamics are in constant flux, but maintain stability through institutional regularities (Moore, 2011).

The world-ecology program is most frequently associated with the work of Jason Moore (2003), Moore (2011), and Moore (2015). For Moore, the modern world-capitalist system was built through consecutive rounds of discovery, dispossession, depletion and geographic expansion. Capitalism implies a particular set of human-nature relationships that organize and transform nature to ensure continued capital accumulation for privileged groups. In Moore's words, "*Historical capitalism does not create ecological crises so much as it has been created through them*. It is the relation between social power and biophysical process. . . that has given rise to such crises" (Moore, 2011, 11, emphasis in original).

In this framework, new waves of accumulation and expansion are enabled by institutional, material and technological arrangements (e.g., scientific discovery, legal and regulatory changes, financial innovation, military conquest) that uncover new frontiers of commodity extraction, or repurpose old frontiers. These 'commodity frontiers' allow for large quantities of land, labor and raw materials (oil, water, minerals, biomass, etc.) to be obtained "cheaply" - i.e. with minimal investment risk and capital outlays. The development of commodity frontiers are shown to help to stabilize the accumulation capacities of the Core, in large part by ensuring continued access to resource flows within Peripheral regions.

In a similar vein, the world-ecology approach can also be seen through the lens of "ecologically unequal exchange" (EUE) (Frey, 2019; Hornborg and Martinez-Alier, 2016). According to EUE theory, environmental degradation and worsening inequality are a consequence of the uneven structure of global exchanges. EUE theory is based on the recognition that the beginning stages of value-added production are generally more pollution-intensive and extractive industries, while later stages in value-added production *particularly 'non-material' branding, marketing, financial services, licensing, high-

tech R&D) tend to rely on minimal *local* environmental transformations and lower *direct* levels of energy and material use.

This implies an undeniable inverse relationship between regional value capture and environmental quality (Piñero et al., 2019). Indeed, this finding has been confirmed in numerous empirical analyses (Dorninger et al., 2021; Jorgenson, 2016; Magalhães et al., 2019). Peripheral regions export a greater portion of their resources to Core countries while facing increasing ecological pressures, social instability, and inequality as a result (Rice, 2007). Meanwhile, Core regions capture the greatest amount of downstream value and therefore tend to suffer the least environmental risks and burdens as they enjoy disproportionate access to the world's resources.

The world-ecology perspective that informs this thesis can be more precisely understood through the lens of its constituent parts: (i) world-systems and dependency theory and (ii) political ecology. In what follows, I will briefly describe some of the key insights from these two fields as they relate to the present thesis.

1.1.2.1 *World-Systems and Dependency theories: Understanding global history and hierarchies to consider peripheral constraints*

An additional strand of research informing this thesis comes from World-Systems and Dependency theories. While some important distinctions and internal debates exist between the two (Palat, 2014), both adhere to a number of similar research objectives and guiding principles.[7] World-Systems and Dependency theories are ideal for updating the ecological macroeconomics framework and for understanding socio-ecological change for three primary reasons: (i) their scope is at once global and historical, providing a coherent framework for understanding long-term shifts in the international ecological relations, (ii) they conceive of global capitalism as inherently uneven and hierarchically structured, (iii) they focus on the specific constraints faced by Peripheral countries and how these are fundamental components in the evolution of capitalism.

First, Dependency and World-Systems theorists pay particular attention to the historical role of colonialism and imperialism in shaping the trajectory of global capitalism beginning in (at least) the "long" 16th Century (Arrighi, 1994). These theories developed as an attempt to recontextualize capitalism as a global project of territorial expansion from its inception (Braudel, 1985; Wallerstein, 2011)). Capital accumulation is argued to depend upon integrating new areas and peoples for the purpose of obtaining resources and labor needed for capi-

7 The intellectual roots of Dependency Frank (1967), and Amin (1976), (Furtado, 1974) and World-Systems theories (Arrighi, 1994; Braudel, 1985; Wallerstein, 1974b) can be found first and foremost in the Marxist works on the relationship between capitalism and imperialism by Lenin and Luxembourg, latin-american structuralism (e.g., Prebisch, 1950), neo-Marxist accounts of monopoly capital (Baran, 1966).

tal accumulation. Through global conquest, Peripheral frontiers were integrated within the circuits of capitalism, and conditioned to facilitate the export of raw materials and labor at low prices to support the dominant modes of production of their colonial powers (Amin, 1976; Hornborg, 2019a)). In this framework, capital accumulation occurs largely by virtue of the capacity of the Core to maintain this subordinate relationship with Peripheral outposts.[8] 'Development' in some regions is therefore seen as inseparable to the "underdevelopment" of others (Frank, 1967).

Second, Dependency and World-Systems theorists argue that the capitalist world-system is constituted by hierarchical relations between competing firms and nation-states. This leads to a situation in which the major centers of accumulation, and classes of wealthy consumer-citizens exert immense sway over the rules, regulations, priorities and social realities of much of the world. This asymmetric structure developed over centuries, and congealed into accumulated economic and biophysical-material benefits for powerful state- and non-state actors (e.g., firms), and institutions that privilege the possibilities of accumulation for those at the top of the hierarchy. While the world-system is highly structured, these structures are perpetually evolving: "groups (and institutions) are constantly recreated, remoulded, and eliminated" (Arrighi, Hopkins, and Wallerstein, 1989, p. 22) over time and space.

A country's position in the global hierarchy has immense bearing on a country's role and relative powers in the stratified system. While any country's position may change over time, the quality of the Core-Periphery relationship remains essential to the process of capital accumulation. From this perspective, dependency is a fundamental condition through which capitalist development takes place.[9]

Third, World-System and Dependency theories focus on the major constraints faced by Peripheral countries, and how these have served the accumulation of the Core. Peripheral countries not only faced subordination through the international division of labor (Emmanuel, 1972) but also through financial means (Amin, 1976; Arrighi, 1994). For example, Peripheral countries were subordinated through colonial currency arrangements (Sylla, 2021) and weak positional integration within global financial and monetary networks that reinforced

8 At the time that these theories emerged, mainstream and even many heterodox theories ascribed to a 'stagist' vision of economic modernization (Rostow, 1959): 'developed' first-world countries were seen as the future image of the 'developing' third-world. World-Systems and Dependency theorists represented an outright rejection of modernization theories.

9 While the state cannot transcend global capitalist dynamics, the state is seen as nonetheless an important mediating component. Above all, the state is seen as the primary "means of assuring certain terms of trade in economic transactions" (Wallerstein, 1974a, p. 16) while in constant tension with other states through global power struggles. States are seen in continuous positional competition to rise within or sustain the existing global hierarchy (Andersson and Lindroth, 2001).

their low position as resource-exporters within global value production (Koddenbrock, 2019; Koddenbrock, Kvangraven, and Sylla, 2021; Patnaik and Patnaik, 2017). Conceição Tavares (1985) in particular was explicit about how Peripheral counties' domestic social and economic sovereignty was constrained by their financial dependence and low status within the global currency hierarchies.

Given their focus on global history and structural unevenness, World-Systems and Dependency theories, go far in helping to better explain the profound structural inequalities that persist both domestically and internationally. From the perspective of these theories, much of the present ecological predicament follows from processes of spatial domination through the extension of centralized hierarchies of power to obtain resources. Moreover, these theories provide greater insight into the particular constraints faced by global Peripheries, and how these constraints may feed into global growth dynamics, even while reinforcing global asymmetries and environmental degradation.

1.1.2.2 *Political Ecology: Understanding socio-ecological change through the lens of power, coevolution, and contradiction*

The final school of research that informs this thesis is political ecology. Political ecology is a field of social inquiry that is broadly aligned with marxist theory, the french regulation school, geography, environmental anthropology, and environmental history. Political ecologists recognize environments are defined, transformed, valued and distributed within society through political conflict. Political ecologists focus on how social life is created within and through interaction with the environment, frequently in uneven ways. Collective meaning-making practices, identities and economic measurements, tools and values are understood to be co-produced with nature (Robbins, 2012). From the perspective of this thesis, political ecology provides three important concepts: (i) the relationship between social power and the distribution of environmental risks and burdens, (ii) the fact that society and nature coevolve, and (iii) the potential for the social structure to have a contradictory relationship to nature.

First, power matters in political ecology because different actors and groups have vastly different concepts about the proper value and use of the environment (Cronon, 2003), as well as different capacities to act and transform environments (or resist change) (Martínez-Alier, 2002). Harmful environmental changes tend to be hidden behind and legitimized by cultural narratives and institutionalized behaviors (Brand and Wissen, 2021). Some groups are more likely to benefit and actively participate in projecting and reifying particular narratives, while others become more vulnerable to their consequences. Structural power is therefore composed of diverse "cultural predispositions, expectations, and relations to others and to the larger world." (Morrison, 2018, p. 4)

Moreover, environmental changes are never uniform. The risks and rewards associated with a given environmental change are distributed unevenly. In the words of Bryant and Bailey (2005, 27–28), political ecologists accept the idea that an unequal distribution of costs and benefits inevitably "reinforces or reduces existing social and economic inequalities . . . [which implies that] environmental conditions and developmental concerns are inseparable- and that any change in environmental conditions must affect the political and economic status quo, and vice versa.". Vulnerability to environmental changes, including the capacity to offload damages, prevent them, and adapt, is directly related to the distribution of social power.

Second, political ecologists have also adopted an understanding of coevolutionary change. The human social system and the environmental system are in constant dynamic interchange. Coevolution is used to understand socio-cultural evolution as inseparable from changes in the human relationship to the environment (Norgaard and Kallis, 2011).[10] Norgaard (Norgaard, 1994, 40, emphasis my own)) writes that.

> "...social and environmental systems coevolve such that environmental systems reflect the characteristics of social systems — their knowledge, values, social organization, and technologies — while social systems reflect the characteristics of environmental systems — their mix of species, rates of productivity, spatial and temporal variation, and resilience. *The coevolutionary description of development explains why, and to some extent how, everything is related to everything else*".

From the coevolutionary perspective, all social action is 'socio-ecological'. Human action rests on an ever-evolving set of normalized behaviors, habits - whether implicit or explicit, conscious or unconscious - which embody certain patterns of relating to and within environments. A given mode of social organization - including cosmology, values, patterns of distribution, knowledge and technology - is necessarily created in relation to the broader environmental context and how this context is understood (Norgaard, 1984). A given pattern of interacting within an ecosystem may be considered dangerously misguided by one group, while praised as the epitome of sustainability and social progress by another. The differences between these come down to

10 The concept of coevolution originates in the biological and life sciences to describe the evolutionary trajectory of two or more closely interacting organisms: one organism adapts to changing circumstances in terms of the other, thereby altering the nature and quality of their relationship - provoking reciprocal responses with other organisms. Coevolution has been used to describe changes within numerous species interactions and ecological subsystems - the formation of a hummingbird's beak and the shape of the flowers from which they feed; the defenses of plants and animals to predators and the predators themselves; and the behavior of bee colonies the development of flowering plants (Norgaard, 1984).

the structures of power, values and beliefs which guide social behavior, and how society views itself in relation to the 'more-than-human' world.

The final concept from political ecology that is worth underlining here is the idea of contradiction: a number of authors have argued that capitalism has an inherently contradictory relationship with nature (Altvater, 1990; Foster and Clark, 2020; O'Connor, 1998; O'connor, 1988)). These authors argue that capitalist firms earn profits largely by shifting costs onto society and the 'external' environment[11]. The attempt to externalize socio-ecological risks and burdens is then an endogenous function of the relations of production within capitalism.

Nevertheless, this situation may ultimately undermine firm profitability. The biophysical conditions of production upon which capitalists depend then become increasingly unstable as rising rates of pollution, environmental breakdown, localized resource scarcity, social strife, and rising health concerns take hold and raise the costs of access and use of nature and labor. The perpetual drive to expand and accumulate then impairs "[capitalism's] own social and environmental conditions" (O'Connor, 1998, p. 159), resulting in an underproduction crisis and declining profitability. This then generates consistent pressure to overcome the crisis by developing 'environmental' fixes (Bakker, 2009; Castree, 2008; Ekers and Prudham, 2018). Environmental fixes include legal, technical and geographic measures that reduce costs and improve firm profitability by offering new opportunities for accumulation. Nonetheless these ultimately serve only to displace the underlying problem (contradiction) in time and space.[12]

Overall, political ecology adds a number of important elements for the present work. With the understanding that nature is valued and organized through conflict and structured vulnerability, this thesis is better able to grasp how political forces shape environments to the detriment of poor and marginalized groups. Additionally, this thesis can more critically examine mainstream (neoclassical) and even heterodox approaches (e.g., ecological macroeconomics) to studying environmental change, which tend to see the environment primarily as an instrument of production (Chester and Paton, 2013). Moreover, such a perspective allows for a more complete research project wherein even seemingly 'dysfunctional' or contradictory relationships between social and ecological systems can be understood as internally consistent, even when wildly out of balance with the rhythms and needs of natural systems, and society at large (Brand, 2016)).

11 See also Kapp (1978)

12 The notion of contradiction is also apparent in some anarchist framings of the ecological crisis. As Bookchin writes, "Environmentally, we are a beleaguered species—not by natural forces that inflict material scarcity and toil as unavoidable features of the human condition, but by social forces that create irrational relations and requirements as utterly needless features of ourlifeways." (Bookchin quoted in Best, 1998, p. 336)

1.1.3 *Potential incompatibility between ecological macroeconomics and world-ecology*

The previous sections described two fields - (i) ecological macroeconomics and (ii) world ecology - and their constituent sub-fields - (a) post-Keynesian economics, (b) ecological economics, (c) World-Systems and dependency theories, (d) political ecology - as broadly complementary. Uniting these visions appears to provide an ideal framework for socio-ecological analysis and criticism adapted to the global scope of the present environmental crisis and the structured asymmetries which support it. However, it is not entirely clear that each of these perspectives are perfectly aligned.

Most importantly for the subject of this thesis, ecological macroeconomists have predominantly taken nature to be an *apolitical* background upon which production processes take place, and from which they draw. The environment exists primarily as "an assemblage of physical components that are subject to human manipulation" (Budds, 2008, p. 60). While this vision can still demonstrate the importance of nature for demand-led production, political ecologists would argue that it privileges engineering solutions and "optimal" technological interventions which effectively depoliticize and dehistoricize contemporary problems. Political ecologists seek to move beyond purely instrumentalist approaches, whereby matter exists to be managed and formed according to specific (socio-)economic purposes. For political ecologists, even attempts to render the economy more 'efficient' can be misguided, particularly if efficiencies for one group come at the expense of others.

Second, ecological macroeconomists are also largely informed by an overly pragmatic interpretation of the nation-state. Taking from its post-Keynesian roots, ecological macroeconomists assume that the state is has natural legitimate powers for market intervention which can be wielded to enhance employment, equality, financial stability and environmental efficiency. National governments are uniquely placed to effect positive social change by shaping markets towards social objectives. From the perspective of world-ecology, however, the (capitalist-)state is a problematic entity that is not likely to successfully regulate human-nature relations towards greater harmony.

To bring in just one example, political ecologists, have tended to see the nation-state less as a fixed entity than as a process. The state is another battleground whose powers are frequently wielded to support unsustainable practices (Loftus, 2020). States carry-out, legitimize and institutionalize particular development pathways that may support stability and equity for some groups, while marginalizing others and laying the path for long-term instabilities (Mitchell, 2011). Indeed, the state itself is sometimes seen as a territorial strategy of simplification

and abstraction (Scott, 1998), or an illegitimate force of hierarchical domination and violence (Springer, 2016).

Third, ecological macroeconomists generally do not see any inherent contradiction between capitalist institutions and social and environmental sustainability. Scholars have therefore focused predominantly on methods for ensuring social stability within a growing or degrowing economy. Indeed, debate is generally centered around whether 'degrowth' is possible within a capitalist economy (e.g., whether growth is a social 'imperative') (Cahen-Fourot and Lavoie, 2016; Jackson and Victor, 2015, 2016), and not whether capitalist social relations are likely to rely upon and reinforce unsustainable behavior.

By contrast, as described in the previous section, scholars from world-ecology are quick to point to the contradictory relationship between capital and nature. For political ecologists, contradiction is an enduring structural feature of capitalist economies. By studying contradiction, political ecologists are the able to "inquire after the mechanisms by which these contradictions are kept from rupturing the surface" and generating overt social conflict (Bridge, 2000, p. 239). In this sense, contradiction becomes a key means for identifying how it is that human-nature relationships are regulated within the society in order to maintain stability and coherence.

Finally, ecological macroeconomists and world-ecologists are likely to clash over their vision of Core-Periphery relations. Ecological macroeconomists, following from post-Keynesian theory, recognize the importance of the Core-Periphery structure. Nevertheless, they tend to identify avenues for "convergence" between the two regions (Galindo, Giulio, and Gabriel, 2020; Guarini and Porcile, 2016). This retains a 'modernizing' framework, wherein the Periphery is held back primarily it's low level of industrial output, weak technological development, and lack of access to finance.

Conversely, world-ecologists, following from world-systems and dependency theory, see the Core-Periphery system as a structural feature of capitalist social relations. On the one hand, "convergence" would likely be problematic for the Core's growth prospects. For example, the Core would find itself increasingly in competition for "cheap" resources. Without sufficient access to inexpensive resources, the Core's productive and monetary stability tend to suffer (Patnaik and Patnaik, 2017). On the other hand, the Core-Periphery relationship largely continues even when previous Peripheries do manage to "converge" with the Core. The meteoric rise of China from the "factory of the world" to major global power would have been unlikely without establishing new Peripheries of extraction from the rest of Asia, Africa, and Latin-America (Svartzman and Althouse, 2020). In short, from the perspective of world-ecologists, the Core-Periphery relationship is fundamental, and capitalism relies on an uneven geography of development and material capabilities.

Despite this potential for conflict between ecological macroeconomics and world-ecology, there is plenty of reason to believe that they are complementary. As will be shown in Chapters 3, 4 and 5, the opportunities for integrating these frameworks far outweigh the potential theoretical conflicts between them.

1.2 STRUCTURE OF THE THESIS

This thesis is divided into four chapters of research. Each tells a story about the limits of dominant ways of understanding socio-ecological change, the constraints of achieving sustainability within present institutional frameworks, and the analytical potency provided by integrating a more *political* view of economy-environment dynamics. In doing so, they can potentially provide some additional perspective into the major obstacles to achieving more harmonious human-nature relations.

Chapter 2 begins with the history and literature review of ecological macroeconomics. This chapter describes ecological macroeconomics as an important step in the evolution of heterodox macroeconomic thought, as well as a necessary departure from mainstream neoclassical 'environmental' economics. I review nearly 60 articles in the field of ecological macroeconomics by dividing them into five core branches of research: (i) Green Keynesianism, (ii) Financial Stability and Socio-Environmental Change, (iii) Socio-Metabolic Dynamics and Constraints, (iv) Capitalist Growth Imperatives, and (v) Postgrowth/Degrowth Futures. By dividing the literature in this way, I develop a clearer understanding of how ecological macroeconomists perceive economy-environment dynamics, how this influences their policy recommendations, to what degree there is any internal confusion or inconsistency, and what limits might arise from within the framework.

Chapter 3 focuses on the primary constraints of the ecological macroeconomics perspective, and offers ways forward. I critically assess the methods, objectives, and understanding of economy-environment dynamics within the field to show that nature is seen largely as an instrument of production whose physical limits are now likely to increasingly constrain growth. The economy must therefore be rendered increasingly efficient in order to achieve an 'optimum scale' to reduce the scale of impacts. Attention therefore turns primarily towards top-down policy directives based largely on "greening" technology, investment, and energy systems to enhance sectoral efficiencies.

I contend that despite the benefits of the ecological macroeconomics paradigm, such a vision demonstrates an *apolitical* view of nature, which ignores the uneven causes and consequences of environmental change. In particular, the field has not been able to grasp the endogenous function of environmental degradation within the social struc-

ture. This has resulted in both some internal confusion within the field, and caused scholars to overlook conflicting empirical evidence demonstrating the functional and ethical limits of an investment-led 'green' transition.

I argue that ecological macroeconomics can gain much greater analytical clarity and empirical validity by integrating insights from the field of political ecology. I cite a vast body of research from political ecology which views nature not as a limit, but as a field of social conflict between competing groups. Nature is seen as unevenly accessed, valued and transformed according to the distribution of social power and vulnerability. From this perspective, environmental degradation, and constituent inequalities, are a *functional* aspect of particular ways of being and relating. From this perspective, without radical changes in the social structure, 'green' efficiency and technology programs are likely to reinforce, rather than relieve social and environmental harms.

Having explained both the value of ecological macroeconomics, and the need to develop an analysis that highlights the uneven causes and consequences of socio-environmental change, the rest of the thesis offers an application of this paradigm. In Chapter 4, I update a post-Keynesian balance-of-payments-constrained growth model to explore how sustainability transitions are also fundamentally issues of ecological conflict and distribution. I model a Core-Periphery system to endogenize a process of "ecologically unequal exchange", whereby growth in the Core depends upon displaced environmental burdens in the Periphery. In this framework, the Core's domestic efficiency and productivity are built in part by offsetting carbon-intensive activities to the Periphery. 'Green' investments and efficiency strategies for decoupling are not inherent sources of sustainability. While new 'green' technologies, sectoral shifts and improved value capture in efficient industries may reduce local environmental burdens in the Core, they are shown to reinforce unsustainable trends, globally.

The chapter then introduces a novel (environmental) interpretation of a "Keynesian coordination game" and develop four potential scenarios to remain within a global carbon emissions constraint: (i) A 'business-as–usual' scenario demonstrates global overshoot of the established emissions constraint in the absence of any intervention; (ii) a 'local sustainability by accumulation' scenario shows how green growth in the Core reduces domestic emissions, but raises global emissions overall, largely by pushing pollution-intensive production to the Periphery; (iii) a 'global sustainability by accomodation' scenario demonstrates how a reduction in the rate of growth ('degrowth') in the Core could accommodate growth in the Periphery, while allowing the world to meet global emissions targets; (iv) a 'global sustainability by cooperation' scenario then shows an ideal future where degrowth in the Core, technology sharing, and additional policy co-

ordination between the Core and Periphery enable global emissions targets to be met, alongside a major improvement in livelihoods in both regions. As opposed to previous research demonstrating the possibilities for 'green' growth, this chapter finds that achieving global sustainability and improving global equity will require an impressive level of coordination between the Core and Periphery, as well as a deaccumulation in the Core.

The understanding that Core-Periphery relations are governed by a profound asymmetry of resource- and pollution-intensive production is deepened in Chapter 5. This chapter adds historical and institutional context to the previous chapter by demonstrating the role of uneven environmental transformations in the making of finance-dominated capitalism. Three major stylized facts of the last fifty years, which have previously been left disconnected, are shown be institutionally coherent, interdependent, and highly dangerous: (i) the increasing material and pollution intensity of global production (IRP et al., 2019; Schandl et al., 2018), (ii) the increasing speed, scale and geographic scope of physical trade via the proliferation of global value chains (Baglioni and Campling, 2017), and (iii) the exponential growth of financial markets and cross-border financial flows that constitute financialized capitalism (Guttmann, 2016).

Whereas most studies posit financialization as an outside, immaterial and increasingly parasitical force upon industrial production, Chapter 5 re-imagines finance-dominated capitalism as a deeply embedded and material process that organizes production and environments to benefit accumulation in the Core. Financialization is shown to be made possible through three co-dependent and hierarchical relations which subordinate Peripheral countries and their environments: (i) money, (ii) production, and (iii) environmental transformation. I demonstrate how the growing power and profits of the financial sector ("financialization") are linked to the subordinate integration of Peripheries within the global monetary system, the reorganization of global value production ("offshoring"), and the intensification and expansion of capital to new frontiers of resource extraction ("commodity frontiers"). These patterns form what I called the "financialisation-offshoring-commodity frontier" nexus, a self-reinforcing institutional arrangement that guarantees new possibilities for capital accumulation, while accentuating the Periphery's vulnerability to financial instability, uneven development and ecological degradation.

These findings suggest that addressing systemic ecological risks and securing more equitable social relations requires a major overhaul of the international monetary and financial system, in a way that may nevertheless limit capital accumulation and GDP growth in Core economies. 'Green' forms of growth are again shown to be both wildly insufficient, and perhaps actively harmful, if not targeted toward the development of new social patterns of care, conviviality, and

cooperation that reduce the structural drive towards ever-increasing accumulation

Chapter 6 summarizes and concludes the thesis. It reviews the lessons learned from the previous chapters, and points the way forward to future research. I discuss how by integrating insights from political ecology, ecological macroeconomics is better able to identify the limits of particular policy frameworks, as well as engage more fruitfully with issues of distribution, environmental justice. This thesis more starkly reveals the contradiction of endless economic growth on a shared planet, as well as the ethical and practical limits to technology and investment-based strategies. I contend that coordinating national and global institutions will be necessary to effectively confront the socio-ecological challenges at hand, and reduce the pressure towards pollution- and resource-intensive avenues of development. Going forward, social and ecological stability will likely require not only a radical effort to degrow economies, but a global ethic to support community sovereignty, local resource governance, and human-environment connection. Rather than 'decoupling' the economy from environmental impacts via efficiency, it will be necessary to more consciously 'couple' our social and economic institutions within, and as expressions of, nature.

1.3 CONTRIBUTIONS

The contributions of this thesis are predominantly conceptual. The goal is to provide an alternative frame of analysis for studying macroeconomics on a shared and unequal planet. Ideally, this will also contribute to more applied approaches and empirical work.

First, this thesis provides an extended summary and analysis of ecological macroeconomics by breaking the field into five dominant research themes. While previous literature reviews have been conducted, they are predominantly focused on research methodology (Saes and Romeiro, 2019), are limited in scope, and are now out-of-date in a rapidly growing field (Hardt and O'Neill, 2017; Rezai and Stagl, 2016). By reviewing the history and state-of-the-art literature in ecological macroeconomics, this thesis is able to contextualize research in the field to understand where it has been, where it is going, what stones have been left unturned, why this might be the case, and to what extent this is problematic.

Second, this thesis also contributes to the literature by critically assessing the views and methods of ecological macroeconomics, and suggesting alternatives. While some critiques have been levied against the ecological macroeconomics (Røpke, 2013, 2016) and related fields (Spash, 2013), these have largely taken the form either of preliminary suggestions, or touched on only some portions of the available litera-

ture (Chester and Paton, 2013).[13] This work adds to the literature by attempting to understand how and why the field's analytical framework may have a limited capacity to grasp the ecological crisis. I also provide the beginnings of a pathway forward for future analyses. I show that ecological macroeconomics can gain greater analytical clarity by integrating insights from the fields of political ecology and dependency and world-systems theory. Through this lens, research in ecological macroeconomics can be amended to incorporate an understanding of environmental 'problems' as inherently problems of class (Huber, 2022), power (Hornborg, 2019b; Moore, 2015) and social distribution (Laurent, 2014), and dominant modes of living and being (Brand and Wissen, 2021)

Third, this thesis is able to reconsider some of the central findings of both mainstream (neoclassical) and heterodox (ecological macroeconomics) approaches to environmental issues. In particular, it provides a new avenue for critiquing 'green growth' and efforts towards 'decoupling' within ecological macroeconomics by contextualizing them within the uneven structure of the 'world-ecological system'. This way, the question of 'green' growth is not a matter of technical faith (e.g., How fast can decoupling occur? How much investment is needed? How much time do we have before climate change becomes overwhelming?) but a matter of relationship (e.g., Who benefits and who loses in the process? What kinds of new social and environmental patterns do 'green' investments bring, globally? How are these inscribed in existing uneven structures? What does the effort to 'decouple' *from* nature say about our collective relationship *to* nature?). By maintaining a focus on globally uneven environmental relations, 'green' growth is not just empirically doubtful but ethically flawed and practically limited.

Fourth, this thesis also contributes in a major way to the literature on financialization. Whereas financialization is typically described as an outside, immaterial force which is undermining industrial production and employment in the Core (e.g., Krippner, 2005), this thesis finds reason to consider otherwise. I describe financialization as an emergent phenomenon of the inequalities of the "world-ecological system". (Moore, 2015). From the perspective of this work, financialization is a deeply embedded and material process, constituted by new methods for organizing, controlling and accessing nature that benefits accumulation primarily within the Core, at the expense of the Periphery.

This finding turns some previous insights on their head, and unites a growing body of research that has not yet been connected: (a) aligning with a growing literature on 'subordinated financialization' (Bonizzi, Kaltenbrunner, and Powell, 2020; Bortz and Kaltenbrunner, 2018) financialization can be seen as a global process that links the Core and

13 See Svartzman, Dron, and Espagne (2019) for a notable exception.

Periphery, rather than geographically isolated in the Core (Christophers, 2012; French, Leyshon, and Wainwright, 2011); (b) financialization is also shown to go hand-in-hand with a changing geography of value-added production, rather than implying a reduction in industrial production (Auvray and Rabinovich, 2019); (c) the 'fictitious' (financial) economy and the 'real' (productive) economy, are shown to rely on profound and unequal material transformations of the Earth system. Financial dynamics alter the scope, scale and intensity of extraction in ways that tend to benefit accumulation in the Core, while subjecting Peripheral environments and people to increasing financial pressure, degradation and toxicity.

Fifth, this thesis adds to an existing debate within ecological macroeconomics about the 'growth imperatives' found in capitalism. Previous research has attempted to uncover to what degree capitalist institutions require growth in order to maintain social stability in the form of high employment, equality, and manageable levels of indebtedness. Most of this research has concentrated on whether the monetary system is the primary driver of growth. More specifically, since money is created by generating interest-bearing debts, growth may be a necessary means to pay off mounting interest charges and increased debt loads. As shown in Chapter 2, section **??**, modeling efforts and analysis from within ecological macroeconomics have pointed out that this may not necessarily be the case.

The majority of existing research, however, has tended to question the growth-dynamics of the monetary system from the perspective of a single country. While I do not comment on the specific role of debt-bearing interest rates internationally, the present thesis looks at money as a global institution that shapes environments in uneven ways. As will be discussed in greater length in Chapter 5 and the Conclusion (Chapter 6), the political ecology of global monetary relations offered here can alter the way the 'monetary growth imperative' is viewed.

In particular, Chapter 5 points out that (i) the global monetary and financial system is hierarchically organized, (ii) that this is crucial for allowing the Core to obtain resources from countries further down the hierarchy, and (iii) that being at the bottom of the hierarchy is socially and ecologically unsustainable. This hierarchical pattern will naturally drive competition to rise within the ranks of the hierarchy and avoid being placed at the bottom (Andersson and Lindroth, 2001). This positional competition between firms and nation-states was already signaled as a potential key driver of unsustainable growth in ecological economics (Georgescu-Roegen, 1971, 1977). Moreover, the link between the global competition for monetary power, capital accumulation, and resources is already a component of Marxist theories of imperialism (see Patnaik and Patnaik, 2017). Nevertheless, these

ideas have not yet been explored in ecological macroeconomics, until now.

Sixth and finally, this thesis adds to the existing literature by providing insight into the practical implications and limited possibilities of 'degrowth' within the context of a Core-Periphery system. To date, the vast majority of literature has attempted to understand how to achieve degrowth within the boundaries of a (high-income) nation-state with no trade or financial obligations. This is a major abstraction from the realities of an interdependent and uneven world-system.

While further research is required, this thesis points to some of the structural limitations of actively reducing growth within the present asymmetries of the global trade, monetary and financial systems. In Chapter 4, for example, it is shown that degrowth in the Core may be necessary to achieve global climate goals and provide greater operating space for material growth in the Periphery. Nonetheless, I argue that it can have counterintuitive effects. In particular, the Core serves as a key source of demand for Peripheral firms. While much of this foreign demand ultimately sustains resource- and pollution-intensive production, there is reason for caution: degrowth in the Core could inadvertently increase unemployment, reduce export earnings, increase indebtedness, and raise inequality in the Periphery. Even if degrowth in the Core is necessary, therefore, this thesis points to greater need for economic cooperation between regions in order to sustainably reduce growth.

Moreover, Chapter 5 further demonstrates that the global monetary, financial and trade systems pose a serious constraint for degrowth policies. On the one hand, this uneven global context will likely intensify the severity of obstacles already discussed by degrowth scholars (e.g., the potential increase in inequality, employment losses, increase in public debts) (Jackson and Victor, 2015, 2020). On the other hand, it brings new potential risks, including those associated with capital flight, exchange rate risks, currency depreciation, imported inflation, and foreign indebtedness. From this perspective, degrowth may only be feasible with significant changes to the international monetary and financial systems.

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2

ECOLOGICAL MACROECONOMICS: EXPLORING THE PAST, ASSESSING THE PRESENT

History...does not refer merely, or even principally, to the past.
On the contrary, the great force of history comes
from the fact that we carry it within us,
are unconsciously controlled by it in many ways,
and history is literally present in all that we do.

— James Baldwin

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Ecological macroeconomics is an approach to macroeconomics which explicitly accounts for the economic system as a sub-system of the planet, and which provides for how materials and energy are transformed through processes of production, distribution and consumption. In the face of interdependent social, economic and ecological crises, the nascent field of ecological macroeconomics has sought to establish itself as a new paradigm that embraces systemic complexities and offers positive solutions to social-environmental challenges. With foundations in post-Keynesian, institutionalist and Marxist thought, ecological macroeconomics has brought fresh perspectives into the dynamics of economy-environment relations, developing a set of meth-odological tools to approach the rapidly unfolding climate crisis and its impacts on employment, financial stability, income growth and distribution (Rezai and Stagl, 2016).

The ecological macroeconomics perspective is frequently distinguished as a clear alternative to the neoclassical paradigm. Whereas neoclassical economics is based in a belief in utility maximization, quantifiable risk, and perfect substitution between 'nature' and other 'factors of production', ecological macroeconomics highlights the social construction of preferences, the uncertainty of knowledge about present and future states of the world, and limited substitutability of nature by capital and labor (Holt, Pressman, and Spash, 2009; Spash and Smith, 2019). Moreover, while neoclassical economists propose a vision of the market economy as identifiably separate from 'external' social and environmental phenomena, ecological macroeconomists view the economy as embedded within society, which is itself embedded within the larger Earth ecosystem (Hardt and O'Neill, 2017). Ecological macroeconomists therefore openly acknowledge that the social system is inherently dependent on - and inseparable from - changes in the environment.

This chapter presents a comprehensive survey of ecological macroeconomics in order to contextualize current and early research, critically appraise the state-of-the-art, and assess the possibilities for a more coherent future for the field. This review categorizes and compares 59 articles that are representative of ecological macroeconomics. As such, the literature review more than doubles the number of studies covered in previous reviews (Hardt and O'Neill, 2017), and includes a more updated frame of reference to match the rapidly evolving field. Five core 'branches' ('themes') are identified: (1) Green Keynesianism, (2) Financial Stability and Socio-Environmental Change, (3) Socio-Metabolic Dynamics and Constraints, (4) Capitalist Growth Imperatives, and (5) Post-growth/Degrowth Futures.

While several reviews of the literature have been conducted, these have focused primarily on methodological choices and classified the models in use within ecological macroeconomics (Hardt and O'Neill, 2017; Saes and Romeiro, 2019). This chapter finds no fault with the

methodological findings of previous reviews of literature, but diverges from them in two important ways: First, multiple studies are cited here which have no specific model (Stratford, 2020; Svartzman, 2020). From the perspective of this paper, these conceptual or theoretical studies are perhaps even more important for understanding the general tenor of the field, and the logics informing them. Closing off to study mathematical or analytical models alone risks reducing the prevalence of certain themes in the research, some of which ask questions that may be difficult or impossible to represent analytically or numerically.

Second, research is categorized according to diverse attempts by ecological macroeconomists to understand a particular facet of economy-environment relations. These themes are built around specific research questions for which multiple potential models and frameworks may apply. Which questions are salient, how the questions are asked, and how they are answered can be revealing in themselves. In this sense, models remain important, yet they take a back-seat to the scope of both the research question and the answers provided.

I ultimately find that ecological macroeconomics holds within it the seeds of an important possible field of critical theory and macroeconomic research. However, the field seems to present conflicting policy advice, particularly in relation to whether there is a need for more 'green' growth or whether degrowth offers a clearer avenue towards more sustainable futures. This internal conflict, along other inconsistencies will be further explored in Chapter 3.

The rest of this chapter is structured as follows: Section 2.1 traces the history of ecological macroeconomics to understand the raison d'être of a field dedicated to linking the economy to its material and energetic foundations. By demonstrating the progressive disconnect between 'economy' and 'environment', this section introduces ecological macroeconomics as a necessary, if perhaps conflicted field that arose from a new promise to re-embed the economy within the environment. Section 2.2 then presents the five primary branches of ecological macroeconomics and reviews the available literature. Section 2.3 discusses and compares the findings to clarify some of the primary points of agreement and contention, as well as obstacles to developing a coherent paradigm. Section 2.4 summarizes and concludes.

2.1 'ROOTS' OF ECOLOGICAL MACROECONOMICS

This section presents a brief history of ecological macroeconomics. The section begins with an introduction to how early economists came to view the relationship between 'economy' and 'environment'. Notions of the 'economy' over the last 250 years appear to have evolved according to the socio-political and material conditions of the time. In particular, as imperial expansion, rapid industrialization,

and access to new fossil energy sources coalesced and solidified ideologies that separated the economy and the environment. As fossil fueled technology and foreign resource appropriation absolved imperial powers of domestic land constraints (i) nature became an epistemological blind-spot and (ii) 'economy' came to mean an increasingly disembodied and disembedded realm of objective statistical aggregates. Economists soon viewed industrial production and economic growth as ends in and of themselves. Separated from its environmental context, economic growth then symbolized 'modern' civilization and social progress.

This separation, however, began to shift back in the 1960s and 70s as mounting environmental distress in the capitalist Core countries provoked a need for radical economic alternatives. Ecological economics came to the fore in an effort to re-embed the economy within its natural context. By appealing to the laws of thermodynamics, ecological economists questioned the reigning beliefs in the substitutability between labor, capital and nature, as well as the capacity to accurately price environmental 'goods' and 'bads'. A concerted macro-level framework began developing in earnest after the 2008 financial crisis. Ecological macroeconomics has since become a catch-all term for research stemming from a number of heterodox schools, primarily post-Keynesians, in the study of economy-environment relations.

2.1.1 *A Brief History of 'Ecology' in Economics*

For classical and pre-classical economists 'political economy' was understood as a social process of establishing proper relationship between individual, society and nature. While system-wide accounts and aggregate statistics appeared as early as the 1660s, 'economy' referred to the governance and employment of available resources. Land was understood to play an especially important role in social welfare. The physiocrats of the 18th century, for example, focused on land as the primary and, indeed, only source of value (Hubacek and Bergh, 2006). Their concept of economic productivity was inseparable from the available natural elements of sun, soil, water, etc., largely considered part of a divine power, that allowed life to flourish (Vardi, 2012). Man produced nothing, but was capable of actively utilizing the already existing wealth provided by nature in the form of food, fuel, fiber, water and minerals to secure basic needs, and manufacture commodities using surplus. François Quesnay's famous "Tableau Économique" made the distinction between two spheres: the *productive* sphere was given by nature, while the *sterile* sphere utilized what was already naturally given.

Likewise, when classical economists spoke of 'economy', they did not refer to a self-contained structure that comprised the relations of production, distribution and consumption of goods and services, but

to the frugality and management of available resources.[1] Economists like Smith, Malthus, Mill and Ricardo described - albeit in very different ways - how production and well-being was dependent on the land. While increases in wealth could expand for some time, it was also assumed that the drive to accumulation would eventually slow down, before returning to a 'stationary state'.

Beginning in the 18th century, human-, animal-, wind- and water-power, however, was increasingly replaced with fire-power within Britain and other imperial centers. The discovery of new methods for accessing, extracting and transporting coal provided new opportunities to reorganize society, as well as to intensify command over colonial outposts. Until the industrial revolution, energy availability was practically synonymous with land availability. Fossil fuels "provided a form of energy that did not compete with food production or other uses of land" while significantly augmenting the productivity of labor (Hornborg, 2013, p. 47). This freed up immense tracts of previously farmed land for alternative use and 'liberated' rural workers to move to cities to fill rapidly growing industrial factories (Pomeranz, 2000).

Coal thus became the lynchpin to the 'illusory emancipation from land' within Western social thought (Hornborg, 2009). The seeming abundance provided by coal-fuelled technological progress gave Europe both physical and "imaginative space" for its expansionary project (Pattberg, 2007). Steam-powered technologies cemented Britain and Europe's industrial and military potential, increasing their capacity to appropriate resources from colonies, as well as to establish new markets to absorb export demand.

The apparent decline in the importance of land solidified the belief among European elites in the value of technology as a tool to tame and control nature, a measure of social progress, and proof of white racial superiority (Manjapra, 2020). Environmental conditions thereby fuelled the growing ideological separation between mind and body, human and Earth. The age of Enlightenment was predicated on new scientific means of controlling and managing nature (Daggett, 2019) and a belief that material dependencies could be escaped through technical dominance. Rapid growth in wealth and industrial manufacturing within Europe provided a sense of limitless progress through human ingenuity. Technological innovation became a symbol of man's dominion of nature, even as European powers relied to growing extent upon overseas territories for land, (slave) labor, and a limited pool of dense, fossilized energy.

1 According to Mitchell, "No political economist of that period refers to an object called 'the economy'. In the sense of the term we now take for granted, referring to the self-contained structure or totality of relations of production, distribution and consumption of goods and services within a given geographical space, the idea of the economy emerged more than a century later, in the 1930s and 1940s." (Mitchell, 2011, p. 125)

At this time, Marx wrote extensively about the capitalist mode of production's tendency to undermine "the original sources of all wealth - the soil and the worker" (Marx, 1992, p. 638). Aside from noting the destruction of common resource ownership and the dependence on 'primitive accumulation' in the beginnings of capitalism, he also discussed at length a growing polarity between burgeoning capitalist cities and the countryside. As agricultural production intensified to meet urban needs, important nutrients were no longer recycled to the soil. This 'metabolic rift' between town and country, resulted in steadily declining land quality, along with systematic attempts to cope with the damage. Colonial powers had become so desperate for fertilizer, for example, that they conducted overseas wars in South America to mine sufficient quantities bat guano needed to maintain domestic soil health (Foster and Clark, 2020).

This, however, was a time of immense technological optimism, sustained by the seeming freedom brought by a seemingly limitless capacity to overcome natural constraints. As Hornborg (2013) writes, fossil-fueled technology brought about a "fundamental transformation of economic rationality" whereby

> natural constraints were no longer absolute but could be transcended with the help of new technology. If British soils had been exhausted of nutrients, they could be replenished through the import of guano and phosphates from islands in the Pacific. The extent to which this relied on slave-like working conditions on those islands as well as in the British coal mines was made more or less invisible by the impersonal logic of the market, as were the ecological consequences. (Hornborg, 2013, p. 47)

With a profound faith in 'modern' technology and increasingly sophisticated mathematics, economists began searching for a scientific interpretation of economic behavior. Rather than the economy expressing a particular quality of relationship with nature, thinkers like Leon Walras became convinced that motions of the economy could be understood with mathematical precision. Walras and his contemporaries were convinced that they "lived in an era of great scientific progress" and had "a boundless optimism that they could describe any aspect of nature in their equations" (Beinhocker, 2006, p. 31). Neoclassical economics was primarily developed assuming that the economy behaved like a physical system, governed by Newtonian mechanics. The economy was understood as a separate, frictionless sphere of interaction that could be described through abstract mathematical axioms.

This eventually set up a major battle over how 'economics' was to be understood. At the end of the 19th and beginning of the early 20th centuries, there were two major camps. On one side was a group of social scientists - notably Thorstein Veblen - which viewed the economy

primarily through the lens of physical flows of materials and energy. These scholars were preoccupied with resource exhaustion, conspicuous consumption, and conservation. In this sense, economics was to be seen as a study of materiality of human relationships and social (re)production. As Veblen wrote,

> In so far as it is a science in the current sense of the term, any science, such as economics, which has to do with human conduct, becomes a genetic inquiry into the human scheme of life; and where, as in economics, the subject of inquiry is the conduct of man in his dealings with the material means of life, the science is necessarily an inquiry into the life-history of material civilization... no theoretical inquiry into this material civilization that shall be adequate to any scientific purpose can be carried out without taking this material civilization in its causal, that is to say, its genetic, relations to other phases and bearings of the cultural complex..." (Veblen, 1909, pp. 627–628)

On the other side were those who focused on the mechanistic relationship between consumer choice, 'market' prices and flows of money. The latter group, led by neoclassical economists, eventually won out. From then on, the economy was reimagined as aggregation of monetary transactions, having little or nothing to do with the material realm. Economics became primarily a

> science of money; its object was not the material forces and resources of nature and human labour, but a new space that was opened up between nature on one side and human society and culture on the other – the not-quite-natural, not-quite-social space that came to be called 'the economy'. (Mitchell, 2011, p. 132).

The reification of the economy as a separate domain unto itself was further entrenched with the development of Keynesian economics. Keynes moved beyond neoclassical visions of the economy to create a macro-level accounting framework for a given national space. Whereas neoclassical economists had seen money as a purely neutral signifier used for exchanges between equal agents, however, Keynes gave importance to money as a social tool which could be used to combat the glaring issues of unemployment and poverty, in the aftermath of the depression. This vision came into favor especially as beleaguered governments sought to mobilize productive forces to alleviate the impacts of the great depression and, ultimately, prepare for war.

With the development of national accounts and 'gross national product' (GNP), monetized behavior was increasingly abstracted from its material implications. The 'economy' came to comprise an en-

tire self-contained system of accounts - national aggregates (e.g. production, consumption, government spending) and synthetic averages (e.g., inflation, price levels, productivity, etc.) - within defined geopolitical boundaries (Mitchell, 2011, p. 137). The development of national totalities came with immense bureaucratic momentum and the illusion of objective measurement (Desrosières, 1998; Fourquet, 1980). While the notion of the 'economy' comprised and promoted only limited elements of human social relations - those with a price attached - it was increasingly conceived of as a discrete element with its own existence (Mitchell, 2008).[2]

The newfound capacity to measure the size and structure of the economy provided additional legitimacy to the growing political and administrative power of the nation-state to serve as a steward for the 'economy'. From then on, economics progressively "superseded law as the technical language of administrative power" and tool of foreign diplomacy (Mitchell, 2011, p. 137). The 'economy' soon became one of the primary prisms through which social policy could be conceived.

These rising incomes and reduced inequalities in the US and Europe were associated primarily with rapid industrial development and technological change, very much in isolation from the resource- and fossil-fuel- intensive lifestyles that were taking hold during the post-war boom (Huber, 2013). Moreover, since the share of national employment and income generated from agriculture and other 'resource-based' sectors had shrunk considerably as per-capita incomes grew, considerably. Sectors that implied a more direct relationship with the Earth were labeled as outdated, unproductive and even unnecessary. In this context, economic growth came to be virtually synonymous with social progress and development, not to mention a key ally in the fight against Communism. National development policies were judged in terms of their ability to serve economic growth and generate structural transformations that raised incomes, employment and productivity.

Heterodox and neoclassical economists alike took on a 'modernizing' vision of national economies. Continuous increases in industrial growth symbolized economic success, social progress, and national security. This was perhaps most famously described by Rostow (1959) and Rostow (1990), who argued that social development occurred through different growth stages that each country will eventually ex-

2 The originator of national income accounts, Simon Kuznets, warned from the start that "The natural desire to have a single measure and to read an unequivocal meaning into it often leads to the treatment of national income as the uniquely objective measure of economic achievement rather than as an appraisal based upon criteria that may differ from country to country, group to group, and time to time. A national total facilitates the ascription of independent significance to that vague entity called the national economy and may induce neglect of the patent fact that this entity comprises millions of individuals and firms, and scores of industries, economic groups, and regions whose efforts add up to the national income total." (Kuznets, Epstein, and Jenks, 1941, p. xxvi)

perience before arriving at industrial maturity and a society of high mass consumption. Increasing wealth through rising rates of productivity and industrialization was thenceforth part of a linear historical progression away from land-based industries. Growth was seen as morally desirable and an inevitable function of economic evolution. Technological development and industrialization were necessary to achieve a modernizing "take-off" (Rostow, 1959); a healthy economy was literally one that had left the ground and disavowed 'traditional' lifestyles based on landed production.[3] Even as this growth remained dependent on rising rates of extraction, the improved material standards seemed to be indefinitely repeatable throughout the 'developed' and 'developing' world.

Yet the apparent successes of rapid and fossil-fuel-induced growth were short-lived. Economists once again began expressing interest in the environment in the 1960s, alongside growing public awareness of environmental distress even within the industrial powers. The post-War optimism in scientific discovery and technological progress had begun to fade as productivity increases slowed, and social fissures and ecological breakdown became more apparent. Mounting fears of a coming population explosion (Ehrlich, 1968) and the resource demands of a constantly growing economy eventually culminated in a landmark report by the Club of Rome's 1972 report on the "Limits to Growth" (Meadows et al., 1972). This report, compiled by a team of international scientists, presented damning evidence that modeled the systemic feedback effects between population growth, agricultural production, resource depletion, industrial output, and mounting pollution.

Additionally, environmental concerns took on increasing prominence in 1973 as flows of oil from OPEC came to a halt in the US and other world powers, driving inflation higher while ensuring economic slowdown. It became increasingly difficult to ignore both the growing interdependence of national economies, as well as their fundamental reliance on a set of finite resources that could no longer be taken for granted.

To address mounting concerns linked to rising rates of pollution, resource extraction and geopolitical pressures over key energy sources, two divergent avenues within economics developed: neoclassical 'environmental' economics and ecological economics.[4]

3 Rostow's belief that human social flourishing could be enforced through dispassionate techno-managerial politics heavily influenced Western development policy (Ish-Shalom, 2006; Pearce, 2001). His insistence on growth, productivity and modernization as both the primary means and ends of a free society remains deeply embedded within both the discipline of economics and the political landscape of the 21st century.

4 See Froger et al. (2016) and Gendron (2014) for greater detail.

2.1.2 *Neoclassical 'Environmental' Economics*

Neoclassical 'environmental' economics was built as an attempt to include environmental considerations within traditional neoclassical growth models. These models are therefore built upon the same micro-foundations as their forebears: individuals are seen as perfectly forward-looking, boundlessly rational, and possessing perfect information within free and competitive markets. Under the optimizing conditions of neoclassical models, price signals are thought to help market actors coordinate to avoid potential environmental threats and achieve market equilibrium. The environment is seen primarily as a collection of potentially valuable goods and services that can be infinitely exploited by market functions.

Environmental economists, however, admitted that there may be some 'market failures' that impede accurate price discovery and therefore lead to a suboptimal equilibrium.[5] In neoclassical environmental economics, one of the primary causes of market failures are environmental 'externalities'. Externalities lead to market failure because the price of the product or service being exchanged does not reflect its 'true' market value. Externalities include costs (or benefits) that impact third parties that do not directly participate in a given market transaction or production process. In essence, externalities exist because those who are harmed (rewarded) by the pollution are not financially compensated (taxed).

Environmental economists therefore insist on developing new ways to 'get prices right' to enable market signals to function. Under optimizing conditions with rational actors, pollution externalities are overcome by assuring that prices are adequately internalized. Externalities can then be eliminated by either imposing taxes on polluting activities, or developing new markets for natural 'goods' (e.g., establishing property rights on communal land, payments for ecosystem services) and 'bads' (e.g. establishing carbon markets and emissions trading schemes).

Such a vision reflects a long-standing faith in the beneficence of market incentives to support innovative solutions to any obstacles posed by 'nature'. Even resource scarcity is thought to be overcome by better defining property rights and eliminating barriers to accurate price discovery. Within the neoclassical framework, environmental degradation and resource exhaustion are, if anything, viewed as bumps on the road towards a more stable and equitable economy. A resource can always be substituted as long as 'ecosystem services' and resource inputs are properly priced. At the core of Robert Solow (1973, 1974)'s neoclassical growth model, for example, lies the as-

5 Arrow et al. (2004) suggest that market prices for nature may not reflect the 'true' price because of (i) poorly defined property rights (ii) market failures and (iii) government subsidies.

sumption that non-renewable material inputs could be easily replaced by labor or capital, thus allowing environmental concerns to fall by the wayside. According to Solow (1974, p. 11), new technological capabilities and factor substitution would mean that even complete destruction of natural resources could be rendered "an event, not a catastrophe".

It is worth noting that even more recent neoclassical frameworks overwhelmingly see environmental destruction as stemming insufficient investment in 'human' and 'manufactured' capital to offset the depletion of 'natural' capital (Arrow et al., 2004, p. 167). Sustainability can then be guaranteed by public policies that support "efficient consumption and investment choices" to better approximate the social cost of environmental destruction (Arrow et al., 2004, p. 168). Mainstream economic models thereby propose a near-infinite capacity for economic growth and resource use, particularly if accompanied by optimal regulations, taxes and the establishment of secure property rights.

2.1.3 *Ecological Economics*

The environmental challenges of the 1960s and 70s also gave birth to a new paradigm: ecological economics. Ecological economics began as an radical attempt to move beyond orthodox thinking, which had been based in the idea markets as self-equilibrating systems and infinite substitution between factors of production. The founders of modern ecological economics - Nicholas Georgescu-Roegen, Herman Daly, Kenneth Boulding, and H.T. Odum, among others - argued that the economic process is inextricably tied to the biophysical flows that enable and constrain all social activity. Rather than positing the economy as primary, ecological economists asserted first and foremost the inescapably material and energetic foundations of human (social) life. Economies were then understood as a subset of human social relations, which are themselves embedded within natural systems.

Ecological economists generally begin from the starting point that society is bound by the laws of thermodynamics (Georgescu-Roegen, 1971). The first law of thermodynamics states that, in an isolated system, energy and matter can neither be created nor destroyed. While the total energy of the system does not change, it's quality does. The second law of thermodynamics states that any isolated system trends inexorably towards greater disorder - higher 'entropy' - until reaching thermodynamic equilibrium, at which point nothing else can happen. The second law relates the fact that as energy is used, its capacity to do work declines as well.

The recognition that there is a one-way drive towards declining availability of useful energy and matter has profound implications for understanding economic systems. Economies can only be sus-

tained only by securing new inflows of natural resources, and generating novel ways to dispose of wastes. As Nicholas Georgescu-Roegen states, "from the purely physical viewpoint, the economic process is entropic: it neither creates nor consumes matter or energy, but only transforms low into high entropy" (Georgescu-Roegen, 1971, p. 281). The first and second laws of thermodynamics are therefore widely accepted as a guiding principle for understanding biophysical limits within ecological economics, and are "arguably the ultimate regulator of both biological and industrial metabolism." (Rees, 2016, p. 138).

From this perspective, the 'economy' could be reconceived as a kind of metabolic superorganism. All social and biophysical life processes require constant access to materials and energy to grow and maintain their structure. Economies transform and redistribute materials and energy and establish 'sinks' for disposing for wastes in order to grow and (re)produce. Social systems must direct, influence and disrupt complex ecosystems to access energy and material inputs or to dispose of wastes. Low-entropy energy and matter are transformed, used, and returned in a 'degraded', less useful state of higher entropy. From a purely physical standpoint, the Earth system is then used as (i) a resource pool, to provide high-quality (low-entropy) materials and energy, and (ii) a sink, to assimilate waste of low-quality (high-entropy) materials and energy. Moreover, the quantity of useful energy outputs is always less than the quantity of useful energy inputs.

Taking seriously a vision of the economy as bound by thermodynamic limits posed fundamental questions to the guiding logics of economic growth and capital accumulation in, themselves. According to Gowdy and Erickson (2005), ecological economics is the

> only heterodox school of economics consistently focusing on the human economy as both a social system, and as one constrained by the biophysical world... [whose] models of economic behaviour encompass consumption and production in the broadest sense, including their ecological, social and ethical dimensions, as well as their market consequences" (Gowdy and Erickson, 2005, p. 208).

Whereas most neoclassical economists had seen accelerated growth as a sign of economic strength, market innovation, and social progress, ecological economists began to see growth as inherently limited, increasingly harmful, and ethically flawed (Boulding, 1966; Daly, 1991; Georgescu-Roegen, 1977). In repositioning the economy as materially dependent and inseparable from its biophysical grounding, ecological economists questioned the utility of further economic growth and determined the extent that environmental impacts related to social institutions and practices.

2.1.4 *Planting the 'Seeds' of Ecological Macroeconomics*

Ecological economics began from the need for a broader systems-wide approach to understand the economy as an expression of social relationships that are fundamentally embedded within the Earth and its interconnected biophysical systems. The finding that economic dynamics could also be described in terms of biophysical transformations and impacts had significant repercussions for the collective understanding of economy-environment relations. Despite its basis in systems thinking, however, the field has traditionally engaged little with theoretical or empirical macro-level analysis. According to Spash and Schandl (2009, p. 1) the field "ha[d] no specific macroeconomic approach" despite the fact that environmental issues have "strong implications for economic growth and how this should be controlled, directed and in materials terms limited". This deficit was crucial, especially given that environmental changes and individual, firm and government actions have emergent properties and feedback effects that become apparent only at the meso- and macro-levels.

As opposed to (neoclassical) microeconomic theory, which focuses on decision-making at the level of the individual, macroeconomic approaches study quantified aggregates to understand the evolution of employment, the stability and growth rate of GDP, and inflation within a given system, typically at the national level. Nonetheless,some ecological economists were heavily influenced by neoclassical economics. Ecological economics developed in the 1980s and, despite its clear heterodox leanings, was 'entrapped by orthodox economic dialogue' (Spash, 2011, p. 344). The field remains internally conflicted (Spash, 2013). Many ecological economists continue to be guided by neoclassical micro-foundations to find optimal growth paths, determine efficient pollution prices through cost-benefit analysis (M'gonigle, 1999; Røpke, 2005), and establish the 'true' value of nature and ecosystem services (Plumecocq, 2014).

Initial forays into macroeconomic modeling with explicit environmental considerations, therefore, "tended to use economic equilibrium theories and concepts of capital, which are inconsistent with some of its basic premises about systems functioning derived from ecology." (Spash and Ryan, 2012, p. 8). Additionally, many models lacked an endogenous view of money, which therefore obscured the role of aggregate demand and the banking system in establishing the relationships between the economy and the environment. Neoclassical integrated assessment models (IAMs), environmentally-augmented neoclassical production functions, even IS-LM[6] modeling frameworks all sought to achieve an optimal growth path and 'ecological equilib-

6 See Lopez Morales (2007) for a review of IS-LM-EE models, which link equilibrium in the goods market - Investment/Savings (IS) - the money market - Liquidity/-Money (LM) - and the environment - Efficiency/Environmental Throughput (EE).

rium'. Turning the economy towards a sustainable pattern of resource use continued to be based in efforts to find Pareto-optimal outcomes and maximizing individual consumer utility (Gowdy and Erickson, 2005).

Herman Daly, one of the founders of ecological economics, noted the lack of specific engagement with macroeconomics in the early 1990s and suggested the need for more explicit efforts to integrate ecological and macroeconomic analyses. Daly (1991, p. 35) considered that "the subject matter of environmental macroeconomics" would be constituted by "[t]he physical exchanges crossing the boundary between [Earth] system and [economic] subsystem". Ecological macroeconomics would therefore have to incorporate an understanding of the economy as an embedded system which provisions and distributes energy and resource flows.

According to Daly, ecological macroeconomics would be primarily concerned with questions of (i) scale, (ii) distribution, and (iii) allocation. In his schema, scale relates to the physical stocks and flows of energy and materials needed to sustain the social structure. Given that the Earth is a closed system and the economy a mere subsystem, Daly argued for stabilizing the economy at an appropriate size (a 'steady' stationary state) to limit throughput. Daly also called for equitable distribution of resources, particularly between low-income and high-income countries. Moreover, questions of allocation involve understanding how to most efficiently use and provide the materials and energy needed in market economies.

The calls for an integrated ecological macroeconomics intensified in the wake of the 2008-2009 financial crisis. Widespread financial and economic instability (Stockhammer, 2013), coupled with intensifying inequality (Piketty, 2014) and growing awareness of the degradation of the Earth system (Steffen et al., 2015) provided a greater push to tackle social, economic and environmental crises as a single coherent issue. Moreover, it provided additional reason to reject the neoclassical orthodoxy, which had failed to prevent or predict the crises, and to open up to heterodox streams of thought (Jackson et al., 2014). Jackson (Jackson, 2009, p. 142), therefore, made the case for a "new macroeconomics" that will be "ecologically and socially literate, ending the folly of separating economy from society and environment". Harris (2009, p. 1) also argued, there is a need for an ecological macroeconomics which can "reflect [these] new realities" of combined social and environmental crises.

The desire to bridge this divide between the economy, society, and nature has been met by growing interest from other economic paradigms, predominantly post-Keynesians. While post-Keynesians have been criticized in the past for "almost totally fail[ing] to pay attention to the environment" (Spash and Schandl, 2009, p. 49) and for favoring growth-centric policies (Chester and Paton, 2013), numerous articles

began to recognize the ontological, epistemological, and methodological similarities between ecological economics and post-Keynesian macroeconomics beginning in the early 2000s (Holt, 2005; Lavoie, 2005; Mearman, 2007).

Ecological economics and post-Keynesians appear to share important methodological considerations: the belief in radical uncertainty, the role of institutions, the importance of distribution in determining social and economic outcomes, limited substitutability between inputs[7], and irreversible time. The crossover between the two would prove to be "a significant step forward" (Spash and Schandl, 2009, p. 49) for creating an ecological macroeconomic paradigm. This eventually culminated in a book dedicated to the topic, titled *Post-Keynesian and Ecological Macroeconomics* (Holt, Pressman, and Spash, 2009).

While the inherent compatibility of ecological economics and post-Keynesian economics remains contested (Chester and Paton, 2013; Mearman, 2009; Svartzman, Dron, and Espagne, 2019), ecological macroeconomics has been undeniably pushed forward largely by utilizing post-Keynesian frameworks to analyze environmental issues and settle longstanding debates amongst ecological economists. Recent works by post-Keynesian authors have laid the broad foundations for a theory of ecological macroeconomics, solidifying its existence as a stand-alone field (Fontana and Sawyer, 2016; Rezai, Taylor, and Mechler, 2013). The domain now incorporates numerous insights from other heterodox schools, including Marxian, Polanyian, Sraffian, neo-Ricardian and Regulationist approaches (Cahen-Fourot, 2020; Rezai and Stagl, 2016), yet remains dominated by post-Keynesian and Kaleckian frameworks.

2.1.5 *'Green Shoots' of Ecological Macroeconomics: Modeling Techniques*

One way of analyzing ecological macroeconomics to date, has been to review its methods of analysis. Indeed, while ecological macroeconomics may not have coalesced into a coherent identity, it appears to be "driven by a need to develop better analytical frameworks to understand economy-environment interactions on a macro-scale and to provide tools to manage the transition towards a sustainable economy." (Hardt and O'Neill, 2017, p. 200). Understanding the models in use is therefore an important step in establishing the foundations of the field, as well as exploring its limitations (Svartzman, Dron, and Espagne, 2019).

Two primary approaches can be distinguished: analytical models and numerical models (Hardt and O'Neill, 2017; Saes and Romeiro,

7 One of the primary features of ecological macroeconomics is that there is no direct substitutability between the resources used in the production function. Ecological macroeconomics adheres to what is called "strong sustainability" which argues that resources are complements, rather than perfect substitutes. As such, capital and labor can only stand in for "nature" in limited circumstances, and never completely.

2019). Analytical models generally include few equations and can be solved analytically. These typically integrate insights from ecological economics within established post-Keynesian and Kaleckian (PKK) frameworks (Fontana and Sawyer, 2016; Rezai, Taylor, and Mechler, 2013). Numerical models, meanwhile, typically include a larger number of equations and generate scenarios based on computer-based simulations. Numerical models include stock-flow consistent models, monetary input-output models, physical input-output models, and system dynamics models. These seek to estimate specific relationships and understand the evolution of sectoral behavior over time using econometric analysis, Input-Output (I-O) models, systems dynamics, and stock-flow consistent (SFC) models.

It is worth noting that ecologically-integrated SFC models are now among the primary workhorses of Ecological Macroeconomics research. SFC models function by accounting for all monetary stocks and flows between each sector and group in the economy (Godley and Lavoie, 2007). Specifically, they illustrate how expenditures by one agent are another agent's income, and how the financial assets of one sector are the financial liabilities of another sector (Jackson and Victor, 2016). SFC models have been used to depict complex financial and monetary dynamics in much of the post-Keynesian literature (Caverzasi and Godin, 2015; Nikiforos and Zezza, 2017).

Ecologically-integrated SFC models include many of the same basic components of previous models, yet generally add an energy sector and/or 'the environment' to depict the inter-relations between economic growth, energy use, and environmental damages. The environment is then accounted for as an evolving and endogenous element of the economic process. Environmental changes in stocks and flows from the supply side (e.g. resource depletion) or the demand side (e.g. accumulation of greenhouse gasses) which feed back to affect the macroeconomy through declining labor productivity or increased rates of capital depreciation (Dafermos, Nikolaidi, and Galanis, 2017). SFC models have also been used to inform long-standing debates in ecological economics, including whether or not a positive rate of interest creates a "monetary growth imperative" (Berg, Hartley, and Richters, 2015; Jackson and Victor, 2015), or whether slow or negative growth can remain stable without rising levels of debt and inequality (Jackson and Victor, 2016).

Each of the models described above represent specific attempts to incorporate environmental considerations within heterodox economic models. The economy (e.g. unemployment, income growth and distribution, inflation) is shown to depend on changes in the natural environment, while the economy also impacts the environment (e.g. CO_2 emissions, resource use), in turn. By linking the monetary and financial systems, the productive system, and the Earth

system, ecological macroeconomists are beginning to shed new light on macroeconomic debates.

2.1.6 *Summary: The Roots of Ecological Macroeconomics*

The previous sections retraced, in broad strokes, how the relationship between 'economy' and 'environment' were conceived throughout different historical periods. It was shown that modern economics was largely informed by a progressive ideological separation of society and environment, and "founded on the hope that industrialization would emancipate society from the constraints of nature" (Gendron, 2014, p. 241). Nature has been almost completely absent from conceptualizations of the world economy, at best treated as an afterthought. While the dissociation between economy, society, and environment remains prevalent in neoclassical 'environmental' economics, ecological economics and ecological macroeconomics were born in large part to reconcile these three, and to highlight their interdependencies. In particular, ecological macroeconomics was established to "inform how [economic, social and ecological] crises are interconnected, which crisis phenomena reduce to the same root cause, and how sustainable and equitable crisis responses could be formulated." (Rezai and Stagl, 2016, p. 184). With such a large task at hand, it is therefore imperative to see to what extent the field succeeds in moving between conventional macroeconomics to appreciate the structural causes and possible solutions meeting these multiple crises head-on.

2.2 'BRANCHES' OF ECOLOGICAL MACROECONOMICS

This section systematically reviews, categorizes and compares 59 articles that are representative of ecological macroeconomics. Ecological macroeconomics is distinguished here as a distinctly heterodox field that rejects the 'pre-analytic vision' of neoclassical economics (Daly, 1991). I discern belonging within ecological macroeconomics based on three criteria: First, the articles specifically mention their position within 'ecological macroeconomics'. Second, the (co-)authors have published previous articles related to 'ecological macroeconomics', and contribute to debates in the field without specific mention. Third, the article broadly aligns with post-Keynesian, institutionalist and/or ecological economic views and cites ongoing debates and papers by ecological macroeconomists. While these distinctions are perhaps rather fluid, great pains were taken to balance discernment and inclusivity without being overly exclusive.

I follow Hardt and O'Neill (2017, p. 201) in excluding any research based on optimizing processes, either for the model as a whole or for agents within the model. In this way, none of the research here provides an 'optimal' solution or development pathway that can maxi-

mize social or individual welfare. All models covered here, where applicable, are aligned with an endogenous view of money-creation. As such, aggregate demand, capacity utilization, distribution, and uncertainty play key roles in determining macroeconomic outcomes. Additionally, authors in ecological macroeconomics adopt a 'strong sustainability' approach, arguing that there is no inherent substitutability between nature, labor, and capital.

The following subsections describe five core research branches of ecological macroeconomics: (1) Green Keynesianism; (2) Financial Stability and Socio-Environmental Change; (3) Socio-Metabolic Dynamics and Constraints; (4) Capitalist Growth Imperatives; and (5) Post-growth/Degrowth Futures.

There is often significant overlap between the various themes, themselves. Moreover, some articles could fall into multiple categories, as the research tackles multiple different issues. For example, research attributed to 'Green Keynesianism' also typically seeks to protect financial stability in the face of climate change, and vice-versa. Nevertheless, the thematic groupings are relatively straight-forward and surprisingly limited, overall.

First (Section 2.2.1), the 'Green Keynesianism' describes how the judicious use of state fiscal resources and monetary policy can generate "greener" forms of growth, accelerate the production of energy efficient innovations, and improve incomes and employment. This broad literature is characterized by a predominantly ad-hoc addition of environmental themes within Keynesian growth models. These additions allow the authors to demonstrate pathways towards greater sustainability (reduced CO2 output), equality and employment, largely by measures supporting investments in 'green' innovations.

Second (Section 2.2.2), "Financial Stability and Socio-Environmental Change" ('Financial Stability') investigates the impacts of climate change on financial stability, and how climate mitigation policies might impact financial markets. This literature focuses on uncovering the diffusion of systemic financial risks as a result of both growing environmental damages and/or as a result of the green transition. Moreover, these articles offer micro- and macro-prudential tools that may be able to offset growing risks and promote a smooth transition.

Third (Section 2.2.3), literature under the "Socio-Metabolic Dynamics and Constraints" theme describes the ways that patterns of growth and accumulation depend upon, and are limited by their material and energetic needs. Socio-technical transitions and economic valuations are ultimately dependent on their material underpinnings and this must be taken into account as a factor in determining the capacity for either shifting towards 'low-impact' sectors, as well as in implementing renewable energy systems.

Fourth (Section 2.2.4), is the literature on "Capitalist Growth Imperatives". Research in this theme studies the extent to which the capital-

ist economy requires additional growth and accumulation to remain stable. These studies use diverse modeling and analytical techniques, along with theoretical reasoning, to investigate various reasons for which growth is a necessary condition for social stability under capitalism. This literature seeks to understand the extent to which the monetary system, alongside other institutional aspects of capitalist economies, underpin the constant drive towards economic growth.

Fifth (Section 2.2.5), the "Post-growth/Degrowth Futures" (herein, "Degrowth") literature seeks to investigate pathways towards economies where accumulation is no longer a primary goal or a central driver of social behavior. The Degrowth theme seeks to both understand the barriers to, and measures needed for, creating a society which more directly seeks to meet social needs, rather than hoping to meet them indirectly, through additional economic growth. Policies such as labor reforms and redistribution are explored to see how to safeguard social and sustainable prosperity while experiencing near-zero or negative rates of investment and deaccumulation.

2.2.1 *Green Keynesianism*

The oldest and most widely cited branch of ecological macroeconomics is 'Green Keynesianism'. Green Keynesians update traditional (post-)Keynesian policy prescriptions to emphasize the need for strong state interventions to direct fiscal and monetary policy towards energy-efficient ('green') sectors and technologies. Following from the Keynesian understanding that capitalism will not necessarily self-correct to provide for full employment, equitable income distribution, or environmental security, this research investigates the potential for enlightened 'green' fiscal and monetary policies to support a sustainability transition. Most commonly, the field has argued for a concerted effort from the state to channel consumption, employment, investment, and innovation away from 'brown' (fossil-fuel-based, low-efficiency, high environmental impact) sectors and towards 'green' ('renewable'-based, high-efficiency, low environmental impact) sectors.

Green Keynesians are primarily concerned with reducing environmental impacts per-unit of output. Economies are thought to achieve sustainable outcomes by a process of decoupling: targeted investments can effectively dissociate the link between economic growth and environmental pressures. Economies can then avoid major negative shocks (declining capital and labor productivity, reductions in capital stock) by meeting technically determined environmental limits. In fact, economic growth, distribution, and employment are frequently assumed to improve alongside environmental equality, as long as the correct policies conditions are met. As Harris (2009, p. 11) writes, by reducing the emissions-intensity of growth, the economy "can grow over time without significant environmental impact, and

indeed have a positive effect in the case of natural capital or energy-conserving investment".

The Green Keynesian paradigm is often aligned with contemporary research in international institutions looking to implement Green New Deal-style policies for enhancing both income growth and environmental efficiency (OECD, 2011; Pollin, 2015; UNEP, 2011). The European Green Deal (EGD), for example, is billed as "a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gasses in 2050 and where economic growth is decoupled from resource use" (Commission, 2019, p. 2). Indeed, Green Keynesian policies are specifically geared to enhance market competitiveness while reducing environmental impacts (Guarini, 2020).

A number of 'green' growth programs, however, retain neoclassical market-based initiatives to 'get prices right' for environmental externalities, develop new financial derivatives, and establish carbon markets to optimize growth potential (Dziwok and Jäger, 2021). Green Keynesians are predominantly critical of many attempts and the models that inform them (Kemp-Benedict, 2018b). Rather than 'getting prices right', Green Keynesians argue for what can be called 'getting policies right': they identify the ways that diverse government policy instruments, subsidies and guarantees can be utilized to support long-term investments, job growth and equality while transitioning the economy away from the use of fossil-fuels (Sawyer, 2020). This applies a much more nuanced understanding of the nature of investment demand under conditions of uncertainty (e.g., the need to create the conditions of financing for speculative or unproven technologies), the limits of financial markets to generate equitable outcomes, and the obvious opportunities for recalibrating the public sphere towards greater environmental protection (e.g., government budgets can expand considerably without generating problems related to growing public indebtedness, or inflationary pressures).

The logic for Green Keynesianism is expressed most completely in some of the earliest writings in the field. Post-Keynesians contributed primarily via ad-hoc additions of the environment into their demand-led macroeconomic models. As Rezai et al. (Rezai and Stagl, 2016, p. 182) write, ecological macroeconomists

> reached into the (Post-)Keynesian growth toolbox early on...early contributions to this new variety of ecological macroeconomics trying to understand how throughput (usually with a focus on fossil fuel emissions) can be stabilized at sustainable levels in macroeconomic models of output and growth. Given that all components of aggregate demand (consumption, investment, government, and, where relevant, net exports) are considered simultaneously

> and that standard policy tools such as tax and employment policy are used as policy instruments, these contributions are using standard macroeconomic reasoning.

Much of the early groundwork in the green Keynesian theme relied on simple equations which relate rising national output to their environmental consequences, generally expressed in energy use or emissions (Kronenberg, 2010; Rezai, Taylor, and Mechler, 2013).

Sustainability is therefore conceived of as an exercise in macroeconomic accounting. As Jespersen (Jespersen, 2009, p. 48) writes, "resource and pollution problems" can be dealt with as "yet another macroeconomic imbalance" which can be analyzed in connection with distribution, balance of payments, inflation, growth, etc. Sustainability is arrived at by choosing those "macroeconomic aggregates [consumption, investment, government expenditure] that we wish to limit, and those that we wish to encourage" in order to "satisfy sustainability criteria" (Harris, 2009, p. 12). This can be seen by observing the standard national accounting equation:

$$Y = C + I + G + (X - M) \tag{1}$$

Equation 1 shows that national income is given by consumption, investment, government spending and net exports. Since net exports must be zero for the world as a whole, the policy variables available are generally limited to consumption, investment and government spending (Fontana and Sawyer, 2015). Aggregate environmental impact, e.g. emissions (E), can then be depicted as a function of output,

$$E = f(C + I + G) = e_c C + e_I I + e_g G \tag{2}$$

Given 2, reducing environmental impacts requires that

i the emissions intensity of one or more macroeconomic aggregate (e_c, e_I, e_g) declines, or

ii one or more of these aggregates must decline, in real terms.

Green Keynesians focus primarily on the former, finding ways to achieve reductions in the emissions intensity of consumption, investment and/or government spending to support more sustainable forms of growth. They therefore concentrate on those national policy instruments that are likely to improve environmental efficiency and achieve 'sustainable' forms of growth.

The rest of this section provides a comprehensive review of the primary green Keynesian articles and introduces the main topic areas. Three sub-themes have emerged that are worth distinguishing: (i) 'Green Consumption and Employment', (ii) 'Green Innovations and Fiscal Policy, (iii) 'Green Monetary and Financial Policy', each of which follow from the above discussion.

2.2.1.1 *Green Consumption and Employment*

One of the avenues towards a more sustainable economy explored in the field has been by dematerializing employment and consumption. In this case, a 'green' structural transformation would come about by shifting demand towards low-impact goods and services, and supporting employment in 'green' (renewable) industries. Any effort to reduce consumption would be problematic in a demand-led framework. Household consumption expenditures affect the distribution of income between workers and capitalists, and any decline in consumption is likely to negatively impact output and employment as well. Authors have therefore suggested policies to shift consumption and employment away from material goods and towards 'immaterial' services and environmentally friendly sectors.

Shifting towards low-impact services can potentially "offer a different kind of growth, in which macroeconomic aggregates grow but throughput does not." (Harris, 2013, pp. 12–13). A number of sectors have been put forward as potential candidates for consumption to increase. While Fontana and Sawyer (2015) suggest an increase in 'marketing and advertising' others argue that these are precisely likely to reinforce existing social divisions and fail to promote well-being. Jackson (2017, p. 220) offers a vision of immaterial consumption that includes "nutrition, education, care, maintenance and repair, recreation, craft, creativity, culture" to enhance social welfare and reduce inequalities.

In theory, green consumption and employment would also enable a slow rate of growth and decrease investment demand, without sacrificing employment and equality. Fontana and Sawyer (2015) explore how fiscal support for a higher rate of 'green' consumption and employment in low-impact sectors could enable such a shift. A low rate of investment (and thus a low rate of output growth) implies a similarly low profit rate, profits, and aggregate savings. In this scenario, firms can scarcely finance their own investment even if they wanted to, and would be hard pressed to take out loans and continue meeting new debt obligations. Since workers are considered to spend everything they have, consumption would have to increase from capitalists in a low-investment growth economy to maintain employment. An effective transition towards a low-growth economy could therefore arise through redistribution policies that support workers, or through a more progressive income tax with active fiscal policy to support consumption of services.

Kronenberg (2010) explores a similar idea for a consumption-based green shift. He creates an input-output modeling framework calibrated for Germany to determine the overall impacts of a shift towards 'immaterial' services consumption resulting from "significant changes in consumer attitudes and social norms". His framework suggests that such a shift could raise total income and reduce the

environmental impacts of consumption and production. However, it also shows that income may be redistributed towards owners of capital (who generally capture a greater percentage of value-added compared to the manufacturing sector). Moreover, the move towards high-income, low-material services would also result in major trade surpluses which would, in the case of a monetary union, prove problematic for trading partners who face increasing debts. To counteract these, Kronenberg suggests that any policy guiding the dematerialisation of consumption would likely have to be combined with deliberate wage increases to eliminate both domestic and international imbalances.

Green Keynesians also argue that the government, acting as the employer of last resort, can step in to ensure that the values and opportunities provided in the marketplace are those which contribute to sustainable goals. Low-energy, labor-intensive jobs can be a net boon to both employment and the environment by accomplishing socially necessary tasks with little material throughput. Forstater (2006), for example, argues for a "Green Jobs Corps" that could help maintain or build new parks and public spaces, retrofit buildings, shift public infrastructures to renewables, promote recycling and creative reuse of waste, and institute community and rooftop gardening schemes. Such measures could be supported by an ecological tax reform, which would include subsidies, quotas, and other incentive-based regulations to reduce inequalities and support the ecological transition.

Following similar logic, Godin (2012) proposes an SFC model to analyze a green-jobs 'employer-of-last-resort' (ELR) program. In this framework, the 'green' ELR sector raises the energy-efficiency of households and public buildings, which supports a shift away from direct energy consumption by households, allowing for an increase in spending on consumer goods with a lower emissions-intensity. This ELR is found to both enhance private sector returns and employment, removes all involuntary unemployment, reduces poverty, and lowers emissions.

In summary, supporting a transition towards 'green' consumption and employment has been a major component of the Green Keynesian research theme. Some of these policies are investigated further in other aspects of Green Keynesian thinking, particularly in supporting 'greener' forms of employment via fiscal policy support.

2.2.1.2 *Green Innovation and Fiscal Policies*

Many Green Keynesian researchers look specifically to develop opportunities to support the diffusion of 'environmentally efficient' technology and renewable energy systems. Subsidies for the development of 'green' innovations, alongside a fiscal push for additional employment in these sectors can seemingly result in a win-win-win scenario: a decline in unemployment, greater equality, and reduced environ-

mental impacts. Economic growth can then presumably be made environmentally friendly via enlightened sustainability policies implemented by the state. One or any combination of fiscal, monetary or technological changes can seemingly support the 'greening' of economic growth and presumably align the economy with the carrying capacity of the environment.

While much of the research in this theme proposes a relatively synergistic relationship between the economy and the environment, many Green Keynesians do admit a difficult task ahead. In one of the first writings to appear under the name 'ecological macroeconomics', Rezai, Taylor, and Mechler (2013) observe the existence of a macroeconomic rebound effect: attempts to mitigate climate change via Keynesian fiscal stimulus may directly reduce environmental impacts, but the associated increase in productivity from growth would also drive increasing energy use. It had long been known that efficiency increases could also result in increases in energy and resource use - due to changes in relative costs of goods (a micro-effect) and relative incomes (a meso-effect). However, this macro-effect demonstrated that interventions meant to increase environmental efficiency may be partially, and perhaps completely sterilized at the level of the macroeconomy. This finding has since become a canonical aspect of ecological macroeconomics thinking, particularly for those seeking to implement "green Keynesian" style policies.

Some researchers in this theme have focused on validating the need for fiscal support to deal with the adverse environmental and social and economic impacts of climate change. Fontana and Sawyer (2016) use a post-Keynesian Kaleckian model to consider growth as a double-edged sword - growth can alleviate persistent levels of high unemployment while also driving environmental degradation. Fontana and Sawyer depict three interdependent rates of growth - (i) the growth of aggregate demand, (ii) the growth rate of the labor supply, and (iii) the environmentally sustainable rate of growth - and remark that no fundamental market force will guarantee that any of them will coincide. The growth of the economy is therefore shown to be, as in traditional Keynesian fashion, driven by the growth of aggregate demand, while nonetheless being constrained by the growth of the labor supply as the economy approaches full employment. Additionally, if the economy grows above its environmentally 'sustainable' rate, it will be increasingly constrained by the depletion of 'natural capital'. This article exemplifies an attempt to understand how diverse macroeconomic factors are impacted by their environmental context and vice-versa. As with other literature in this theme, however, achieving more sustainable rates of growth are seen to "require control over the volume and composition of investment", alongside a mix of government policies to "[bring] the growth of output towards a sustainable path" (Fontana and Sawyer, 2016, p. 194)

Other articles are far more sanguine about the possibilities for green Keynesian policies. Pollin (2015) meticulously examines the improvements in efficiency that would need to occur in order to achieve a global reduction in emissions of 40 per cent by 2030. He posits that by investing just 1.5 - 2 per cent of global GDP on an annual basis towards renewable energy production, global growth can continue unabated, meeting international climate objectives while revitalizing industries, employment and incomes.

Taylor, Rezai, and Foley (2016) build a demand-driven model to capture the interaction between so-called "slow" environmental changes and "fast" economic variables (e.g., distribution, employment, productivity) to depict boom-bust cycles between the two. Economic activity is driven by demand, which itself is driven by the functional distribution of income between capitalist profits and wages for working households. Increasing growth and capital accumulation bring higher levels of greenhouse gas emissions, leading to declining levels of output, high rates of capital depreciation, and declining labor productivity. The authors find that macroeconomic interventions to avoid climate damages can be a relatively quick and inexpensive process. They present the possibility for full emissions abatement in a fairly optimistic scenario whereby "climate change mitigation policy can stabilize the economy at higher levels of income and lower levels of atmospheric carbon at relatively low cost: mitigation investments of about 1% of world GDP can mitigate almost all of net carbon emissions over time." (Taylor, Rezai, and Foley, 2016).

Similar work by Rezai, Taylor, and Foley (2018)) shows how climate change affects profitability and raises the rate of capital depreciation, which reduces investment demand and output. In the short run, this decline in output negatively impacts employment. In the long run, labor productivity and income levels drop, "lead[ing] to a dystopian income distribution with affluence for few and high levels of unemployment for the rest" (Rezai, Taylor, and Foley, 2018, p. 164)). Fiscal tax-and-spend policy on firms to support mitigation efforts, however, are shown to increase incomes and employment and bring climate change within acceptable limits.

This research is very much aligned with the idea of establishing a 'green' entrepreneurial state (Mazzucato, 2015), whereby state-directed innovation programs should be able to reduce investment uncertainty for new frontier technologies that would otherwise be too risky for firms, thereby promoting necessary environmental innovations for a sustainable economy (Sawyer, 2020). In theory, government regulations, fiscal stimulus, can help to de-risk clean energy investment and transform the productive apparatus to meet desired social and environmental goals. Indeed, public financial institutions have historically been key for supporting high-risk technologies, and appear to

take on the bulk of portfolio positions in renewable energies today (Mazzucato and Semieniuk, 2018).

Many researchers, for example, have proposed variations of using greater spending on 'green' R&D to generate new market opportunities, processes, and product innovations geared towards raising environmental efficiency. These are supposed to strengthen firm competitiveness, enhance exports, reduce environmental impacts, and raise long-run economic growth. Guarini (2020) uses a post-Keynesian growth model to explore the effectiveness of environmental innovations, accounting for any macroeconomic rebound effects induced by higher rates of growth. The author finds a clear relationship between support for environmental innovations and a sustainable growth path. Guarini and Porcile (2016) develop a balance-of-payments constrained growth (BOPCG) model to study how environmental innovations can help improve growth prospects, employment and sustainability of 'developing' countries. In this model, fiscal spending drives environmental innovations, raising the international competitiveness of exports and enhancing the rate of growth in the Periphery. Galindo, Giulio, and Gabriel (2020) extend this BOPCG framework to show that 'green' taxes and industrial policy can increase environmental efficiency, raise growth, and improve domestic wages.

Naqvi and Stockhammer (2018) develop a multi-sector SFC model to study technological changes in resource-saving technologies as an endogenous function of R&D investment in competing and complementary inputs. By modeling how portfolio decisions respond to relative changes in input costs, they determine what kinds of policies allow for a transition towards resource-saving technologies. They investigate both (i) a one-off carbon tax increase and (ii) a continuous increase in resource taxes. Their model suggests that continuously rising resource taxes (alongside rising government spending) are necessary to avoid both shortfalls in aggregate demand and to reduce environmental pressure by transitioning towards resource-saving, rather than labor-saving technologies.

Deleidi, Pariboni, and Passarella (2019) develop an SFC model to examine the role of a green entrepreneurial state to support green industrial structural changes. They measure the impact of government supported 'mission-oriented innovation spending' on economic growth and the environment, including how environmental damage can feed back to impact growth (e.g., higher rates of capital depreciation from material and energy depletion, reduced rates of investment, and reduced propensity to consume). Their model shows that mission-oriented spending is the best available option for governments, resulting in lower overall government debt, higher rates of growth, income and employment than other scenarios. These policies are indeed likely to reduce environmental pressures associated with

economic growth. However they also highlight that 'ecological feedbacks' will also reduce the effectiveness of these policies.

Other studies have looked more specifically at how fiscal support for renewable energy systems and technologies can also bring greater and greener forms of growth. Naqvi (2015) develops an SFC model that is calibrated to study the transition towards renewable energy sources for a region calibrated to the EU. His model shows that a mix of carbon taxes and investment in mitigation technologies can help to bring about an absolute decoupling between growth and emissions while protecting employment and income distribution. Green investments are shown to "solve" these issues "simultaneously" by shifting energy production towards renewable sources.

Similarly, Ponta et al. (2018) use an agent-based SFC model to study the shift from fossil-fuel-based energy to renewable energy systems. They examine the effect of "Feed-in Tariffs" (FiTs) to support the transition, the fiscal costs of such subsidies, as well as the benefits of lower fossil fuels imports. The authors find that the feed-in-tariff policy (guaranteeing prices for renewable energy producers) can be effective in supporting an energy transition by increasing the share of renewable energy use and production, increasing sustainable investments, and reducing the level of greenhouse gases. While the policy appears to have no significant effects on employment and government finances, they find that a stronger feed-in tariff policy is associated with reduced purchasing power of consumption goods by households.

(Mercure et al., 2018b)) develop a large-scale global integrated assessment model (E3ME-FTT-GENIE) to assess the effectiveness of diverse green fiscal policies, including feed-in tariffs, subsidies for renewables in heating systems, carbon prices, and taxes on fossil fuels. This model combines a post-Keynesian macro-econometric simulation model of the global economy, a model to simulate technology diffusion, and a detailed climate model with an integrated carbon cycle. Their model details how a combination of policies can help to achieve the goals of the Paris Agreement ($< 2°C$ warming), though with some caveats. They find that, while electricity prices may rise, causing a fall in disposable income and reducing employment, green public investment can serve to counteract these effects. However, those regions that specialize in fossil-fuel production are negatively impacted as export revenues decline, implying an improved trade balance for importing regions.

(Carnevali et al., 2020) present a first attempt at building an open-economy SFC model to study similar themes in the context of a 'world economy'. This allows them to highlight the potentially unseen negative consequences of 'green' investments and consumption when escaping a purely national perspective. They study the interactions between two regions (one 'green' and one 'brown') with dif-

ferent relative environmental efficiencies. Their model results suggest that the effectiveness of green consumption and investment policies depend on the relative rates of growth in each region, and the impact of cross-border financial flows on exchange rates. For example, as international investors search to invest in 'green' assets, either to reduce climate-related investment uncertainty or due to preferential interest rates, capital will flow outward from the less sustainable ('brown') region to the more sustainable ('green') region. In a situation of free capital flows and floating exchange rates, this may cause an appreciation of the 'green' region's currency. Following the currency appreciation, the 'green' region's rate of growth falls as net exports and incomes decline. Moreover, this results in an increase in the consumption of less environmentally-efficient products from the 'brown' region, and a rise in output in that region. While some efficiency gains may occur, this study demonstrates a global rise in greenhouse gas emissions that occur despite concerted environmental programs. Thus, even by incentivising 'green' portfolio decisions, the environmental outcomes may be counterproductive from the stated goals.

2.2.1.3 *Green Monetary and Financial Policies*

Aside from primarily fiscal support, some studies look more closely at how the financial system and monetary policy can also be turned 'green'. This research identifies the impact of using selective credit measures, alongside the use of 'green' government bonds and 'green' quantitative easing, to support the sustainability transition. Following Sawyer (2020, p. 1), these tools will be fundamental to a sustainability transition, as "the key requirements for a socially beneficial financial system are that it develops in ways which are consistent with the environmentally sustainable rate of growth, and that it channels funds into the socially desirable types of investment." As with previous models focusing primarily on fiscal policy, financial and monetary measures are also used to channel investments towards more 'sustainable' forms of growth and enhance environmental efficiency by increasing the size and share of low-carbon industries. Typically, this implies monetary interventions that make 'green' capital investments more financially attractive than 'brown' investments.

Part of the reasoning behind 'Green Monetary and Financial Policies' stems from the Keynesian understanding that investment uncertainties are likely to stifle green investments. For example, Campiglio (2016) argues that carbon pricing may be a necessary but insufficient measure to stabilize both the climate and the economy. Indeed, commercial banks will not necessarily lend to firms to support low-carbon activities even when carbon is priced because of certain 'market failures' (e.g., market uncertainty during climate change, investment risk for new technologies). Campiglio argues that non-price measures may be necessary. Monetary policies and macropruden-

tial financial regulation could alter the incentive structure and constraints of private banks as they determine their lending strategy. For example, differentiating reserve requirements depending on the destination of lending would potentially better support lending to low-carbon sectors than a carbon tax. While Campiglio does not build a formal model to test his theory, this understanding sets the stage for additional work combining central bank policies and financial regulations to support a green transition.

Dafermos, Nikolaidi, and Galanis (2017), for example, build a comprehensive ecological macro-econometric model to provide a formal look into how physical stocks, flows and funds are related within the monetary production economy. They combine a traditional SFC model with Georgescu-Roegen's flow-fund model to show how financial and monetary policies can shift production towards lower-impact 'green' sectors, using selective credit rationing and interest rate policies to favor 'green' lending. Supply constraints arise in the form of resource depletion (e.g., declining stocks and damaged resource funds) while a growing stock of emissions and environmental degradation pose constraints to aggregate demand (e.g., higher rates of capital depreciation, alongside reduced capital productivity, labor productivity, and consumption). Calibrating the model to global data, they show that, as leverage ratios increase, environmental damages reinforce negative environmental impacts, causing greater financial instability and uncertainty. Green financial policies were, however, able to reduce environmental pressures and the financial fragility of firms.

Dafermos and Nikolaidi (2019) extend the use of their SFC model to compare the use of carbon taxes with green public investment, and green loan subsidies to compare how those three programs affect the economy, financial stability, and the environment. First, they find that carbon taxes are likely to reduce global warming, yet may exacerbate financial risks because of impacts on firm profitability and credit availability. Second, they show that although green subsidies and green public investment can raise environmental efficiency, their impacts are partially offset by inducing economic growth (the macroeconomic rebound effect). Finally, they show that a combined green fiscal policy mix can provide for more sustainable socioeconomic, financial, and environmental outcomes.

Monasterolo and Raberto (2018) use an SFC model (EIRIN) to determine the effects of both green fiscal policies and green sovereign bonds on investment on shifting from 'brown' to 'green' capital. Their simulations reflect how directed government policy can influence firms' expectations and commercial lending to achieve sustainability goals. Subsidies for greener forms of production are funded by green bonds or taxes. The model demonstrates a generally positive solution for a green transition subsidized via sovereign bonds: green investment rises alongside increased employment and reduced import of

raw materials. However, they also find that green monetary policy risks a short-run increase in inequality and higher public indebtedness in the long-run. Meanwhile, green fiscal policies supported by incentives and taxes tend to have negative effects on income and employment.

Monasterolo and Raberto (2019) extend this model to explore the implications of progressively eliminating fossil fuel subsidies. They calibrate their SFC model (EIRIN) to depict a typical European country with a high level of energy dependency. Along with phasing out subsidies for fossil energy, fiscal policies or green bonds are used to subsidize investments in 'green' capital to promote renewable energy. They find that such a phase-out improves macroeconomic performance, reduces inequality and provides fiscal space necessary for government investment in sustainability measures. Higher rates of taxation and green bonds are shown to be far more supportive of the transition, as simply phasing out subsidies on fossil energy maintains the country's dependence on foreign mining and carbon-based energy sources.

2.2.1.4 *Summary: Green Keynesianism*

The search for more sustainable forms of structural change via 'Green Keynesian' policies is by far the most widely researched thematic area within ecological macroeconomics. Researchers in this theme overwhelmingly contend that economy-environmental relations can be properly managed by applying traditional Keynesian policy tools to reduce environmental impacts, raise incomes, and sustain a (typically growing), greener economy. This section pointed out three overlapping sub-thematic areas - 'Green Consumption and Employment', 'Green Innovations and Fiscal Policies', 'Green Financial and Monetary Policies' - all of which investigate the potential to apply Keynesian demand-management to induce more environmentally (and socially) friendly growth path. By shifting industrial growth patterns from 'brown' to 'green' technologies, consumption and production can seemingly provide additional economic benefits while alleviating environmental burdens.

Research Theme	Research Sub-Themes	Representative Paper	Scale of Analysis	Reason for Economy-Environment Conflict	Technological Change...	Inequalities...
Green Keynesianism	*Green Consumption and Employment* *Green Innovation and Fiscal Policies*	Dafermos et al. (2017)	Mixed: Primarily Nation-State. Some regional interactions and modeling	The increasing concentration of emissions in the atmosphere will reduce economic growth, employment and equality. This arises because there is insufficient market-guidance to support less polluting sectors and technologies and/or economic resiliency in the face of climate-related damages	...is the primary source of enhancing efficiency and reducing environmental impacts.	...are likely to worsen if swift action is not taken to reduce economic impacts on the environment. Nonetheless, green-growth-based can potentially both reduce environmental impacts and improve equality nationally and internationally.
			Sustainability requires...	**Key Questions**	**Key Findings**	**Policy Advice**
	Green Monetary and Financial Policies		...achieving a lower emissions-intensity of economic growth while safeguarding employment, equality and income growth	(i) How can economic policies effectively decouple growth from environmental impacts?; (ii) How can 'green' fiscal and monetary policies support a transition to renewable energy systems, efficient technologies, and low-impact sectors?; (iii) How can the environmental crisis be turned into a new opportunity for investment, income and employment growth?	(i) Decoupling can be achieved via strategic 'green' policies; (ii) 'Green' policies can serve a 'win-win-win' scenario wherein society becomes more environmentally efficient, equitable and wealthy; (iii) Reducing environmental impacts via fiscal and monetary policies may be the only opportunity for achieving sustainability.	Government policy should support a shift to 'green' sectors and industries via targeted investment strategies, subsidies, taxes, fiscal spending and monetary policy.

Table 1: Green Keynesianism Overview

2.2.2 *Financial Stability and Socio-Environmental Change*

The second theme that has become apparent in ecological macroeconomics is 'Financial stability and Socio-Environmental Change' ('Financial Stability'). Research in this theme connects to an already growing literature from central bankers, policy makers and economists that explore how investors, corporate, bank and government balance sheets are exposed to mounting environmental degradation and mitigation policies. The literature highlights two primary avenues that may provoke asset revaluation and financial distress: 'physical' ('environmental') risks and 'transition' risks. Physical risks include the ways that climate change, among other forms of environmental degradation, can destroy firms' physical capital, reduce profitability, and contribute to growing investment uncertainty that may raise the risks of default. Transition risks include the ways that existing assets are exposed to the movement away from fossil-fuel based sectors. A shift towards 'green' investment and consumption priorities, reduced subsidies for fossil-fuel extraction and production, carbon prices, quotas and/or moratoriums on additional extraction could leave a large percentage of projected fossil fuel reserves devalued. These 'stranded assets' would weigh heavily on investors, firms, and governments whose wealth depended on expected returns from continued extraction. Sudden revaluations of financial contracts and investment portfolios, alongside the prospect of sudden capital outflows, pose risks that could reverberate through the financial and non-financial sectors. Researchers in this theme therefore look to both understand the causes and transmission of instability, as well as identifying appropriate mechanisms to avoid either a 'climate-driven Minsky moment' (Carney, Galhau, and Elderson, 2019) or a 'Green Swan' event (Bolton et al., 2020).

The question of physical and transition risks are increasingly on the minds of central banks and financial institutions (**goulard_climate_2020**; Allen et al., 2020). Research in this field, however, has relied on the optimizing assumptions found in supply-side, neoclassical models. Large-scale integrated assessment models (IAMs), general equilibrium models (DSGE) and financial models, like capital asset pricing models (CAPMs) form a suite of neoclassical models used to compare the 'costs' and 'benefits' of global warming, and/or to determine the optimal price of carbon or transition policy (see Campiglio and Ploeg, 2021). In these models, macro-financial transitions are modeled with forward-looking agents with rational expectations, market-clearing prices, and probabilistic risks. Such models are heavily criticized, particularly because they leave little possibility for catastrophic damages or major financial losses, even if warming from climate change extends well beyond what scientists recognize to be a 'safe operating space for humanity' (Keen, 2020).

Ecological macroeconomists, by contrast, have contributed to this literature by bringing a demand-led approach based on radical uncertainty, and systemic complexity. Ecological Macroeconomic models - typically SFCs - incorporate a non-equilibrium understanding of production and financial markets, where demand shortfalls and rising indebtedness can prove destabilizing. Post-Keynesian SFCs incorporate an endogenous money approach that more fully depicts the behavioral dynamics of financial institutions. For example, they can integrate backward-looking and adaptive expectations by investors that can allow for emergent properties at the system level (Dunz, Naqvi, and Monasterolo, 2021). Moreover, these models are open to the possibility of non-linear climate damages that can prove devastating to 'real' and 'financial' values.

The rest of this section explores two underlying research tracks within the theme of 'Financial Stability and Environmental Change'. The first, 'Reducing Risks to Financial Stability' includes research which models the propagation of financial instability as a result of climate change and investigates ways in which it could be overcome via macro-financial policy. The second, 'Transition Risks to Financial Stability' seeks to understand how financial instability is caused by asset stranding and devaluations brought on by environmental degradation and/or a sustainability transition.

2.2.2.1 *Assessing and Reducing Risks to Financial Stability*

The first group of research in this theme includes those articles focused on reducing climate-related instability. Much like in the Green Keynesian branch, scholars working in this field are interested in creating a 'smooth' ecological transition that avoids financial downturns associated with defaults, and collapses in stock market value, both for financial firms and non-financial firms. In particular, they analyze how green monetary and prudential policy, tax reforms and carbon pricing can be used to avoid the destabilizing effects of private (and public) indebtedness, often while serving to enhance a green transition.

Bovari, Giraud, and Mc Isaac (2018) combine a predator-prey (Lotka-Volterra) model with an SFC model to show how climate change and rising levels of private indebtedness coincide, resulting in increased economic and financial instability. To reduce emissions and safeguard financial stability, they propose a gradually rising carbon tax to drive emissions reduction among private firms. Their model shows that, while a rise of +2C is likely already out of reach, a high enough carbon tax can bring carbon emissions in line with a +2.5C target. It is also possible to achieve this result without significant declines in economic growth if policies support redistribution towards wages and demand stabilization. However, their simulation indicates a major shift towards ever increasing carbon taxes would be needed to

achieve the goal of net-zero emissions by as early as 2045, and before 2080 to keep warming below +3C.

While steps can be taken to reduce the risk and uncertainty of systemic failure, climate change impacts and regulatory responses, future financial risks are impossible to quantify. Studies in this theme are quick to point out how traditional methods of risk evaluation are unlikely to be helpful because of the fact that they are deeply uncertain, non-linear and endogenously created. According to Chenet, Ryan-Collins, and Lerven (2021), current regulatory frameworks tend to focus on identifying short-term disruptions while ignoring potentially catastrophic financial-ecological consequences in the long-term. In the absence of 'efficient' price discovery and risk assessment potential, central bankers and financial market regulators may need to update financial stability mandates. For this reason, the authors argue that a 'precautionary principle'-type of understanding should be embedded within financial stability policy to gear macroprudential regulations (e.g. capital adequacy requirements), monetary policy (e.g., asset purchases and collateral criteria) towards both avoiding physical and transition risks and to help steer financial markets towards lower-carbon options.

To that end, some models in ecological macroeconomics have been developed to integrate macro-financial policies that can both reduce instability and enhance the 'green' transition. Dunz, Naqvi, and Monasterolo (2021), for example, develops an SFC model to test the role of a carbon tax and a 'green supporting factor' (e.g., lower capital requirements for green investments) on the evolution of financial risk. Their model also innovates by embedding a behavioral equation to endogenize banks' climate sentiments "as a function of expectations of the climate-aligned policy, of firms' past performance, and of future expected profitability". This allows the authors to demonstrate the role that a banks' climate sentiments will play in fostering financial stability and in helping or hindering a 'green' transition. Banks with stronger climate sentiments anticipate the introduction of macroprudential climate regulations and thereby revise the cost of credit between 'brown' and 'green' firms, expecting changes in the profitability and credit risk of firms. Banks with weak climate sentiments do not make such changes, choosing to continue their normal investment plan regardless of the potential for policy changes. Their results suggest that a green supporting factor would not be an effective policy to support green investment, and could potentially weaken financial stability by decreasing the banks' capital-adequacy ratio, alongside raising interest rates for carbon-intensive (brown) firms. However, a carbon tax was found to help shift the share of bank's loans towards green sectors. Additionally, stronger bank's climate sentiments appeared to smooth the risk for financial stability and encourage green

lending by reducing price volatility and signaling gradual shifts in interest charges.

Dafermos, Nikolaidi, and Galanis (2018) use an SFC model to study how differentiated capital requirements will affect green lending, carbon emissions, and financial stability. The authors study how global warming is likely to affect household portfolio decisions and drive a search for safe assets, particularly government bonds, resulting in a declining price of corporate bonds. They therefore test the possibility of a 'green' quantitative easing (QE) program, wherein central banks buy up to a quarter of 'green' corporate bonds worldwide. Their model suggests that central bank bond purchases can subsequently reduce financial instability and restore firms' profitability, as investment becomes less dependent on bank credit. Their results confirm that 'climate-induced financial instability' is likely to reinforce the negative economic impacts of climate change by reducing the flow of credit. Nevertheless, they determine that a 'green' QE programme can both mitigate global warming and climate-induced financial instability. While the effectiveness of this programme will depend on the responsiveness of green investment to changes in bond yields - and the way that 'green' is ultimately defined - it suggests a new possible tool for central bankers and financial regulators looking to participate in a transition to a more sustainable economy.

2.2.2.2 *Stranded Assets and Financial Stability*

Another potential for financial risk that has been researched in this field explores how (i) resource degradation and depletion, (ii) technological changes and (iii) climate transition policies could leave a fraction of existing mineral and fossil energy reserves unused and devalued. Valuations in the present are based on predictions of future revenue and continued exploitability of fossil fuel reserves. The diffusion of low-carbon technologies, greater energy efficiency, supply quotas, and other environmental policies (e.g., stringent or costly regulations) may reduce demand for fossil fuels, make extraction financially infeasible, or legally impossible, resulting in 'stranded assets'. The balance sheets of commercial and central banks, governments, and privately held financial portfolios could be heavily impacted by changes in the valuation of current reserves. These may result in rising indebtedness, default, exchange rate depreciations, and/or a collapse in stock market value. Contagion and network effects from stranding could further result in macro-financial instability and upend any hope of a 'smooth' transition.

Mercure et al. (2018a), for example, study the global transmission of risk as a result of a "carbon bubble" within a disaggregated post-keynesian macroeconomic model. They ask whether the current pace of low-carbon technology development is likely to result in stranded fossil fuel assets. In this model, stranded assets result either from

the transition towards energy-efficient technologies and or the implementation of stringent climate measures to keep warming below +2C. Their model shows that major energy producing countries are heavily exposed to stranding in the context of climate change, particularly as global demand for fossil fuels decreases due to the low-carbon technical transition. This impact of stranding depends on the relative costs of extraction: energy production is likely to concentrate among lower-cost fossil-fuel producers (e.g., OPEC), while some regions with higher marginal extraction costs face the prospect of large production declines (e.g. Russia), or potentially the loss of the entire oil and gas industry (e.g. Canada, US).

Their model also indicates that certain geopolitical factors must be taken into consideration. For example, low-cost fossil fuel producers may amplify the financial impact of stranded assets if they decide to increase fuel production to minimize losses. In any case, both the technology transition and the climate mitigation policies lead to declining fossil-fuel prices and the potential for large financial losses in producer countries. Stranding has some positive impacts on GDP growth and employment for net energy importers. Their model supports the notion of a carbon bubble, and projects a global loss of asset value of between $1tn and $9tn under different scenarios, likely to be concentrated in high-cost extraction areas, which would be many times the size of losses which ultimately triggered the subprime mortgage crisis in 2008 (roughly $0.25tn).

Cahen-Fourot et al. (2021) also develop a model to understand the financial impacts of stranded assets. The authors consider how fossil fuel asset stranding could have knock-on impacts, causing physical asset stranding "virtually anywhere in the economy". Indeed, fossil fuels have a clear material relevance in any other sector (e.g., mining, transport, manufacturing). Any move away from fossil fuels as an input could result in "cascades" of asset stranding along global chains of production. The authors develop a framework to calculate the potential monetary value of capital stocks at risk of stranding, given a loss of fossil fuel inputs within an interdependent production network. Using data for cross-sectoral accounting in 43 countries they study the potential for a supply-side capital stranding which cascades through international production networks. Using an input-output framework, they rank countries at greatest and least risk of physical asset stranding: Those countries most dependent on exported fossil fuel production, and with a high capital intensity importing this production (France, Australia and Slovakia) are most at risk. Meanwhile major fossil fuel producers whose production is largely consumed onshore (USA, China) are least at risk of cascaded stranding impacts.

Semieniuk et al. (2021) study the distribution of transition risks linked to ownership of assets backed stranded fossil-fuels in a large-scale integrated assessment model (E3ME-FTT-GENIE). They find that

continued efforts to decarbonise will result in global stranded assets totaling $3.4 trillion within the oil and gas sector. The authors trace the equity risk of ownership of these assets to their ultimate owners, and find that market risk is amplified across financial networks, and held primarily by private investors in OECD countries. Much of this exposure was found to be concentrated in non-bank financial institutions, particularly pension funds. After calculating multiple possible transition scenarios, the authors contend that a devaluation comparable to that seen during the 2007-08 crisis - roughly $700 billion - is at stake.

2.2.2.3 *Summary: Financial Stability and Socio-Environmental Change*

Research in the theme of 'Financial Stability and Socio-Environmental Change' has largely agreed that financial markets are at serious risk of price volatility and devaluations as a result of transition risks and as a result of climate change. This literature provides insights into the sources of environment-related financial risk, the consequences of ignoring systemic risk, and the potential for limiting exposure via macro-financial policy. Until now, the field has almost been exclusively focused on climate change, though other other forms of environmental degradation, particularly biodiversity loss are also beginning to be examined as co-existing risks (Svartzman et al., 2021). Nevertheless, the underlying message is clear: the financial system is deeply affected by socio-environmental change, and this must therefore be taken seriously by policymakers. These articles provide important insights into how financial risks may propagate and how they may be overcome.

Research Theme	Research Sub-Themes	Representative Paper	Scale of Analysis	Reason for Economy-Environment Conflict	Technological Change...	Inequalities...
Financial Stability and Environmental Change	*Assessing and Reducing Risks to Financial Stability*	Mercure et al. (2018b)	Mixed: Primarily Nation-State. Some geo-political considerations	The increasing concentration of pollution in the atmosphere will likely impact financial stability and socio-economic health. Instability can arise because of (i) *insufficient* market-guidance to support less polluting sectors and technologies and/or economic resiliency, (ii) as well as *sufficient* institutional guidance to support non-fossil energy resources and socio-technical change, resulting in stranded assets and devaluation, (iii) physical damages and/or depletion of fossil resources, resulting in stranded assets and devaluations.	...is a necessary source for enhancing sectoral efficiencies and reducing environmental impacts. However, this relationship is complicated by potential financial instability caused by switching away from fossil fuels.	...are likely to worsen if swift action is not taken to reduce economic impacts on the environment. Macro-financial stability can, however, be protected in the face of climate change and environmental transitions, thereby safeguarding inequality.
			Sustainability requires...	**Key Questions**	**Key Findings**	**Policy Advice**
	Stranded Assets and Financial Stability		...achieving a lower emissions-intensity of economic growth without sacrificing financial stability.	(i) What are the causes of financial instability in the era of global climate change?; (ii) How can economic policies ensure a 'smooth' transition towards renewable energy systems?	(i) Both climate damages *and* efforts to avoid them can result in financial instability; (ii) financial instability is geographically divided: assets will become stranded based on the physical accessibility and quality of available depostis; risks will be concentrated amongs assets owners in few countries; risks also depend on whether fuels are used for export earnings or domestic consumption.	Macroprudential regulations and microprudential oversight are key to ensuring financial stability in the era of climate change and major social transitions.

Table 2: Financial Stability and Environmental Change Overview

2.2.3 *Socio-Metabolic Dynamics and Constraints*

The third research theme in ecological macroeconomics distinguished here is 'Socio-Metabolic Dynamics and Constraints' (herein, 'Socio-Metabolic Dynamics'). This theme includes a range of approaches that reflect the material basis of economic processes and constraints. The economy is understood as a socio-metabolic process that is both dependent on and limited by its material and energetic dependencies. Topics in this theme focus on the primacy of environmental 'inputs' in the economic dynamics, the nature of socio-technical change as well as the physical limits to achieving a 'decoupled' economy. This allows authors to highlight the material/energetic foundations of economic growth, and provide a more realistic perspective on decoupling growth from environmental pressures.

2.2.3.1 *Materiality of Growth*

The majority of articles in this theme are concerned with unearthing the material and energetic basis of economic growth. Indeed, "we live in a material world in which 'the economy' is fundamentally (although not exclusively) a process of material transformation through which natural resources are converted into a vast array of commodities and by-product wastes" (Bridge, 2009, p. 1218). Researchers in this theme shed light on the fact that the economy is a hybrid social and biophysical process. Economic aggregates then reflect the ways that societies collectively value, use, and transform labor and nature. By investigating the connection between flows of value and flows of materials and energy, ecological macroeconomists have begun linking the 'real' economy - the so-called productive sphere - and the 'real-real' economy - its biophysical basis (Kallis, Martinez-Alier, and Norgaard, 2009).

Following Herman Daly (1995) economic values can be understood as built through complex social arrangements which rely - rather precariously - upon a narrow base of ('low-value') natural resource inputs. The value addition process within capitalist economies can then be described as an "inverted pyramid". As Daly writes,

> The importance of mere stuff is frequently downplayed by pointing out that the entire extractive sector accounts for a mere 5 or 6 percent of GNP. But if the 95 percent of value added is not independent of the 5 percent in the extractive sector, but rather depends upon it – is based on it – then the impression of relative unimportance is false. The image this conjurs [sic] in my mind is that of an inverted pyramid balanced on its point. The 5 or 6 percent of the volume of the pyramid near the point on which it is resting represents the GNP from the extrac-

> tive sector. The rest of the pyramid is value added to extracted resources...since the value of the extracted resources themselves (the 5 or 6 percent of GNP) represents mostly value added in extraction, practically the entire pyramid of value added is resting on a tiny point of near zero dimension representing the in situ value of the resources. (Daly, 1995, pp. 455–456)

The concept of the inverted pyramid provides a framework for understanding two primary concerns of ecological economics that have since been taken on by ecological macroeconomists:

First, the inverted pyramid demonstrates the inescapable materiality of economic production. High value-added processes in industrial and service economies remain tethered to low value-added extractive processes and material transformations. Each step of value addition is therefore interdependent with previous steps. Accounting for the environmental impact of any one firm, sector or country then requires looking at the entire chain of production which enabled it (Althouse et al., 2022; Piñero et al., 2019).

Kemp-Benedict (2014), for example, operationalizes this idea to express GDP as a sum of economy-wide markups on the cost of inputs (labor and raw materials) along the chain of production. This work illustrates how industrial production cannot be dissociated from extractive sectors, which have strong forward linkages for the rest of the economy. Cahen-Fourot et al. (2020) extend this framework using an input-output model to measure the direction of raw material flows through eighteen European economies. They show that a small number of low value-added mining and processing industries form the base which feeds into the rest of the economy. Moreover, the degree of forward linkages is stable across all countries. While it may appear on the surface that developing a high-income economy implies a reduction in the significance of natural resources (declining cost-share of the extractive sector), this research suggests that even seemingly immaterial service sectors are supported by large volumes of extracted and transformed resources. High-income service sectors - digital platforms, software development, and financial services - rest upon vast networks of physical infrastructures and energy- and material- intensive inputs.

Second, the inverted pyramid suggests that, by definition, the more value-added in an economy, the smaller the share of aggregate (expenditure) on natural resources. Whereas neoclassical theory predicts that the value of a resource is equivalent to its cost-share in the economy, ecological macroeconomists claim that the exact opposite is the case. Paradoxically, a relatively low share of expenditure on energy and matter in GDP may also be indicative of their overwhelming importance in the value production process. For example, Berg, Hartley, and Richters (2015) utilize an SFC-IO framework to model the

importance of energy flows, despite its low cost-share. Their model found that even small changes in energy prices "can depress real wages, lower demand, and therefore trigger recessions" (Berg, Hartley, and Richters, 2015, p. 17). While extractive industries - agriculture, forestry, mining, etc. - comprise only a small portion of global GDP relative to the manufacturing and services sectors, the cost-share of material and energy inputs has important consequences for economic outcomes. Even when their cost-shares are small, rising prices of key commodities are associated with major financial and economic disruptions, implying a systemic need to maintain access to 'cheap' resources.

2.2.3.2 *The Limits of Decoupling*

Related to the above discussion, other works in this theme try to understand the limits of achieving a sustainability transition by 'decoupling' energy use and emissions from economic growth. The dominant paradigm within heterodox and mainstream ecological macroeconomics, particularly amongst 'Green Keynesians', has been a focus on the decoupling. Decoupling can occur in two forms, relative and absolute. Relative decoupling implies that a given percentage increase in GDP is associated with a smaller percentage increase in emissions. Absolute decoupling occurs when any given percentage increase in GDP is associated with a zero or negative percentage change in emissions output. While instances of relative decoupling have been widely observed, episodes of absolute decoupling are virtually non-existent (Haberl et al., 2020; Hickel and Kallis, 2019; Parrique et al., 2019).

Some ecological macroeconomists have therefore attempted to understand why this might be the case, and what the limits of decoupling might be. These articles link the material and energetic foundations of growth to the development of 'renewable' and resource-saving technologies. Here, innovations are viewed as socio-technically limited and materially dependent systems, rather than as automatic tools for achieving sustainability, as in much of the 'Green Keynesian' research. The apparent sustainability of any investment or technology must then be contextualized within the governing social and biophysical relations within which they emerge. In this research, decoupling is viewed as limited by (i) the function of technological development within the social system and (ii) the physical properties and dependencies of those technologies, and (iii) the uneven geography of physical production.

Kemp-Benedict (2018a) for example, examines why decoupling economic output from energy and material throughput appears to be possible only in relative, and not in absolute terms. Using a post-Keynesian growth model, this article analyses how cost-share induced productivity changes may make it impossible for absolute decoupling to occur. In the model, innovations that save on inputs used in the pro-

duction of goods and services are biased towards finding efficiency for those inputs with a higher cost-share. Assuming that resource prices rise alongside growing demand and that resource productivity improves as the resource cost-share grows, technological change will be biased towards relative, rather than absolute decoupling. This research suggests that there is no reason to believe that absolute decoupling is likely to occur in the near future without significant changes in the incentive structure of social innovation systems.

Such findings are particularly important given the well-researched decline in energy returned on energy invested (EROI). This decline is considered to be the result of depleting stocks of easily accessible energy resources, and the transition to 'greener', low-EROI alternatives. A declining EROI means that energy extraction requires increasing quantities of energy inputs in order to access energy outputs. This implies rising energy prices and less net energy available to society. Certain forms of socio-economic developments may then be made impossible, and could present social and physical limits to low-carbon energy transition. Jackson and Jackson (2021) develop an SFC model to study the effects of a declining (EROI) on the macroeconomy. Their model innovates by showing how efforts to green the economy with directed investments must take into account the physical requirements of the entire energy system.[8] A declining EROI is shown to bring about an increase in energy prices and rising rates of inflation, unemployment and inequality. These effects grow as the EROI falls, indicating that countervailing fiscal measures and redistribution policies would also have to be an important aspect of any transition to avoid recessionary tendencies.

2.2.3.3 *Summary: Socio-Metabolic Dynamics and Constraints*

The 'Socio-Metabolic Dynamics' branch captures a broad range of research to reflect the material and energetic basis of growth and socio-technical change. This paradigm has proven capable of exploring the nature of socio-economic developments as inseparable from the material and energy resources upon which they depend. Unlike in the Green Keynesian theme, however, which tends to view economies in terms of being more or less efficient, this literature sees economies more as structured institutional processes which depend upon, and thereby cannot escape, their material limitations.

8 For this reason Capellán-Pérez, De Castro, and González (2019, p. 18) contend that transitioning the whole energy system would be "well below the range of the [EROI] thresholds identified in the literature as necessary to sustain high levels of development in current industrial and complex societies". Moreover, Vaclav Smil (2010) has also argued that a renewables-based economy is likely limited by massive land requirements that would be needed from giving up fossil energy. A low EROI of wind and solar energies would require vast tracts of land that would displace or remove farmland from agricultural production, dispossess communities and dramatically raise food prices.

Research Theme	Research Sub-Themes	Representative Paper	Scale of Analysis	Reason for Economy-Environment Conflict	Technological Change...	Inequalities...
Socio-Metabolic Dynamics and Constraints	*The Materiality of Growth*	Cahen-Fourot (2020)	Mixed: Primarily Nation-State	Economic values and socio-technical changes have strict material dependencies. This limits the capacity to 'decouple' growth and resource use.	...is a necessary source for enhancing sectoral efficiencies and reducing environmental impacts. However, a transition towards renewables and sectors with enhanced environmental efficiencies is likely to be limited.	...are likely to worsen if swift action is not taken to reduce economic impacts on the environment.
			Sustainability requires...	**Key Questions**	**Key Findings**	**Policy Advice**
	The Limits of Decoupling		...(i) balancing the materiality consequences and dependencies of growth with its material limits. (ii) taking into account the likely physical limitations to socio-technical transitions.	(i) To what extent does the 'the economy' and economic value depend' on 'the environment'; (ii) What are the physical and institutional limits to 'decoupling'?	(i) Economic growth and valuation is highly dependent on physical inputs of material and energetic resources, limiting the possibilities to 'decoupling' growth and environmental impacts; (ii) Extractive 'resource' sectors must be understood not as low-value but as the basis of further valuation; (iii) Even with sufficient available financing, socio-technical transitions innovations are not necessarily going to be directed towards resource saving technologies, (iii) Societies may face physical limitations in implementing renewable energy systems.	(i) Degrowth may be necessary, particularly in wealthy regions, to avoid mounting socio-ecological problems; (ii) Regional inequalities must be taken into account when considering the nature and the distribution of environmental change; (iii) Non-capitalist institutions may need to play a central role in supporing any actual movement towards a 'green' economy.

Table 3: Socio-Metabolic Dynamics and Constraints Overview

2.2.4 *Capitalist Growth Imperatives*

The fourth theme of research within ecological macroeconomics is "capitalist growth imperatives". Research in this theme investigates the ways in which capitalist institutions make continued economic growth a social necessity. While low and negative rates of growth are a recurring phenomenon within capitalist economies, these are generally associated with rising poverty, unemployment, indebtedness, among other forms of social and ecological distress. This literature therefore explores under what conditions growth is driven by, or even required to maintain social and economic stability within capitalism. Following Richters and Simoniet (Richters and Siemoneit, 2019), 'growth imperatives' can be distinguished from 'growth drivers': Growth imperatives include any "exterior conditions that make it necessary for an agent (such as an individual, firm, or state) to increase their economic efforts as to avoid existential consequences" (Richters and Siemoneit, 2019, p. 129). Growth drivers, on the other hand, include internalized social pressures with non-existential consequences that may, nevertheless, reinforce existing growth imperatives.

Two broadly-defined growth imperatives are investigated in the literature: the 'monetary growth imperative' and the 'political growth imperative'. Whereas the former points to the requirements to grow as stemming from the credit-creation system, the latter points to the social relations of distribution and production as imposing a self-fulfilling need for growth.

2.2.4.1 *Monetary Growth Imperatives*

One persistent debate in the ecological economics literature concerns what is called the "monetary growth imperative". Proponents of the monetary growth imperative argue that a stationary (zero-growth or 'steady state') or degrowing (negative-growth) economy are incompatible with a system in which money is created as interest-bearing debt. In this view, debt-based money with positive interest rates structurally propell further GDP growth.

Indeed, the vast majority of money is created ex-nihilo; money is loaned into an existence by commercial banks and comes attached with a positive rate of interest. However, only the principal of the loan enters into circulation. Debtors must repay the full principal of the loan, plus mounting interest payments. Accordingly, in order to avoid increasing indebtedness, the total value of sales in the economy has to rise. The increase in the value of sales is only possible in two ways, (i) prices must grow or (ii) the economy must grow.

The first option is problematic. When firms raise prices, this redistributes income towards capitalists, causing a fall in real wages for workers. Redistribution towards capitalists means less disposable income for consumers. When workers have less disposable income, this

can dampen aggregate demand and generate additional pressure to increase the value of sales (raising prices) yet again. In this case, rising indebtedness results in a cycle of increasing social inequality, economic stagnation, and inflation. Moreover, not all firms have the same power to raise prices. Inflation is therefore likely to reinforce the unequal distribution of incomes - both between workers and capitalists, and amongst capitalist firms - and have recessionary effects.

The second option also poses problems. Basing his analysis on the laws of thermodynamics, for example, Frederick Soddy (1931), noted that financial debts ('virtual wealth') may increase exponentially, but that this depended on transforming a finite stock of natural resources ('real wealth'). In Soddy's mind, the constant use of economic growth to sustain an economy based on interest-bearing debts would cause society to consume all available resources, and suffer scarcity and pollution. Indeed, economic growth (e.g. via additional lending and/or increasing the volume of sales) appears to be an important mechanism to stave off mounting debt burdens. As long as the economy grows and more output can be sold, mounting debts and interest payments are unproblematic for the economy as a whole.

Failure to sustain constant credit and consumer demand, however, results in growing indebtedness. Even putting aside the risk of financial crises and social hardship caused by rising debt burdens, an interest-bearing-debt based monetary system seems to present a profound challenge to collective well-being. As such, many ecological economists have argued for alternative monetary arrangements, including bank nationalization, and full-reserve banking (Røpke, 2017).

This question has provided fertile ground for post-Keynesian ecological macroeconomists, eager to apply their knowledge of the functioning of a credit-based money economy to ecological issues. In particular, various articles have been published using SFC models to determine whether a stationary (non-growing) economy can be stabilized or if interest charges on debt create a growth imperative. This was first explored in an SFC-IO by Berg, Hartley, and Richters (2015), and later extended by Jackson and Victor (2015), who use an extended SFC model that includes trade flows, private credit creation and private equity.

The post-Keynesian literature overwhelmingly finds that a 'growth imperative' is not brought on by force of the positive rate of interest on debt. Cahen-Fourot and Lavoie (2016) use a Cambridgian–Kaleckian model to study the possibility for a zero-growth, stationary state with positive interest rates. Moreover they bring a deep reflection about the nature of money and post-Keynesian theory. In this perspective, credit money comes into being only "when economic agents have a credit-worthy demand for it" Cahen-Fourot and Lavoie (2016, p. 164). It is therefore the growth in production that drives the growth of the money supply, and not the other way around. As they put it, "the rise

in production takes shape in the mind of producers before money is created and is effectively realized when credit is granted and money is created to finance it." (Cahen-Fourot and Lavoie, 2016, p. 165) The growth of the money supply and the process of money creation are therefore not responsible for driving growth of output, but a logical conclusion of the relations of production. For them, money facilitates, but does not cause, production and exchange.

Typically, the post-Keynesian frameworks demonstrate that the possible compounding debt effects of positive interest rates can be mediated by taxation and/or consumption out of wealth and income. Richters and Siemoneit (2017) review five different models and determine that the parameter "consumption out of wealth" is the key variable for achieving a stationary state with positive interest rates. A steady-state is possible as long as consumption out of wealth is sufficiently high. As the authors write,

> "For an attracting stationary state to exist, consumption out of wealth has to be above a threshold that increases with the interest rate in all the models, if tax rate and consumption out of income are kept constant. The thresholds do not depend on parameters describing reserve, equity or liquidity requirements, thus these parameters do not influence the stability of the stationary state." (Richters and Siemoneit, 2017, p. 8))

From a pure accounting perspective, stability in a stationary economy with positive interest rates on loans therefore depends on the consumption decisions of creditors, firms and households. Given that income flows remain constant in a stationary economy, if any sector accumulates net wealth, other sectors must run deficits and accumulate debt. A high enough rate of consumption out of wealth can bring overall net saving to zero, a state consistent with a net investment rate equal to zero that implies no net accumulation. If creditors consume or invest their interest income, money flows back into the economy and reduces the structural drive towards growth. Growth only becomes a necessity if capitalists and creditors prefer to hoard their profits. In this case, the growth imperative may be less a question arising from the money system in itself, but more a question of distribution and aggregated consumption decisions. The monetary growth imperative is therefore more linked to efforts to maximize profits, financial speculation, or individual desires for ever-increasing income and wealth.

Despite these seemingly robust conclusions about the monetary growth imperative, the issue remains hotly debated. A recent working paper by Arnsperger et al. (Arnsperger, Bendell, and Slater, 2021) pretends to 'debunk' the 'debunking' of the monetary growth imperative. Meanwhile, Hartley & Kallis (Hartley and Kallis, 2021) review 10

historical cases - reaching back as far as ancient Mesopotamia (24th-16th C. BCE) - and find that compound interest-bearing debt is always associated with exponential increases in indebtedness within slow or non-growing economies.

In perhaps the most complete rebuttal, Svartzman et al. (Svartzman et al., 2020) write that arguments against the monetary growth imperative actually miss how "the 'social' endogeneity of money...[is] intrinsically related to the birth and reproduction of capitalism's multiple growth imperatives" (Svartzman et al., 2020, p. 267). In particular, they contend that previous modeling attempts have provided an 'a-historical' analysis of money that tries to understand the monetary growth imperative as a pure matter of technical accounting. Debt-based money, they argue, is a deeply embedded construct within capitalist societies, and has a powerful sway on the direction of human social change. The authors retrace the history and institutional development of interest-bearing money and propose an alternative ontology of money. They show that positive interest rates have been an important function in legitimizing the use of money as a store of value since at least the Middle Ages.

By seeing money as a mere accounting tool, previous models fail to capture socio-cultural drivers of monetary developments. This misses how financial arrangements co-evolve with practices of accumulation. Most authors have therefore discarded the need for reforming the monetary system in favor of critiquing the relations of production, despite the fact that "the rise of interest-bearing debt money is precisely what reshaped the productive structures of our economies and realigned the social relations of production toward a capitalist goal of perpetual accumulation and growth." (Svartzman et al., 2020, p. 268). In this sense, interest rates are intimately connected to the social conditions which give rise to productive relations, and the strong impulses to grow in the economy. While a strict accounting definition of the monetary growth imperative may be disproven, the relationship between monetary institutions and growth appears far from decided.

To conclude, Svartzman et al. (2020) argue that alternative frameworks, particularly those found in environmental history, geography and french regulation theory, may be necessary to understand monetary institutions, nature, and society as a set of co-evolving relations. This aligns with earlier work by Svartzman, Dron, and Espagne (2019) which criticizes the post-Keynesian approach to understanding of economy-environment relations. Focusing too heavily on the pragmatic application of monetary accounting functions to understand what is technically possible, may ignore both the existing institutional momentum, or the possibility for alternatives. Monetary relations embody a collective language of value whose capacity to establish commensurability and comparability is rooted in political compromise. Money therefore gives structure to, and is structured by, the prevail-

ing socio-ecological context within which it arises. Monetary orders should then be understood as fundamentally

> institutional arrangements that reflect broader power dynamics but also worldviews and ethical principles shaping life in society, and the existing monetary order seems incompatible with the emergence of a much-needed new ethics of human-nature relationships. (Svartzman, Dron, and Espagne, 2019, p. 117)

As such, it appears that more institutionalist and political perspectives will be necessary to clarify the monetary growth imperative, as well as to establish new ways of envisioning monetary relations.

2.2.4.2 *Political Growth Imperatives*

While growth might not be strictly necessary on the basis of money creation, it would be difficult to imagine a stationary state under capitalist social relations. As Cahen-Fourot and Lavoie (2016, p. 167) argue, growth may nonetheless be pushed by other factors, including "population growth, the social relations of production between workers and capital owners, market competition, spreading commodification and accumulation for itself –several of which are peculiar to a historically situated economic system that is capitalism." Although profits could accumulate in a non-growing economy, for example, competitive pressures among firms or worker demands for higher wages would cause the profit rate to fall, thereby undermining the tenuous stability of a stationary state.

Moreover, achieving a socially sustainable stationary state with positive interest rates and a positive rate of profits would be a special case. Such a situation would require an impressive redistribution program and low rates of savings out of profits - both of which seem anathema to the overwhelming drive to accumulate in modern capitalism.

For these reasons, other researchers have contended that growth is driven primarily by the relations of production and distribution capitalism. Rather than a 'monetary' growth imperative, capitalism may then be characterized by 'political' growth imperatives.

Following Marx and Schumpeter, Richters and Siemoneit (2019) single-out the need for technological innovation as a primary growth imperative within capitalism. Firm survival within capitalism relies on maintaining price competitiveness, consumer demand and profitability. Firms are therefore under immense pressure to innovate via the process of 'creative destruction'. Profits must be constantly reinvested to support production processes that minimize costs (e.g. replacing labor or resources), develop new products, generate hype, and establish market dominance. This competitive process requires continuous investment, driving an endless cycle of growth, technological change and increases in productivity. Without constant increases

in the level of production, unemployment is likely to rise as technological advances reduce the need for labor. Without aggregate economic growth, the process of creative destruction brings about continuous increases in unemployment.

Moreover, this process arises alongside an intense inter-state competition to capture incomes, employment and material resources, and to sustain public debt at socially acceptable levels. In this context, failure to support continuous increases in growth would result in major political upheaval and a structural tendency towards economic and social crisis. The authors argue that this confluence of conditions creates a political growth imperative within capitalist social relations that makes alternatives to economic growth 'unrealistic'.

Much as was criticized in the monetary growth imperative literature, however, technological changes are embedded within social institutions (Svartzman et al., 2020). Increasing labor productivity does not happen in a political vacuum. 'Technological' unemployment, for example, can be countered by collective reductions in working time. Indeed, one structural feature of capitalist growth for much of the first half of the 20th century was that steady increases in labor productivity were compensated by union demands and political pressure to reduce working time. The intensification of globalization and decline in union power since the 1970s, however, put an end to this pattern. The possibilities for reducing working time in order to stabilize employment is also widely researched within the research on degrowth and post-growth (Section **??**). From this perspective, any growth imperative within capitalism appears to stem less from technological change but more directly from relations of social distribution and class power.

Indeed, distributional issues are at the core of the notion of a 'political' growth imperative. Jackson and Victor (2016) develop an SFC model to challenge the hypothesis - made famous by Thomas Piketty (2014) - that slow growth rates lead to rising inequality. Piketty argued that inequality rises when the rate of return to capital is greater than the rate of growth ($r > g$). Staving off inequality would therefore require higher rates of income growth. A slow-growing or degrowing economy would result in exponentially increasing inequality.[9] In theory, growth is then a necessary aspect of capitalist production which helps to avoid rampant social conflict caused by rising inequality. Yet the authors find, contrary to Piketty, there is no automatic mechanism which forces inequality to rise as growth slows. Indeed, inequality can be reduced significantly or even completely with adequate fiscal and redistributive policies. The critical variable in this case appears to be the elasticity of substitution between labor

9 Piketty's formulation has been subject to numerous critiques by post-Keynesians and Marxists. For formalized critiques, see especially Ederer and Rehm (2020), López-Bernardo, López-Martínez, and Stockhammer (2016), and Rowthorn (2014)

and capital. When it is easier to substitute capital for labor, inequality rises as predicted. However, a low elasticity of substitution allows for a low-growth economy without rising inequality. This implies that a socially-equitable degrowth economy could feasibly be achieved by investing in labor-intensive services and focusing on worker protections.

Jackson and Victor (2018) follow up on this paper with a more in-depth analysis of the conditions for maintaining equality in a degrowing economy. After confirming their previous results, they test three policies meant to support equality: a progressive income tax, a tax on capital and a universal basic income. Interestingly, their model shows that no measure is sufficient to reduce inequality in the context of degrowth as long as the elasticity of substitution of capital to labor is high and firms 'aggressively' favor capital over labor. However, when the elasticity of substitution of capital to labor is low, the conditions for workers are more favorable. The authors claim that tax and income redistribution measures can eliminate inequality almost entirely, even as the rate of growth declines.

Stratford (2020) meanwhile, puts forward a rent-based theory of the growth imperative. Stratford argues that opportunities for rent extraction compel capitalist societies to pursue output growth, and therefore also form a 'political' growth imperative. Economic rents are made possible by mobilizing the power to exclude others from access and use. Forms of legal ownership and private property rights, for example, are institutions that provide special powers and protections for rentiers. Namely, they are afforded the possibility to demand payments for access and use, as well as to claim a share of future income streams. Stratford shows that a higher capacity to extract rents drives (i) unemployment (e.g. labor productivity improvements are appropriated by rentiers), (ii) rising poverty and inequality (e.g., monopoly pricing and financial extraction via interest payments concentrate income among rentiers), and (iii) debt-fuelled asset-inflation that create boom-bust cycles and high debt-to-GDP ratios. Growth has typically been, at least in part, an indirect means to stave off the worst effects of rent extraction. However, growth tends to reinforce these socially unequal and ecologically unsustainable production patterns. Moreover, if opportunities to *expand* production are limited (e.g, due to environmental protections, planned degrowth, or recession), rentiers may seek to increase their income and wealth by making more powerful claims to social production. Stratford therefore argues that redistribution policies and efforts to socialize 'unavoidable' rents are necessary in order to reduce growth without spiraling inequality and unemployment.

2.2.4.3 *Summary: Capitalist Growth Imperatives*

The 'Capitalist Growth Imperatives' theme is dedicated to a clear understanding of the actual social forces which propel capitalist accumulation and the obstacles to reducing the size and scope of the economy. If infinite growth on a finite planet is impossible, understanding the mechanisms which drive growth is therefore an important key to paving the way towards a sustainable transition. Researchers have debated two broadly defined aspects that may make growth an existential necessity: a monetary growth imperative, and a political growth imperative.

Given the strong, seemingly unshakable correlation between economic growth and resource and energy use (Krausmann et al., 2017; Wiedmann et al., 2020), this research offers important insights into both the limits and possibilities of capitalist institutions. Determining whether a non-growing or de-growing capitalist economy is socially, economically or politically feasible ultimately points to deeper questions about whether capitalist institutions can be 'reformed' or must undergo more revolutionary changes to avoid increasingly catastrophic futures. If capitalist institutions are unable to provide social stability in a steady-state or negative growth environment, then envisioning non-capitalist forms of social provisioning becomes a biophysical necessity, rather than a theoretical exercise. In this vein, the next theme highlights alternatives to the use of economic growth as a means of meeting social priorities.

Research Theme	Research Sub-Themes	Representative Paper	Scale of Analysis	Reason for Economy-Environment Conflict	Technological Change...	Inequalities...
Capitalist Growth Imperatives	*Monetary Growth Imperatives*	Jackson & Victor (2015)	Nation-State	Economic growth is strongly linked to growing environmental pressures. Capitalism may be inherently driven towards growth in order to maintain systemic stability, implying a fundamental economy-environment contradiction.	...is a major potential source of what drives growth, in the first place. This tendency must therefore be contained by redistributive measures, work sharing, and working-time reductions.	...are a major potential source of what drives growth, in the first place. They must, therefore be contained through redistributive policies.
			Sustainability requires...	**Key Questions**	**Key Findings**	**Policy Advice**
	Political Growth Imperatives		...undermining those aspects of capitalism that drive perpetual increases in economic growth.	(i) Are low- or no-growth pathways technically or institutionally feasible within capitalism?; (ii) What aspects of capitalism create a necessity and/or strong tendency towards growth?; (iii) What role does the monetary and financial system play in driving growth within capitalism?; (iv) To what extent is growth driven by political and distributional factors?	(i) From an accounting perspective, there is likely no fundamental necessity for growth within capitalism, even when interest rates are positive; (ii) Nevertheless, the monetary and financial systems provoke a strong institutional tendency towards growth; (iii) Multiple other 'political' drivers - competitive firm pressures, unequal distribution of income and wealth, private property - may make low- or slow growth destabilizing without strong interventions by the state.	(i) Relieving the pressures to grow within capitalism will likely require significant redistribtuion of income and assets; (ii) Work-sharing and reduction in working hours can reduce the drive towards growth from firm competition; (iii) Alternative property arrangements (e.g., public and common ownership) may be necessary to alleviate growth pressures.

Table 4: Capitalist Growth Imperatives Overview

2.2.5 *Post-Growth/Degrowth Futures*

The final theme in ecological macroeconomics is 'Macroeconomic Stability of Degrowth/Post-Growth Futures' (herein, "Degrowth"). While the previous theme on capitalist growth imperatives answered questions about whether low or negative growth was technically or institutionally possible within capitalism, this research actively envisions pathways towards a degrowth/post-growth society, and tests their macroeconomic viability. Researchers in this theme aim to describe an economic future where (i) growth is no longer a social priority and well-being is achieved through various other means and/or where (ii) degrowth is deemed an explicit and necessary goal in order to promote greater social and environmental justice. As such, this research investigates how well-being can improve both because of - and in spite of - any decline in GDP, as long as the correct social and environmental protections are in place.[10] In the words of Jackson (Jackson and Victor, 2019, p. 244)

> ...beyond a certain point, and for a variety of reasons, relentless economic growth may be neither desirable nor indeed feasible. Whether for secular reasons, or from a decline in resource quality, or from the need to curtail damaging environmental impact, proponents of these ideas attempt to envision the social conditions (and economic implications) of a world in which, for the advanced economies at least, it is necessary to 'manage without growth'.

The Degrowth branch is characterized by some similar elements as many of the previous branches, particularly in its use of post-Keynesian tools to identify how concerted social and environmental policies can help to achieve macroeconomic and social and ecological stability. Nevertheless, it represents new territory for heterodox macroeconomists who have traditionally focused on achieving social goals by increasing the rate of growth. For instance, it stands in contrast to Green Keynesians, who feel that economies can be made increasingly sustainable with the judicious application of government support, even while growing. Degrowth researchers ultimately reject strategies

10 In an earlier review of the literature, Hardt and O'Neill (2017) identify the compatibility of models within ecological macroeconomics with the post-growth/degrowth platform. They cite eight tenets of a post-growth agenda: (1) Reduce environmental impacts from economic activity; (2) Reduce inequalities in income and wealth; (3) Reform the monetary system so that it provides stability and serves the goals of society; (4) Promote life-styles with less material consumption, (5) Reduce paid work and share it more equally to provide security. Promote jobs in low-impact sectors; (6) Promote business models that incorporate fair participation of workers and that are focused on enhancing the common good; (7) Reform the regulation of international trade and finance to reduce inequality between countries stronger controls of tax havens and tackle tax evasion; (8) Promote the creation of more self-reliant and resilient local communities.

that rely on a growing economy, particularly within Core countries. Growth in 'green' investment for new technologies is, at most, part of a short- and medium-term transition towards an alternative economy where growth is no longer a goal, and socio-ecological needs are met through more direct means: decommodification, work sharing and improved local and community resource governance are seen as keys to support equitable access and distribution.

Ecological macroeconomists are contributing to literature on post-growth futures identifying the necessary institutional changes to bring about a degrowth society, as well as by modeling how such policy changes impact macroeconomic stability. The rest of this section highlights some of the major contributions to the degrowth/post-growth research in ecological macroeconomics, focusing on two categories of research, 'The Macroeconomic Necessity and Potential for Degrowth' and 'Degrowth by Changing Consumption Patterns'.

2.2.5.1 *Macroeconomic Necessity and Potential for Degrowth*

The first group of research that can be distinguished in the Degrowth theme seeks to unveil the macroeconomic stability conditions of de-accumulation in the short- and medium- run. Just as research on 'Capitalist Growth Imperatives' presented a stark picture about the nature of institutional changes that would be required in order to ensure that negative rates of accumulation would not result in rising inequality and indebtedness, research in this theme attempts to depict some of those institutional changes. Moreover, it creates a general framework for showing why degrowth might also be necessary for socio-economic stability, as well as to capture how implementing these policies can potentially be both socially and ecologically beneficial and economically feasible. Degrowth theorists largely believe that if degrowth does not come 'by design' it will most certainly come 'by disaster' (Victor, 2008). Without a movement through careful planning towards a slimmer and more sober economy, worsening environmental degradation will place socio-economic institutions and engender increasing chaos.

In one of the earliest representations of a degrowing economy, Victor and Rosenbluth (2007) and Victor (2012) develop a dynamic demand-led model (LowGrow) to simulate a no or low growth transition within Canada by 2035.[11] While the model is relatively simple compared to later iterations (e.g. no explicit monetary and financial sector), the authors are able to examine diverse scenarios to test the economic and environmental effects of a fall in net investment, population and labor force growth, productivity growth, and the net trade balance decline to zero. In business-as-usual scenarios, they show a predicted downward spiral of employment and incomes alongside

11 While this model takes the form of a Cobb-Douglas production function, growth is nevertheless driven by investment demand, rather than saving.

continued overshoot of domestic emissions targets. The introduction of countercyclical policies are able to counteract the rapid decline, environmental impacts, unemployment and poverty remain at unacceptable levels. Finally, the authors depict a negative growth scenario where economic stability, low employment, a stable debt-to-GDP ratio, low poverty, and emissions reductions are successfully achieved. This comes from a decline in the average work week, active labor management policies by the government through re-education and job provision, a massive redistribution plan (via transfers and progressive taxes on households and corporations), and a revenue neutral ($200/ton) carbon tax.

Jackson and Victor (2020) use an SFC model (LowGrow) to show the possibility for significant social and 'green' structural changes to provide for low or near-zero rates of growth while still maintaining social, environmental and economic stability over the next 50 years.[12] The authors develop a "Social Performance Index" (SPI) based on a weighted sum of multiple social and environmental variables (Gini coefficient, GDP per capita, 'Environmental Burden Index', unemployment rate, average hours worked, etc.) to measure the benefits of a transition in terms not solely measured by GDP. Their model depicts a baseline scenario, a Carbon Reduction scenario (decarbonization alongside a rising tax on carbon emissions), and a Sustainable Prosperity scenario (more aggressive carbon reductions alongside investments in broader environmental protections, social benefits and redistribution, and work reduction). Their results suggest that improved social and environmental outcomes are possible even as the rate of growth falls to zero. While this requires a momentous shift in social and economic policy, such a post-growth scenario is associated with better quality of life, greater social equality and lower environmental impacts. Interestingly, it was also the only scenario associated with an improvement in the SPI.

D'Alessandro et al. (2020) use a post-Keynesian dynamic macroeconomic model to simulate the environmental and distributional consequences of three scenarios ('green growth', 'policies for social equity', and 'degrowth') in the French economy. In the first scenario, fiscal support for green technology development and various environmental measures (carbon taxes) are shown to reduce carbon emissions, yet result in rising income inequality and unemployment. The 'policies for social equity' scenario adds a jobs guarantee program that privi-

12 This paper takes into account two types of 'green' investment - those that are "productive" and those that are "non-productive". Whereas 'productive' forms of investment may reduce environmental impacts, they will also add to productive capacity (e.g broad electrification, decarbonisation of electricity and non-electricity sector). 'Non-productive' green investments - are those that may have an exceedingly low rate of return - or even a net cost - and are therefore not competitive with other investments. These investments are non-productive in the sense that they do not add to the productive capital stock (e.g. environmental conservation), despite their obvious potential to impact long-term growth (e.g. by protecting biodiversity).

leges green jobs, resulting in a similar environmental outcome while also improving social equity. Most importantly, the authors add that

> despite the presence of mitigating factors... [these scenarios] are not able to reach the desired emissions reduction, since they only rely on energy efficiency and environmental policies for decarbonization. This supports the thesis that economic policies ought to go beyond the stimuli for technological solutions and move away from the growth imperative to achieve large-scale reductions in emissions. (D'Alessandro et al., 2020, p. 332)

The proposed degrowth scenario is the only scenario capable of meeting emissions targets and reducing inequality. This scenario combines the previous policy measures, alongside reductions in working time, the propensity to consume and the growth rate of exports, while raising the tax on wealth.

2.2.5.2 *Degrowth by Changing Consumption Patterns*

Another group of literature in the 'Degrowth/Post-Growth' theme inquires into the possibility for building a degrowth/post-growth society by changing consumption patterns. Some of these articles are reminiscent of SECTION 3.3.1, which described 'Green Keynesian' literature on shifting consumption and employment to low-impact services and 'green' forms of consumption. In that literature, an *increase* in consumption and specific forms of low-impact employment are seen as a means to improve incomes, and secure greener growth. Here, the research explicitly references a need to transition to a low- or no-growth economy, and explores *reductions* in consumption that would achieve such a goal. Such changes in consumer lifestyles and the structure of employment could feasibly provide for social-ecological needs. Additionally, as is common within the 'Degrowth/Post-Growth' literature, a change in the structure of employment is seen as a complement to reduced working hours and work-sharing in order to reduce environmental throughput. As such, the policies here are centered broadly on changing the social relationship to consumption and work in order to reduce economic growth while sustaining economic stability.

For example, Kemp-Benedict and Ghosh (2018) explore the potential for a voluntary shift of workers' labor and consumption practices within middle- and high-income countries to support the transition towards a low-carbon future. In the first scenario, economic 'downshifting' occurs because households willingly reduce the number of hours worked in order to increase their personal well-being. When conducted at a sufficiently large scale, voluntary downshifting via labor withdrawal was shown to bring about major beneficial environmental changes, even in the absence of private sector or government action. While a smaller pool of labor was shown to

bring an increase in wages, leading to greater consumer spending and (labor-saving) technological innovation, the emissions-increasing effects were smaller than the impact of work sharing. In the second scenario, consumers willingly reduce their consumption of non-essential and pollution-intensive goods. A reduction in consumption was shown to have mixed effects, depending on the size of the reduction. Whereas the economy maintained a consistent output and employment path with smaller reductions in consumption (7.5 per cent) these became heavily negative in the more extreme scenario (15 per cent), contributing to both recession and price deflation.

Hardt et al. (2020) study the possibility of enacting major structural changes towards labor-intensive services (environmental impacts of physical production and provide meaningful work in a post-growth economy. They compare the embodied energy intensity and embodied labor productivity of economic sectors in both the UK and Germany between 1995 and 2011 using a multi-regional input-output framework. They identify five labor-intensive service sectors (Hotels and Restaurants, Public Administration, Health, Education and "Other Services") which combine both low embodied energy intensity and low growth in embodied labor productivity. While a major shift towards labor-intensive sectors with low embodied energy intensity could be a major step towards a sustainable transition, the authors find that such a shift would be insufficient on its own.

Following Baumol's 'cost disease' theory, Hardt and co-authors argue that increasing the share of labor-intensive service sectors could become problematic because of rising relative costs and prices. Sectors with a high direct energy-intensity and low labor-intensity also tend to have low or negative rates of price inflation. Meanwhile, labor-intensive services are generally characterized by low rates of labor productivity growth and have relatively higher rates of price inflation. Taking these into account, structural changes towards labor-intensive services may result in price inflation, without any meaningful decline in the share of energy-intensive production. The pathway towards a non-growing economy would therefore likely require redistributive measures to offset some of the worst effects of cost increases and support low energy-intensity services. The authors suggest (i) heavier relative taxes on energy use and emissions, rather than labor, (ii) promotion of more labor-intensive services, particularly an obligation for firms to offer repair services, and (iii) an increase in the non-market provision of services via community organizations or the state. While not specifically mentioned in the paper, working-time reductions or work-sharing is another standard post-growth policy response to increasing the labor-intensity of production and services sectors.

Monserand (2019) investigates the theoretical possibilities for a stable degrowth transition in a neo-Kaleckian model. The author finds that by adding the rate of capital depreciation to the canonical model,

a stable macroeconomic equilibrium can be achieved. The author tests a number of pathways that would provide the necessary 'space' for arriving at an equilibrium with a negative rate of accumulation: increased overhead labor costs and taxes on capital, decreased autonomous consumption expenditures and a decline in the budget deficit. While these might appear to be recessionary, Monserand contends that concerted 'democratic government action' can promote a shift towards sustainable lifestyles that provide for socially and economically stable degrowth. This would include transforming transportation, insulating buildings, reducing the advertisement and marketing industries, eliminating planned obsolescence by forcing manufacturers to make long-lasting and reparable goods. By drastically constraining or reducing forced expenditures

> people do not need to buy, insure, fuel, maintain and eventually replace a private car any more; they do not need to heat or cool their home as much; nor do they need to replace (artificially) broken non-repairable home appliances and furniture etc. They are also less prone to consuming goods and services they would not have consumed, had advertisement not pushed them into doing so.(Monserand, 2019, p. 18)

The model then includes dynamics that can both "push" the economy and "pull" the economy towards a stationary state at a sustainable level of emissions output by stabilizing aggregate consumption.

2.2.5.3 *Summary: Post-Growth/Degrowth Futures*

The 'Post-Growth/Degrowth Futures' literature expresses a new line of investigation for heterodox macroeconomic researchers. By highlighting the apparent necessity, potential benefits, and feasibility of low- and negative rates of growth, scholars in this theme bring together an understanding of demand-led macroeconomic forces, alongside the social and ecological goals of reducing the scope and scale of the economy.

Research Theme	Research Sub-Themes	Representative Paper	Scale of Analysis	Reason for Economy-Environment Conflict	Technological Change...	Inequalities...
Post-growth / Degrowth Futures	*Macroeconomic Necessity and Potential for Degrowth*	D'Allessandro et al. (2020)	Nation-State	Economic growth is strongly linked to growing environmental pressures, and fails to meet human needs. A social logic of growth is inherently unsustainable and increasingly damaging to the environment and human livelihoods, particularly for the poor.	...is an important, though limited tool for reducing environmental impacts. It should not be counted on as the primary means of doing so, and should be supported by altenative policies, including redistributive measures, work-sharing and working-time reductions.	...are likely to worsen if swift action is not taken to reduce economic impacts on the environment. Given the 'limits to growth', strategies towards degrowth remain the only possible option for safeguarding equality and social stability.
			Sustainability requires...	**Key Questions**	**Key Findings**	**Policy Advice**
	Degrowth by Changing Consumption Patterns		...(i) actively reducing growth while finding more direct means for meeting human needs that also relieve environmental pressures; (ii) reducing unnecessary consumption (e.g., from planned obsolesence); (iii) shifting towards sectors with low environmental impacts; (iv) policies that promote greater equality and reduce the total quantify of work.	(i) Why might degrowth be both desirable and necessary?; (ii) How can a degrowing economy improve both social welfare and reduce environmental pressures?; (iii) What are the conditions of stability for a degrowing economy?; (iv) How might alternatives to work and (commodified-)consumption in order to support a degrowth transition?	(i) 'Green' Investments and efficiency increases - without sufficient policies meant to curb wealth inequalities, overcomsumption and overwork - may not be enough to achieve sustainable outcomes; (ii) Large-scale reductions in emissions likely require efforts towards degrowth; (iii) Stable degrowth scenarios are feasible and can improve social and environmental outcomes; (iv) Policies that help shift social prerogatives away from work and consumption can help achieve degrorwth.	(i) Degrowth can be made possible and even desirable when combined with policies supporting working time reductions, job and income guarantees, heavy taxes on wealth, income and emissions. (ii) Other possibilities include: subsidies to promote more labor-intensive services, obligations for firms to offer repair services; eliminating planned-obsolecense; curbing advertising and marketing; decommodification of essential goods and services

Table 5: Post-Growth / Degrowth Futures Overview

2.3 TOWARDS A COHERENT ECOLOGICAL MACROECONOMICS?

The previous section reviewed more than 58 theoretical, analytical and quantitative works within ecological macroeconomics to identify five dominant themes within the field: (1) 'Green Keynesianism', (2) 'Financial Stability and Socio-Environmental Change', (3) 'Socio-Metabolic Dynamics and Constraints', (4) 'Capitalist Growth Imperatives', (5) 'Post-growth/Degrowth Futures'. Each of these themes corresponds to a particular pathway taken by ecological macroeconomics researchers in trying to better understand the pathways and impediments to reducing environmental impacts, the links between financial stability and climate change, the material grounding of socio-economic changes, the forces driving exponential economic growth, and the possibilities for reducing achieving generating greater social and environmental justice while reducing growth. These works demonstrate a growing interest amongst heterodox economists in studying the economy as a subset of the environment, as well as the development of new tools for doing so. Much of the field overlaps, given a generally consistent methodological basis, and common interests in exploring how the financial and monetary system, distribution conflicts, institutional dynamics, and the Earth system relate. Nevertheless, a few key discrepancies are apparent. This section will first provide a brief comparison of the different branches based on a few key facts. Second, it will discuss the primary points of similarity and contention within the field.

2.3.1 *Key Facts and Figures*

Looking at tables ?? ??, it is interesting to note that of 59 reviewed articles, half (29) of all publications appeared in the journal *Ecological Economics*. No other journal published more than two articles related to ecological macroeconomics. Moreover, as can be seen in Table ??, the greatest proportion of articles reviewed here (28) belong to the 'Green Keynesianism' theme. This indicates an increasing interest amongst (post-)Keynesians to rehash traditional modeling techniques to achieve environmental priorities. It may also reflect the age of the theme, since it also is the first theme to have developed in ecological macroeconomics. The other four themes have a relatively balanced representation in the rest of the research in the field, with nearly equal share of the remaining 31.

Author(s)	Year	Title	Journal or Book (Publisher)	Research Theme	Sub-Theme	Model Type	Model Name	Citations
Fontana & Sawyer	2015	The Macroeconomics and Financial System Requirements for a Sustainable Future	Finance and the Macroeconomics of Environmental Policies' (Palgrave)	Geen Keynesianism	Green Consumption and Employment	PKK		18
Forstater	2012	Green Jobs: Public Service Employment and Environmental Sustainability	Challenge					75
Godin	2012	Guaranteed Green Jobs: Sustainable Full Employment	Levy Economics Institute of Bard College Working Paper			SFC		20
Kronenberg	2010	Finding Common Ground between Ecological Economics and Post-Keynesian Economics	Ecological Economics			IO		95
Carnevali et al.	2020	Cross-Border Financial Flows and Global Warming In a Two-Area Ecological SFC Model	Socio-Economic Planning Sciences		Green Innovation and Fiscal Policies	SFC		12
Deleidi et al.	2019	Sraffian Supermultiplier, Mission-Oriented Innovation Policies and Ecological Sustainability: A Stock-Flow Dynamic Model	IIPP Working Paper			SFC		0
Fontana & Sawyer	2016	Towards post-Keynesian ecological macroeconomics	Ecological Economics			PKK		131
Galindo et al.	2020	Environmental innovations, income distribution, international competitiveness and environmental policies: a Kaleckian growth model with a balance of payments constraint	Structural Change and Economic Dynamics			BOPCG		7
Guarini	2020	The Macroeconomic Impact of the Porter Hypothesis: Sustainability and Environmental Policies in a Post-Keynesian Model	Review of Political Economy			PKK, Econometric		4
Guarini & Porcile	2016	Sustainability in a post-Keynesian growth model for an open economy	Ecological Economics			BOPCG		31
Harris	2013	Green Keynesianism: Beyond Standard Growth Paradigms	Global Development and Environment Institute, Working Paper			PKK		57
Harris	2019	Responding to Economic and Ecological Deficits	Global Development and Environment Institute, Working Paper					3
Mazzucato	2015	The green entrepreneurial state	The Politics of Green Transformations (Routledge)					137
Mazzucato & Semieniuk	2018	Financing renewable energy: Who is financing what and why it matters	Technological Forecasting and Social Change					390
Mercure et al.	2018a	Environmental impact assessment for climate change policy with the simulation-based integrated assessment model E3ME-FTT-GENIE	Energy Strategy Reviews			IAM		75
Naqvi	2015	Modeling Growth, Distribution, and the Environment in a Stock-Flow Consisten Framework	WU Institute for Ecological Economics Working Paper Series			SFC		37
Naqvi & Stockhammer	2018	Directed Technological Change in a post-Keynesian Ecological Macromodel	Ecological Economics			SFC		28
Ponta et. al.	2018	An agent-based stock-flow consistent model of the sustainable transition in the energy sector	Ecological Economics			SFC		89
Pollin	2015	Greening the Global Economy	(MIT Press)					100
Rezai et al.	2013	Ecological macroeconomics: An application to climate change	Ecological Economics			PKK		113
Rezai et al.	2018	Economic Growth, Income Distribution, and Climate Change	Ecological Economics			PKK		50
Sawyer	2020	Financialisation, industrial strategy and the challenges of climate change and environmental degradation	International Review of Applied Economics					11
Taylor et al.	2016	An Integrated Approach to Climate Change, Income Distribution, Employment, and Economic Growth	Ecological Economics			PKK		97
Campiglio	2016	Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy	Ecological Economics		Green Monetary and Financial Policies			405
Dafermos et al.	2017	A stock-flow-fund ecological macroeconomic model	Ecological Economics			SFC	DEFINE	160
Dafermos et al.	2019	Fiscal policy and ecological sustainability: A post-Keynesian perspective	Frontiers of Heterodox Macroeconomics (Springer)			SFC	DEFINE	24
Monasterolo & Raberto	2018	The EIRIN Flow-of-funds Behavioural Model of Green Fiscal Policies and Green Sovereign Bonds Author links open overlay panel	Ecological Economics			SFC	EIRIN	129
Monasterolo & Raberto	2019	The impact of phasing out fossil fuel subsidies on the low-carbon transition	Energy Policy			SFC	EIRIN	71

Table 6: Ecological Macroeconomics Literature

In terms of citations,[13] it is also clear that the 'Green Keynesian' branch held far more citations in total, due to its larger number of articles, and the fact that it is an older branch of ecological macroeconomics. Average citations for the branch was among the highest (83.8), and median citations was by far the highest, with 64. Interestingly, while both 'Financial Stability and Environmental Change' and

13 Citations are based on Google Scholar results, as of 16 February 2022.

Author(s)	Year	Title	Journal or Book (Publisher)	Research Theme	Sub-Theme	Model Type	Model Name	Citations
Bovari et al.	2018	Coping with collapse: a stock-flow consistent monetary macrodynamics of global warming	Ecological Economics	Financial Stability and Socio-Environmental Change	Assessing and Reducing Risks to Financial Stability	SFC		92
Chenet et al.	2021	Finance, climate-change and radical uncertainty: Towards a precautionary approach to financial policy	Ecological Economics					32
Dafermos et al.	2018	Climate Change, Financial Stability and Monetary Policy	Ecological Economics			SFC	DEFINE	253
Dunz et al.	2021	Climate Transition Risk, Climate Sentiments, and Financial Stability in a Stock-Flow Consistent Approach	Journal of Financial Stability			SFC		25
Monasterolo	2020	Embedding Finance in the Macroeconomics of Climate Change: Research Challenges and Opportunities Ahead	CESifo Forum					9
Cahen-Fourot et al.	2021	Capital stranding cascades: The impact of decarbonisation on productive asset utilisation	WU Institute for Ecological Economics Working Paper Series		Stranded Assets and Financial Stability	IO		41
Mercure et al.	2018b	Macroeconomic impact of stranded fossil fuel assets	Nature Climate Change			IAM	E3ME-FTT-GENIE	251
Semieniuk et al.	2021	Stranded Fossil-Fuel Assets Translate into Major Losses for Investors in Advanced Economies	UMass, Amherst Working Papers			IAM	E3ME-FTT-GENIE	2
Berg et al.	2015	A stock-flow consistent input–output model with applications to energy price shocks, interest rates, and heat emissions	New Journal of Physics	Socio-Metabolic Perspectives of Economic Dynamics and Constraints	The Materiality of Growth	SFC-IO		96
Cahen-Fourot et al.	2020	Looking for the Inverted Pyramid: An Application Using Input-Output Networks	Ecological Economics			IO		19
Kemp-Benedict	2014	The inverted pyramid: A neo-Ricardian view on the economy–environment relationship	Ecological Economics			IO		20
Jackson & Jackson	2021	Modelling energy transition risk: The impact of declining energy return on investment (EROI)	Ecological Economics		The Limits of Decoupling	SFC	TranSim	6
Kemp-Benedict	2018	Dematerialization, Decoupling, and Productivity Change	Ecological Economics			PKK		37
Arnesperger et al.	2021	Monetary adaptation to planetary emergency: addressing the monetary growth imperative	IFLAS Working Paper	Capitalist Growth Imperatives	Monetary Growth Imperatives			2
Cahen-Fourot & Lavoie	2016	Ecological monetary economics: A post-Keynesian critique	Ecological Economics			PKK		59
Hartley & Kallis	2021	Interest-bearing loans and unpayable debts in slow-growing economies: Insights from ten historical cases	Ecological Economics					2
Jackson & Victor	2015	Does Credit Create a Growth Imperative? A Quasi-Stationary Economy with Interest-Bearing Debt	Ecological Economics			SFC	FALSTAFF	108
Richters & Simoneit	2017	Consistency and stability analysis of models of a monetary growth imperative	Ecological Economics			PKK		51
Svartzman et al.	2020	Money, interest rates and accumulation on a finite planet: revisiting the 'monetary growth imperative' through institutionalist approaches	Sustainable Wellbeing Futures (Edward Elgar)					7
Jackson & Victor	2016	Does slow growth lead to rising inequality? Some theoretical reflections and numerical simulations	Ecological Economics		Political Growth Imperatives	SFC	SIGMA	117
Jackson & Victor	2018	Confronting inequality in a postgrowth world — Basic income, factor substitution and the future of work	CUSP Working Paper			SFC	SIGMA	1
Stratford	2019	The Threat of Rent Extraction in a Resource-constrained Future	Ecological Economics					23
Richters & Simoneit	2019	Growth imperatives: Substantiating a contested concept	Structural Change and Economic Dynamics					29
D'alessandro et al.	2020	Feasible alternatives to green growth	Nature Sustainability	Post-growth/Degrowth Futures	Macroeconomic Stability and Potential for Degrowth	SFC	EUROGREEN	91
Jackson & Victor	2020	The Transition to a Sustainable Prosperity-A Stock-Flow-Consistent Ecological Macroeconomic Model for Canada	Ecological Economics			SFC	LowGrow SFC	14
Victor	2012	Growth, Degrowth and Climate Change: A Scenario Analysis	Ecological Economics			Cobb-Douglas	LowGrow	252
Victor & Rosenbluth	2007	Managing without growth	Ecological Economics			Cobb-Douglas	LowGrow	166
Hardt et al.	2020	Structural Change for a Post-Growth Economy: Investigating the Relationship between Embodied Energy Intensity and Labour Productivity	Sustainability		Degrowth by Changing Consumption Patterns	MRIO		12
Jackson & Victor	2016	Does slow growth lead to rising inequality? Some theoretical reflections and numerical simulations	Ecological Economics			SFC	SIGMA	117
Kemp-Benedict & Ghosh	2018	Downshifting in the Fast Lane: A Post-Keynesian Model of a Consumer-Led Transition	Economies			PKK		1
Monserand	2019	Degrowth in a neo-Kaleckian model of growth and distribution? A theoretical compatibility and stability analysis	CEPN Working Paper			PKK		3

scale=.7

Table 7: Ecological Macroeconomics Literature (cont.)

'Post-Growth/Degrowth' had less the half the number of articles as the 'Green Keynesian' branch, they had also held a relatively high number of absolute and average citations. This likely reflects a growing interest in some of the themes touched on by ecological macroeconomists within other fields. In particular, the relationship between financial stability and climate change is of increasing concern for policymakers and central banks. While the Degrowth field remains relatively marginalized in policy discourse, it is nonetheless part of a small yet active academic community. Understanding the possibilities and stability of Post-Growth/Degrowth transitions therefore appears to provide additional scientific support for these researchers.

Research Theme	Articles	Citations	% Total Citations	Average Citations	Median Citations
Green Keynesianism	28	2345	54.8%	83.8	64.0
Financial Stability and Environmental Change	8	705	16.5%	88.1	36.5
Socio-Metabolic Dynamics and Constraints	5	178	4.2%	35.6	20.0
Capitalist Growth Imperatives	10	399	9.3%	39.9	26.0
Post-growth / Degrowth Futures	8	656	15.3%	82.0	52.5
Total	59	4283	100.0%	329	199.0
Average Total	12	857	20.0%	65.9	39.8

Table 8: Ecological Macroeconomics Theme Statistics

It is also worth pointing out, as in Table ?? that roughly one-third (20) of the models utilized a stock-flow consistent framework. Half of these were used in the 'Green Keynesian' theme. The broad use of post-Keynesian models in each theme demonstrates the obvious presences of some methodological consistency. Each theme stands out as having rejected neoclassical optimizing assumptions and the belief in infinite substitutability between nature, labor and capital. As such, these branches exhibit a strong desire to link issues of distribution, finance, socio-technical innovations to study environmental change (Rezai and Stagl, 2016). Indeed, most of the other modeling types are specific to the post-Keynesian field, including broader analytical post-Keynesian-Kaleckian (PKK) models (Fontana and Sawyer, 2016), and balance-of-payments constrained growth models (BOPCG) used to demonstrate environmental and economic relations between a high-income Center region and lower-income Periphery (Galindo, Giulio, and Gabriel, 2020). Given the presence of post-keynesian research, the field has therefore tended to approach complex environmental issues through mostly ad-hoc additions to canonical Keynesian models. The discussion is thereby predominantly limited to assessing the macroeconomic stability of diverse policy interventions, enhancing 'environmental efficiency' and protecting financial and macroeconomic stability via traditional Keynesian policy levers - whether in a growing or degrowing economy.

Research Theme	Theoretical	Analytical Models		Numerical Models				Total	% Total
		PKK	BOPCG	Input-Output (IO, MRIO)	Stock-Flow Consistent (SFC-IO)	Integrated Assessment Model (IAM)	Cobb-Douglas		
Green Keynesianism	7	7	2	1	10	1	0	28	47.5%
Financial Stability and Environmental Change	2	0	0	1	3	2	0	8	13.6%
Socio-Metabolic Dynamics and Constraints	0	1	0	2	2	0	0	5	8.8%
Capitalist Growth Imperatives	5	2	0	0	3	0	0	10	16.9%
Post-growth / Degrowth Futures	0	2	0	1	3	0	2	8	14.0%
Total	14	12	2	5	21	3	2	59	100.0%
% Total	23.7%	20.3%	3.4%	8.5%	35.6%	5.1%	3.4%	100.0%	

Table 9: Ecological Macroeconomics Model Statistics

Roughly one fifth of the articles listed here were specifically theoretical. As such, by focusing only on modeling techniques, previous reviews (Hardt and O'Neill, 2017; Saes and Romeiro, 2019) have missed a large portion of contributions to ecological macroeconomics literature captured here. Input-Output (IO) and Multi-Regional Input-Output (MRIO) models also played a growing role in the field, with 5 contributions using these frameworks. These may become increasingly important, particularly as scholars look to disaggregate analyses and understand both the material constitution of value production (Cahen-Fourot et al., 2020), as well as its geographic character (Røpke, 2016)

2.3.2 *Similarities and Differences in Ecological Macroeconomics*

Ecological macroeconomists appear to have made considerable efforts to embed the economy within the biophysical limits of the planet. As opposed to work in neoclassical economics, which poses nature as an infinitely substitutable source of production, ecological macroeconomists see nature as a complement to production processes. Rather, nature is treated in nearly all models as an instrument of production, predominantly understood as a 'flow' of resources and pollution, a 'fund' of environmental services and 'stock' of finite resources which ultimately has important impacts on macro-financial stability (Dafermos, Nikolaidi, and Galanis, 2017).

Moreover, across each theme, the human economy, embedded within the Earth system is posed as an expanding sphere of material and energetic transformation. As long as economic growth is tied to growing resource use and pollution, the economy is on a one-way drive towards planetary destruction and macroeconomic instability. As environmental impacts increase, economic health is destined to suffer from (i) the destruction of capital stock; (ii) reductions in labor productivity from declining health of workers; (iii) reduced stock of 'natural capital' inputs (e.g. supply constraints from exhaustion or deterioration) and (iv) changing consumption and investment decisions that reduce macro-stability, and (v) financial devaluations (Dafermos

and Nikolaidi, 2019). Great efforts must therefore be made to avoid rising emissions and resource use while "meeting stringent environmental targets" (Jackson and Victor, 2020, p. 2). This has sparked each theme to consider what it will take to reduce environmental impacts, and the limitations of different strategies. Overall, there appears to be a broad recognition among each theme that much more can be done to relieve environmental pressures, particularly in regards to enhancing public power to finance a transition towards a more sustainable future. Most articles are primarily concerned with how a Keynesian welfare state can successfully manage the economy in a warming world with intimate material dependencies. Where once unemployment, investment demand and distribution were the primary obstacles to achieving macroeconomic stability, reducing environmental impacts has turned into an equally necessary policy concern.

Much as there will be no natural tendency towards full employment, these articles demonstrate that there is no natural tendency to ensure a sustainable scale of resource use. There is therefore broad acceptance that the state holds the legitimate seat of control, and a high degree of potential to regulate employment, investment, and pollution.[14]

Acceptance that much greater room of maneuverability for fiscal and monetary support to reduce environmental impacts exists, however, has not cleared the considerable confusion that exists within the field. Most fundamentally, there is some confusion about what a sustainable future looks like. Ecological macroeconomists agree that a concerted plan is needed to reduce environmental impacts, yet debate what is necessary to arrive at this common space. Whereas some see immense possibility for decoupling from environmental impacts via an increasingly efficient capital stock (Green Keynesianism, Financial Stability & Socio-Environmental Change), others see 'green' technological change as institutionally and physically limited (Socio-Metabolic Dynamics). Still others view technological changes as a primary driver of growth and a source of inequality (Capitalist Growth Imperatives), or at best a limited component of a more holistic sustainability transition (Degrowth/Post-Growth Futures).

In general, it appears that the differences lie primarily in the vision of (i) whether growth is necessary, feasible, or stable in the long term, given worsening environmental impacts and (ii) the relative degree of optimism surrounding the future of 'efficient' technology, and (iii) the amount of time available for the transition before exceeding planetary boundaries. Disagreement then lies in each theme's own relative beliefs in state-fiscal and monetary incentives to stabilize capitalist institutions in the face of climate change and rising inequalities, the po-

14 In the words of Harris (2013), for example, "The main barrier to implementation of Green Keynesian policies is not economic or environmental limits, nor deficits and debt. Rather, it is a broadly-held but erroneous perception that government action is the problem rather than the solution." (Harris, 2013, p. 13)

tential for technological change to be sufficiently 'green' to enable decoupling, the time available to achieve this decoupling, and the long-term feasibility of continued growth. Investment growth and technological developments are either potential solutions to socio-ecological problems, or are short-term positions, which misapprehend the way that continued growth impacts and must be accompanied by broader institutional changes.

The 'Green Keynesianism' and 'Financial Stability and Environmental Change' themes appear to have a number of major overlapping points. Both of these fields look more generally to understand systemic stability as relating both key financial and economic variables to the environment. Part of this lies in their common understanding of how social and environmental changes will propagate throughout the macroeconomy and financial system. Moreover, they are both fundamentally concerned with developing new ways to support macroeconomic health and financial resilience while managing a 'smooth and rapid' environmental transition (Campiglio and Ploeg, 2021). As can be seen in Table ??, this is typically achieved by internalizing costs (e.g., carbon taxes) alongside proactive 'green' fiscal (e.g., R&D, taxes and transfers, subsidies), monetary (e.g., quantitative easing, green lending) policies, and macro- and micro-prudential regulations. Ideally, these will help to ensure that energy-efficient projects are fed with long-term lending to support structural changes towards a more efficient economy. Such policies are supposed to help avoid drastic financial devaluations from climate breakdown, unemployment and income loss.

Interestingly, however, the 'Financial Stability' research also demonstrates some indication that smooth and rapid transitions are complicated by their impacts on financial instability. Moreover, this theme shows the beginnings of a geopolitical understanding of climate change that appears to be missing in the Green Keynesian literature. Whereas Green Keynesians are primarily concerned with harnessing public power towards climate action, research in 'Financial Stability and Environmental Change' highlights that any transition will result in a varied geography of financial losses with potentially major consequences for certain firms and governments, and even the global financial system. With this in mind, climate (in)action comes to be less a matter of political willingness to utilize the self-financing capacities of the state. Rather, it turns on geopolitical concerns that link inter-state, firm and investor power, the ability to claim, access, consume and/or sell fossil resources, and the uneven geography of asset ownership. While these findings remain underdeveloped, it points to potentially new directions in available research

The 'Financial Stability' theme appears to relate strongly to work in 'Socio-Metabolic Dynamics'. In both cases, it is clear that financial stability and economic valuations are highly dependent on material

resources, and that this fact complicates capacities for achieving the sustainability transitions that might have been envisioned by Green Keynesians. 'Socio-Metabolic Dynamics' research presents an even starker picture about the relationship between economic growth and the physical properties of energy. Not only are fossil energy and fossil asset ownership unevenly distributed - implying a geography of potential risks even with a major socio-technical transition away from fuels - but globally declining energy returned on energy invested (EROI) and the low energy density of renewables poses serious questions about the physical limits of a 'sustainability transition'. Sustaining sufficient energy capacity in a constantly growing economy may then become problematic, particularly as energy costs and land requirements increase (Capellán-Pérez, De Castro, and González, 2019; Smil, 2010).

Additionally, this literature demonstrates the material underpinnings of even seemingly 'dematerialized' service sectors (Cahen-Fourot et al., 2020). This further demonstrates the limits to 'green' investments and subsidies for shifting economic production towards low-impact services. If seemingly low-impact sectors depend on continued levels of resource extraction and other high-impact sectors with high rates of pollution and resource transformation, then the pathways towards a truly green society are significantly curtailed.

The work on 'Capitalist Growth Imperatives' is much less focused on energy and resource use than the above research themes. Whereas the other themes have looked at the potential for limiting the social and environmental impacts of economic growth, this research stands alone as an investigation into the monetary and political reasons for which growth appears to dominate in capitalist economies. As such, this research continues to see the environmental crisis as a crisis of the tendency for economies to grow and, through that growth, cause environmental harm. If growth cannot be easily separated from environmental impacts, and capitalism rests upon a growth 'imperative', then capitalist institutions must be altered. However, if growth is not necessarily a systemic imperative then fiscal and redistributive policies may be able to overcome both the monetary and political drivers of growth, without fundamentally altering the institutions which underpin global capitalism.

Finally, the 'Degrowth' theme is the only theme that actively sees a need to reduce economic growth. In contrast to the other themes, Degrowth researchers are more skeptical about the possibilities for 'green' innovations to achieve the kinds of social transformation necessary to limit CO_2 emissions necessary to avoid catastrophic climate change. Scale appears to be consistently outrunning efficiency increases. If the possibilities for decoupling are limited, a new avenue for meeting social needs, outside of growth is necessary. Reducing the size of the economy is described as presenting much more breath-

ing space for nature and, by extension, economic stability. However, it is argued that by focusing on meeting human needs directly via redistributive programs, rather than policies meant to bolster growth, economic and environmental crises can be averted.

This is not to say that new forms of technology are unimportant for the Degrowth literature. On the contrary, even much of the Degrowth literature is interested in reducing impacts by *combining* a shift in scale and efficiency projects attained through green investing. Even if investments alone are viewed as insufficient, it is argued that these projects add to the overall efficiency of the capital stock, which reduces environmental impacts and thereby relieves macroeconomic instability and ecosystems from economic pressures. For Jackson and Victor (2020, p. 5), for example, green investment plays "quite a fundamental role in protecting the ability of our economies to produce anything at all".

Overall then, ecological macroeconomists have developed a number of different avenues for investigating economy-environment relations with a distinct methodological approach and a clearly consistent vision of improving public service provision, and financing, redistribution, and reducing environmental impacts. Nonetheless, this vision has resulted in an ongoing debate that may not be easily bridged. Whether economists can ultimately trust in economic growth and technological change to bring about the desired changes to ensure macroeconomic stability, or whether degrowth will ever be socially feasible or socially sustainable within capitalism, may not be easily answerable within available macroeconomic models. While data collected on past socio-technical transitions can potentially serve as useful guides, for example, each theme appears to have learned opposing lessons from history about the long-term stability of (de)growth (Jackson and Victor, 2020; Pollin, 2018; Pollitt, 2022), the sources of growth imperatives (Hartley and Kallis, 2021; Svartzman, Dron, and Espagne, 2019), and the feasibility of major transition towards renewable energy (Haberl et al., 2020; Hickel and Kallis, 2019). This presents an interesting dilemma for ecological macroeconomics, particularly as it seeks to serve as a coherent domain of research that unifies economy, ecology and society under one roof.

2.4 SUMMARY AND CONCLUSIONS

This chapter retraced the history of ecological macroeconomics and investigated its present perspectives. While ecological macroeconomics is a relatively new field of heterodox political economy, it was shown to have evolved out of a long line of research in economics. This evolution occurred through distinct ideological battles to describe the social relationship to nature. On the one hand were methods born from a desire to master and escape nature. On the other hand are meth-

ods that reveal the 'embeddedness' of the economy within nature, linking the real and monetary spheres to their material dependencies. Ecological macroeconomics seeks to participate in the latter.

This chapter also described the rapidly growing literature in the field. This literature was broken into five distinct themes ('branches') of research: (1) Green Keynesianism, (2) Financial Stability and Socio-Environmental Change, (3) Socio-Metabolic Dynamics and Constraints, (4) Capitalist Growth Imperatives, and (5) Post-growth/Degrowth Futures. A number of similarities between each branch of ecological macroeconomics, particularly in terms of model development and analytical foundations in post-Keynesian economics.

While the field has come to a relatively consistent framework for analysis, it is striking that there appears to be a profound discrepancy over how to best achieve a sustainable society. This debate - between growth and degrowth - may be unanswerable from within the current framework. Indeed, the technical feasibility of a green-growth transition and the political and social stability of a degrowth transition may not be answerable without appealing to a degree of faith and optimism in present institutions. To that end, ecological macroeconomics may require insights from alternative theories to see past this present stalemate.

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3

CRITICALLY ASSESSING ECOLOGICAL MACROECONOMICS: TOWARDS A POLITICAL VIEW OF NATURE

Until society can be reclaimed by an undivided humanity that will use its collective wisdom, cultural achievements, technological innovations, scientific knowledge, and innate creativity for its own benefit and for that of the natural world, all ecological problems will have their roots in social problems.

— Murray Bookchin

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The preceding chapter provided a general overview and history of ecological macroeconomics. It was shown that ecological macroeconomics represents a new attempt to blend heterodox theories - particularly post Keynesian, Polanyian, Marxist and Institutionalist theories - with ecological economics (Rezai and Stagl, 2016). Moreover, it explained that ecological macroeconomics came to the fore with the explicit goal of embedding macroeconomic theories within the Earth system. In contrast to neoclassical approaches, which see nature as inherently substitutable, ecological macroeconomists contend that nature is a complement to the economic process: the economy is propelled by investment demand, yet constrained by its material dependencies. Ecological macroeconomics was described by detailing five major branches of research. Each branch was shown to reveal, in distinct - and sometimes conflicting - ways, the interdependence between the financial, productive and biophysical realms.

This chapter utilizes the information gathered in the previous chapter to critically assess the field of ecological macroeconomics and to offer pathways forward. I focus on three pillars of the ecological macroeconomics perspective - (i) means, (ii) goals and (iii) context - in order to highlight the limitations of the framework. Upon investigating each of these pillars a similar pattern becomes apparent: While ecological macroeconomics has made great strides to move beyond a neoclassical framework it retains some problematic elements of mainstream approaches.

Indeed, the ecological macroeconomics adheres to a framework of economy-environment dynamics that has been widely criticized by ecological economists (Spash, 2013), political ecologists (Gorz, 1993; Robbins, 2012; Swyngedouw, 2007, 2015), among others (Chester and Paton, 2013; Sullivan, 2009) as 'narrow', 'shallow' and 'depoliticized'. In particular, ecological macroeconomists achieve sustainability primarily by expanding opportunities for ('green') finance, private investment, and industrial technology. Researchers concentrate overwhelmingly on manipulating policy levers to achieve a scientifically-determined 'optimal scale'. As such, ecological macroeconomists have tended to prioritize top-down and technocratic policy-measures to manage the macroeconomic consequences of climate change and control environmental impacts.

In this chapter, I argue that the theoretical constraints of ecological macroeconomics stem from a simple fact: ecological macroeconomics is a heterodox theory of *political economy* that lacks an understanding of how *ecology is also political*. Research in ecological macroeconomics has overlooked the historical inequalities that provoke harmful environmental changes, as well as the way that contemporary struggles for power to access, value, transform and distribute nature. The field is therefore weakly positioned to grasp the *endogenous* production of environmental degradation within capitalism (Kapp, 1978; O'Connor,

1998), as well as its varied social causes and consequences. This narrow vision of human-nature relations has resulted in some internal inconsistencies, such as the continued debate between growth and degrowth (Pollin, 2018; Pollitt, 2022). More importantly, it limits the field's capacity to provide a holistic framework for understanding the way that human-nature relations are frequently regulated to support dominant groups, and dominant patterns depend on and reinforce environmental degradation.

To that end, this chapter argues that ecological macroeconomics can develop a more grounded framework to analyze economy-environment dynamics by integrating research from fields like political ecology. Political ecology is a catch-all term that incorporates insights from a number of fields of research, including environmental history, feminist economics, dependency theory and French regulation theory. Political ecologists highlight that social life co-evolves within and through nature (Hinchliffe, 2007; Moore, 2011; Robbins, 2012). Ecology is political because social conflicts between competing groups determine how human and non-human natures are defined, valued, transformed and distributed (Bryant, 2015; Smith, 2008). Social structures emerge and stabilize to regulate human-nature relations to serve particular modes of living and producing (Brand and Wissen, 2021). Different structures necessarily redistribute ecological risks and rewards over time and space (Hornborg, 2020). Political ecologists therefore explain the ways that climate change, biodiversity loss, and other forms of environmental degradation are both reflected and reinforced by imbalances of power and social vulnerabilities.

I contend that connecting heterodox macroeconomics with political ecology can help to reveal many of the existing limitations of ecological macroeconomics research, and eliminate present inconsistencies in the field. In particular, research can better focus on the relations of power and the larger systems dynamics that drive unsustainable behaviors and vulnerability to them (Frey, 2019; Robbins, 2012). Furthermore, it can provide a more solid ground from which to question the mainstream and open up opportunities for more radical alternatives.

The rest of this chapter is written as follows: Section 3.1 briefly reintroduces the reader to ecological macroeconomics. Section 3.2 then reviews criticisms of ecological macroeconomics. I cover the methodological, epistemological and ontological limitations of ecological macroeconomics by critically assessing three pillars of the field - (i) means, (ii) goals and (iii) context. Section 3.3 introduces political ecology as a well-established alternative that can form part of a more grounded ecological macroeconomics paradigm. Section 3.4 then describes two key insights from political ecology that can help push ecological macroeconomics forward: a focus on scale and a focus on space.

3.1 ECOLOGICAL MACROECONOMICS: AN OVERVIEW

Ecological macroeconomics is an approach to macroeconomics that describes the economy as embedded within the planet Earth. Ecological macroeconomists integrate knowledge from ecological economics and heterodox schools of economics to describe systems of production, distribution and consumption as a sub-system of the Earth system. In particular, the economy is understood as dependent on the stability of biophysical processes and access to key materials. The 'real' economy, and financial and monetary systems are therefore considered to be fundamentally constrained by strict biophysical limits.

Following from its post-Keynesian foundations, ecological macroeconomists treat the economy as demand-led, yet increasingly constrained by the quantity and quality of available 'natural capital' to guarantee social and economic stability (Fontana and Sawyer, 2016). As opposed to work in neoclassical economics, which posits nature as an infinitely substitutable source of production, ecological macroeconomists see nature as a complement to production processes. A sufficient base of natural capital is seen as a necessary precondition for continued production and growth and macroeconomic stability. For example, many models integrate the environment to show that, as environmental impacts increase, economic and social stability are destined to suffer from (i) the destruction of capital stock; (ii) reductions in labor productivity from declining health of workers; (iii) reduced stock of 'natural capital' inputs (e.g. supply constraints from exhaustion or deterioration); (v) financial devaluation, and (iv) changing consumption and investment decisions that reduce macro-financial stability (Dafermos and Nikolaidi, 2019; Dafermos, Nikolaidi, and Galanis, 2018; Dunz, Naqvi, and Monasterolo, 2021).

Ecological macroeconomists of all stripes agree, therefore, that great efforts must be made to avoid rising emissions and resources, and associated financial and macroeconomic instability. A suite of government interventions can then limit the economy's deterioration of ecosystem functions, and the effects of ecosystem deterioration on the economy. A vast majority of contributions to ecological macroeconomics attempt to find ways to stabilize CO2 emissions and environmental throughput at sustainable levels, and/or explain some of the limitations to doing so.

The previous Chapter 2 found five general branches of ecological macroeconomics research. Here I briefly touch on some of the main aspects of each theme as a quick reminder.

Green Keynesians seek to harness public- and private forces in order to transition the economy towards the economic activities that will reduce environmental impacts. 'Green' forms of growth are seen as opportunities to assert the possibility for state-led managerial solutions and technological improvements that promote greater synergy

between the environment and the economy. Effective 'green' demand management via fiscal and monetary policy is shown to guarantee a number of positive outcomes in both the environment and the economy.

By siphoning employment and investment away from 'brown' (high-polluting) and towards 'green' (low-polluting) sectors, industries and technologies, the economy can become increasingly efficient, raise incomes, and 'decouple' the economy from growing environmental impacts (Dafermos, Nikolaidi, and Galanis, 2017; Fontana and Sawyer, 2016). 'Green' public investment, R&D spending, and infrastructure development (Naqvi, 2015; Naqvi and Stockhammer, 2018; Taylor, Rezai, and Foley, 2016), 'green' consumption (Fontana and Sawyer, 2015; Kronenberg, 2010a), 'green' jobs (Godin, 2012), 'green' taxes and tariffs (Ponta et al., 2018), green' quantitative easing (Dafermos, Nikolaidi, and Galanis, 2018; Monasterolo and Raberto, 2018), macroprudential and microprudential support for 'green' lending (Dafermos, Nikolaidi, and Galanis, 2017; Dunz, Naqvi, and Monasterolo, 2021) are all seen as measures that will enhance environmental efficiency, protect social and financial stability, raise incomes and improve equality between classes and nations.

Not all researchers are equally optimistic about the potential for 'green' Keynesian policies. For some, greening the economy is also a potential source of financial instability, particularly because fossil-fuel assets may become "stranded" and lose their value (Cahen-Fourot et al., 2021). Others highlight the socio-metabolic limits to greening the economy Cahen-Fourot et al. (2020), for example, point out that seemingly low-impact service sectors remain heavily dependent on extractive industries, upstream. Others, like Jackson and Jackson (2021) recognize the potentially devastating effects of a decline in energy-returned-on-energy-invested (EROI) associated with the transition to renewable energy and declining availability of fossil fuels. Nevertheless, the vast majority of ecological macroeconomists see countervailing investment, tax and redistribution programs as generally as effective policies for reducing instabilities and supporting a rapid transition (Bovari, Giraud, and Mc Isaac, 2018; Dunz, Naqvi, and Monasterolo, 2021).

Finally, given the seeming inseparability between economic growth and resource use, and the limited capacity for sectoral and technological changes to 'green' capitalism, many ecological macroeconomists have begun questioning whether growth can or should be done away with altogether. This has led to two divergent camps: On the one side, researchers have explored whether there are any growth 'imperatives' within capitalism. Ecological macroeconomists have asked whether a debt-based monetary system with positive interest rates makes continued growth a social necessity (Cahen-Fourot and Lavoie, 2016; Jackson and Victor, 2015), while others have explored how inequalities of

income and wealth can also play a role in driving growth (Jackson and Victor, 2016; Stratford, 2020).

On the other side, researchers have focused on the potential for degrowth. Degrowth scholars argue that purposefully reducing growth - implying 'deaccumulation' - is an essential for staying within planetary boundaries. In the words of Jackson (2019, p. 244),

> ...beyond a certain point, and for a variety of reasons, relentless economic growth may be neither desirable nor indeed feasible. Whether for secular reasons, or from a decline in resource quality, or from the need to curtail damaging environmental impact, proponents of these ideas attempt to envision the social conditions (and economic implications) of a world in which, for the advanced economies at least, it is necessary to 'manage without growth'.

Degrowth is deemed an explicit and necessary goal in order to promote greater social and environmental well-being, and maintain system stability (D'Alessandro et al., 2020). Indeed, ecological macroeconomists writing in this stream believe that if degrowth does not come 'by design' it will most certainly come 'by disaster' (Victor, 2008). Without a movement through careful planning towards a slimmer and more sober economy, worsening environmental degradation will eventually lead to strong declines in economic growth and potentially collapse.

Overall, ecological macroeconomics has provided valuable insights into the biophysical foundations of modern capitalist economies. Research has been particularly adept at illuminating how material and pollution stocks and flows are linked to monetary and productive systems. The field therefore brings an important macroeconomic perspective to understand the environmental basis of growth and economic stability (Berg, Hartley, and Richters, 2015; Cahen-Fourot et al., 2020; Kemp-Benedict, 2014), the possibilities and limits of technology and innovation policy (Jackson and Jackson, 2021) and the availability of financing a 'sustainable' transition - whether towards a growing and degrowing economy.

3.2 A CRITICAL ASSESSMENT OF ECOLOGICAL MACROECONOMICS

Despite the obvious contributions of ecological macroeconomics to an understanding of economy-environment dynamics, a number of researchers have doubted whether it can serve as a coherent, consistent and ethically grounded paradigm (Svartzman, Dron, and Espagne, 2019). While ecological macroeconomists have mostly sought to distinguish themselves from the mainstream, they have also been accused of falling into many of the same traps that plague neoclassical approaches (Chester and Paton, 2013). In both camps, for exam-

ple, nature is viewed as inherently amenable to state-market adjustments and private investment (Svartzman, Dron, and Espagne, 2019). 'Environmental' problems and negative macroeconomic impacts are thereby controlled with primarily technical solutions and aggregate demand management. Ecological macroeconomists are further criticized for failing to identify the systemic drivers of environmental degradation (Chester and Paton, 2013; Røpke, 2016), particularly at the international level (Røpke, 2013). Finally, focusing on technical solutions constrains the paradigm from grasping the historical causes consequences of harmful environmental change, as well as the ethical dimensions of particular patterns of living and relating (Spash, 2013; Svartzman, Dron, and Espagne, 2019).

It is interesting to note that many of the same criticisms leveled against ecological macroeconomics have plagued the field of *ecological economics* since its inception (Gendron, 2014). As Spash (2020, p. 2) writes "strategic and pragmatic concerns" for resolving environmental problems arguably "opened the door to the absorption of the fledgling ecological economics movement into the very paradigm [neoclassical economics] it had set out to reform."

The ecological economics paradigm is also criticized as a weak field of knowledge for its transdisciplinary openness (Røpke, 2005; Spash and Ryan, 2012). Without a coherent set of values, methods and ontology, the field is at risk of becoming patently 'uninteresting' as well as "los[ing] its bite and becom[ing] a sub-field of neoclassical environmental and resource economics modeling links between ecosystems and the economy." (Røpke, 2005, p. 287). This split has caused the majority of ecological economics to turn towards ecosystem valuations and cost-benefit analyses that reinforce the status quo (Plumecocq, 2014), rather than to unveil human-nature relations as terrain of politics and social struggle (M'gonigle, 1999).

In the interest of building a consistent and coherent ecological macroeconomics, such critiques should be taken seriously. Whether ecological macroeconomics can fulfill its initial promise as a holistic "third perspective" beyond neoclassical and post-Keynesian economics or will be a "missed opportunity" (Røpke, 2016, p. 243) - presenting old wine in new bottles - depends on whether it can find solid theoretical grounds upon which to stand. Without a strong theoretical base, ecological macroeconomics will likely be unable to escape some of its own internal debates, deepen our collective understanding of present social and ecological crises, or develop novel ways of moving beyond them (Spash, 2020).

Before moving forward, it is important then to define the terms of the debate. If both ecological macroeconomics and ecological economics are criticized as limited, in what ways might this be the case? Below, I describe two possible visions for approaching economy-environment dynamics: 'political' and 'apolitical' ecologies. Each frame-

work expresses diverging visions of what 'nature' is, how humans relate within it, where the root cause of economy-environment conflict lies, and how best to overcome it. After doing so, it will be possible to understand the theoretical limitations of ecological macroeconomics framework, as well as to point how to move beyond them.

3.2.1 *'Political' and 'Apolitical' Ecologies*

In order to reveal the source of the limitations of ecological macroeconomics, and offer solutions, it is first necessary to introduce two perspectives for understanding socio-ecological change: 'political' and 'apolitical' ecologies (Robbins, 2012). While each term has been referred to differently by other scholars[1], yet each refer to the same basic conflict over how comprehensively understand and analyse economy-environment dynamics. A more detailed description of the divergent methodological, epistemological and ontological foundations between political and apolitical approaches can be found in Spash (2011, 2020) and Spash (2012). For simplicity, I explain below just some of the primary differences between political and apolitical ecologies.

'Political' understandings of human-nature dynamics identify broader systems dynamics to account for environmental problems, rather than blaming proximate and local forces, or 'external' / 'natural' limits. Moreover, they view environmental systems as power-laden - and therefore subject to social conflict - rather politically inert (Robbins, 2012, p. 16). Researchers therefore demonstrate how environmental harms are an endogenous aspect of social relations (Kapp, 1978). As such, political views of human-nature relations reveal how social and ecological outcomes are not easily fixed by 'pragmatic' scientific calculations, market adjustments, or 'win-win' solutions (Sovacool, 2021). Instead, there are always winners and losers, hidden costs, and relations of power and vulnerability that influence how environments are shaped, transformed, valued and distributed. Researchers are therefore concerned with understanding environmental changes by studying 'environmental distribution conflicts' and in highlighting injustices that come at the expense of vulnerable groups (Martínez-Alier, 2002).

Political views of nature also contextualize environmental harms within a long history of political, cultural and ecological domination. Social and environmental crises are woven into the fabric of prevailing modes of living and producing (Brand and Wissen, 2018, 2021). In particular, the uneven geographies of extraction and resource appro-

1 'Apolitical' approaches have been understood as 'shallow', 'pragmatic', 'post-political' 'consensus' and 'cornucopian'. 'Political' approaches have also been referred to as 'deep' or 'conflict'-based (Hornborg, 2003; Spash, 2013; Sullivan, 2009; Swyngedouw, 2007, 2015)

priation that characterized colonial interstate competitions are understood to continue in the 'post'-colonial era and remain a living legacy in the 'colonial present' (Bhambra, 2020; Goldstein, 2014; Gregory, 2004). The state, monetary and productive systems as well as the institutions underpinning modern financial globalization are therefore heavily implicated in continuing and reinforcing social and ecological inequalities.

Finally, political views of nature attempt to undermine the foundational Western beliefs in the separation between humans and nature (Moore, 2015).[2] While it is useful to establish an analytical distinction between the social and the environmental domains, political ecologies express social processes as 'co-evolutionary' movements (Norgaard and Kallis, 2011) and 'hybrid' (Whatmore, 2002) processes. As such, social structures and values are inseparably connected to the physical properties of environments and environments are in turn shaped through the regulation of the human social system.

In contrast, ecologies are *apolitical* when they identify and treat the symptoms of environmental change rather than identify the power-laden systems dynamics to understand nature-society dynamics (Robbins, 2012). 'Apolitical' views of nature are founded on three beliefs that are mutually reinforcing: separation, environmental limits and modernization. First, 'apolitical' ecologies - consciously or unconsciously - position nature as an ahistorical and separate element from society. Nature tends to be seen as an external object that is either (i) amenable to manipulation and management by the economy, or as (ii) fragile and in need of protection from the economy. For this reason, apolitical ecologies also tend to advocate for methods that enhance 'decoupling' and 'dematerialization' in order to avoid conflicts between 'the economy' and 'the environment'. Sustainability is therefore arrived at through 'trophic detachment' via a range of technologies and regulations that should reduce the footprint of the economy on nature, and vice-versa (Quilley, 2011, p. 82).

In 'apolitical' frameworks, nature is presented as a fundamental constraint to human society. These may stem from resource scarcity, population growth (Ehrlich, 1968), 'planetary boundaries' (Steffen et al., 2015) and 'limits to growth' (Meadows et al., 1972). Constraints then must be dealt with either by fixing market prices (neoclassical economics) or state-market adjustments to aggregate demand (heterodox political economy). Researchers then seek to ascertain thresholds of extraction, pollution, population and/or economic growth that can be socially or environmentally sustained, as well as to suggest methods to avoid overstepping these limits.

2 As Thomas Pincen writes "if there were a single philosophical position in environmental thought, adhered by all who are concerned about environmental destruction, it is that at the root of that destruction is human's separation from nature" (Princen, 2010, p. 82)

Finally, 'apolitical' ecological theories are underpinned by theories of ecological 'modernization' and/or sustainable 'development'. These commonly see the environmental crisis as stemming from a lack of sufficient finance, technology and growth (Magalhães, 2021). In either case, sustainability is a future state arrived at by minor shifts in present institutions, rather than a radically different way of living within and through nature (Medovoi, 2010).

The historical inequalities, social logics, world-views and institutions that support unsustainable behavior therefore tend to be obfuscated by a commitment to 'green' technological progress and 'sustainable' finance. Apolitical views therefore privilege technocratic policies and expert-led opinion to manage economic impacts on nature, and nature's impacts on the economy. Regulatory media - taxes, pricing instruments, standards, technologies, etc. - are then utilized to channel investor and consumer behavior towards specific policy objectives. As Gorz (1993, p. 56) writes, expert-led frameworks seek to functionalize the existing set of values, motivations, interests and attitudes towards new objectives, rather than considering what set of values and relations are needed to 'reconcile' human livelihoods and the larger life-world.

Political and apolitical approaches to interpreting economy-environment dynamics lead to clear differences in methods, policy objectives. These reflect diverging understandings of what nature *is* and how humans relate within it. In particular, the central question seems to reflect the degree to which nature is understood as an external limit to social life, or a foundational aspect of our mode of living and relating.

3.2.2 *Ecological Macroeconomics as an 'Apolitical' Ecology*

Having distinguished between political and apolitical frameworks, it is now possible to argue that ecological macroeconomics suffers from an insufficiently political view of nature. In the following sections, I scrutinize three pillars of the ecological macroeconomics to demonstrate the 'apolitical' features of the field: (i) *means*: Ecological macroeconomists assume that aggregate demand management is a valid method for resolving any economy-environment contradictions; (ii) *goals*: Ecological macroeconomists focus on 'optimizing' the scale of the economy and environmental impacts to procure macroeconomic stability and avoid 'limits to growth'; (iii) *context*: Ecological macroeconomists have a pre-analytic vision of nature as a form of natural capital that can be unproblematically integrated and managed within capitalism. The economy must also find ways to stay within planetary 'limits' caused by depleting natural capital.

In critically analyzing these three main areas, it becomes clear that ecological macroeconomics has developed a framework that can de-

tract attention from the primary structural drivers of environmental change, and is likely to offer inconsistent, incomplete and potentially maladaptive policy guidance, without a shift in perspective. I mobilize empirical and theoretical support from a broad range of literature in ecological economics, political ecology, critical geography, and environmental history, to suggest that ecological macroeconomics predominantly suffers from an insufficiently 'political' view of human-nature relations.

3.2.2.1 *Means: Achieving sustainability through demand management*

Ecological macroeconomics began with great enthusiasm as a seemingly natural bridge between heterodox macroeconomics - primarily post-Keynesian economics - and ecological economics (Berr, 2015; Holt, Pressman, and Spash, 2009; Kronenberg, 2010b; Rezai and Stagl, 2016). However, not all of the tools from heterodox theories are necessarily valid for environmental issues. This is particularly evident in ecological macroeconomics: environmental issues have been tagged on to existing macroeconomic models on an 'ad-hoc' basis (Spash and Ryan, 2012, p. 1098). Indeed, the general focus of ecological macroeconomics therefore been more on "integrating the ecological dependency of the economy into existing macroeconomic frameworks, and less on redefining the scope and goals of the macroeconomy" (Hardt and O'Neill, 2017, p. 208).

Yet it is unclear if the post-Keynesian toolbox, on which much of ecological macroeconomics is based, will be sufficient to fully comprehend the nature of environmental crises, or to offer alternative solutions (Araghi, 2010; Chester and Paton, 2013). In particular, post-Keynesians are criticized for relying heavily on channeling aggregate demand as a blanket policy response that may not be well-adapted to environmental issues (Goldstein and Tyfield, 2018; Sheppard, 2016; Sunley, 1992). Bello (2009, p. 78) calls attempts to resolve ecological destruction through demand management "the great lacuna" of Keynesianism.[3]

Paradoxically, the focus on demand management may be hindering post-Keynesians from moving beyond some of the most problematic tendencies of (supply-side) neoclassical economics. The similarities are brought into clarity when considering their respective approaches to resolving environmental issues. As Mearman (Mearman, 2005, p. 125) contends, while "post-Keynesians have the methodology and approaches which would allow them to avoid the mistakes of neoclassical economics [in regards to the environment], they re-

3 Bello (2009, p. 78) continues, arguing that "given the primordial drive of the profit motive to transform living nature into dead commodities, it is increasingly doubtful that the reconciliation of ecology and economy can be done under capitalism—even under the state-managed technocratic capitalism promoted by Keynes."

main torn as to whether all orthodox baggage should be dispensed with".

Both 'green' heterodox and mainstream economists, for example, largely agree that the environmental crisis is ultimately a crisis of insufficient investment and technology to achieve a sustainability transition. Notwithstanding important differences between the two fields, socio-environmental crises reflect a growing need to attract private investment that can alter the productive structure towards more efficient sectors and technologies (Magalhães, 2021).

Whereas neoclassical economists seek to achieve an influx of green investments by 'getting prices right', 'green' Keynesian ecological macroeconomists see ample opportunities for making investments harmonize with the environment by 'getting policies right': In the neoclassical vision, 'getting prices right' implies the need to correct market failures to unleash entrepreneurial innovation by creating new markets and allowing private actors, often with public support, to find the true price of natural 'goods' and 'bads'. Once the true risks and costs of environmental degradation (or the benefits of environmental protection) are internalized, market actors change their consumption preferences and investment plans accordingly. When prices can be made to reflect underlying values, a flood of investment will automatically fill in a 'sustainable finance gap', allowing for new cleaner forms of growth via more efficient output.

For ecological macroeconomists, 'getting policies right' differs considerably but maintains the same goal: Market signals must be corrected in order to unleash the power of finance and technology to achieve more efficient and equitable outcomes. The field strongly criticizes the idea that markets are self-adjusting, or that they will achieve optimal, socio-ecologically efficient or equitable outcomes, alone. Ecological macroeconomists also recognize that Investment potential in new technologies and sectors is hindered by imperfect competition and market uncertainties. Nevertheless, post-Keynesian ecological macroeconomists recognize that the supply of money is largely determined by the demand for private credit. As such, they focus on the power of fiscal and monetary policies to reduce investment uncertainty and channel aggregate demand. Ideally, this will attract long-term 'green' investment and provoke the structural changes necessary for a 'smooth and rapid' transition (Campiglio and Ploeg, 2021, p. 2).

In the 'getting policies right' paradigm, sustainability is viewed primarily as a matter of enlightened state-industrial and monetary policy to overcome market failures (e.g., investment uncertainty) to channel private finance towards efficient sectors and technology development. The 'environmental state' (Mazzucato, 2015) can then help in the "provision of patient long-term public investment guided by democratically determined missions" alongside "policy coordination between fiscal, industrial, financial, and regulatory spheres, *in order*

to create the enabling conditions for markets to succeed." (Kedward and Ryan-Collins, 2022, 288, emphasis added).

This green investment paradigm forms the core of most efforts to render the economy more environmentally efficient - both among advocates of 'green' growth and 'degrowth' (Jackson and Victor, 2020). Market-based initiatives, state subsidies, and efficiency standards can then shift the economy towards low-impact sectors that "offer a different kind of growth, in which macroeconomic aggregates grow but throughput does not." (Harris, 2009, pp. 12–13). Courvisanos (2005, p. 189) writes, for example, that "a new investment paradigm" can provide the necessary conditions such that "the dilemma of sustainable economic growth and sustainable ecological diversity dissolve into a positive programme of cumulative causation." 'Greening' the economy is ultimately treated through 'mission-oriented' industrial strategies that will support major ('green') structural transformation (Kedward and Ryan-Collins, 2022). Widespread environmental degradation is thought to be overcome or significantly reduced by adjusting specific policy parameters.

Yet such a perspective implies a narrow vision of interrelated social, economic and ecological crises. By approaching environmental crises as crises of aggregate demand management, the field has come to focus predominantly on controlling environmental impacts and adapting to consequences of dominant socio-ecological relations. This reduces environmental problems to "a parable of policy failures correctable by [state-]market solutions" (McAfee, 1999, p. 133). Environmental damages are therefore seen as stemming from inadequate policy guidance to internalize the necessary market signals, a lack of investment, and insufficient access to efficient 'green' technologies.

Whereas support for 'green' investments is a common response within both heterodox and mainstream circles, there is ample reason to doubt their ability to transform society into supporting more 'sustainable' relations. In particular, the current framework is likely to foreclose more radical alternatives and overlook the structural drivers of ecological degradation, while generating inconsistent policy advice.

Here, I outline just ten reasons for which to be skeptical of achieving sustainability through private and public investment initiatives: First, sustainability via 'decoupling' is empirically unfounded. There is now a wealth of evidence that absolute 'decoupling' has not happened on any significant scale at the global level (Haberl et al., 2020; Hickel and Kallis, 2019; Parrique et al., 2019). High-income countries appear increasingly capable of reducing local environmental pressures largely by *displacing* pollution-intensive industries towards low-income countries (Dorninger et al., 2021; Frey, 2019). In fact, green investments and technologies are increasingly understood to reinforce or even *rely upon* resource extraction and environmental degradation

elsewhere (Bonds and Downey, 2012; Sovacool, 2021). Understandably then, the emissions- and material-intensity of economic growth at the global level has been increasing, rather than decreasing (Duro, Schaffartzik, and Krausmann, 2018; Thombs, 2018; Wiedmann and Lenzen, 2018; Wiedmann et al., 2020).

Second, sustainability cannot be reduced to a single variable. What counts as 'green' has been nearly impossible to decipher, even along a 'simple' dimension like accounting for Co2. When considering the entire lifecycle of a product, as well as its relationship to the rest of the productive structure, carbon footprint measurements are highly uncertain and variable. This ambiguity makes it nearly impossible to measure and validate the sustainability of any firm, sector, or technology (Goldstein, 2021). Understandably, environmental, social, and governance (ESG) ratings of 'green' investments diverge significantly between ratings agencies, leading to 'aggregate confusion' about what it means to be sustainable, how to evaluate it, and who has the correct tools to do so (Berg, Koelbel, and Rigobon, 2019).

Third, sustainability cannot be reduced to a single dimension. Even if one could assume that a given investment actually helps to reduce GHG emissions, there is no guarantee that it would not contribute to unsustainability along other dimensions. There is no reason to believe that even massive investments in low-carbon technologies will also protect biodiversity, reduce chemical toxicity, halt deforestation, etc. The risks of and uneven burdens of any one project are are all entangled in a complex web of impacts that nullify any sense that 'green' is a scientific calculation: nuclear power, rare earth extraction for 'renewable' technologies, wetland destruction by hydroelectric dams, land degradation and foregone food production for biofuels and solar panels.

Fourth, sustainability is not necessarily urban. Investing in 'green' forms of industrialization supported by 'climate-smart' agriculture and mass 'renewable' energy programs may come with an implicit urban bias (Ajl, 2014, 2021). This bias either implicitly or explicitly, discounts the role of rural livelihoods in supporting more sustainable relationships to the land, as well as the increasingly precarious position of rural people within global capitalism. Without accounting for the need to restore rural communities and the relations that support local sustainable agriculture, 'green' investment programs are likely to privilege the energy-intensive rural-urban split that characterizes modern capitalism (McMichael, 2018) forge an increasingly unsustainable rift between regions (Foster and Clark, 2020).

Fifth, sustainability means different things to different groups. Nature's 'values' are ultimately incommensurable (Martinez-Alier, Munda, and O'Neill, 1998). Whereas a 'forest' has aesthetic or spiritual values for some, for others it is a 'carbon sink', for others a potential source of income, still for others it is an obstruction to greater income to be

made by mining below-ground. What is truly 'green' then, is likely to diverge significantly according to the way that natures are valued.

Sixth, sustainability is therefore political. Without an objective way to ascertain nature's 'value', what is to be sustained, why it should be sustained, how it should be sustained, and who gets to decide is a matter of conflicting interests and power relations. As Magalhaes (Magalhães, 2021, p. 3) contends, "the question of whether something is green or not – i.e., the environment – is the source of conflicts between social groups seeking to impose their own definition (i.e., the one that serves their interest)" Ethical, moral and 'commercial' values of nature "cannot be separated from the social context in which they originate" (Douai and Montalban, 2012, p. 1213). Diverse values are expressed and embedded in material realities and the every-day practices of diverse social groups. Competing value claims are resolved and negotiated through regulatory schemes, political processes and - often violent - struggles for power (Nixon, 2011).

Seventh, if sustainability is political, it is therefore inseparable from questions of social distribution. By focusing on the apparently 'sustainable' character of any given investment, scholars unwittingly divert attention from the political contests that determine environmental provision, access and distribution that drive environmental degradation. Environmental outcomes are always implicated within deeper 'environmental distribution conflicts' (Scheidel et al., 2018). Indeed, socio-ecological impacts of environmental changes "fall unevenly, along existing divisions of wealth/poverty, power/powerlessness... [and] tend to occur in a way that reproduces and exacerbates existing social inequalities...[that are] embedded in the very fabric of modern societies." (Szasz and Meuser, 1997, p. 113).[4]

Eighth, sustainability - and the lack of it - has history. The environmental crisis is not simply a recent phenomenon, only now appearing to impact national economic health and firm profitability as 'the economy' reaches limits. Rather, it is a culmination and continuation of hundreds of years of unsustainable relations, dispossession, appropriation, extraction and ruptures in the global socio-ecological fabric (Moore, 2015). These have been provoked primarily by a small class of wealthy individuals, powerful firms and countries at the expense of vulnerable and low-income communities 'Peripheral' and 'frontier' zones. If the governing institutions of modern society - particularly the global monetary, financial and productive systems - were historically created to facilitate social and environmental inequalities, then the historically uneven structure and causes of the crisis must be accounted for (Svartzman and Althouse, 2020). In viewing the environ-

4 Laurent (2014), for example, details how social inequalities (i) permit wealthy groups to consume irresponsibly, (ii) heighten the pressure towards economic growth, (iii) reduce social resilience and adaptation capacity, (iv) decrease the environmental sensitivity of individuals, firms and governments, and (v) impair cooperation and collective action efforts that would protect and preserve environments.

mental crisis as a crisis of investment, research ultimately signals a policy platform that does not consider what is driving unsustainable relations, how these relationships are carried out and institutionalized, or which groups benefit or suffer the most.

Ninth, sustainable energy transitions are a misnomer (Bonneuil and Fressoz, 2016; Fressoz and Bonneuil, 2017). New sources of energy do not come to dominate because of their inherent efficiency, productivity or cost. Rather, they arise within a social context. Power struggles between different classes or groups, geopolitical contests, etc. drive the development of energy infrastructures as well as the introduction of alternatives (Christophers, 2021; Malm, 2016; Mitchell, 2011). Instead of determining whether energy investments are 'green' or 'brown', it is more fruitful to understand how energy is accessed and employed, who owns it, and for what ends it is being used.

Tenth, sustainability may not be profitable. A sustainable investment paradigm assumes that the speed, scale and scope of profit-oriented 'green' efficiency projects are likely to (or will automatically) coincide with the rhythms and requirements of the biosphere (Harris, 2019). This overlooks research suggesting that environmental degradation is endogenous to the functioning of capitalist economies (Foster and Clark, 2020; Kapp, 1978; Moore, 2015; O'Connor, 1998), and is a key means by which firms earn profits, in the first place. As firms seek to augment their potential to accumulate profits and enhance market power, they try to reduce the costs of access and use of the conditions of production (e.g. labor, nature) upon which they depend. Profits are therefore made possible via 'cost-shifting successes'. Cost-shifting implies a systematic displacement of (i) resource- and pollution-intensive activities, (ii) socio-ecological hardships, and (iii) financial pressures to vulnerable people and places.

In this sense, seemingly 'external' negative consequences of economic functions "...are not isolated cases but are widespread and inevitable phenomena under conditions of business enterprise" (Kapp, 1971, p. 8). Despite the potential for regulations to implement more 'patient' and equitable forms of finance, or to screen for socially necessary projects (Sawyer, 2020) if profits are made largely by shifting environmental risks and burdens onto society and nature, there is no reason to suggest that more investments will bring about more sustainability.

While an understanding of demand management tools and investment capacities is crucial, they are perhaps a necessary but insufficient condition for developing a fully-fledged ecological macroeconomics (Chester and Paton, 2013). It was shown here that measures to stimulate aggregate demand do not so much resolve environmental problems, as they alter the social relationship to nature (Svartzman, Dron, and Espagne, 2019). From this perspective, a massive global investment program, requiring trillions of dollars flowing into new

physical infrastructures - no matter if it is brought about by 'getting prices right' or 'getting policies right' is likely to have a limited ability to bring about more 'sustainable' outcomes. For ecological macroeconomics to develop into a coherent and consistent framework, therefore, it will need to embrace the political nature of socio-ecological changes and understand how aggregate demand management is likely to have unintended consequences.

3.2.2.2 *Goals: Defining economic scale within planetary limits*

Much like the previous section, this section will demonstrate that the *objectives* of ecological macroeconomics also stem from a depoliticized interpretation of economy-environment dynamics.[5] In particular, I criticize the view that research should be geared towards finding the appropriate 'scale' of the economy. By focusing on scale, research is shown to overlook the structural drivers of ecological degradation, opting instead for top-down policies that can reinforce status quo relations and blunt alternatives.

Ecological macroeconomists are predominantly focused on finding ways for the economy to remain within planetary 'limits'. The economy is understood as an evolving set of monetary, financial and 'real' productive relations which (i) affects the environment by drawing on finite resources and emitting wastes and, in turn, (ii) suffers from those negative environmental changes, and therefore must be made increasingly efficient and resilient (green) or lean (degrown). As the scale of economic impacts grows, the economy begins to outstrip planetary boundaries, with increasingly devastating consequences.

Ecological macroeconomics has therefore become a field that seeks to find a balanced and 'appropriate scale' of the economy (Jackson and Victor, 2020; Rezai and Stagl, 2016). For example, In a review of the field, Victor (Victor, 2022, p. 4) contends that:

> "*...if consumption and production at the level of individual households and firms have an optimal scale, why does the aggregate of these activities not have an optimal scale as well?* These are questions that arise from the preanalytic vision of ecological macroeconomics but not from mainstream economics or most other heterodox approaches to economics. It has become increasingly clear that the scale of the human economy has become so large that ecosystems at all levels, from local to global, are in decline. A macroeconomics that understands the significance of the scale of the macro economy would seem essential in the twenty-first century."

5 Again, while this critique applies strongest for 'green' Keynesian arguments, similar arguments could be made for those espousing a need for degrowth *for reasons of scale* (Huber, 2022; Trantas, 2021).

In practice, finding an 'optimum scale', appears to mean finding efficiencies and reducing impacts. This allows the economy to stay within environmental 'limits' and to safeguard macroeconomic stability. What matters is the degree to which policy-makers can (i) manage the scale of environmental impacts to avoid worsening financial and macroeconomic instabilities, or (ii) manage the scale of financial and macroeconomic systems in order to avoid worsening environmental instabilities.

The focus on finding an 'optimal scale' has already been a source of criticism for the field. For example, the idea of an 'optimal' or scientifically 'appropriate' scale privileges solutions through top-down governance mechanisms and technological management. Specific environmental problems then become problems "of optimisation, not about the interrelationships of the economy with the environment" (Chester and Paton, 2013, p. 109). As such, heterodox economists then search for technical solutions to socially created problems. While the proposals for overcoming the present situation are numerous, they rarely address "the causal mechanisms of the current crises, or structural issues facing social ecological transformation; they are concerned only with controlling for [local] impacts and adapting to consequences, not with the bio-physical relations of the economy with non-human nature. (Spash and Smith, 2019, p. 212).

Analysis then focuses predominantly on implementing a suite of policies meant to achieve a scientifically-determined 'appropriate' or 'optimum' level of pollution, income and employment. From this perspective, a sustainable and appropriate scale is achievable as an objectively measurable state (e.g., ppm of atmospheric CO_2) arrived at through the pragmatic application of public financing, technological innovations, and redistribution programs. According to Jackson, for example, the task of ecological macroeconomics is to "create the conditions for an economy that works for everyone, within the constraints of a finite planet. . . that task is precise, definable, pragmatic and achievable." (Jackson, 2019, p. 245).

Moreover, by focusing on scale, attention is placed on the *symptoms* of environmental degradation as the primary *source* of economic crisis, and vice-versa. Spash (2013, p. 352) refers to this as a 'shallow' interpretation of socio-ecological change. Shallow ecological theories diagnose socio-ecological crises as stemming from two sources: First, environmental symptoms - e.g. temperature increases, declining environmental quality, increasing pollution loads and resource depletion - caused by the growing scale of the economy. Second, economic symptoms - e.g. reduced productivity and growth rates, unemployment, etc. - caused by the size of environmental impacts. Research then attempts to reduce or avoid impacts without necessarily changing the nature of the relationship between the environment and the economy.

Yet as Clapp and Helleiner (2012) contend, political economy researchers reveal deep-seated disciplinary biases when positing 'causal arrows' to demonstrate how the economy affects the environment, or how rising ecological burdens are likely to affect the economy. In part, this tends to separate the two spheres, typically subordinating the environment to the economy.

Strategies for managing the scale of the economy can therefore provide support for present relations to continue without significant change, even while deepening environmental risks and inequalities (Goldstein and Tyfield, 2018). Indeed, fiscal and monetary policies are also put forward to enhance the resilience of certain key sectors and infrastructures to avoid negative environmental impacts, thereby 'climate-proofing' the economy. Economic scale is unproblematic as long as the financial resources are available to continually invest in new 'fixes'. Since ecological macroeconomists are quick to recognize the virtually limitless self-financing capacities of the state, there remain many opportunities for creating measures that overcome local environmental devastation, or for investing in new methods to displace it elsewhere. Understandably, some have argued that so-called 'green' finance and investment initiatives are part of an evolving 'economy of repair' (Fairhead, Leach, and Scoones, 2012) and 'accumulation by restoration' (Huff, 2021).

From this perspective, by focusing on scale, researchers and policymakers are left with the unenviable challenge of "trying to manage both the spectacular power and resources of capitalism and its tendencies to (re)produce inequalities and, left to its own devices, environmental devastation." (Newell, 2011, p. 5). As Swyngedouw (2019, p. 253) contends, the focus on scale has sent governments and private enterprises in a hurried global search for new "eco-prophylactic remedies" which promise salvation by "assuring that civilisation as we know it can continue for a little longer". Green political and regulatory tools and innovations are then part of a 'post-political' push to manage impacts and "permit a sustainable continuation of the present world's way of life." (Swyngedouw, 2007, p. 16).

Research then tends to overlook the structure and institutional regulation of economy-environment relationships, the drivers of unsustainable behaviors, the divergent vulnerabilities of different groups, as well as the history of uneven environmental appropriation and destruction. Managing environmental problems becomes abstracted from imbalances of financial, material and political power between the Core and Periphery, urban and rural, landed and landless, workers and capitalists, etc. (McAfee, 1999). As long as the harm from environmental impacts can be contained or minimized, there is no *a priori* contradiction between the dominant relations of accumulation and the environment; what Bina (2013) has referred to as 'almost-business-as-usual'. Spash (2013, p. 352) contends that paradigms fo-

cused on scale ultimately sustain a vision of "health and affluence" in terms defined largely by high-income countries, without sufficiently dealing with "human alienation from and domination over Nature, as built into modern patriarchal society".[6], one that would guarantee future generations "a set of options at least as wide as that possessed by the current generation" (Courvisanos, 2005, 191, citing Vercelli 1998, p. 5).

In summary, the objectives of ecological macroeconomics are geared principally towards addressing the scale of environmental impacts on the economy, and the scale of economic impacts on the environment. Researchers thereby tend to divert attention away from the actual structures and relationships that rely on and reinforce unsustainable behavior. Such a research program can provide for interesting - and perhaps internally consistent - results, yet risks participating in many of the same processes that it wishes to upend.

3.2.2.3 *Context: Exploiting / Protecting natural capital within planetary limits*

The final subsection in this critical assessment of ecological macroeconomics concerns its conceptual framework for understanding economy-environment dynamics. I explain how the *context* of ecological macroeconomics is based on an 'apolitical' view of understanding where and how the economy is situated within nature: First, the field overwhelmingly approaches nature as a form of 'natural capital'. Second, is the idea that nature is inherently 'limited' and, as such, the economy must be made to fit within planetary boundaries or risk widespread disruption. Both of these reveal a weakly political approach to human-nature relations that instrumentalize nature as external, universal and limited, while obscuring the relations of power and distribution at the heart of socio-ecological change.

NATURAL CAPITAL: NATURE AS EXTERNAL, UNIVERSAL, AND INSTRUMENTAL As opposed to work in neoclassical economics, which poses nature as an infinitely substitutable source of production, ecological macroeconomists see nature as a complement to production processes. Nature is nevertheless still treated as an instrument of production, predominantly understood as a 'flow' of resources and pollution, a 'fund' of environmental services and 'stock' of finite resources which ultimately has important impacts on macro-financial stability (Dafermos, Nikolaidi, and Galanis, 2017). This approach composes a set of ideas, discourses, and practices which tend to treat nature as an external, uniform and universal substance (e.g., "natural capital", "ecosystem services", Co2 in the carbon cycle, H20 circulat-

6 Indeed, some ecological macroeconomists have attempted to define sustainability as "the capacity of a process to be endured or to be maintained and improved" (Arestis, 2022, 1, citing Vercelli, 2017, p. 15)

ing in the hydrological cycle). Such an understanding of economy-environmental dynamics privileges a managerial attitude towards nature and reinforces a separation between the two spheres, and ignores the historical and distributional root causes of environmental problems, in favor of win-win solutions.

While nature might not be substitutable by 'man-made' or 'human' capital in the ecological macroeconomics, diverse natures appear to be imminently substitutable amongst themselves. As a form of capital, nature is treated much like a storehouse of physical assets. Each asset can be effectively replaced and displaced - one landscape can be substituted for another, or one environmental 'bad' can be exchanged for an equivalent amount of an environmental 'good' (Harris, 2013). Nature is made transferable and commensurable: Socio-environmental damages in one context can then be mitigated by efficiency practices or conservation elsewhere, which create new opportunities for expansion and profitability (Igoe, 2016, p. 17). A ton of CO_2 *emitted* from cutting down an old-growth forest in one area is equivalent to a ton of CO_2 *not emitted* by a more efficient downstream process, which is equal to a ton of CO_2 *offset* by a carbon-capture technology which is equal to a ton of CO_2 *captured* by a forest plantation in another region.

The pre-analytic vision of 'nature' as a form of 'natural capital' (Fontana and Sawyer, 2016) gives nature an uneasy place within ecological macroeconomics (Svartzman, Dron, and Espagne, 2019). First, it gives the impression that all emissions objectives and efficiency targets are scientifically rational and objective achievements. Environmental efficiencies are therefore perceived as both imminently *quantifiable*, universally *positive* and applicable in virtually all contexts. Certain policies (e.g. 'green' fiscal and monetary measures) tools (e.g. 'green' technologies, solar, hydroelectric, etc.) and sectors (e.g., marketing, advertising, healthcare, finance) embody inherently 'sustainable' qualities in and of themselves that can reduce pressure on and even help regenerate 'natural' capital (Campiglio, 2016; Harris, 2019). Such a vision risks subordinating the 'environment' to calculable macroeconomic relationships, distracting from deeper questions of ethics, distribution and power. New investments and fiscal programs can thereby advance the perception of sustainability and climate adaptation, while nonetheless further entrenching the types of socio-ecological relations which further climate change and degradation (Castree, 2008). As long as environmental efficiency of an economy refers primarily to protecting or improving natural capital, the ways that nature is used, extracted, valued, transformed and distributed go unnoticed.

Second, the idea of natural capital conceives of economy-environment relations through the language and tools of economic accounting. Indeed, models have tended to abstract nature into another macroeconomic aggregate which can be seemingly extracted from the broader relational assemblages in which they are embedded. Properly directed

government actions are then used to offset losses such that 'ecological deficits' (by drawing down and degrading nature) are compensated by 'ecological surpluses' (by investing in renewables and promoting ecosystem regeneration) (Harris, 2019). Complex natural processes are thereby visualized within the credit/debit binary of double-entry accounting necessary for modeling (Huff, 2021). In doing so, human-nature relations are reduced to a collection of cardinal numbers that can be instrumentally measured and objectively compared (Svartzman, Dron, and Espagne, 2019), while rationalizing nature as fungible, timeless and devoid of place and culture and history.

Modeling efforts that integrate the concept of 'natural capital' provide the illusion that environmental problems can be "got on top of" (Sullivan and Hannis, 2017, p. 12) and can be unproblematically managed through state-market governance mechanisms. For this reason, Svartzman, Dron, and Espagne (2019) argue that by treating the biophysical realm as 'natural capital' within a monetary production economy, ecological macroeconomists employ an economistic view of nature. In doing so, researchers

> "impose[s] specific financial logics on the patterns of the biophysical sphere, in a way similar to the neoclassical focus on price and market mechanisms. In other words, it leads to the treatment of the biophysical sphere as if its processes could function at the same pace, substitutability, and flexibility as financial processes." (Svartzman, Dron, and Espagne, 2019, p. 119).

In this sense, ecological macroeconomics risks reinforcing a predominantly "instrumental view of nature" that aligns with neoclassical economics in merely promoting "a synthesis of expertise and 'better policy' which accepts market logic but places macro limits through government regulation…" (Chester and Paton, 2013, p. 110).

Indeed, by proposing nature as a form of capital, economy- environmental relations are frequently understood as manageable through stakeholder arrangements in partnership with firms, investors and technical and scientific experts to obtain measurable policy outcomes. Nature is viewed as "an eco-functional medium, which can be recalibrated" to serve economic growth, financial stability, equality and ecosystem health (Igoe, 2013, p. 17). In effect, nature and ecosystems continue to be valued primarily as services for firm profitability and macroeconomic stability. Nature then serves as a "warehouse of potential commodities" (McAfee, 1999, p. 134) and/or a portfolio of 'green' assets that can be unproblematically owned, traded, and drawn upon for for-profit service provision and value creation.

'Green' forms of production are therefore considered to be a key means of environmental protection and conservation (Harris, 2013). With sufficient long-term funding and appropriate policy frameworks, environmental processes are even thought to function according to

the needs and expectations of profit-orientated market actors (Sawyer, 2020). Environmental outcomes can then seemingly improve while strengthening firm competitiveness and raising long-run economic growth and reducing inequality (Galindo, Giulio, and Gabriel, 2020; Guarini and Porcile, 2016).[7]. Guarini (2020) for example, finds that green investment initiatives can "compensate for negative externalities caused by increase in the ecological footprint. . . [and] propel ecological conversion of the production system through structural changes and innovations." (Guarini, 2020, p. 2).[8]

Finally, the idea of 'natural capital' also solidifies an ideological separation between environmental problems and the broader political-economic context in which they arise (Lohmann, 2016). For example, by considering nature as a form of capital, nature is already understood as a ready-made aspect of the economic process which can be drawn upon to support the economic process. Stocks, flows and funds of resources within ecological macroeconomic models, for example, exist outside of the sphere of social conflict and distribution (Dafermos, Nikolaidi, and Galanis, 2017). 'Externalities', for example, are seen as an unfortunate byproduct of the production process, and not an endogenous function of the relations of production (Kapp, 1978). Moreover, resources are viewed as pre-existing quantities and qualities that are already valued and available for extraction and transformation.

The availability and quality of 'natural capital', however, has no existence outside of the social relationship to nature. Natural capital, if it has any meaning, is a political construction. For example, before a resource becomes an input(or output) of production, it must first become a resource (Bridge, 2009; Huber, 2021). This only occurs through a constellation of forces - valuation processes, social logics, technologies, legal battles, and often violent conflict - that are bounded in time and space. The accessibility, distribution, quality, quantity and distribution of nature is never fixed but is in fact dependent on relations of social power to define, value and transform nature in particular ways (Labban, 2010; Ortiz, 2020).

7 Much of this research is predicated on the "Porter Hypothesis" (Porter and Linde, 1995). Porter proposed that well-designed environmental regulations can bring about environmental innovations and green productivity growth which raise income and promote sustainability. The potential for raising incomes and enhancing competitiveness is seen to offset any of the short-term initial costs of regulatory compliance. Advanced production technologies are assumed to increase economy-wide efficiency and lower production costs of 'green' products by achieving economies of scale. Greater external financing and firm competitiveness is also said to generate new market opportunities for venture capital and start-ups, resulting in enhanced long-run economic growth (Acemoglu et al., 2012; Porter and Linde, 1995)

8 While the notion of 'environmental externalities' is sometimes criticized in ecological macroeconomics (Dafermos and Nikolaidi, 2019), it remains widely used (Guarini, 2020; Monasterolo and Raberto, 2019; Naqvi and Stockhammer, 2018).

Overall, the concept of natural capital is an extremely limited framework for understanding economy-environment relations. While utilizing natural capital allows macroeconomic models to integrate nature and determine some key macro-environmental relations, it also plays an ideological role. Natural capital functionalizes nature as an inherent aspect of the monetary-production system that obscures its contextual specificities and historical contingencies.

THE LIMITS TO 'LIMITS' IN ECOLOGICAL MACROECONOMICS

human and earthly limits, properly understood, are not confinements, but rather inducements to formal elaboration and elegance to fullness of relationship and meaning

— WENDELL BERRY

One of the pre-analytic visions of ecological macroeconomists is the idea that there are clear 'limits to growth' and definite 'planetary boundaries' that constrain economic activity. In the words of Rezai and Stagl (2016), the value of an ecological macroeconomics paradigm "springs from the simple and most basic tenet... [that] the world is finite. As the scale of the world economy continues to grow, humanity is increasingly confronted with the planet's biophysical limits." (Rezai and Stagl, 2016, p. 181). Ecological macroeconomists therefore seek to develop "a much better understanding of how a capitalist economy operates in a natural environment with limits to growth" (Kronenberg, 2010b, p. 1488).

The primary debate within ecological macroeconomics, then, is not in establishing if 'limits to growth' exist, but in the relative optimism about how to best transform a capitalist economy to live within them (Fontana and Sawyer, 2016). The field therefore looks to achieve what has (previously) seemed impossible: Stay within planetary boundaries by (i) separating environmental impacts from economic growth (Haberl et al., 2020; Hickel and Kallis, 2019) and/or (ii) render a non-growing or degrowing capitalist economy socially sustainable (Jackson and Victor, 2020).

This way of conceiving of the economy-environment dynamics comes from a particular reading of early writings that inspired ecological economics, namely those related to the 'limits to growth' (Meadows et al., 1972) report and research on the thermodynamic limits to growth due to the tendency towards increasing entropy (Georgescu-Roegen, 1971). Planetary limits and boundaries are external facts of existence with which the economy must contend. Both economic scale and environmental quality are assumed to decline dramatically as limits are reached. Limits are therefore seen as absolute constraints on economic activity, not simply points beyond which economic growth results in worsening environmental degradation. As Jackson points out, "the climate may just turn out to be the mother of all limits" (Jackson, 2009, p. 13).

The so-called 'limits-to-growth' argument is based on two assumptions. First is that there are strict physical limits to economic growth: If economic growth drives the transformation and consumption of 'natural resources', additional growth causes and contributes to ecological crisis. Second, the ecological crisis is, in turn, generating a crisis in the macroeconomy. Ever growing increases in production and material consumption undermine natural systems upon which the economy depends. By extension, the economy faces increasingly dire social consequences as it butts up against natural limits and planetary boundaries (Sullivan, 2009). Soon enough, social inequalities and financial instability become problematic, putting an end to growth - 'by disaster', rather than 'by design' (Victor, 2008).

The language of limits and boundaries has become one of the most widely used and understood environmental metaphors within contemporary discourse to combat the belief that environmental problems are able to be smoothly dealt with through business-as-usual policies. The concern for limits is therefore a marked improvement on neoclassical discourses, which argue that all of nature can be completely substituted by labor and capital, as long as markets can be adjusted to reflect the 'true' underlying prices of pollution or an ecosystem service.

Nevertheless, a focus on hypothetical limits - the limits of technologies, the crossing of specific planetary boundaries (e.g., biodiversity loss, climate change, soil degradation, water scarcity), physical limits (e.g. entropy and the thermodynamic limits to growth, resource scarcity), or social systemic limits (e.g., the capacity of institutions to support growth or degrowth) - may not provide sufficient framework for analysis on their own. While the concept of limits appears to mobilize some concern for the environment, it is unclear if the present paradigm of assessing the 'limits to growth' is a useful or even scientifically appropriate line of reasoning for guiding ecological macroeconomics research. The 'limits' metaphor "may be already failing us on the one hand and part of the problem on the other" (Norgaard, 1995).

The debate at hand is not whether human activity is conditioned by material constraints, or whether human activity is resulting in increasingly destructive consequences. Human activities are certainly resulting in destructive environmental changes at a scale and pace unprecedented in human history. Moreover, any specific natural resource must be finite and there are absolute constraints to using them (Davidson, 2000). The question, however, is whether the limits metaphor can serve as a useful analytical tool for 'ecological macroeconomics' to approach economy-environment dynamics.

First, 'limits' do not exist in the way they are typically framed. The idea of 'limits' suggests that there is some amount of toxicity or physical barrier beyond which the social-biological system dramatically

transforms or collapses. The idea that organisms can tolerate a certain threshold of toxicity - though perhaps not beyond - and continue on living normally without serious consequences underpins a majority of regulatory frameworks. Yet organisms typically become a little sick on small amounts of pollution, and more sick at greater amounts. Moreover, while phase shifts and non-linearities exist in nature, thresholds are rare and

> "even when there are thresholds, there are usually many thresholds to choose between. Scientists and the idea of objectivity have come under fire, both by the industries that produce and use the toxics and by those concerned with public safety, for making these value choices for us" (Norgaard, 1995, p. 130).

A focus on 'limits' can then also obscure the fact that limits are ultimately social choices that are collectively made, rather than scientific facts that are assessed and implemented with calculable certainty.

Second, the question of 'limits' does not necessarily provide a useful metaphor for policy guidance or concerted action. The impacts of widespread environmental destruction and toxicity are undeniable, but if 'limits' are not ultimately limiting, they do not provide sufficient guidance for understanding or responding to present circumstances.

For the idea of limits to be productively useful, physical and thermodynamic limits must be roughly quantifiable. This has not proven possible (Davidson, 2000). Unless it is possible to identify the actual limit, and the size of the global economy relative to those limits, appealing to biophysical laws is not necessarily capable of defining where barriers 'will' or 'should' exist. Indeed, it is telling that continued global economic growth remains somehow feasible even as scientists proclaim additional planetary boundaries are crossed.[9] If ecological degradation from pollution is gradual, lagged, and geographically isolated, an ever-increasing scale of the economy and economic impacts may not result in either ecological or economic collapse. Instead, it is likely to imply continuous increases in environmental degradation to which some groups will find it increasingly difficult to adapt, while other groups find increasing opportunities for accumulation.

Third, consequently, focusing on 'limits' can obscure the uneven distribution of vulnerabilities in a system. The vulnerability of any organism to negative environmental change are contingent on a number of social factors (e.g. access to care), biological traits (e.g. comorbidities) and environmental conditions (e.g. level of other toxins

9 Five of nine 'planetary boundaries' - climate change, biosphere integrity, land-system change, nitrogen and phosphorus pollution, and chemical pollution - have apparently already been crossed (Persson et al., 2022).

and stressors). Exposures of any social group to environmental harm, resilience to them, and capacities to adapt are always unevenly distributed (Adger, Eakin, and Winkels, 2009). Indeed, some groups and regions are considered 'double exposed': they suffer disproportionately from the effects of climate change and the constraints imposed by their Peripheral status in the global economy (O'Brien and Leichenko, 2000). From this perspective, the idea of 'limits' hides the fact that vulnerability to environmental change is a social and political fact and not an external physical fact.

Fourth, consequently, the 'limits' metaphor ignores the function of crises within capitalism. Capitalist institutions evolve not *despite* social-ecological crises, but *through* them (Moore, 2015). In this sense, there may be ample room for economic growth for some groups, even as social and ecological risks accumulate. This poses a particular issue for finding sustainability within capitalism: Firms and states compete over opportunities to exploit profitable outcomes within a complex web of social, economic and material capabilities (Andersson and Lindroth, 2001). Vulnerabilities in one place are frequently a means of accumulation in another. Indeed, firms earn profits specifically by offloading the risks and burdens associated with environmental degradation on society at large (Martínez-Alier, 2002). The poor tend to bear the majority of these burdens (Laurent, 2014). From this perspective, it is more fruitful to identify the structures supporting unsustainable relationships that exist, who benefits and who suffers, rather than utilizing a blanket critique of 'limits to growth'.

Fifth, the 'limits' framework is widely regarded to reflect modern Western preoccupation with social and natural control. The desire to overcome material boundaries and scarcities is deeply rooted in Western European cosmologies (Norgaard, 1984; Pattberg, 2007) and economic frameworks (Kallis, 2019). Indeed, material scarcity and limits are posed as ontological facts within neoclassical economics.[10] In this sense, presupposing limits also presupposes a particular way of living, relating and viewing our place within nature (Robbins, 2012). The vision of limits does not reflect the open-endedness of socio-ecological change and co-evolution that form the basis of both ecological economics and life sciences (Norgaard and Kallis, 2011).

Sixth and finally, the language of 'limits' distracts attention from the actual social construction of environmental problems and their solutions. Rather than decrying the coming limits and the passing of planetary boundaries (Kallis, 2019) it may be more beneficial to point out the expansionary dynamics, power relations, and uneven structures of modern societies that generate and rely-upon unsustain-

10 For neoclassical economists, it is the idea that humans have limitless wants within a materially limited universe that appears to drive economic dynamics in the first place. That neoclassical theory describes how 'free' market exchanges allow the two to coincide indefinitely is likely a major part of its draw.

able human-nature relations (Brand et al., 2021). As Kallis (2021, p. 1) writes,

> 'limits' is a metaphor... that presumes our desire for that which is limited. Gravity, for instance, is a limit if you want to jump out of the window, but not if you want to stay on your couch....Seeing the world as an external force that imposes limits on us is an integral part of capitalism's ideology of scarcity and growth. In our culture, a politics of invoking catastrophic external limits only fuels capitalism's promise of 'more'

While the metaphors of 'limits' and planetary 'boundaries' have served a purpose as a clear break with the idea that natural capacities can be infinitely substituted, it may be time to move beyond them to guide future research. The metaphor of planetary boundaries and limits is not scientifically valid, empirically testable, and may even detract from social vulnerabilities and social possibilities. To that end, ecological macroeconomists need to develop an alternative vision from which to approach its understanding of socio-ecological change. Such a pathway should not only be able to better clarify the present while shining a light on possibilities for a future that lies beyond overcoming or adapting to external constraints (Kallis, 2019).

3.2.3 *The Need for a 'political' ecological macroeconomics*

From the above it is clear that there are a number of consistent deficiencies across these three domains. Despite the promise of ecological macroeoconomics to serve as a holistic vision of economy-environment dynamics, it has been held back in its *means*, *goals* and *context* by an insufficiently 'political' view of nature and socio-ecological relations. These sections revealed how attention to aggregate investment demand, economic scale, natural capital, and natural 'limits' can actually distract researchers from the uneven structures of power and inequality that provoke and reinforce environmental harm.

This finding is striking. Ecological macroeconomics borrows heavily from political economy research that specifically recognizes that the role of distribution, class conflict, and power are fundamental to understand economic and social developments (Monvoisin and Rochon, 2007). There is no reason why this should be excluded from the field's understanding of environment. As Spash (2019) recognizes, the importance of a political economy perspective is "re-established because who gets exploited and polluted and who gets to extract and use resources is fundamentally about power relations in society" (Spash, 2019, p. 2).

In order to address the lacuna of ecological macroeconomics, then, it is worth considering other fields and visions with complementary

strengths. If ecological macroeconomics requires a more political view of nature, there is perhaps no greater way forward than to integrate insights from the field of political ecology.

3.3 POLITICAL ECOLOGY: A HOLISTIC POLITICAL ECONOMY OF THE EARTH SYSTEM

Political ecology can serve as a counter-balance to the aforementioned deficiencies of ecological macroeconomics. Political ecology is a field of study which describes environmental changes and material conditions as shaped by, and providing shape to, social conflict and power relations. Political ecologists seek to unveil the sometimes hidden drivers and consequences of environmental change across space and time, and highlight differential power dynamics which bring about these outcomes. Political ecology offers ecological macroeconomics a new lens to study the relationships between humans and their environments as they unfold within historically situated structures of power.

Political ecology attempts to accomplish a dual task: it highlights the function of social power in the transformation of ecological systems, while simultaneously explaining how the very frameworks for understanding them are constructed through political-economic processes and institutionalized practices (Leff, 2015). Rather than claiming a coherent agenda or synthetic model, political ecology "encompasses a celebration of diverse sets of inquiries with a common focus or shared concern for addressing inequality, injustice, and asymmetric power relations at the nexus of people and the environment." (Sovacool, 2021, p. 3). Political ecologists therefore critically engage with and question dominant accounts of environmental change while exploring opportunities for creative alternatives (Schulz, 2017).

Political ecology is built upon a set of core understandings that have driven research since its inception (Paulson and Gezon, 2004; Robbins, 2012)): (i) *power*: socio-natural systems are organized to perform in particular ways in order to meet the (contested) demands of powerful groups; (ii) *distribution*: dominant groups are typically able to offload risks and appropriate the rewards of environmental change, at the expense of marginalized groups; (iii) *vulnerability*: since political, economic, and ecological developments may be mutually reinforcing, environmental degradation is both a cause and consequence of social vulnerability and marginality; (iv) *plurality*: there are a plurality of positions, interests, value systems and rationalities that develop in relation to the environment, that embody alternative ways of organizing, being within, and transforming nature; (v) *coevolution*: environment and society co-exist in dialectical relationship. Environmental 'constraints' shape the range of choices, behaviors and attitudes for individuals and groups, yet these reshape environments,

in turn; (vi) *scale*: extralocal political and socio-economic processes transform local spaces, and are transformed by them, implying that scale of analysis is fundamental to understanding ecological matters; (vii) *space*: social life does not take place within an inert material background. Society 'produces' space (nature) in accordance with social habits, ideologies, institutions and material demands; (viii) *contradiction*: the social system can be guided by particular harmful logics and structures with nature that must be regulated or 'fixed' via stopgap measures to maintain social and systemic stability; (ix) *history*: the distribution of environmental qualities are not reducible to human impacts on a pristine environment. Environments evolved over thousands of years of human-nature interaction, creating a tapestry of patchwork landscapes, biodiversity, environmental qualities and quantities.

Political ecology has two broadly-defined streams of research: First, the field has brought existing notions of class, access, and ownership in political economy research to study environmental changes. Here, political ecology draws heavily from Marxist understandings of the social relations of production, to investigate the (social-)ecological foundations of class conflict and capitalist global power relations (Harvey, 1993, 1996). This was perhaps most clearly exemplified in an early text by Blaikie and Brookfield (1987) which demonstrated how structural forces within the global economy were resulting in deforestation and soil erosion among rural communities in Nepal. By focusing on the broader dynamics within the (capitalist) world-system, land degradation could not be blamed on purely local causes, but on a pattern of structural relations which assure that "one person's degradation is another's accumulation" (Blaikie and Brookfield, 1987, p. 14).

Second, political ecology has also been heavily influenced by post-structuralist and post-modern thought (Escobar, 1999; Peet and Watts, 2004). In this stream, nature is not an external object of individual or social knowledge, but is both materially and ideologically constructed through cultural practices, discourses and linkages within prevailing socio-economic institutions (Castree, 2001; Daggett, 2019).

Political ecology therefore distinguishes itself from 'pragmatic' managerialist and 'consensus'-based technocratic approaches by placing attention on asymmetrical relations of power and the frameworks used to describe, measure and promote social-environmental change (Hornborg, 2017). Powerful groups and actors (NGOs, states, international institutions) are understood to frequently mask pervasive structural inequalities and ecological injustice through discourses, and the promotion of seemingly scientific and objective calculations.

Political ecology is therefore explicitly concerned with relations of power in environmental decision-making. Decisions over the speed, direction, meaning and value of certain environmental changes redis-

tribute ecological benefits and burdens among groups. Scientific measurements, financial valuations, production standards, price-setting, etc. always take part in a larger systemic exercise of economic power. As Harvey (1993, p. 25) writes

> "all ecological projects (and arguments) are simultaneously political-economic projects (and arguments) and vice versa. Ecological arguments are never socially neutral any more than socio-political arguments are ecologically neutral. Looking more closely at the way ecology and politics interrelate then becomes imperative if we are to get a better handle on how to approach environmental/ecological questions."

Political ecologists are therefore skeptical of projects that are marketed as universally beneficial, absolute or 'scientific'. Terms like environmental efficiency, technological progress, 'green' growth, 'decoupling', 'sustainable' development, and 'ecological' modernization are criticized because they are frequently employed to mobilize support for hegemonic political-economic goals and programs that can exacerbate social vulnerabilities and entrench dominant power relations (Fletcher and Rammelt, 2017; Peet and Watts, 2004; Sneddon, Howarth, and Norgaard, 2006).

Moreover political ecologists are well aware of the complexities that arise when attempting to determine the 'sustainability' of a given instrument or project. Management decisions that may appear just or sustainable at one scale may be understood as unjust and environmentally destructive at another (Cederlof and Hornborg, 2021). How the terms of environmental change are defined, by whom, and over what scale changes are determined as effective or ineffective are therefore exercises of power. Political ecologists document the material, social and economic struggles of different actors to assert control and legitimacy in decision-making, and who suffers and benefits from the consequences from different decisions. More broadly, they link social structure to the organization and regulation of environments to explain how and what it is that *powers* power.[11]

3.4 PATHS TOWARDS INTEGRATING POLITICAL ECOLOGY AND ECOLOGICAL MACROECONOMICS

While much of the above may appear foreign to ecological macroeconomics, there is ample opportunity for cross-over between the two fields. By blending with political ecology, ecological macroeconomics can shift its attention away from efficiency concerns, and towards 'critically bearing witness' (Alhojärvi and Sirviö, 2018) to the ways that

11 See Ahlborg and Nightingale (2018) and Svarstad, Overå, and Benjaminsen (2018) for an interpretation of power from a political ecology perspective. For the purposes of length and clarity, I will not go into this much-debated topic here.

environments are transformed, in order to spotlight social vulnerabilities and uneven power relations. Ecological macroeconomics can then emphasize the internal dynamics of capitalism that reinforce unsustainable behaviors and environmental injustice over time and space.

Political ecology can also sharpen ecological macroeconomics' critiques of neoclassical approaches, particularly by enhancing the contrast between the two. Much like ecological macroeconomists, political ecologists already work to "disrupt normal expectations [and] undermine inherited assumptions" of environmental knowledge in mainstream discourse by paying particular attention to the asymmetries of power at play in environmental change (Robbins, 2012, p. 98).

Moreover, ecological macroeconomics and political ecology can be complementary in their scholarly ambitions. Political ecologists aim to be both a 'hatchet' and a 'seed': The former refers to the capacity for scholarship to critically engage with and "aggressively dismantle politically reactionary and hierarchy-intensifying explanations of environmental stress" (Robbins, 2012, p. 98). The latter refers to an ethical commitment to conceptual openness, solidarity with marginalized groups, and a reclamation of alternative pathways for living and relating. This presents an opportunity for ecological macroeconomics to tackle new subject areas from a distinctly macroeconomic perspective, which is partly missing in the annals of political ecology.

In what follows, I explore just two key insights from political ecology that can improve ecological macroeconomics and bring forward a more holistic study of economy-environment dynamics: (i) scale and method of analysis, (ii) a theory of space.

3.4.1 *Scale and Method of Analysis*

The first contribution that a political ecology framework can bring to ecological macroeconomics is a recognition that 'solutions' are dependent on the scale from which problems are defined and analyzed. Environments take shape through relationships across the local, meso, national and global scales (Massey, 2005). Understanding socio-ecological changes therefore necessitates a methodological framework capable of integrating insights that cut through multiple scales. To that end, political ecology provides scope for recognizing how power functions at and across various scales, and is "embedded in causal processes and structures rather than in particular individuals or artifacts [or levels]." (Lawhon and Murphy, 2012, p. 367).

Political ecology research is built through lines of questioning that reveal how socio-ecological problems are embedded in a "messy bundle of relationships" (Moore, 2011), that are inevitably "multi-scalar" (Sovacool, 2021), "teleconnected" (Adger, Eakin, and Winkels, 2009) and even "wicked" (Sediri et al., 2020). It is therefore important for researchers to avoid limiting any understanding of environmental is-

sues to a single scale, driver or cause. Rather all environmental harms, as well as instruments and strategies to promote resilience, adapt or transform the economy exist within a broader socio-political context.

Theorizing scale is particularly important for a political ecology approach, which seeks to connect local practices and agency to the global processes and structures of power within which actors behave and relate. This perspective is perhaps most clearly exemplified in a foundational text on the politics of soil erosion by Blaikie (1985). International organizations, NGOs and locals had blamed worsening soil deterioration in Peripheral countries on overgrazing and deforestation by rural farmers. However, following a 'chain of explanation', Blaikie contextualized this pattern within the wider social and class dynamics: rural farmers had become increasingly poor and marginalized because wealthy landowners were consolidating land holdings, even as crushing world-market prices forced farmers to intensify and expand production to make ends meet. Soil erosion was then more directly connected to the 'accumulation possibilities of dominant classes' in which farmers were entangled, rather than the farmers themselves (Blaikie, 1985, p. 8). Soil erosion could then be understood as a symptom of larger social processes. Attempting to merely alleviate the symptom (i.e. through the application of more modern agricultural techniques or reducing herd sizes) would therefore overlook alternatives that might better respond to the actual issue at hand (i.e. land redistribution, price floors, import tariffs, etc.).

Political ecologists therefore highlight connectivities amongst different scales. Environmental problems are often the outcome of scalar conflicts: power asymmetries at diverse scales and geographic locations shape the way that socio-environmental systems are transformed (Neumann, 2009). Frequently, the seat of decision-making is far removed from where impacts are felt in time and space (M'gonigle, 1999). Scalar conflicts can therefore result in positive feedback-loops that reinforce the underlying causes of the problem.

The problem of scale in political ecology undermines the idea of linear-aggregation that predominates in both mainstream (methodological individualism) as well as many heterodox theories (methodological nationalism). The whole is far more than the sum of its parts. Beyond identifying the 'appropriate scale' of the economy, then, engagement with political ecology can help ecological macroeconomists to also be wary of 'appropriate scale' of analysis for interpreting socio-ecological change, as well as the 'appropriate scale' of organization through which problems can be effectively managed.

Much of available research in ecological macroeconomics, for example, relies on a perspective centered strongly around the nation-state. Even when extending their analysis to two interacting regions, ecological macroeconomists have tended to view sustainability transitions between two interacting, though not fully interdependent regions. Ef-

ficiencies in one region, for example, can then be added (subtracted) to the other region to enhance (detract from) global sustainability (Galindo, Giulio, and Gabriel, 2020; Guarini and Porcile, 2016). Taylor, Rezai, and Foley (2016, 81, emphasis added), for example, writes that "rapid current economic growth rates for well-performing developing countries suggest that they are driving up the worldwide level of GHG accumulation; *the evidence is less clear for the industrialized world*." Here, 'poor' (sic) countries are assumed to be a growing risk pushing the world beyond planetary emissions boundaries. Meanwhile, wealthy countries are becoming increasingly efficient, and therefore potentially reducing global burdens.

From a political ecology perspective, however, the Core and Periphery co-evolve within a 'world-ecological system' (Hornborg, 2020). Political ecologists highlight the long trajectory of exploitative relations that allowed wealthy countries to develop seemingly 'efficient' high-value productive structures. Political ecologists therefore work to unveil how socio-ecological dynamics express unevenly between regions. Apparent 'efficiencies' in one region are frequently garnered at the expense of 'efficiencies' in another (Bonds and Downey, 2012; Sovacool, 2021). Indeed, political ecologists argue that Peripheries are 'inefficient' not because they lack access to cutting-edge technology, but because they have been historically conditioned to export low-value, resource- and pollution-intensive goods at cheap prices (Hickel, 2021; Magalhães et al., 2019). Such a finding is only possible when considering how scalar dynamics are always at play in economy-environment relations.

In sum, following a multi-scalar approach can reveal a more complex knot of relations to better explain environmental problems. While a political ecology perspective can significantly complicate both the methods and the objectives of ecological macroeconomics, it can serve to provide much more nuanced understandings and help the field to avoid reinforcing unobserved patterns that do not take into account alternative scales of analysis.

3.4.2 *Towards a Macroeconomic Theory of Space*

Another contribution that political ecology can bring to ecological macroeconomics is a framework for understanding the importance of space. Political ecologists recognize that human action and relationship occurs within and through space. For political ecologists, space is the seat of social life and a constitutive elements of social power. Space serves as the locus of human connection to the natural world, and the actual terrain of political contest and institution building (M'gonigle, 1999). For Massey, "conceptualising space as open, multiple and relational, unfinished and always becoming, is a pre-

requisite for history to be open and thus a prerequisite, too, for the possibility of politics" (Massey, 2005, p. 59).

In political ecology, spaces are seen as socially produced (Lefebvre, 1991; Smith, 2008). Much like other animals, humans are essentially ecosystem engineers. Socially constructed narratives, political and 'economic' institutions are never purely abstract ideas. Rather, they are embodied and carried into the world through human action (Dale, 2005; Graeber, 2001). In this way, social institutions are fundamentally "material forces in and of themselves constituted in lived practices and relationships" (Ekers and Prudham, 2017, p. 5). Spaces are actively organized and reconfigured through practices and relations with a diversity of meanings and values (Smith, 2008, p. 89). As such, space where political conflict 'takes place'.

By integrating political ecology, ecological macroeconomics can better account for how space is constantly reconfigured, and reimagined to sustain the relations of production and consumption within capitalism. This marks a profound change for heterodox economic theory, which has typically emphasized time as the primary axis of social change. Indeed, post-Keynesian and ecological macroeconomics distinguish themselves from neoclassical economics largely by understanding the economy as a process in historical, rather than procedural, time.[12] Moreover, post-Keyesnains and ecological macroeconomists have, until now, regarded space as either unimportant (Kaldor, 1970; Robinson, 1978) or secondary (Victor and Jackson, 2020).

While the temporal dimension should not be forgotten, research in political ecology demonstrates the need for a spatial understanding for developing a holistic framework (M'gonigle, 1999). Indeed, the focus on time to the exclusion of space within the social sciences coincides with materialist notions of economic 'progress' and industrial 'modernization' that are at the core of the present ecological crisis (Lefebvre, 1991; Massey, 2005; Mbembe, 2003; Sheppard, 2016).

By ignoring how the production and monetary systems are spatially embedded, the field risks repeating the mistakes of its intellectual forbears (Sheppard, 2016; Sunley, 1992). In both post-Keynesian and ecological macroeconomics, for example, countries are discrete units of space, reducible to aggregate sectoral balance-sheets, and distinguished primarily by differences in their industrial structure. According to Kaldor (1970), for example, boundaries are arbitrary abstractions which, from an accounting perspective, hold little economic, or social significance. Boundaries, "are...a given fact one need not enquire about", and as such, "the prevailing distribution of real income in the world-the comparative riches or poverty of nations, or regions-is largely to be explained...by the unequal incidence of de-

12 Joan Robinson (1978, p. 12) for example, claims that if "post-Keynesian has a definite meaning; it applies to an economic theory or method of analysis which takes account of the difference between the future and the past".

velopment in industrial activities." (Kaldor, 1970, p. 337). Following Kaldor's insights, ecological macroeconomists recognize that industrial structures are likely to lead to cumulative differences in economic growth. Spatial unevenness is therefore only the outcome of economic structures, and not foundational to their operation.

Political ecologists, in contrast, highlight the actual mechanisms by which spaces are produced to enable industrial or financial structures. Boundaries are not imaginary lines, but political-material constructs. Boundaries are created and maintained by political-economic, legal and military contest and coordination. Political ecologists therefore research how inequalities of power are spatially embedded and actively held together. Research then is able to deeply analyse the way that spaces are built, divided, valued, and transformed; how and where resources are accessed and appropriated; the degree, distribution and intensity of degradation, etc.

Ecological Macroeconomics can gain significantly from the 'spatial turn' of works in political ecology and human geography (Smith, 2008; Warf and Arias, 2008). In these works, capitalism is described as having distinct spatial dynamics of expansion and contraction, unequal exchange, uneven development, and chronic financial, commercial and material imbalances that cannot be reduced to the growth rates of individual countries or their relative production structures. (Hornborg, 2020).[13]. Moreover, capital accumulation is understood as evolving through processes of territorial expansion, material transformation, and political contest (Bunker and Ciccantell, 2005). Integrating a spatial dimension would allow researchers to link the diverse ways that geographic unevenness feeds ongoing environmental problems, and vice-versa. Researchers can also delve into how particular growth patterns have distinct material dependencies - coal during British imperialism (Hornborg, 2006), oil under Fordism (Huber, 2013), critical raw materials in the 'green' transition (Bonds and Downey, 2012) - that shape the evolution of the macroeconomic structure, the geography of production, and the distribution of environmental impacts.

In particular, inspiration can be taken from recent works that blend political ecology and French Regulation theory (Becker and Raza, 1999; Cahen-Fourot, 2020; Cahen-Fourot and Durand, 2016; Douai and Montalban, 2012). These articles analyze how global socio- environmental changes are shaped by institutional compromises to sustain capital accumulation by establishing an 'ecological' regime of accumulation. Ecological regimes include the formal and informal patterns of governance, technologies, class structures and institutions, beliefs, attitudes and incentives that coordinate human-nature relations (Cahen-Fourot, 2020). Diverse 'market' and 'non-market' structures

13 See especially work in french regulation theory and world-systems theory, notably Guttmann (2016)

ensure the necessary qualities and quantities of flows of energy, food, materials, and labor-power for the process of capital accumulation in time and space.[14] These relations then establish the intensity and scale of environmental demands at home and abroad (Cahen-Fourot and Durand, 2016). Ecological regimes are therefore also a means of organizing and transforming nature in time and space (Moore, 2015). (Moore, 2017, pp. 4–5), for example, describes cycles of accumulation "over large space and the longue duree" as periodic socio-ecological configurations:

> Could one write a history of the 17th century Atlantic without reference to the Spanish Empire's socio-ecological reshaping of the Andes in the service of the silver mining frontier, and the dilapidation of Castile's agricultural regime (Moore 2010a:46-48; Moore 2010e)? Or of British hegemony in the late 19th century, without an analysis of botanical imperialism, or the Empire's role in the catastrophic famines that swept through the colonial and semi-colonial world (Davis 2001; Brockway 1979)? Or of American hegemony without considering successive agro-ecological revolutions from the Midwest to California to the Punjab (Friedmann 1978; Walker 2004; Perkins 1997)? (Moore, 2011, p. 111)

By including a political ecology perspective, individual country growth rates and production structures can be contextualized in the broader geo-political context, and unveil the spatial-material needs of accumulation (Hornborg and Martinez-Alier, 2016; Patnaik and Patnaik, 2017).

In sum, by borrowing from political ecology, ecological macroeconomics can better understand the spatial-material dimensions of capitalism as foundational components of economic change. The dynamics of accumulation (or deaccumulation), are anchored within a spatially-extensive biophysical system. By blending with political ecology, ecological macroeconomics can develop new conceptual tools for studying the geographic interdependencies of capital accumulation that have - as yet - gone unnoticed in the framework.

3.5 SUMMARY AND CONCLUSIONS

In a world increasingly buffeted by socio-natural disasters, geopolitical conflict over resources, and increasingly dire warnings from Earth scientists, economists must wake up not only to the severity of the present crisis, but also the limits of their frameworks to conceive of them. The growing interest in ecological macroeconomics is

14 According to Moore (2015, p. 158), ecological regimes are global projects, generally organized by the powerful Core nation-states that "have sustained and propelled successive phases of world accumulation since the long sixteenth century".

not surprising, as it offers key improvements from mainstream approaches. Nevertheless, this chapter has demonstrated that ecological macroeconomists should proceed with caution when adapting old frameworks to meet new issues.

This chapter reviewed some of the fallacies at the heart of ecological macroeconomics by investigating the field along three dimensions: (i) means; (ii) objectives; and (iii) context. It was shown in all three cases that ecological macroeconomics suffers from an insufficiently political view of nature. Research is therefore geared towards top-down and expert-led policy shifts and an instrumental view of nature that tends to overlook the root causes and uneven consequences of environmental degradation. As such, the field specializes in managing symptoms and controlling the consequences of economic (de)growth, rather than providing a new platform for analyzing socio-ecological change.

Moreover, it was shown that by integrating with research in political ecology, ecological macroeconomics can more thoroughly and critically engage with the social relations of power and distribution that drive environmental degradation. Accounting for (i) scale of analysis and (ii) space can likely improve theory and provide key insights into the uneven and material construction of accumulation.

The following two chapters in this thesis will explore how ecological macroeconomics and political ecology can be fruitfully blended to produce unexpected results. Chapter 4 shows how 'green' investment policies must be contextualized within the inequalities of the global economic system. Policies meant to increase economic efficiency in the Core, are likely to displace pollution- and resource-intensive production to the Periphery. Without undermining the competitive drive towards economic growth and technological advancement, both global inequalities and emissions are likely to increase, pushing the world past established climate goals. Chapter 5, explores how similar dynamics are at play in the global monetary and financial system. Financial globalization is described as an ecological regime of accumulation, where capital accumulation rests upon a set of asymmetric *material* relations. In particular, accumulation in the Core is supported by an interlocking set of monetary, productive and ecological relations that subordinate Peripheries and push them towards low-value resource-extraction and pollution-intensive activities.

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4

SUSTAINABILITY IN A CORE-PERIPHERY SYSTEM: THE LIMITS OF 'GREEN' GROWTH AND THE NEED FOR EQUITABLE GLOBAL POLICY COORDINATION

It's not easy being green.

— Kermit the Frog

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As global average temperatures continue to exceed year-to-year record highs, the negative impacts of climate change are readily apparent. To deal with the rapidly unfolding crisis, policymakers, international organizations, and academics have increasingly rallied behind a global push for "green growth" (Dale, Mathai, and Oliveira, 2016; OECD, 2011; UNEP, 2011; World Bank, 2012). Green growth strategies apply pricing mechanisms and Keynesian-style demand management, to resolve the present socio-environmental by promoting more efficient forms of economic growth. A combination of environmentally-minded price, fiscal and monetary measures are put forward to supporting efficiency-enhancing investments and break the connection between global GDP growth, resource use and emissions production.

In theory, green growth policies can result in a virtuous shift towards high value-added sectors (e.g. in renewable technologies or services) with limited environmental impact, thereby raising economic growth to improve employment, sustainability, and even global equality (Altenburg and Assmann, 2017). For this reason, economic growth is thought to remain an acceptable, and even desirable, method of enhancing social and environmental sustainability for all nations (Pollin, 2019). The fundamental obstacle to resolving the climate challenge is understood as a lack of adequate demand for sufficiently "green" investments (Courvisanos, 2005; Harris, 2019). As long as investment can be shifted to increasingly efficient technologies, there should be no inherent contradiction between economic growth and socio-technical "harmony with nature" in any part of the world (Hickel, 2019).

The emerging field of "ecological macroeconomics", spearheaded by post-Keynesians, has also prioritized the climate-mitigating potential of greener economic growth. Many of the available models utilize fiscal and monetary policies as instruments for channelling investments to accumulate "green", as opposed to "brown", forms of capital (see Svartzman, Dron, and Espagne, 2019). As the stock of efficient technologies increases, greenhouse gas emissions are reduced such that continued economic growth no longer poses a considerable threat to socioeconomic and environmental well-being.

Recent research, however, has raised serious doubts as to whether such growth-based approaches can ever be sustainable in practice (Hickel, 2019; Hickel and Kallis, 2019; Parrique et al., 2019; Ward et al., 2016). For simplicity, in the rest of the paper, we refer to the challenge of stabilizing the earth system as avoiding "climate change", keeping in mind that current patterns of production and consumption are fuelling environmental conflict and degradation across multiple dimensions (Steffen et al., 2015).

There is now an international consensus that rapid reductions in the absolute level of global emissions are necessary to stabilize the earth's climate system and avoid increasingly catastrophic damages.

At current rates of emissions production, the global carbon budget needed to avoid a 1.5 °C temperature change above pre-industrial levels will be surpassed in little over a decade, with 2 °C change coming swiftly afterwards (5-10 years). At 2 °C, most reports indicate massive increases in the number of poor and starving people, large cross-border migrations, and growing domestic and international conflict as ecological crises devolve into humanitarian disasters (IPCC, 2018). Reducing the absolute level of emissions should therefore be a high national and international priority, given the fast approaching carbon deadline.

Thus far, however, a fall in the absolute level of emissions relative to GDP has remained elusive on a global scale. Achieving climate objectives in the time needed to avoid increasingly catastrophic scenarios would require global emissions reductions at multiple times historical rates of decarbonization, *even in the absence of population and income growth* (Hickel and Kallis, 2019).[1] Moreover, while there are signs of emissions reductions at the country-level, trade-weighted measurements of environmental impacts reveal that "successful" instances of growth-based decoupling have nearly always been achieved by outsourcing pollution and resource-intensive activities to poorer countries (Duro, Schaffartzik, and Krausmann, 2018; Teixidó-Figueras et al., 2016; Verones et al., 2017; Wiedmann and Lenzen, 2018; Zhu et al., 2018).

Indeed, it is widely recognized that global trade relations are built through a fundamental environmental asymmetry between low-income and high-income nations. Core, technologically advanced countries are able to systematically offload the most socially and environmentally destructive aspects of production to the Periphery (Frey, 2019; Hornborg, 2001, 2006; Rice, 2007). This asymmetry feeds the Core's demands for 'cheap' sources of fuel and materials, validating their environmentally-intensive growth patterns (Moore, 2015). These relationships of "ecologically unequal exchange" allow the Core to maintain its own environmental quality and satisfy domestic resource demands at the expense of the Periphery (Bunker, 1985; Bunker and Ciccantell, 2005). As such, policies that appear environmentally advantageous from the domestic perspective may actually reinforce globally unsustainable trends. This suggests that addressing the structure of the international political economy and the relations between economic and environmental inequalities in different regions will be key to guarantee any successful transition. For instance, environmental justice movements, and the UNFCCC itself, acknowledge the prin-

1 The Paris climate accords set individual-country and global emissions targets, seeking to limit temperature increases to "well below" 2°C above pre-industrial levels, with the hope of limiting warming to 1.5°C. If implemented in full, established measures are still insufficient to prevent climate destabilization, pushing warming above 3 °C (Steffen et al., 2018). Few countries are now on track to comply with their national commitments.

ciple of common but differentiated responsibilities to tackle climate change (Brunnée and Streck, 2013; Roberts and Parks, 2009).

These findings raise a number of fundamental questions for ecological macroeconomics, which has been relatively silent about the prospects for the global sustainability transition in an open economy context (Guarini and Porcile, 2016). By focusing primarily on wealthy, industrialized nations in the closed economy, available models likely project overly optimistic scenarios for global climate mitigation. Present mitigation pathways rely heavily on (uncertain) future innovations to decarbonize and neglect the way technological developments restructure the geographic distribution of environmental benefits and burdens (Bonds and Downey, 2012). In light of the uneven structure of global trade, ecological macroeconomics may need to seriously consider the limits of its present methodological toolbox to address the deeper technical, institutional and ethical dimensions of truly sustainable economic pathways (Røpke, 2016; Svartzman, Dron, and Espagne, 2019).

This chapter seeks to address these limits by investigating possible pathways to social and environmental sustainability in a Keynesian "environmental coordination game". We depict a world economy characterized by a technologically advanced industrial "Core" and lagging "Periphery". While technical change and green fiscal strategies can enhance domestic environmental efficiency, some portion of pollution reductions in the Core are assumed to be achieved at the expense of rising emissions in the Periphery.

We explore four different scenarios for achieving a successful transition to negative global emissions growth using a balance-of-payments constrained growth model. The model highlights the difficulties of achieving global social and environmental goals while maintaining long-run macroeconomic stability: countries must stay within the global carbon budget while also avoiding fiscal and balance of payments disequilibria. The scenarios are as follows: First the "Global Unsustainability by Business-as-Usual" scenario depicts a situation in which no intervention occurs and world economic growth and emissions exceed the sustainable limits. Second, the "Local Sustainability by Accumulation" scenario shows how a "green growth" strategy from the Core can enhance local efficiency at the expense of emissions efficiency of the Periphery. The world drastically overshoots the available carbon budget and global sustainability would imply a reduction in growth from the Periphery. A third scenario, "Global Sustainability by Accommodation", describes a situation in which wealthy countries purposefully reduce growth. This allows developing countries the opportunity to improve their material consumption, while global emissions are falling, albeit at a reduced rate of economic growth. Finally, "Global Sustainability by Cooperation" describes an ideal scenario; global sustainability is achieved via a major coordinated inter-

national effort. Here, the Core both agrees to degrow and shares its technology with the Periphery such that a sustainable development program in the Periphery can improve income growth and efficiency without significantly overshooting the carbon budget.

By considering global emissions in an open-economy framework, this chapter investigates how technological efficiencies can heighten the unequal distribution of environmental benefits and burdens and reinforce global inequalities (Frey, 2019; Rice, 2007). Domestic technology and investment policies do not *a priori* present clear "win-win" pathways, making them perhaps necessary but insufficient steps to meet *global* targets. Green investments alone cannot, therefore, be counted on to automatically bring about greater socio-ecological harmony and equality (Hickel, 2019; Hickel and Kallis, 2019). Sustainability will likely require a reduction in investment (e.g. degrowth) in many presently wealthy countries, as well as a major change in lifestyle and social needs provisioning. Moreover, much closer coordination between countries will be necessary to raise material consumption in the Periphery without overstepping global emissions limits. While such policies are highly unlikely in the current political setting, they may be the only option for improving equality while safeguarding long run socioeconomic and environmental stability.

The rest of the paper continues as follows: Section 4.1 briefly surveys the literature on ecologically unequal exchange to incorporate key insights into the existing post-Keynesian ecological vision. Special focus is placed on reevaluating green investment strategies in the open economy, and the utility of existing Core-Periphery models to demonstrate unequal environmental relations. Section 4.2 provides the analytical background of the Core-Periphery framework by introducing the classical Keynesian coordination game and highlighting its main limitations. Section 4.3 updates the model to incorporate a global environmental constraint and pollution displacement to analyze the potential for global economic sustainability under conditions of ecologically unequal exchange. Section 4.4 describes each of the four scenarios outlined above in an "environmental coordination game". Section 4.5 summarizes findings and draws conclusions.

4.1 SUSTAINABILITY IN AN UNEQUAL WORLD SYSTEM: RECONSIDERING GREEN GROWTH

Recent attempts from post-Keynesians and heterodox researchers to incorporate ecological considerations in their models have tended to exclude open-economy issues, with the notable exception of Dunz and Naqvi (2016), Galindo, Giulio, and Gabriel (2020), and Guarini and Porcile (2016). Considering economies in isolation, however, is a major abstraction from the present day world ecological system (Hornborg, 2003; Moore, 2015). Local natural systems are under in-

creasing pressure to fulfill ever-larger global demands as the scale and speed of trade expands (Bunker and Ciccantell, 2005; Ciccantell and Smith, 2009). Moreover, the costs and benefits of these pressures are distributed unevenly across the world. Capturing the dynamics of these ecological inequalities is an important step for the nascent field of ecological macroeconomics. As researchers seek for sustainable solutions to ongoing environmental and social crises, "green" policies must be understood holistically, or risk reinforcing unsustainable patterns.

A growing literature on ecologically unequal exchange (EUE) has identified the ways in which global trade is hierarchically structured along both economic and environmental lines. EUE theorists argue that by capturing higher stages of value-added production, some regions are systematically provided with a greater claim on global resource stocks and natural sinks (waste assimilation capacity) (Ciccantell and Smith, 2009; Hornborg, 2001, 2006). Resources flow "vertically" upwards through chains of value production towards the industrial Core (Piñero et al., 2019). Those regions which export natural resources or specialize in pollution-intensive production face increasing environmental costs from extraction and production, while global centers of demand offset their environmental footprints via imports (Bunker, 1985; Bunker and Ciccantell, 2005; Jorgenson, Austin, and Dick, 2009; Rice, 2007, 2009). This has led to a conspicuous inverse relationship between a country's demand for natural resources and its degree of domestically felt environmental burdens (Hornborg, 2001; Jorgenson, Austin, and Dick, 2009; Roberts and Parks, 2009; Srinivasan et al., 2008).

The empirical literature on EUE is particularly instructive that whether one is discussing emissions (Jorgenson, 2012; Prell and Sun, 2015), ecological footprint (Moran et al., 2008), water pollution (Shandra, Leckband, and London, 2009), biodiversity loss (Shandra et al., 2009), or deforestation (Jorgenson, 2016)), economic growth is accompanied by a structural displacement of ecological burdens between the centers of value capture, and the peripheries of ecological value extraction (Hornborg, 2001; Piñero et al., 2019; Rice, 2007).

Trade enables technology leaders to preserve domestic environmental quality while using Peripheries as waste sinks or resource pools (Bunker and Ciccantell, 2005; Rice, 2007). Those at the bottom of value hierarchies must suffer the consequences of extractive, resource- and pollution-intensive production (Boons, Baumann, and Hall, 2012; Ciccantell and Smith, 2009; Selwyn, 2016). As resources are depleted and natural systems undermined, inter- and intra-country income distribution worsen (Bunker, 1985; Srinivasan et al., 2008).

This situation is increasingly counterproductive for efforts to meet global social and environmental objectives. Despite increasing alarm over the need to significantly reduce greenhouse gas emissions, envi-

ronmental loads are systematically displaced, provoking an increase in the global emissions and material intensity of production (Hao, 2020; Plank et al., 2018; Thombs, 2018). As pollution intensive production concentrates in global Peripheries, lax environmental regulations, low levels of enforcement, and the use of less efficient production techniques have resulted in a global re-coupling of emissions and resource use with economic growth. In this light, even seemingly "green" attempts at growth must therefore be scrutinized for exacerbating global asymmetries of economic and environmental quality (Bonds and Downey, 2012).

This represents an intriguing challenge to post-Keynesians, for whom investments in technological efficiency form the backbone of their contributions to ecological macroeconomics (Svartzman, Dron, and Espagne, 2019). In the post-Keynesian tradition, investment demand is the key driver of technical change, productivity, employment and income growth. Investments in resource-efficient technologies can raise productivity and lead to cumulative cycles of economic expansion (Kaldor, 1970; Myrdal, 1957). Increased resource efficiency has historically been an important driver of economic growth (Sakai et al., 2019). In the open economy, specializing in increasingly resource-efficient capital goods enhances productivity and export demand, thereby also relieving the balance of payments constraint with greater foreign currency inflows (Guarini and Porcile, 2016). Countries can then seemingly undergo a virtuous shift towards higher rates of growth, even while domestic emissions production falls.

As such, "green growth" policies are commonly viewed as "win-win" solutions to environmental and social crises (Hickel, 2019). Not only will resources be more efficiently and effectively used, but incomes should also rise while unemployment falls. Sustainable development programs also consider "green structural change" and "green industrialization" (**altenberg_green_2017**) to be inherently beneficial mechanisms to bridge the technological divide between developed and developing countries. Doing so should allow the Periphery to specialize in clean, high value-added production stages, while reducing inequalities and environmental pressure.

Seen from a global perspective, however, growth of demand and income may simply improve access to resource- and emissions-intensive goods abroad (Hornborg, 2001, 2003, 2006). In essence, improvements in technical efficiency and productivity are more likely to raise a country's capacity to import resources and outsource pollution (Bonds and Downey, 2012). Investment policy - "green" or otherwise- may not so much increase global efficiency as evolve new ways of distributing material and energy resources and the locations of production (Ciccantell and Smith, 2009; Schaffartzik, Duro, and Krausmann, 2019). Even seemingly "dematerialized" services are heavily dependent on raw material and energy inputs and may be better regarded

as drivers of global emissions growth than methods for reduction (Cahen-Fourot and Durand, 2016; Fix, 2019). Becoming a technological leader can improve a country's position in the hierarchy of value and resource transformation (Andersson and Lindroth, 2001; Piñero et al., 2019), but cannot fundamentally reduce environmental pressure under present socio-ecological relations (Hornborg, 2001).

For this reason, despite major technological changes and enhanced efficiency, income growth has in no way been separated from demands for resources or emissions production at the global level (Hickel and Kallis, 2019; Krausmann et al., 2017; Schandl et al., 2018; Schröder and Storm, 2018; UNEP, 2016). As climate change and environmental degradation worsen, additional calls for investment growth - green or otherwise - are more likely to generate a zero-sum game than a progressive march towards sustainability and development (Hornborg, 2009).

Indeed, the socioeconomic and ecological costs of environmental degradation continue to fall hardest on the developing world, particularly affecting the poor (Adger et al., 2003; ECLAC, 2012, 2016; Thomas and Twyman, 2005). The consumption and production capacities of many Peripheral countries are already constrained by deteriorating environmental quality (Rice, 2007; Wackernagel et al., 2019), a situation that will only worsen with climate change. Improving the material standards of living for many of the poor in the developing countries may be impossible if global emissions are not significantly reduced in the near future (Daly, 1991; Schaffartzik, Duro, and Krausmann, 2019; Wackernagel et al., 2019).

Formal macroeconomic models, however, have thus far yet to make explicit the effects of unevenly distributed environmental damages between unequal regions, focusing instead on potential synergies for income growth and convergence (Guarini and Porcile, 2016). This represents an opportunity for ecological macroeconomics to incorporate key insights from fields like human geography, political ecology and environmental sociology (**smith_uneven_2010**; Harvey, 2001; Jorgenson, 2016) to highlight that vulnerability to environmental harms, and their distribution between groups and regions, are a symptom of the structure of social relations (Hornborg, 2006, 2009).

A wealth of research, particularly amongst post-Keynesians, already exists for modeling the relationship between interconnected yet unequal regions in an open economy. The most commonly used is the Balance-of-Payments-constrained growth model (BOPCG). BOPCG models identify the structural impediments to growth faced by developing countries while trading with already technologically advanced trading partners. Interestingly, the BOPCG framework was heavily influenced by Latin American Structuralist thought (Thirlwall, 1997, 2011), particularly the ideas of Raul Prebisch, which later inspired notions of unequal exchange in Dependency and World Systems the-

ories (Roberts and Parks, 2009). The dynamics of ecologically unequal exchange therefore provide a useful new avenue for ecological macroeconomics to better incorporate nature into existing heterodox frameworks.

Furthermore, sectoral transformations resulting from technical change are linked to changes in the geography, quantity and quality of resource use and degradation in different regions of the world system (Bunker and Ciccantell, 2005; Hornborg, 2003). Since the open-economy framework found in BOPCG models focuses on long-term structural dynamics, these models are able to investigate the relationship between technological development and resource flows. Ecological macroeconomics is thus well-placed to integrate the economy-wide mechanisms that underpin environmental distribution conflicts into existing models of the open economy.

In the following section, we introduce a 'Classical' Keynesian Coordination game to more fully outline the Core-Periphery (BOPCG) framework. Afterwards, we extend the model to include a carbon budget constraint and a mechanism of pollution displacement from the Core to the Periphery. We then develop four alternative scenarios to find pathways to sustainability in an uneven world system, particularly focusing on ways to improve the material living standards of the poor, without overshooting environmental limits.

4.2 THE "CLASSICAL" COORDINATION GAME IN A CORE-PERIPHERY SETTING

Keynesian Coordination Game Open economy models in the Keynesian

tradition, such as the BOPCG, argue that in the long run the current account-to-GDP ratio should be constant. Otherwise, the country would be following an explosive path, piling up reserves of foreign exchange or raising its external debt to GDP ratio. Since the focus of this model is on convergence and environmental sustainability, we make the simplifying assumption of zero capital flows in the international economy, which implies that the current account balance should always be zero. Based on export and import demand functions with constant price and income elasticities, it is possible to show that the dynamic condition for equilibrium in the current account is the following :

$$y^{P*} = \frac{\epsilon}{\pi} y^{C*} + \frac{(\mu_X - \mu_M - 1)}{\pi} \hat{R}, \tag{3}$$

where y^P represents the proportional rate of growth of the Periphery ($y^P \equiv \frac{\dot{Y}}{Y}$), y^C is the rate of growth of the Core, ϵ is the income elasticity of exports, π is the income elasticity of imports, μ_X is the price elasticity of exports and μ_M the price elasticity of imports of the

Periphery. The variable $\hat{R}$ represents the rate of growth of the real exchange rate, R, defined as $R = \frac{P^C E}{P^P}$, where P^C refers to the price level in the Core, P^P prices in the Periphery and E the nominal exchange rate (price of the foreign currency in terms of the domestic currency). As Equation 3 implies equilibrium in the external sector, then y^{P*} is the rate of economic growth of the Periphery which is consistent with such equilibrium—a Balance-of-Payments-constrained rate of growth (the superscript $*$ in the variables indicates equilibrium). In the long run, the real exchange rate should be stable and hence $\hat{R} = 0$.[2] This gives the long-run rate of growth of the Periphery consistent with equilibrium in current account, which is the following:

$$y^{P*} = \frac{\epsilon}{\pi} y^{C*} \tag{4}$$

Equation 4 is known as Thirlwall's Law (see Thirlwall, 1979, 2011). The ability of the Periphery to diversify its production base and move towards more dynamic sectors in the international markets (e.g., high-tech manufactures and services), allows the Periphery to change the elasticity of demand for exports and imports (Nassif, Feijo, and Araújo, 2016). To do so, the Periphery should boost its technological capabilities, which means reducing the technology gap with respect to the Core.

In the short run, the equilibrium and the effective rate of growth may differ. The effective rate of growth is given by the Kaldorian Equation 5:

$$y^P = \alpha a + \beta x \tag{5}$$

y^P in the short run depends on the growth of autonomous expenditure a and the growth of exports (x). The parameters α and β are a function of the relative weight of autonomous expenditure and exports, respectively, in total income, along with the income elasticity of demand for imports (π) which for simplicity is assumed constant in the paper.[3] The effective and the equilibrium rates of growth converge based on changes in the rate of growth of autonomous expenditure (for a discussion of the mechanisms leading to this convergence, see Guarini and Porcile (2016). The latter variable endogenously adjusts to ensure that the external constraint is not violated.

The dynamics of the Core-Periphery system can be described by a simple two-country model based on McCombie and Thirlwall (1994), Blecker (2013), Cimoli and Porcile (2011) and Bárcena and Porcile

2 Boggio and Barbieri (2016) and Blecker (2016) find that international competitiveness depends on *both* price and non-price characteristics, leaving a role for changes in the real exchange rate and terms of trade. For simplicity, we follow the standard Thirlwall model.

3 A more detailed derivation of Equation 5 can be found in the A

(2018). Figure 2 represents different scenarios of adjustment in the Core-Periphery system. The curve P represents the effective rate of growth of the Periphery (y^P) as a function of the growth in the Core (y^C), while the curve C represents the effective rate of growth of the Core as a function of growth in the Periphery. The BP schedule represents the equilibrium rate of growth, defined by the rate of growth which keeps the current account in balance (Balance-of-Payments constrained growth). Beginning at the initial position z, both the Core and Periphery grow in line with external equilibrium. z is on the BP schedule, which gives all the combinations of the effective rates of growth in Core and Periphery that comply with the Balance of Payments constraint, i.e satisfies $y^{P*} = \frac{\epsilon}{\pi} y^{C*}$.

Assume now that—with a view to improving employment and income distribution—the Periphery raises autonomous expenditure and the curve giving the effective rate of growth shifts from P to P′. The new (transitory) position of the economy is z°, where both Core and Periphery grow at a higher rate than before. At point z°, however, the Periphery experiences a trade deficit that raises the external debt-to-GDP ratio. This deficit cannot be easily or safely sustained in the long run.

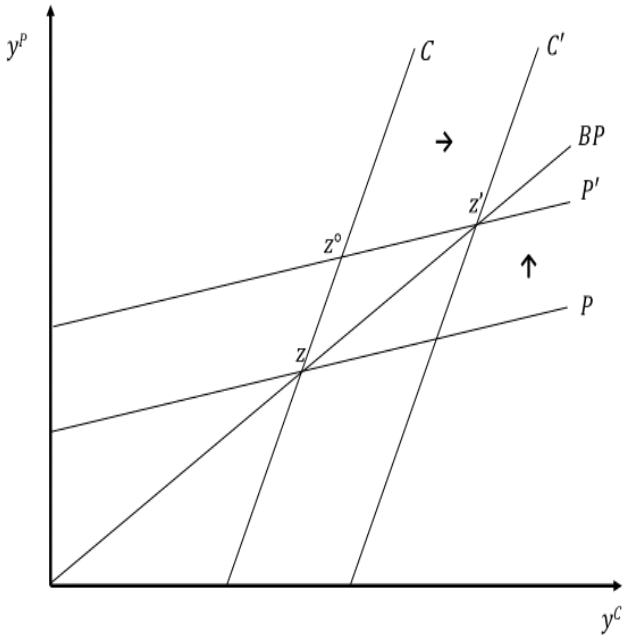

Figure 2: 'Classical' Keynesian Coordination Game

If Core and Periphery coordinate fiscal policies, then the Core responds to the expansion of fiscal policy in the Periphery by increasing its own rate of growth of autonomous expenditure. C shifts to C′ and the new equilibrium position is z'. This position implies higher growth with external equilibrium in both Core and Periphery. This

classical coordination game, however, is no longer possible in a world in which current patterns of growth compromise the stability of the planet. A more complicated coordination game emerges, which is the topic of the next sections.

4.3 THE MISSING CONSTRAINT: THE ENVIRONMENT IN A CORE-PERIPHERY SYSTEM

Environmental Coordination Game The previous analysis presented the

mutually beneficial effects of adopting expansionary policies for two interdependent economies. The classical Keynesian coordination game, however, takes place outside of environmental constraints. When accounting for a planet with finite resources and limited pollution absorption capacities, policies with positive effects on growth and income distribution may harm global sustainability efforts in the long run. In other words, even if perfect Keynesian coordination were possible (with full employment and convergence between Core and Periphery), such coordination would be compromised by environmental disequilibria. Both the causes and effects of these environmental disequilibria, as has been stressed, will overwhelmingly impact the poor and populations in the Periphery.

In the rest of this section, we update the Keynesian coordination game to highlight both the environmental constraints to growth and the distribution of environmental burdens in an unequal world system. Our model illustrates the spatial displacement of pollution as an inherent aspect of world trade, and emphasizes the global ecological dilemma given strict and fast-approaching limits.

We focus on the relationship between greenhouse gas emissions and economic growth to consider the potential for an absolute decoupling of emissions at the global level. As mentioned in Section 4.1, technology has thus far failed to bring about an absolute decline in energy and resources used or carbon emitted. The framework provides a macroeconomic tool for depicting the co-evolution of regional economic growth, technological advancement, and the environment through the lens of "emissions efficiency".

While the trends we identify are instructive for understanding general patterns of environmental offloading in the world-system, different types of decoupling (e.g., for material resources or different waste products) obey fundamentally different (bio)physical constraints. Nonetheless, all economies are materially-energetically constructed. As such, references to changes in resource use and intensity are meant to reinforce, rather than detract, from the spotlight on emissions. Economic growth implies the transformation of resources through the applica-

tion of energy, and is therefore intimately tied to emissions production.

Our model shows that improvements in efficiency have distributive and potentially counterproductive consequences on a global scale. Local efficiencies can result in global inefficiencies and reinforce environmental load displacement between regions with divergent economic and technological capabilities. Even seemingly sustainable growth patterns must therefore be scrutinized for exacerbating global asymmetries (Bonds and Downey, 2012; Hornborg, 2009).

Emissions Growth and "Green Efficiency" To see how climate change constrains the Keynesian coordination game, we take as a point of departure a simplified version of the IPAT identity, assuming constant population (normalized for simplicity to one)[4]:

$$H = Y(\frac{H}{Y}) \tag{6}$$

where H is global pollution, Y is global output, and $\frac{H}{Y}$ is the stock of CO2 emissions per unit of output. In a two-region system (see ECLAC, 2019), this becomes:

$$H = H^C + H^P = Y^C(\frac{H^C}{Y^C}) + Y^P(\frac{H^P}{Y^P}) \tag{7}$$

$$Q^i = \frac{Y^i}{H^i}, \text{ with } i = C, P \tag{8}$$

$$H = H^C + H^P = Y^C(\frac{1}{Q^C}) + Y^P(\frac{1}{Q^P}) \tag{9}$$

Equation 8 gives the variable Q, defined as the inverse of $\frac{H}{Y}$. Q represents "green efficiency", denoting the technology-driven relationship between the level of output per unit of pollution (e.g., tons of CO2). Taking logs and differentiating with respect to time, we obtain the rate of growth of the global emissions as a function of growth in Core and Periphery and the rate of technical change driving improvements in emissions growth relative to the growth of output:

$$h = h^C(1-s) + h^P s = (1-s)(y^C - q^C) + s(y^P - q^P) \tag{10}$$

4 The IPAT identity (Commoner, 1972) represents a measurement of the environmental Impact; the original formulation is Impact = Population x Affluence x Technology where each component can measured by pollution, population, GDP per capita, and pollution per unit of GDP, respectively.

In the previous equation, q is the rate of growth of output per unit of emissions, which can be understood as the rate of growth of "green efficiency" in each economy. In turn, s is the share of total global emissions produced in the Periphery, making $(1-s)$ the share of the Core. h is the rate of growth of global emissions, now shown to depend on the evolution of technical change in each country.

The following Equationdescribes the rate of growth of green efficiency in the Periphery as depending on technological developments, social capabilities in the Periphery, and emissions exported by the Core:

$$q^P = f(G, w) - by^C, f_G > 0, f_w > 0, b > 0 \tag{11}$$

Following the Schumpeterian literature on the evolution of the technology gap, the higher the technology gap (G), the higher the potential for technological spillovers from the Core to the Periphery (for a discussion see Verspagen (1991). For this reason, the rate of growth of green efficiency q^P is positively associated with G. A large technology gap offers more opportunities for "catching up" based on the existing technology in the Core.[5] A small (green) technology gap indicates that the Periphery is already near the technological frontier; closing the technology gap at the margins become more difficult, and this is the reason why improvements in efficiency tends to slow down. In turn, w represents what Abramovitz (1986) calls "social capabilities" and the neo-Schumpeterian literature calls "absorption capabilities" (Narula, 2004), which refers to the ability of the Periphery to master, diffuse, improve and adapt foreign technology. The extent to which potential green technological spillovers become effective spillovers depends on these social capabilities. w depends on the strength and coordination of public and private institutions for green science and technology - the National System of Innovation (see Lundvall, 2007). A more detailed analysis of the evolution of green efficiency as it relates to the technology gap and social capabilities can be found in the mathematical A.

5 The concept of technological catching up was used in this chapter in the sense of the evolutionary Schumpeterian school. This school sees catching up as an opportunity to absorb more advanced technology through investments in R&D, indigenous capabilities and technological diffusion. In this sense it is different from the conventional use of this term in the convergence literature. If "catching up" systematically reproduces underdevelopment and environmental degradation vis-a-vis other regions, it cannot be globally sustained. Here, we discuss the ecological implications of "catching up" (e.g. global environmental catastrophe and growing inequality) and thereby undermine its value as an economic objective, without needing to engage directly in a debate about modernization or progress through growth. If income convergence (through the development of modern technology) is globally destructive, then "catching up" is undesirable. The vision is then a non-starter as economic policy and debate must then turn to what, specifically, is socially and ecologically desirable to grow, what must shrink, and where it should occur.

Finally, the term by^C is a measure of pollution transfers to the Periphery. Part of the pollution emissions of the Core is effectively offshored to the Periphery. Empirical data show that decoupling of domestic emissions and resource use from output growth has coincided with rising pollution- and resource-intensive production elsewhere (**hao_study_2019**; Jorgenson, 2012; Jorgenson, Austin, and Dick, 2009; Plank et al., 2018; Thombs, 2018). Including the pollution transfer term is therefore a necessary addition to capture the global "rebound effects" of decarbonization efforts (Wei and Liu, 2017). If technological developments translate into greater production of resource- and emissions-intensive goods abroad, then counting solely on efficiency improvements to resolve environmental crises is unwise. *The Core-Periphery Environmental Frontier (CPEF)* In order to achieve an absolute reduction in the level of emissions, the growth rate of emissions output must be negative. The pathway towards a zero-carbon economy begins with a negative-carbon-growth economy. Moreover, such a pathway must be achieved in the context of competing regions with divergent technological capabilities, institutional power, and resource availability. This section develops the modeling framework to consider situations that can bring the global economy within a declining carbon growth budget.

Assume that the level of emissions output (H) is required to fall at a rate e in order to prevent global temperatures from rising more than 1.5 °C above pre-industrial levels. Therefore, e is the environmental target rate of emissions decline consistent with the internationally agreed-upon maximum safe limit of emissions output. From Equation 6 it is possible to find all the combinations of output and emissions growth in the Core and Periphery that are consistent with this target (i.e. that makes $h = -e$). We call this a *Core-Periphery Environment Frontier (*CPEF*)*:

$$y^P = \frac{(s-1)y^C}{s} + \frac{(1-s)q^C - e}{s} + q^P, \text{ or} \tag{12}$$

$$y^P = \underbrace{\frac{(s-1)y^C}{s}}_{A} + \underbrace{\frac{q^C - e}{s}}_{B} - \underbrace{(q^C - q^P)}_{C} \tag{13}$$

Equation 13 considers the growth rate of the Periphery as a function of three components: the rate of growth of the Core (A), the rate of growth of green innovations (represented by the rate of growth of green efficiency in the Core) as compared to the rate of growth of green efficiency required to stabilize the planet (B), and the rate of growth of the green efficiency gap between Core and Periphery (C).

Technological innovations allowing for an increase in green efficiency q^C are assumed to be produced in the Core. To simplify notation, we also assume that all technical change is directed to improve q in the Core and Periphery; we therefore assume complementarity between green and standard innovation processes (Guarini, 2015; Johnstone, Labonne, and Thevenot, 2008; Mazzanti and Zoboli, 2008). Technical change in the Core grows at an exogenous rate. Both technical change and the growth of green efficiency in the Periphery, however, are endogenous to the model.

Note that the growth rates of the Core and Periphery ($y^{C,P}$) consistent with $h = -e$ must follow strict criteria. Growth rates can increase under the condition that (i) the growth of green efficiency $q^{C,P}$ is sufficiently large and increasing through time out of technical change, and (ii) the rate of growth of the "green technology gap" ($q^C - q^P$) is small. Transfers of emissions from Core to Periphery can improve q^C at the expense of q^P. From an analytical perspective, pollution transfers make the CPEF curve steeper and imply less growth in the Periphery for any rate of growth in the Core. In turn, a reduction in the technology gap or an improvement in the absorption of technology spillovers shifts the CPEF to the right, implying that the Periphery can grow at a higher rate without overstepping climate boundaries.

Efforts to maintain global climate goals and promote sustainable development will likely require an impressive level of coordination between the Core and Periphery. For the Periphery to grow at a higher rate without overshooting the global carbon budget, the Core's growth should not result in a transfer of pollution to the Periphery. In addition, if technical change does not reduce emissions levels fast enough, a second sustainable economic pathway for the global economy that allows for a growing Periphery would require a zero or negative growth condition for the Core, i.e $y^C \leqslant 0$.

A negative-growth-of emissions constraint likely entails a fall in trade such that the Core is no longer importing raw materials and pollution-intensive goods from the Periphery. This condition does not rule out the possibility for positive growth in the Core, as long as that growth is achieved without any increase in domestic emissions or offsetting emissions in the South. The possibilities of doing so are severely restricted.

Below we show how the addition of the environmental constraint (CPEF) can shed light on available scenarios for achieving a *globally* negative rate of pollution growth.

4.4 ENVIRONMENTAL COORDINATION GAMES: FOUR SCENARIOS FOR GLOBAL (UN)SUSTAINABILITY

The previous section has detailed the modeling framework to develop different scenarios for setting the global economy on a sustainable

pathway, defined as a negative rate of pollution growth. In what follows, we sketch an outline of four potential scenarios (with varying degrees of political likelihood) and their potential for achieving a sustainable outcome. First, "Global Unsustainability by Business-As-Usual" describes a situation in which no direct actions are taken to improve domestic or global sustainability. Second, "Local Sustainability by Accumulation" shows the potential effects of a "green growth" agenda in the industrial Core. Third, "Global Sustainability by Accommodation" depicts what may happen as a result of a strong degrowth policy in the Core to accommodate higher levels of output in the Periphery. Fourth, "Global Sustainability by Cooperation" shows how international cooperation to raise income growth in the Periphery and decrease growth in the Core could improve material well-being for the poorest. Scenarios calling for degrowth in the Core and positive growth in the Periphery require the addition of capital flows into our original model. To reduce confusion in the main text, we make the necessary changes and a brief discussion in Appendix A.3.

4.4.1 *Scenario 1: 'Global Unsustainability': Business-as-usual*

The first scenario describes the actual situation of the present global economy, shown in Figure 3. Here, both the Core and Periphery grow at different rates with respect to each other as shown by their respective curves, C and P. Moreover, both regions are growing in line with the global long-run balance of payments equilibrium (BP). However, Core-Periphery environmental frontier (CPEF) is well below equilibrium growth rate. This means that the growth rate of the world economy is out of sync with global sustainability. In the 'business-as-usual' scenario, there is no coordination and no "green" fiscal efforts from each country. Moreover, there are no automatic mechanisms which force global economic growth into the negative emissions growth territory. Business-as-usual therefore implies long run instability as climate change and other ecological crises worsen. It is necessary to turn towards public policy to stabilize the earth system.

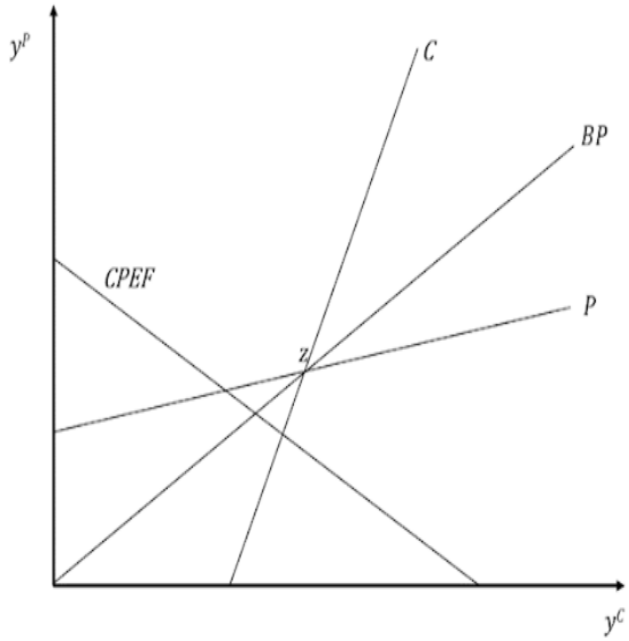

Figure 3: Scenario 1: 'Global Unsustainability'
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4.4.2 *Scenario 2: 'Local Sustainability by Accumulation': Green growth in the Core brings global unsustainability*

In this scenario we assume that the Core initiates a "green growth" strategy that successfully makes domestic emissions growth negative. Such strategies have already been explored in much of the existing literature in post-Keynesian ecological macroeconomics (see Svartzman, Dron, and Espagne, 2019). While approaching the subject in multiple different ways, these studies detail the negative impacts of climate change on output, income, employment and even inequality. Green Keynesian fiscal and monetary policies are put forth to counteract emissions growth and improve both environmental and social outcomes. However, such "win-win" solutions are not easily found. Domestic growth and technology-based policies are conducted in the absence of intervening measures, thereby resulting in a transfer of pollution to the Periphery and a continuation on a globally unsustainable path.

Seeking to improve domestic sustainability and environmental efficiency, the Core implements green fiscal and monetary measures to

6 In reality, the most likely result under a "Business-As-Usual" Scenario is that the rate of growth for the Periphery required by the CPEF is negative for any positive value of the rate of growth in the Core. For simplicity, we assume that the Core always attains a positive growth rate.

channel investments towards efficient technologies and raise its rate of growth, seen in Figure 4 as a move from C to C′. Green policy incentives allow the Core to set $y^C = y^C{}_e$, where $y^C{}_e$ is given by the equality $y^C{}_e = q^C - e \Rightarrow h^C = -e$.

With a higher rate of technical efficiency, the Core can now obtain a rate of growth, $y^C{}_e$ (on C′), consistent with a negative rate of emissions growth.[7] This implies that green investment policy in the Core effectively shifts production towards "decoupled", low-emission high-tech industries and services such that emissions growth domestically is negative, reflecting an instance of absolute decoupling of *domestic* emissions from GDP growth in the Core.

At the same, however, a higher rate of growth in the Core is matched by an increase in the growth of demand for resource- and pollution-intensive goods. The CPEF curve becomes steeper due to an increase in the pollution transmission mechanism (an increase of b). The new CPEF′ curve reflects that, while local production is more environmentally efficient, the Core's output expansion must be partially fed by an increase of imported goods and resources, extracted and processed in the less-efficient Periphery.

Figure 4 draws attention to this important caveat built into domestically oriented "green growth" policies.[8] Locally efficient growth in the Core has led to a rise in the scale and intensity of pollution-intensive production in the Periphery. Export demand in the Periphery therefore increases, raising its rate of growth. The P curve shifts upwards to P′, meeting the C′ curve at z'. However, z' is not on CPEF′. Emissions growth in the Periphery is not negative, and thus $y^P > q^P - e$. The decoupling strategy of the Core has produced a domestic drop in emissions that is balanced by an increase in the growth of emissions globally. There has been no absolute decoupling of emissions on a global scale; depending on the size of the transmission term, global emissions intensity may have increased.

Furthermore, the external-constrained equilibrium rate of growth in the Periphery is higher than the rate of growth required for achieving a decline in global emissions (point z'_e). With a steeper CPEF′ curve, it is now more difficult for the Periphery to remain in line with the global carbon budget for any rate of growth of the Core. Achieving global sustainability in this scenario would require a strong downward shift in the effective rate of growth in the Periphery to meet the CPEF′ curve at z'_e.

7 Note in Figure 4 that the C′ curve is now primarily determined by the desire to maintain the environmental target rate of growth $y^C{}_e$, and is thus a vertical line. While the Periphery's rate of growth depends on the growth of the Core, the Core no longer depends on growth in the Periphery.

8 We have abstracted from changes in the BP curve to keep the story simple.

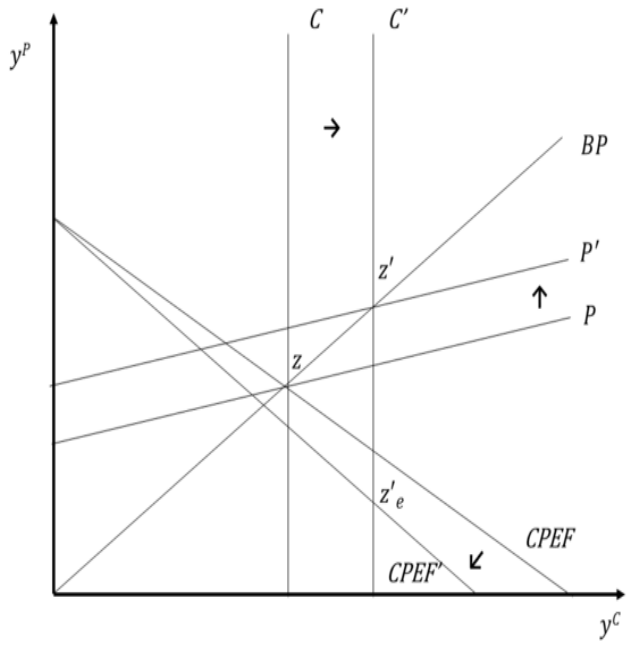

Figure 4: Scenario 2: 'Local Sustainability by Accumulation'

Scenario 2 demonstrates that global emissions may rise both *in spite of* and *because of* an emphasis on purely technological fixes to environmental problems. The Core's emissions are displaced spatially via the pollution transmission mechanism. The institutional and political economy requirements for achieving global sustainability are therefore more demanding than changing fiscal expenditure and/or implementing policies in support of technological innovation. Sustainability transitions must be contextualized for the ways that they redistribute social and ecological inequalities. If the Core wishes to focus on a growth-enhancing policies alone to improve efficiency, staying within the global carbon budget would require a major reduction in growth from the Periphery. Given that much of the population in the Periphery consumes an insufficient quantity of resources, and the Periphery is least responsible for accumulated environmental demands, such a situation is untenable. The following two scenarios present alternative pathways that can promote global sustainability, focusing in particular on redistribution and equality.

4.4.3 *Scenario 3: 'Global Sustainability by Accommodation': Degrowth in the Core accommodates weak growth in the Periphery*

The "Global Sustainability by Accommodation" scenario depicts a Core that takes responsibility for its share of global emissions production. The Core acknowledges that most of the stock of CO_2 in the atmosphere was accumulated over centuries during their own pro-

cess industrial economic growth (Roberts and Parks, 2009). Industrialized countries therefore make a concerted effort to reduce pollution-intensive consumption and investment. In this case, green fiscal and monetary policy would support strategic *divestments* from the most environmentally harmful industries, and would significantly reduce growth in the Core. Scenario 3 further assumes that the Core encourages a large-scale transfer of green technology to the Periphery, and a rise in Peripheral exports, to avoid a major fall in incomes in the Periphery. To take into account degrowth, as in scenarios 3 and 4, a BP line with an intercept is introduced: this new version entails a Balance of Payments with positive net capital flows, which we had avoided in previous scenarios for better analytical tractability. A formal explanation and derivation of the update is provided in the Appendix A.3.

Not only would low (zero) or negative growth in the Core reduce domestic emissions production, it could also provide the environmental "breathing room" necessary for the poor to increase material consumption. Such policies have been put forth as a necessary aspect of a global redistribution program to allow the world to remain within ecological limits (Daly, 1991; Jackson, 2009). Daly (1991, pg. 148) has argued that

> the underdeveloped countries are not ever going to develop [...] unless the overdeveloped countries moderate their demands on world resources and absorption capacities. [...] In addition, underdeveloped countries will have to revise their expectations downward regarding their own growth.

Indeed, widespread environmental degradation is already hindering many poor countries from developing the infrastructure and institutions necessary to meet even basic needs (Rice, 2007; Wackernagel et al., 2019). Dependence on resource extraction frequently results in declining environmental quality, as well as vicious cycles of poverty-induced environmental deterioration that can prolong and reinforce underdevelopment (Bunker, 1985). Without a degrowth policy in the Core, socially necessary consumption and investment in the Periphery will be increasingly impaired. A warming climate, erratic precipitation, rising pollution and resource extraction will also likely worsen domestic and international inequality (Gough, 2017). Since resource- and pollution-intensive demands from within the industrialized world tend to exacerbate environmental degradation and vulnerability in developing countries (Jorgenson, 2016), finding ways to reduce demand in the Core is also a matter of environmental justice (Martinez-Alier, 2012; Martínez-Alier, 2002; Schneider, Kallis, and Martinez-Alier, 2010).

Under a zero or negative growth condition, ($y^C \leqslant 0$), the Core economy is no longer growing and no additional emissions are exported

via pollutive imports. This approach would require a major restructuring of the Core's economy. The degrowth platform suite of policy options provide a useful guide to what would allow a country to reduce growth and emissions in a socially and economically sustainable manner (Kallis, 2011, 2017; Sekulova et al., 2013; Videira et al., 2014). While investments in efficiency increases and a national focus on low-impact sectors with high technological capabilities may remain an important aspect of the program, the Core will complement these by instituting policies in line with broader socioeconomic and environmental goals. Such investments would likely include major investments in public infrastructure and public or community provision of goods and services such as health, housing, education and transportation. A reduction in working hours (e.g., via a work-sharing program), alongside investment in projects for natural restoration and other public works with low or positive environmental impact (Forstater, 2006), could feasibly reduce unemployment and improve well-being. Nevertheless, degrowth would also require downsizing sectors that are particularly environmentally damaging, as well as an economy-wide negative rate of investment.

Figure 5 reflects a scenario in which the Core significantly reduces its rate of growth, seen here as shifting from C to C′. At the new rate of growth g^C has declined to make room for the Periphery to grow without overstepping the environmental frontier. The Core and Periphery agree on the need to reduce emissions and move from the environmentally unsustainable equilibrium in z to sustainable equilibrium in z'_e (which is both upon both the BP schedule and CPEF schedule; see Figure 5). The global economy moves towards the CPEF while at the same time "accommodating" rising emissions and material consumption in poor countries.[9]

9 For the sake of simplicity, in Figure 5 it is assumed that technical change has shifted the BP curve, but not yet the CPEF schedule.

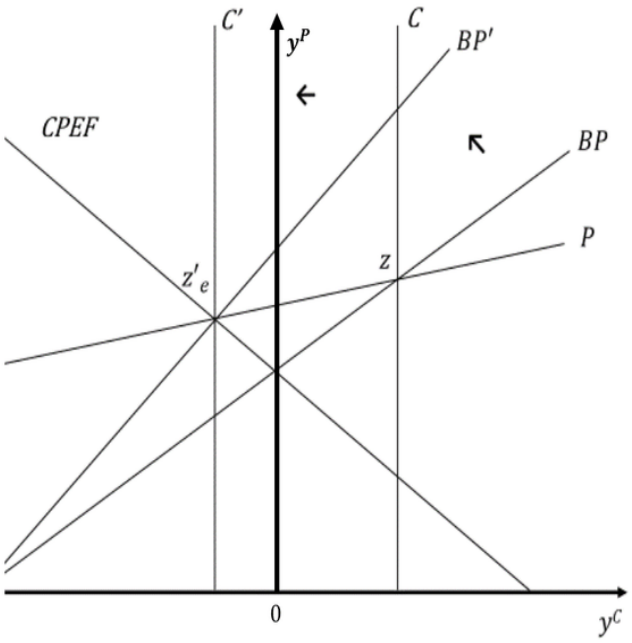

Figure 5: Scenario 3a: 'Global Sustainability by Accommodation'

However, the decline in growth in the Core would also necessarily shift the BP curve in a way that harms output in the Periphery. While much of the growth of the Core can be traced to socially and ecologically harmful production in the Periphery (Bonds and Downey, 2012; Downey, Bonds, and Clark, 2010; Srinivasan et al., 2008), it nonetheless represents a major source of economic demand and supports socioeconomic stability under existing institutional frameworks. A sudden and significant drop in demand from the Core would result in declining human welfare, higher unemployment and inequality in the Periphery if conducted in the absence of regional policy coordination and improved social policy implementation. Degrowth in the Core must also be considered in relation to its effects on the Periphery (Jackson, 2009, p. 175), a fact that is not frequently discussed in degrowth literature (Weiss and Cattaneo, 2017, p. 224).

To avoid an immediate and major contraction in Peripheral growth, two additional policies are required. First, policies in the Periphery that improve social (technological) learning capabilities can be adopted to speed up technological absorption and "catching up" with the Core. This shifts the BP curve out to BP′, which represents a more diversified production structure in the Periphery and a higher elasticity ratio of exports to imports. Second, the Core must also be ready to allow higher imports from the Periphery to keep external equilibrium at both Core and Periphery.

In Figure 5 we assume that this coordination is successful and income elasticities adjust to avoid a sudden fall in growth in the Periphery. Note that the new combination of rates of growth is given by

point z'_e. The P curve remains stable in this case, but the Periphery's rate of growth declines to be compatible with the lower rate of growth of the Core, the CPEF schedule, and external equilibrium (BP′).

The sequence of actions is as follows: the Core reduces its rate of growth; the Core facilitates exports from the Periphery in order to allow for some degree of convergence; the BP curve shifts to the left from BP to BP′; the Periphery grows at a lower rate than before (because it exports less to the Core).

As investment transitions towards meeting better local social and ecological needs, there may also be a large improvement in green efficiency in the Core that reduces (i) import needs from the Periphery, as well as (ii) pollution transmission. Technological upgrading in the Periphery may affect both the BP and the CPEF curves, as seen in Figure 6. In this case, the CPEF can experience a large change, as both terms in the pollution transmission mechanism change: $b'y^{C'}$, where $b' < b$; $y^{C'} < y^{C}$. The CPEF moves to CPEF′ which highlights that technological "catching up" in the Periphery raises competitiveness (and hence economic growth in equilibrium) and reduces the rate of growth of pollution at the same time.

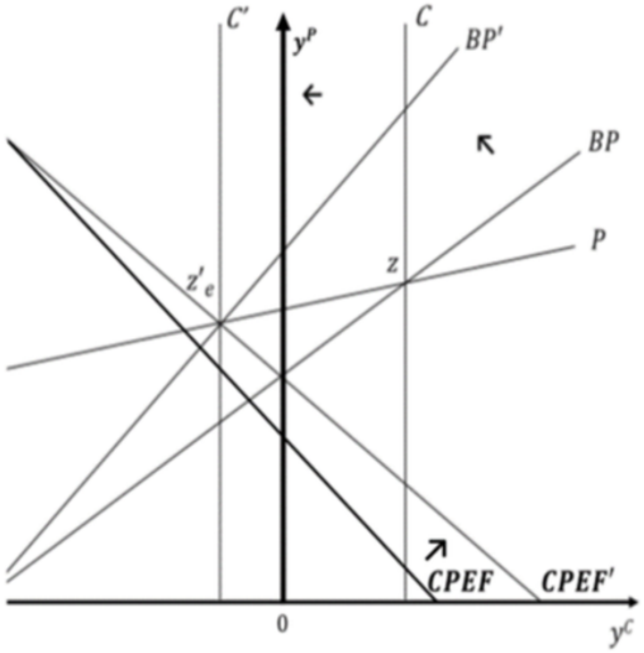

Figure 6: Scenario 3b: 'Global Sustainability by Accommodation' (with reduced pollution transmission)

Scenario 3 shows that global convergence and sustainability would require a serious transformation in global economic structure and considerable coordination between regions. Most of the change will likely come from the Core, whose negative growth rate leaves suffi-

cient environmental space for the Periphery to grow without overshooting ecological limits.

It should be noted that it would be unwise for Peripheral countries to simply follow in the same footsteps as the Core. Daly (1991) has warned that world-wide adoption of a Western-style high mass consumption economy would be an environmentally impossible and socially undesirable goal. Developing a technologically advanced, diversified economy, is a long and painstaking process that requires decades of investment in infrastructure, capital development, education and training, and immense volumes of materials and energy. Emerging Peripheral countries with technologically advanced export structures are presently repeating many of the same environmental mistakes as the Core, offloading environmental degradation onto poorer Peripheries (Meng et al., 2018). If pollution and resource extraction are simply transmitted from one country to another, absolute decoupling on a global level will remain elusive. Even with substantial support from an accommodating and cooperative Core, as in Scenarios 3 and 4, a global transition is likely to be socially and ecologically disruptive. Achieving global sustainability will require a perhaps impossible feat: As growth decelerates in the Core, the Periphery must establish a low-emissions, high-value export structure in an incredibly short time. Successfully reconciling rising effective demand against growing emissions - locally or globally - required for increased production represents a considerable challenge.

4.4.4 *Scenario 4: 'Global Sustainability by Cooperation': Degrowth in the Core Permits Green Growth in the Periphery*

The "Sustainability by Cooperation" scenario, much like in the previous section, requires a major reduction in growth from the Core to support continued growth in the Periphery. However, in this case global cooperation is key. The Core finds ways to reduce growth sufficiently to allow the Periphery ample room to initiate its own "green" industrial change and investment program (Altenburg and Assmann, 2017). Not only does the growth rate in the Periphery rise, but the global green efficiency gap closes ($q^C - q^P < 0$), as the Periphery catches up in technology.

Serious efforts from the Core to share technology and help the Periphery to build endogenous capabilities, combined with other social policies, allow global efficiency to increase alongside improvements in material conditions for the Periphery. This is the most cooperative possible move by both countries, and would likely result in the quickest and fairest policy for reducing emissions growth while improving livelihoods, within our framework. This scenario highlights

the benefits of cooperation between the Core and Periphery to both accommodate growth where it is needed while also quickly raising technical standards to meet climate targets.

As shown in Figure 7, a reduction in growth from the Core, mixed with a focus on social and environmental policies that include green economic restructuring in the Periphery, result in a leftward shift of C to C′, and an upward shift of P to P′. Differentiated responsibilities imply that the Core will not use its technological capabilities to maximize advantages in trade, but to encourage international technological diffusion (see A). The Periphery, in turn, invests heavily in building endogenous learning capabilities (including institutional capabilities) to absorb this technology. The increase in global efficiency shifts the CPEF schedule upwards to the right (from CPEF to CPEF′).

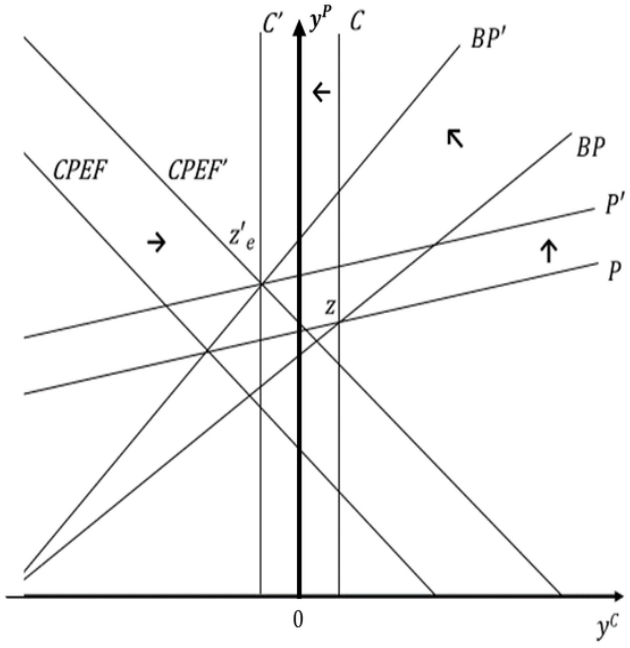

Figure 7: Scenario 4: 'Global Sustainability by Cooperation'

In the process, it is likely that (at least temporarily) the income elasticity of imports in the Periphery increases as new technology is imported, which moves the BP schedule to the right. Regardless, the result of this internationally coordinated strategy are improved socioeconomic performance, greater material well-being for the poorest countries, and global sustainability.

From the graph in Figure 7 it is evident that a massive shift of the CPEF to the right could feasibly alleviate the economic "sacrifice" of degrowth. A positive or (low) growth rate in the Core could then be environmentally sustainable and appropriate for the economic aspirations of the Periphery. While this situation is theoretically practicable from the political point of view, its technological feasibility is severely

limited, as we have shown. Indeed, our analysis emphasizes the trade-offs and the inextricable relationships between the economic, technological, political and environmental dimensions of sustainability in the context of a global economy.

4.5 SUMMARY AND CONCLUSIONS

This chapter has explored four possible scenarios for global climate mitigation in an "environmental coordination game": global unsustainability; local sustainability; global sustainability with negative growth in the Core and reduced growth in the Periphery; and global sustainability with negative growth for the Core and a green growth-stimulus for the Periphery. By modeling the possibilities for coordination in an environmentally-constrained Core-Periphery system, we highlighted several important challenges and opportunities for a truly global response to the present environmental crisis. The environmental coordination game presented here demonstrates interesting political economy differences with the traditional Keynesian coordination game. In the Keynesian game, all actors gain from an expansion of aggregate demand and the pursuit of higher levels of employment and capital utilization in the economy. In the environmental game, gains and losses depend on interrelated technological, social and ecological dimensions.

The present work has also extended and deepened the "shallow" lens of ecological macroeconomics in four important ways (Spash, 2013; Svartzman, Dron, and Espagne, 2019). First, we have highlighted the inseparability of socioeconomic and environmental conditions between regions, presenting the economy as a world ecological system, "in which one country's environmental problems may be the flip side of another country's growth." (Hornborg, 2003, pg. 215). Second, we have reconsidered the role of green investments from within the post-Keynesian framework, by questioning their sustainability-enhancing properties at the global scale. Technological progress is largely contingent on relations of unequal exchange between regions. Successful climate mitigation and adaptation efforts will need to better understand how technical changes distribute environmental risks and rewards unevenly between different regions and social groups. Third, we introduced degrowth as a viable, and perhaps necessary alternative or complement to "green growth" policies. Nonetheless, degrowth in the Core has important implications for the Periphery, and must be balanced with growth-enhancing policies to avoid a negative income shock in Peripheral countries. Finally, we stressed a third dimension that has been underserved by previous research in the ecological macroeconomic framework: environmental justice. The proposed scenarios aimed to capture two key dimensions in environmental justice: the right of future generations to inhabit a stable and healthy planet,

and the right of those presently left behind to improve their material well-being. The desire to enhance global equality while restraining pollution presents a major challenge of redistribution both between and within countries (Laurent, 2014; Roberts and Parks, 2009).

Our analytical framework has allowed us to discuss different scenarios of economic growth and emissions production with instructive clarity, through with some limitations. While we could successfully illustrate the unequal distribution of emissions, the model cannot be used to show long-run trends in growth or degrowth, the geopolitical changes that would result from a re-localization of production, or the complex environmental damages that would shape production possibilities as climate change (and sources of degradation) intensify.

Scenarios calling for more growth in the Periphery, for example, can only be transitory. Otherwise, the Periphery would simply replace the Core as the environmentally harmful engine of the world. Similarly, planned degrowth is only a temporary part of the ecological transition and obviously cannot be sustained *ad infinitum*.

Furthermore, since the Peripheral economies are significantly more vulnerable to environmental risks, we could not show the difficulty of finding successful adaptation pathways in the present crisis. At high enough levels of greenhouse gas content in the atmosphere, there may be no means for many Peripheral countries to successfully grow their material well-being (Steffen et al., 2018; Wackernagel et al., 2019) due to irreversible damages to land and food production, widespread water scarcity, intensified disease vectors, frequent storms etc.

Future researchers may wish to analyze the effects of a large reduction in trade (e.g., "Global Sustainability by Relocalization") in both the Core and Periphery. In theory, this would be the strongest move towards global sustainability (Cobb and Daly, 1990), especially if paired with local development efforts to build resilient communities on the principle of environmental sovereignty and democratic accountability (Fischer, 2017). The institutional changes required to achieve such a scenario, however, are far outside the purview of the present modeling framework.

Achieving a sustainable economic pathway under present economic and environmental constraints implies a difficult road ahead for the global community. Many of the institutional changes necessary for achieving social and environmental sustainability are daunting. Political and economic control rests firmly in the hands of rent-seeking elites whose power will not be easily wrested, especially in the Periphery. Even attempts at improving basic social protections face enormous political opposition, let alone policies that would significantly reduce corporate profits, such as liberating patents for international knowledge sharing.

Moving forward, it will be increasingly necessary to account for the ways in which well-meaning economic and environmental policies

can exacerbate the vulnerabilities of less advantaged groups across geographic space and time (e.g. future generations). Strategies for raising living standards and sustainability often have unseen or unacknowledged negative consequences (Bonds and Downey, 2012; Hickel, 2019). If efficiency improvements merely alter the location, scale and intensity of environmental pressures (Bonds and Downey, 2012; Bunker, 1985; Bunker and Ciccantell, 2005), investment policy alone cannot be counted on to resolve ecological conflicts and crises. On a shared and increasingly fragile planet, ecological macroeconomics must make a decisive turn towards identifying other means of securing sustainability and well-being outside of GDP growth.

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5

BRINGING SUBORDINATED FINANCIALIZATION DOWN TO EARTH: THE POLITICAL ECOLOGY OF FINANCE-DOMINATED CAPITALISM

It is possible to get out of a trap.
However, in order to break out of a prison,
one first must confess to being in a prison.

— Wilhelm Reich

Take the biggest guy in the world,
shatter his knee and he'll drop like a stone.

— Dalton, *Roadhouse*

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While financial and economic activities are measured in abstract monetary flows, political ecologists, ecological economists and geographers have long shown that social systems of production, exchange, and credit coevolve with ways of accounting, transforming, and directing *physical* flows of energy and materials (Georgescu-Roegen, 1971; Gowdy and Erickson, 2005; Martínez-Alier et al., 2010). Despite growing awareness of these biophysical foundations of the economy in several strands of heterodox economics – most notably in the emerging field of ecological macroeconomics (Althouse, Guarini, and Porcile, 2020; Svartzman, Dron, and Espagne, 2019) – nature is still too often introduced as an "optional extra, an area for specialists, outside the central concerns of the profession rather than of fundamental importance to understanding economic systems, their organization, operation and reproduction" (Spash and Smith, 2019, p. 215). The same limitation applies to understanding the global economy. As Hornborg (2006) argues, the task of reconnecting the patterns of the world-system (e.g. uneven development) and those of the Earth System (e.g. climate change) is still in the early stages. It is therefore necessary to develop a coherent analytical framework to appreciate how socioeconomic and socio-ecological phenomena coevolve (Cahen-Fourot and Magalhães, 2020).

This chapter builds on attempts aimed at connecting studies of the world-system and the Earth System by investigating the biophysical underpinnings of financialization. The financialization of the economic system generally refers to the increased importance of financial activities beginning in the late 1970s and early 1980s (Sawyer, 2013). The growing penetration of finance into all manner of corporate (e.g. Krippner, 2005), economic (e.g. Stockhammer, 2004), social (e.g. Lapavitsas, 2013) and environmental (e.g. Kemp-Benedict and Kartha, 2019) life is often described as a process in which capital owners and the financial sector wield increasingly predatory power over the 'real' economy (Bezemer and Hudson, 2016). The supposed 'detachment' of finance from the economy is then assessed as having contributed to a decline in wages, investments and economic growth (Krippner, 2005; Mazzucato, 2013; Stockhammer, 2004).

We contribute to growing efforts aimed at re-contextualising these claims by moving beyond the view of financialization as an outside, immaterial force acting upon economic, social and ecological life. Bridging two currently unconnected streams of research - both of which highlight the uneven structure of Core-Periphery[1] relations in the

1 Following World-systems and dependency theories (Wallerstein, 1974), we use the term "Core" to refer to countries that are often called "advanced" or "developed" economies. We use the term "Periphery" to refer to countries that are often called "developing" or "emerging" economies. This choice emphasizes the relational interdependence between regions in the global economy and avoids perpetuating a linear vision of socioeconomic progress and development through economic growth. We nevertheless approach the Core-Periphery relation through an evolutionary and

dynamics of capitalism - we argue that financialized capitalism has developed through profound changes in socio-ecological relations. Rather than a growing 'detachment' from the 'real' economy, the rise of finance is part of an evolving institutional dynamic which organizes, transforms and distributes nature to enhance capital accumulation in the Core (see Moore, 2015; Ouma, Johnson, and Bigger, 2018).

The first stream, "subordinated financialization" (Bonizzi, Kaltenbrunner, and Powell, 2020; Bortz and Kaltenbrunner, 2018; Kaltenbrunner and Painceira, 2018), argues that present financialization scholarship, by focusing primarily on the financialization of Core capitalist economies and on nation-states as the main unit of analysis, largely sidesteps the global strategies of accumulation for financial and non-financial firms, as well as the ways that different regions are organized and integrated within the structural dynamics of global capitalism. In particular, the international financial integration of the past decades has contributed to the financial and socioeconomic subordination of Peripheral economies to the industrial Core (Bortz and Kaltenbrunner, 2018), generating new forms of external vulnerability that constrain domestic policy autonomy, heighten instability (Kaltenbrunner and Painceira, 2015; Ocampo, 2009), and reinforce their inferior position within global production networks (Bonizzi, Kaltenbrunner, and Powell, 2020).

The second approach, which builds on recent insights from scholars in disciplines such as political ecology and geography, highlights the rise and reproduction of finance-dominated capitalism as a spatially uneven phenomenon (Christophers, 2012; French, Leyshon, and Wainwright, 2011) with profound implications for the way resources are used and socio-ecological vulnerabilities are distributed (Moore, 2011). In particular, the financialization of non-financial corporations and the internationalization of financial flows have enabled Core economies to benefit from a situation of "ecologically-unequal exchange" (Bunker and Ciccantell, 2005b; Frey, 2019): Peripheral countries tend to be driven to export more energy and materials than they import, thereby providing Core economies with cheap resources. They then suffer the bulk of the social and ecological consequences from specializing in low value-added, extractive and polluting sectors.

By merging these two perspectives, this paper proposes the theoretical beginnings of what may be called a "political ecology of financialized capitalism". Finance-dominated capitalism appears to be supported by three interlocking patterns of Peripheral subordination: (1) a currency hierarchy which structurally reinforces the Periphery's financial dependence on the Core; (2) a hierarchy of production, developed through disaggregated global commodity chains, which concentrates low value-added sectors in the Periphery; and

context-specific lens (see Kvangraven, 2021) rather than a static, one-size-fits-all framework.

(3) an ecological hierarchy, constituted by the expansion and intensification of resource- and pollution-intensive activities towards Peripheral frontiers of commodity extraction ("commodity frontiers" (Moore, 2000)). These three patterns can be summarized through the "financialization-offshoring-commodity frontier" nexus described in this paper, a self-reinforcing institutional framework which serves financial accumulation in the Core by reorganizing and intensifying human-nature relations across the world-system.

This paper therefore contributes to the literature on subordinated financialization by providing evidence that these three seemingly disparate hierarchical patterns can be understood as mutually reinforcing and interdependent. While previous studies of subordinated financialization have reconnected the financial and productive spheres, this, to the authors' knowledge, is the first elaboration of subordinated financialization as a process evolving through uneven environmental relations. In doing so, we distinguish financialization as a fundamentally global and necessarily 'grounded', material phenomenon.

This novel theoretical framework will require further empirical work (although it largely builds upon empirical studies) but carries critical insights for policy recommendations. In particular, it suggests unaddressed blindspots and serious limitations to 'progressive' economic agendas that aim to 'definancialize' global economic relations to promote 'green' productive investments and achieve more just and sustainable outcomes. Indeed, insofar as financial, productive and ecological patterns are interdependent and benefit capital accumulation in Core countries, it seems that safeguarding opportunities for shared prosperity and planetary health requires a major overhaul of the international monetary and financial system, alongside significant deaccumulation (degrowth) in the Core to reduce the structural drive towards environmental degradation, particularly in the Periphery.[2]

The paper is structured as follows: in the following section 5.1, we highlight the literature on subordinated financialization, which links uneven development and new forms of external vulnerability in the Periphery to the hierarchy of currencies and the hierarchy of production. This allows us to emphasize the link between financialization and 'real' global value production through the so-called "financialization-offshoring" nexus. Section 5.2 then shows how financialization has reinforced a hierarchy of environmental transformation. We describe how offshoring has both enabled and relied upon the continuous outflow of inexpensive resources to the Core - the "commodity frontier-offshoring" nexus - and how financialization

2 This does not suggest that individual countries have no agency to successfully definancialize and reduce environmental impacts while raising their position within global value hierarchies. However, it does suggest that there are significant obstacles to doing so, and that proposals for a "Global Green New Deal" (UNCTAD, 2019a) must better account for interdependent socio-ecological patterns on a global scale, if they wish to be effective.

has expanded and intensified extractive potential in the Periphery - the "financialization-commodity frontier" nexus. In section 5.3, we suggest that the possibilities for both global environmental and economic sustainability under financialization are deeply circumscribed, and offer potential solutions. Finally, section 5.4 summarizes and concludes, stressing the need to bridge socioeconomic studies of the world-system with natural studies of the Earth system to better envision equitable socio-ecological futures.

5.1 SUBORDINATED FINANCIALIZATION: THE GLOBAL MONETARY AND PRODUCTIVE DIMENSIONS OF FINANCE-DOMINATED CAPITALISM

The term "financialization" includes a broad range of approaches and definitions (e.g. Lapavitsas, 2013; Zwan, 2014). Regardless of the framework used, studies have tended to assess financialized capitalism as a process in which the financial sector wields increasingly predatory power over the 'real' economy, the state, and individuals, i.e. as a "pattern of accumulation in which profits accrue primarily through financial channels rather than through trade and commodity production" (Krippner, 2005, p. 174). Regarding non-financial corporations in particular, the growing power acquired by shareholders and managers (at the expense of workers) is seen as having privileged stock buybacks and dividend redistribution over reinvesting profits to expand production (Mazzucato, 2013; Stockhammer, 2004). From this perspective, persistent low wages and weak investment demand under financialized capitalism would largely explain the lower rates of economic growth achieved over the past decades in Core countries, as well as the rise of debt-financed and wealth-based consumption which would have partially compensated for declining economic growth while fueling new speculative bubbles (Stockhammer and Wildauer, 2016; Tridico, 2012).

This literature has been invaluable in illuminating important social and economic aspects of finance-dominated capitalism. However, by focusing primarily on the financialization of Core economies and on individual nation-states as the main unit of analysis, it risks drawing incomplete conclusions about the causes, features and implications of financialization. By tending to "fetishise the national scale" (Christophers, 2012, p. 272), most framings of financialization provide an "anemic" understanding of financialization, ignoring the geographic reach and systemic needs of global capitalism (French, Leyshon, and Wainwright, 2011, see also).

This blind spot has been recently addressed through the perspective of "subordinated financialization" (Bonizzi, Kaltenbrunner, and Powell, 2020; Kaltenbrunner and Painceira, 2018). This emerging literature seeks to understand how financial globalization in Core coun-

tries creates new forms of external vulnerability in Peripheral economies (Kaltenbrunner and Painceira, 2015) and constrains their monetary and fiscal policy autonomy, as financial investors exert increasing influence over the conditions of integration and stability within global markets.

5.1.1 *Financialized subordination and the hierarchy of currencies*

The Periphery's subordinated position within finance-dominated capitalism is primarily structured by the existing hierarchy of currencies. The international monetary system privileges the stability of some currencies over others, with different levels of trust attributed to each national currency (Angrick, 2018; Palludeto and Abouchedid, 2016). These levels of trust can be measured through the liquidity of national currencies, which corresponds to the willingness of all agents in the system to hold those currencies and accept them as payment (Paula, Fritz, and Prates, 2017). The US dollar stands at the top of the currency hierarchy: it has the highest degree of liquidity because it is the unit of account used in most international trade and the most demanded as a store of value.

The currencies issued by most Peripheral economies stand at the bottom of this hierarchy: these are non-liquid currencies, meaning that investors are less willing to hold them unless they are paid a risk premium (Paula, Fritz, and Prates, 2017). As a result – and in contrast to Core economies that do not face foreign exchange constraints – political and economic autonomy in Peripheral countries is structurally constrained (Ocampo, 2009). These countries are often unable to borrow in their domestic currency or attract long-term foreign finance to pursue their own development agenda[3], due to the limits imposed on their balance-of-payments by international markets and institutions (Rochon et al., 2003). Peripheral countries typically need to offer higher interest rates if they are to retain investor demand (Kaltenbrunner and Painceira, 2018), which increases borrowing costs relative to the Core, and impedes long-run development planning.

The financial globalization of the past decades – including a sharp increase in cross-border capital flows – has reinforced the subordination of Peripheral economies to the actions taken in the Core. For instance, high interest rates make Peripheral countries' currencies prime targets for unstable carry trade operations and entice firms to borrow in foreign currencies. This exposes Peripheries to greater exchange rate volatility, indebtedness and constrains political and economic autonomy. Peripheral economies have also become more

3 Some exceptions exist, most notably China in recent years. China's recent 'success', however, should nevertheless be understood through historical contingencies (e.g. Weber, 2021) that have precisely enabled it to escape the constraints imposed by the 'Core' upon the vast majority of Peripheral countries.

vulnerable to short-term speculative actions, as any change in international liquidity preference can cause a dramatic outflow of capital to the currency offering a higher premium (Bortz and Kaltenbrunner, 2018). Such vulnerabilities can partially be managed, but only at the cost of strong interventions in foreign exchange markets that imply a loss of monetary and financial policy autonomy (Paula, Fritz, and Prates, 2017). In short, the threat of sudden capital outflows and the ensuing balance-of-payment or currency crises imposes an ever-present "survival constraint" (Angrick, 2018), meaning that they are in constant need of net liquidity inflows to avoid growing indebtedness in foreign-denominated currencies.

To relieve these pressures, Peripheral countries are generally led to develop short-term export-led strategies for products with low added value and remain unable to develop long-term industrial strategies focused on high value-added production (Vernengo, 2006). The short-term export-led development model places Peripheral states in direct competition to capture a share of the limited import demand from Core countries. This pressures Peripheries to offer incentives (e.g. tax breaks, wage suppression, and low labor and environmental regulations) to attract investors, which limit the potential socioeconomic benefits of foreign investment. The reduced costs of production and investment in Peripheries then enhance firm profits and sustains consumer demand in the Core.

In short, the currency hierarchy plays an important role in limiting the economic and political autonomy of the Periphery and exacerbating their financial fragility relative to the Core. International financialization appears to reinforce this subordinate relationship both financially and in terms of their capacity to produce and capture value flows (Bortz and Kaltenbrunner, 2018).

5.1.2 *Financialized subordination and the hierarchy of production: the "financialization-offshoring" nexus*

A key dimension of this close relationship between currency hierarchy, financialization and productive structures at the global scale can be observed empirically through what some authors have coined the "financialization-offshoring" nexus (Auvray and Rabinovich, 2019; Milberg, 2008; Milberg and Winkler, 2010), the first of the three nexus explored in this paper. Over the past four decades, non-financial firms have increasingly profited from offshoring (and outsourcing) to Peripheries by disaggregating value-added production through global value chains (GVCs). GVCs have restructured the distribution of power within production networks and fundamentally altered the geography of value creation and capture. As such, GVCs express a deepening of hierarchical value-added relations within the 'real' sphere of production.

Through GVCs, Core firms have been able to restore falling profit rates by securing monopoly position through the control of intellectual property and by concentrating on high-value capacities, like branding and R&D (see Durand and Milberg, 2020). Lead firms have therefore gained immense power to earn profits by setting production standards and by offsetting many of the risks and uncertainties associated with production to distant suppliers (Rikap, 2018). While this has benefited lead firms and their 'skilled' workers in Core regions, Peripheral areas tend to be reduced to specializing in low-value input assembly with little potential spillover for generative industries and employment (Carballa Smichowski, Durand, and Knauss, 2021; Selwyn, 2019). As investment in inputs, plants, equipment and personnel have shifted to cheaper sites, profits rose alongside stagnating wages and divestment in the Core. Lead firms in the financial era have therefore become "awash in cash" (Milberg, 2008, p. 435) by remaking the geography of production and intensifying their capacities for value capture.

The "financialization-offshoring" nexus arises at the intersection of the hierarchy of currencies and the hierarchy of production. First, the Core's position within the global monetary and financial hierarchies provides them with the ability to claim a disproportionate share of the world's output (Schwartz, 2019b). Core countries, particularly the US, can cheaply generate globally demanded assets that they issue in their own currency. These are then exchanged for goods and services produced elsewhere. The Core can therefore also wield the financial capital needed to support domestic production, develop new industries by channeling funds into R&D for new technologies and products, or bail out struggling firms. Firm profits can then be further invested at home or abroad to chase high-yielding assets across borders, again raising profitability in the Core (see Winecoff, 2020).

Second, because the US and other Core countries (e.g. UK, Canada, France, Australia) are able to run persistent trade deficits, they drive global demand for GVC production, sustaining firm profitability and domestic asset values, while also strengthening the position of their currencies (Schwartz, 2019a).[4] This has been key to supporting the financialized growth regime. For example, by importing high volumes of inexpensive consumer goods from abroad, Core countries could sustain (increasingly debt-financed) consumer demand, despite decades of stagnant wages. Moreover, by validating export-led growth in the Periphery, the Core's deficits render lead firms' GVC strategies increasingly profitable. Part of these accumulated profits are then 'recycled' in the Core to purchase financial and 'real' assets (e.g. sovereign bonds, real estate) denominated in the currency of Core

4 Some Core countries run trade surpluses (e.g. Germany, Japan) because of their high position within the production hierarchy and GVCs. The Core is nonetheless distinguished by its general ability to run persistent trade deficits and accumulate foreign indebtedness without facing financing issues or borrowing in foreign currency.

countries (Milberg, 2008). Indeed, the combination of persistent US current account deficits and rising GVC profitability appears to have played an important role in inflating asset values, while strengthening the infrastructural power of Core currencies, particularly the US dollar (Schwartz, 2019b).

By contrast, the Periphery's low position on the currency hierarchy prefigures their subordinated insertion within global production and further enhances the infrastructural power of the dollar (Palludeto and Abouchedid, 2016). Since most borrowing, lending and cross-border transactions take place using the Cores' currencies, Peripheral countries are hard-pressed to maintain continuous inflows of 'hard' currency (Angrick, 2018). Peripheral countries must therefore compete for a limited share of external demand from the Core, often by providing low-tax, low-wage, low-regulation business environments to attract dollar investment. This provides immense leverage for lead firms to enhance GVC profitability, offering the choice of a potentially large number of low-cost, 'disciplined' host countries and suppliers (Malm, 2012). Moreover, as Peripheries have become increasingly export-oriented, they continuously recycle dollars through their domestic banking systems and back into the global economy. This consolidates the habitual use of dollars domestically, increasing dependence on the monetary policy of Core countries, and supporting assets denominated in Core currencies (Schwartz, 2019a).

Hence, contrary to arguments that financialization took place at the expense of production (e.g. Krippner, 2005; Mazzucato, 2013), it appears that finance-dominated capitalism is at least partially predicated on new geographic arrangements of global commodity production and value capture (Auvray and Rabinovich, 2019). Firms in Core countries rely on production and rents in the Periphery while recycling profits in Core countries, the latter having strongly contributed to financialization. In other words, current financialization scholarship must account for the global strategies of financial and non-financial firms, as well as the ways that different regions are organized and integrated within the structural dynamics of global capitalism (Bonizzi, Kaltenbrunner, and Powell, 2020; French, Leyshon, and Wainwright, 2011).

5.2 ACCOUNTING FOR THE ECOLOGICAL DIMENSIONS OF SUBORDINATED FINANCIALIZATION: THE HIERARCHY OF ENVIRONMENTAL TRANSFORMATION

The claims made so far have shown that financialization is better understood as a global phenomenon, with close connections to the international currency hierarchy and to the shifting geography of hierarchical production structures. This analysis, however, does not account for how the financialization of capitalism unfolds through profound

and uneven environmental transformations, and depends on the mobilization of vast quantities of energy and materials.[5]

Scholars in fields such as political ecology, ecological economics and geography, have aimed to ground the understanding of economic dynamics within the biophysical flows that enable and shape social evolution. Moore (2015), for example, proposes the concept of "world-ecology" to assess the different waves of capitalist hegemony over five centuries through their ecological components. This literature highlights that the drive towards accumulation creates immense pressure to sustain access to resources and labor at low-cost. Global financial, monetary and productive structures have therefore evolved through successive waves of geographic expansion and restructuring to establish new "commodity frontiers" (Moore, 2000): zones of resource extraction, most often located in Peripheral countries, that provide new sources of "cheap" energy, materials and labor. The development of new technologies, organizational, legal and physical infrastructures, and financial schemes have therefore been instrumental to intensify extractive efforts and "cheapen" environments (Bunker and Ciccantell, 2005a; Patnaik and Patnaik, 2017, see also).[6]

Similarly, Hornborg (2006) calls for a more unified theory of the Earth system and the world-system, emphasizing how financial, monetary and productive power is built by the asymmetric access to natural resources around the globe. Indeed, a large literature describes how Core-Periphery relations are constituted through a pattern of "ecologically-unequal exchange", whereby Peripheral regions are structurally led to export more "embodied nature" (extracted energy and matter) than they import (Frey, 2019). Low-income countries specialize in the beginning stages of value-added production, which tend to be in the most extractive and pollutive industries. The ecological degradation associated with these sectors has been shown to severely limit the consumption and development potential of Peripheries (Rice, 2007) while generating intense socio-ecological conflicts (Martínez-Alier et al., 2010).

Meanwhile, Core countries consume the vast majority of the world's resources and capture the final stages of value-added production, par-

5 Some scholars have aimed to describe how financialized power and practices are so pervasive that they have extended to the realm of ecological 'assets' through what is considered the "financialization of nature" (Kemp-Benedict and Kartha, 2019; Ouma, 2014). Nonetheless, they tend to depict the environment as a passive agent, increasingly being enveloped within the fast-growing financial realm. By contrast, this paper focuses on how financialization is a particular way of organizing nature and society.

6 Market-oriented regulatory restructuring, the development of new financial techniques, relaxed environmental and labor regulations, as well as major investments in infrastructures for resource extraction and transport have all been important steps to expand extractive potential. Commodity frontiers themselves are established through a process of "accumulation by dispossession" (Harvey, 2003) whereby publicly owned or communally managed spaces are converted through acts of enclosure, privatization and exclusion.

ticularly through monopoly ownership of intangible property (Piñero et al., 2019). The Core is thereby able to preserve domestic environmental quality by using its share of global purchasing power to appropriate foreign lands and labor. Empirical evidence for this global ecological hierarchy at the root of international trade is overwhelming (Frey, 2019). Dorninger et al. (2021), for example, found that between 1990 and 2015, every region outside of a small group of high-income countries were net exporters of raw materials, and the value-added per ton of exports was eleven times greater in high-income countries than in those with the lowest income.

In fact, the systematic transfer of resources and energy from the Periphery to the Core appears to be an ever-present component of all regimes of accumulation (Bunker and Ciccantell, 2005a). According to Arrighi (1994, p. 34) capital accumulation in the Genovese, Dutch, British and American empires could continue only to "the extent of their command over scarce resources" such that territorial control became "a means and a by-product of the accumulation of capital". For instance, British industrialization would have been impossible without expanding into new frontiers to find cheap resources like cotton, iron and cereal, alongside imported slave labor from the colonies (Hornborg, 2006; Moore, 2011). In the same manner, the economic expansion in the U.S. and Europe during the Fordist-Keynesian "Golden Age" was enabled not solely by collective wage negotiations and a prominent welfare state – as covered by many scholars – but also by the extraction of diverse natural resources, most notably oil, from the "resource veins of the colonial and semi-colonial worlds" (Moore, 2015, p. 69).

In this respect, a critical perspective of this paper is to note that the transition from the 'Fordist-Keynesian' regime that dominated in the post-WWII era to the 1970s financialized regime of accumulation, is also marked by new strategies to guarantee the asymmetric transfer of resources and the expansion of commodity frontiers to support growing demands for materials, energy and labor (Ouma, Johnson, and Bigger, 2018; Svartzman and Althouse, 2020). A comprehensive account of financial subordination as an emergent means of organizing nature, however, has not yet been offered, despite budding works on the interactions between ecological and socioeconomic patterns in the era of financialized capitalism (Cahen-Fourot, 2020; Cahen-Fourot and Durand, 2016; Cahen-Fourot and Magalhães, 2020).

The rest of this paper aims to overcome this lacuna by recontextualising the financialized capitalism within a "world-ecological system" (Hornborg, 2006). In particular, we argue that the monetary and productive hierarchies at the base of financial accumulation are biophysically rooted: subordinated financialization is both a means of (and is permitted by) continuously expanding resource extraction and intensifying environmental transformation in the Periphery. Our con-

cern is therefore not to assess how financialization generates environmental problems, but rather to unveil a political ecology of finance-dominated capitalism.

To show more fully how financial patterns and processes are constructed through massive transformations of the natural environment, we describe the "financialization-offshoring" nexus as contingent on two ecologically-grounded nexus: a "commodity frontier-offshoring" nexus and a "financialization-commodity frontier" nexus.

5.2.1 *The "commodity frontier-offshoring nexus"*

The geographic expansion of production through GVCs described in the "financialization-offshoring" nexus is not only a fundamental pillar in the hierarchy of production and the hierarchy of currencies, but also the hierarchical ordering of environments. In the second of our three nexus, the "commodity frontier-offshoring" nexus describes a profound reorganization of ecological patterns at the heart of finance-dominated value relations. The financial subordination of the Periphery relies on and enables the uneven capture, transformation, and transport of raw materials and labor.

The spatial disaggregation of production through offshoring and outsourcing along global value chains has only accelerated dominant patterns of environmental transformation and the expansion towards new territories where resources can be cheaply extracted (Ciccantell, 2019). At their base, GVCs are an institutionalized process for coordinating the transformation of material and energy over time and space. This physical determinacy influences the direction of socio-ecological relations and the geography of value appropriation. The push for material control therefore plays a crucial role in the evolution of firm power, and is a primary element in geopolitical cooperation and conflict (Bunker and Ciccantell, 2005a). As (Havice and Campling, 2017, p. 295) describe, power within GVCs depends heavily on the "environmental conditions of production", those factors which determine how firms capture and value nature, displace environmental risks, gain material leverage within the chain, and enhance political power.

With an enhanced ability to offset environmental risks, multinational enterprises are shown to be far more polluting than domestic, non-multinational firms within the same sector (Duan and Jiang, 2021). Global firms utilize their power within chains to intensify material production and extraction (Labban, 2014) while pushing for new rounds of market restructuring and privatization to establish new frontiers and enhance profitability (Büscher, 2012; McCarthy, 2012). Indeed, the drive to control resource flows and open up new commodity frontiers represents a largely "unacknowledged 'causal driver'" in the evolution of global value relations over the past several decades (Baglioni and Campling, 2017).

Empirical research confirms that the shift towards global value chains has intensified the long-standing environmental inequalities between the Core and the Periphery (Althouse et al., 2022). Beginning in the 1970s, a significant decline in domestic energy production in Core countries gave way to rising energy consumption via imported goods (Cahen-Fourot and Durand, 2016). GVCs appear to have pushed resource-intensive production to Peripheral countries and contributed to declining terms of trade for commodity producers (Rivera-Basques, Duarte, and Sánchez-Chóliz, 2021). The systematic displacement of pollution-intensive production through GVCs is part of what Duan, Ji, and Yu (2021, p. 9) refer to as "global pollution chains". In their study of global value and pollution flows between 1995 and 2009, the authors found that the pollution-intensity of exports grew in proportion to the per capita income gap between importing and exporting countries. Through GVCs, the wealthiest countries and individuals are increasingly capable of using their share of global purchasing power to offload degradation elsewhere (e.g. Dorninger et al., 2021).

The "commodity frontier-offshoring" nexus is a material expression of the hierarchical currency and value relations described in Section 2. As Peripheral countries seek to accumulate foreign reserves and guarantee a steady inflow of capital, they must integrate within highly competitive value chains. This creates a collective drive to provide amenable i.e., reliably "cheap" environments for international investors and foreign firms (Selwyn, 2019). The power to guarantee a steady flow of profits, resources and labor has therefore been a key component of Peripheral integration within GVCs (Baglioni, 2021). For instance, Malm (2012, p. 153)'s "fossil capital hypothesis" argues that global capital flows are most likely to concentrate where labor is cheap and disciplined, as well as where fossil energy is readily available and cheaply accessible.

The case of China is particularly informative for how the globalization of value-added production is closely related to the development of new commodity frontiers. China became the "factory of the world" not only because of its low labor costs and environmental regulations, but also because of its abundant and easily exploitable coal (Ciccantell, 2019). Chinese authorities were well-aware of the advantage offered by their coal resources: they deregulated the coal market in 2001 to permit thousands of new mining sites and invested massively in transport networks and energy infrastructures to avoid power outages (Malm, 2012).

Cheap and stable flows of energy encouraged an impressive inflow of foreign capital, which was essential to China's export-led growth. Whereas in 1980 foreign-invested enterprises produced just 0.1 per cent of Chinese exports, this rose to 70 per cent by 2005, including more than 90 per cent for advanced technological products (Malm,

2012). China's coal-powered trade surpluses were later recycled back into US treasury securities, which supported the dominance of the dollar and provided stability to the dollar-pegged Chinese currency (Sager, 2016). In short, the exploitation of China's commodity frontiers has been critical to the development of financialized capitalism.

From this perspective, the "commodity frontier-offshoring" nexus implies a refined capacity among Core countries to capture resources and displace environmental burdens to Peripheral frontiers. This nexus offers a view to understanding how financial patterns operating within currency and 'real' value hierarchies are materially and energetically constructed. While an exhaustive analysis of the varied mechanisms that make up this nexus are beyond the scope of this paper, the following subsection details how different features of financialized capitalism have been critical in enabling these patterns.

5.2.2 *The "financialization-commodity frontier" nexus*

Based on a transdisciplinary literature that borrows from political ecology, ecological economics and geography, we identify three primary co-evolutionary processes which constitute a "financialization-commodity frontier" nexus (the third nexus of our analytical framework): (1) The increasing pressure placed by financialized dynamics on the extraction of resources at the commodity frontiers; (2) The increased vulnerability of Peripheral countries to commodity boom-bust cycles, which reinforces; (3) The disciplining effect of financial players which increases the extraction of resources from the Periphery.

5.2.2.1 *Increased financial pressures on Peripheral resources*

Financialized narratives, values and practices represent an emergent pattern of socio-ecological governance. As financial logics and motives increasingly restructure social patterns, they alter the way that environments are understood, measured and valued (Ouma, Johnson, and Bigger, 2018). Here, we describe how this process has magnified pressure on Peripheral resources, focusing on two prominent trends: the financialization of firms and the financialization of development.

There is a breadth of research detailing how the rising power of large private institutional investors (notably pension funds) and shareholder value orientation, two of the defining features of financialization, have facilitated strategies aimed at expanding and intensifying extractive activities. Financialization has reinforced the view of firms, suppliers, host environments and nation-states as "a bundle of assets which must be continually reshuffled and adjusted to target favoured metrics" (Bowman, 2018, p. 394), while reducing countervailing forces to such views (e.g. deregulation of financial markets). This powerful ideological shift has contributed to a territorial "disem-

bedding" of social-ecological relations (Parker, Cox, and Thompson, 2018, p. 64), where the value of the natural world has become increasingly "conditioned by its co-existence as an interest-bearing asset" from which future value can be extracted (Bracking, 2020, p. 218).

These patterns have led to drastic changes in how lead firms manage relationships with suppliers, significantly altering the dynamics of commodity extraction. Shareholders demand that firms develop sufficiently ambitious plans of future value generation that increase the volumes of production and new reserves. Extractive enterprises – from large-scale oil (Labban, 2014), mining (Bowman, 2018; Reyes, 2017), and agrifood operations (Baines and Hager, 2021), to smallholder farmers and petty commodity producers (Clapp and Isakson, 2018) – are pressured into "an endless cycle of intensifying productivity and increasing the scale of production" to maximize profitability for downstream firms and investors (Nascimento, Frederico, and Saweljew, 2019, p. 274). Financialized investment strategies, particularly in extractive firms, therefore appear to serve "as a lever to expand material operations across extraction sites" (Arboleda, 2020, p. 122). Such operational expansions are linked to short-termism, cost-cutting measures, and rapid divestitures which "exacerbate financial fragility, social inequality and environmental destruction" (Baines and Hager, 2020, p. 7) in the Periphery.

Changing firm practices have coincided with increasingly financialized 'development' strategies. There is a deepening effort to reorganize development policy to align with global finance and escort capital into frontier markets (Mawdsley, 2018). This 'Wall Street Consensus' is part of a longstanding "strategic ideological adjustment" to re-imagine the state as a "promoter, supervisor, and owner" of capital (Alami, Dixon, and Mawdsley, 2021, p. 1295) and to create new opportunities for financial accumulation by 'de-risking' development assets (Gabor, 2021). All manner of social and environmental programs - poverty alleviation, resource-based production, conservation, climate risk, mitigation and adaptation - are thereby increasingly understood, measured, and managed through financial narratives, instruments and markets. In this way, financialization represents a distinct ontological shift in global socio-ecological governance (Ouma, Johnson, and Bigger, 2018), which is "fast becoming a common denominator for thinking about the organization of social life in relation to the environment" (Bridge, 2010, p. 821).

Financialized development strategies are likely to seriously restrict the possibilities for a just transition to low-carbon future (Gabor, 2021), particularly as state- and non-state powers seek to control global social and environmental transformations via financial markets. Indeed, financialized arrangements "promise to cope with both the economic and the environmental crisis by opening new fields of accumulation, articulating dominant forces and integrating relevant subaltern

ones" that enhance "the appropriation of labor and nature from elsewhere" (Brand and Wissen, 2014, p. 30). First, new methods of socio-ecological governance are predicated on shifting the burdens of 'risk management' to Peripheral states and peoples. This has been shown to heighten their vulnerability to financial volatility and indebtedness, reduce their capacity to respond to climate change impacts, and entrench pressures to mobilize greater amounts of resources and labor (Bernards, 2021; Ouma, Johnson, and Bigger, 2018).

Second, financialized development patterns are characterized by a global race to finance and manage large infrastructure projects, in an effort to "convert space into money" (Loftus and March, 2019, p. 2292). Such projects provide a strong gravitational pull towards expanding resource-intensive production patterns.[7] New "mega-infrastructures" are resource-intensive in both their material composition and their function: mega-corridors are built for transport (e.g. airports, shipyards, motorways), energy infrastructure (e.g. power plants, hydroelectric dams), as well as for resource extraction, refinement and conveyance. Because these projects must retain profitability to compensate investors, they tend to lock in existing extractive frameworks and "fuel the competitive scramble for natural resources" within Peripheral frontiers (Tricarico and Sol, 2016, p. 57)

Even seemingly 'green' infrastructures have dubious environmental potential (Knuth, 2018). Under finance-led capitalism, green infrastructures tend to express dominant narratives of techno-optimistic development that "foreclos[e] more subtle alternatives or perhaps more radical change towards low-carbon energy systems." (Quitzow and Rohde, 2021, p. 1). This is compounded in today's world-wide "infrastructure scramble" (Kanai and Schindler, 2019), where powerful states and investors compete to secure value chains and material flows by financing and controlling infrastructures throughout the Periphery - often under the guise of 'sustainable' development aid.

In summary, the shifting practices, narratives and ideologies of extractive firms and the international 'development' agenda are key to understanding the ecological foundations of Peripheral subordination. Financialization is built upon and reproduces uneven development by placing additional pressure on Peripheral resources through new methods of environmental governance.

7 Indeed, infrastructures are material expressions of the very "political-economic interests and imaginaries their foundations [are] cast within" (Cederlöf, 2015, p. 654). Infrastructures tend to embody historically-specific rationalities and ruling class values, while obviating alternatives. As such, they are imbued with immense material inertia which "almost by definition, reproduces [established] material relations" (Cowen, 2020, p. 469)

5.2.2.2 *Increased vulnerability to commodity price swings*

In this context, Peripheral commodity-exporting economies are acutely vulnerable to financial market volatility and the changing demands of far-flung shareholders. Financial practices frequently generate "speculative frenzies" alternating with "flights to safety" that drive price developments in raw materials sectors, concentrate investment flows, and alter the geography of resource extraction (Arboleda, 2015, p. 7). For example, a body of research shows how recent swings in commodity prices over the past decades are due in large part to stronger links between commodity and financial markets (Baines and Hager, 2021). As commodity markets are viewed as avenues for profit making and risk diversification by portfolio investors, commodity futures markets have seen a major influx of new investment capital (Labban, 2010).

Such tactics have fed into recent commodity price bubbles, notoriously playing a role in the rapid increase in the price of staple food goods which ultimately pushed millions of people into hunger in 2008 (Ghosh, 2010). In light of this, hedge funds, pension funds, and sovereign wealth funds are now purchasing large swaths of global agricultural lands throughout the Periphery to speculate on commodity price movements. These 'land grabs' have intensified water scarcity, deforestation, and land degradation, while also displacing rural populations in many of the most fragile low-income countries (see Oliveira, McKay, and Liu, 2021).

While commodity booms can provide some benefits to resource exporters, including the ability to funnel rents into social programs (Brand, Dietz, and Lang, 2016), they also tend to reinforce the status of Peripheries as commodity-exporters. Increasing foreign direct investment (FDI) flows often cause the domestic currency to appreciate while hollowing out investment in non-commodity sectors (Gallagher and Prates, 2014). Peripheral countries then come to depend increasingly on resource and pollution intensive exports to sustain foreign investment and public budgets. Indeed, the commodity price boom of the last two decades has brought a stark increase in commodity-dependency and widespread reprimarization within the Periphery (UNCTAD, 2019b).

Moreover, since Peripheral countries tend to reinvest capital inflows during boom periods within - high-liquidity, low-interest - US treasury bonds and other dollar-denominated financial assets to mitigate exchange-rate risks, Peripheral resources are often diverted away from alternative domestic programs while subsidising patterns of the Core (see Painceira, 2009). The recycling of profits from resource-intensive growth back into US treasuries has been a key factor in sustaining low interest rates in the Core, alongside growing asset bubbles (Sager, 2016; Svartzman and Althouse, 2020).

Subsequent commodity busts then exacerbate the structural difficulties of Peripheral countries. Capital outflows induce exchange rate depreciations which increase the local costs of indebtedness for domestic firms that borrow in foreign currency, resulting in large economic contractions and continued focus on primary sectors. As a result, Peripheries can find themselves locked into "a vicious Ponzi finance cycle, where more heavily indebted nations face rising costs of borrowing, thereby increasing their overall indebtedness, while further undermining their ability to repay their debt" (Tcherneva, 2016, p. 19). The "increasing amalgamation of resource flows and financial flows" under financialization has therefore meant that "resources crises have become financial crises", and vice-versa (Labban, 2010, p. 550). Moreover, commodity busts tend to bring about new rounds of value extraction via cost "disciplining" by lead firms and governments, often at the behest of investors (Labban, 2014). To meet profit targets, extractive firms reduce their workforce and intensify production, or shut down operations entirely, generating a vicious cycle of unemployment, rising debt, and ecological degradation (Bowman, 2018).

5.2.2.3 *Environmental disciplining*

Peripheral countries' vulnerability to international financial and commodity cycles therefore places them in a heavily disadvantaged position, reinforcing their dependence on commodity exports and foreign lending. In this context, donor states and international creditors have additional leverage to coerce debtor states to accept draconian policies as a condition for access to markets and continued financial stability. Indeed, the uneven structure of transnational finance "augment[s] the power of credit to serve as an effective form of social discipline" (Soederberg, 2005, p. 928) and environmental (re-)organization.

Creditors frequently require that Peripheral countries relax social and environmental regulations and slash public budgets - in part by selling off key assets like state-owned infrastructures and natural resources (Bryant and Bailey, 2005; Gallagher and Prates, 2014). For instance, following the emerging market debt crises of the 1980s and 1990s, "structural adjustment" programs liberalized extractive frontiers to meet creditors' repayment demands. The structural need for access to dollars necessary for trade and/or paying debts has proved an important leverage point for expanding foreign control over Peripheral resources, a process which continued in the wake of the 2008 financial crisis (Büscher, 2012), and the COVID-19 slowdown (Kentikelenis et al., 2020).

For this reason, crisis periods are well known to bring an "intensification of environmental transformation, exploitation, and degradation" as the need to stabilize foreign capital inflows and meet debt payments causes private and state actors to "accelerate their efforts

to turn bits of the environment under their control into marketable commodities" (McCarthy, 2012, 185=186). Indeed, trade deficits in the Periphery tend to be financed through greater volumes of physical outflows, i.e. by accelerating the exploitation and export of domestic natural resources (Samaniego, Vallejo, and Martínez-Alier, 2017). As such, empirical evidence also demonstrates that high levels of external debt in Peripheral countries are strongly correlated with higher rates of deforestation (Culas, 2006), water pollution (Shandra, Shor, and London, 2008), and biodiversity loss (Shandra et al., 2010).

The disciplining effects of financialization also function to restrain progressive social movements that would undermine the power of financial institutions and enable less extractive forms of development. In a study of Latin American presidents in the financial era, Campello (2015) finds that currency crises and capital flight are an ever-present threat through which investors 'discipline' governments, particularly when left-leaning candidates are in office or expected to win election. Even political candidates with strong popular support to oppose the 'financialized order' were driven to abandon their platforms in order to establish confidence with investors via market-friendly policies because of currency pressures.[8]

This is not to say that Peripheries have no agency under current global monetary financial arrangements - the ongoing rise of China from a Peripheral to Core country being the most obvious case in point. Both creditor and debtor states engage in "financial statecraft", seeking economic, political and environmental advantages through the use of credit, investment and currency levers (Armijo and Katada, 2015). When commodity prices are high and interest rates are low, the disciplining power of investors is circumscribed (Campello, 2015). Access to alternative lenders, such as China, can reduce dependence on traditional sources of external finance. In some cases, this offers greater leverage in negotiations with financiers and international organizations, while alleviating some political constraints. Moreover, domestic popular mobilization can enhance the possibilities that Peripheries support state-led development and reign in finance, despite opposition by foreign creditors and domestic financial elites (Naqvi, 2019).

However, greater financial control and state-led development have historically been insufficient to halt global extractive dynamics. In most cases, inward-looking development supported by domestic or alternative foreign funding sources have merely shifted the direction of resource control and supported the rise of new regional or global material hegemons (Svartzman and Althouse, 2020).

8 This may provide additional perspective to understand why apparently left-leaning Latin American governments throughout the 2000s branded (neo-)extractivist policies as tools for enhancing national sovereignty and social development, despite their obvious consequences and contradictions in the long term (Brand, Dietz, and Lang, 2016).

In conclusion, the deepening integration of Peripheries within financialized patterns and practices is intimately tied to the extension and intensification of extraction to new commodity frontiers. Financialization alters the logics of extractive firms, generates vicious commodity price cycles, and conditions social and environmental policy to provide greater access and availability to key energy and materials often at the expense of Peripheral firms, workers and natural environments.

5.3 FINANCIALIZATION AS A GLOBAL SOCIO-ECOLOGICAL REGIME

5.3.1 *The 'functional' role of subordinated financialization in the world-ecological system*

By connecting the three nexus points described in this paper, we move beyond geographically-isolated and ecologically-disembedded visions of financialization to provide a more holistic framework of financialized capitalism using three interlocking hierarchies: (i) a hierarchy of monetary relations through the international currency system that permits the subordinated financialization of Peripheral countries (ii) a hierarchy of production through spatially disaggregated value chains, and (iii) a hierarchy of environmental transformation, characterized by the continuous and uneven flow of resources from Peripheral commodity frontiers to the Core.

Together, these hierarchies form three primary nexus relations which support financial accumulation: "financialization-offshoring", "commodity frontier-offshoring" and "financialization-commodity frontier" nexus. This framework, seen in Figure 8, enables us to analyze financialized capitalism as a global socio-ecological regime, whereby capital accumulation reproduces uneven geographies of money, value-capture, and ecological change.

This suggests not only that financialization is better assessed as a global phenomenon (as already emphasized by the literature on subordinated financialization) but also that Peripheral financial subordination plays a necessary or at least institutionally consistent ecological function enabling the continuous access to resources and the financialized patterns of accumulation in the Core.

Indeed, the expansion and maintenance of monetary power, the development of the global financial system and the uneven geography of value capture can be traced to the systematic need to sustain a steady inflow of resources. As Patnaik and Patnaik (2017) describe, high priced commodities pose a direct threat to the Core's regime of accumulation: Rising commodity prices can harm the profitability of downstream firms, reduce consumption and investment demand, and undermine monetary and financial stability in the Core. Cheap commodities therefore support the dominant consumption and in-

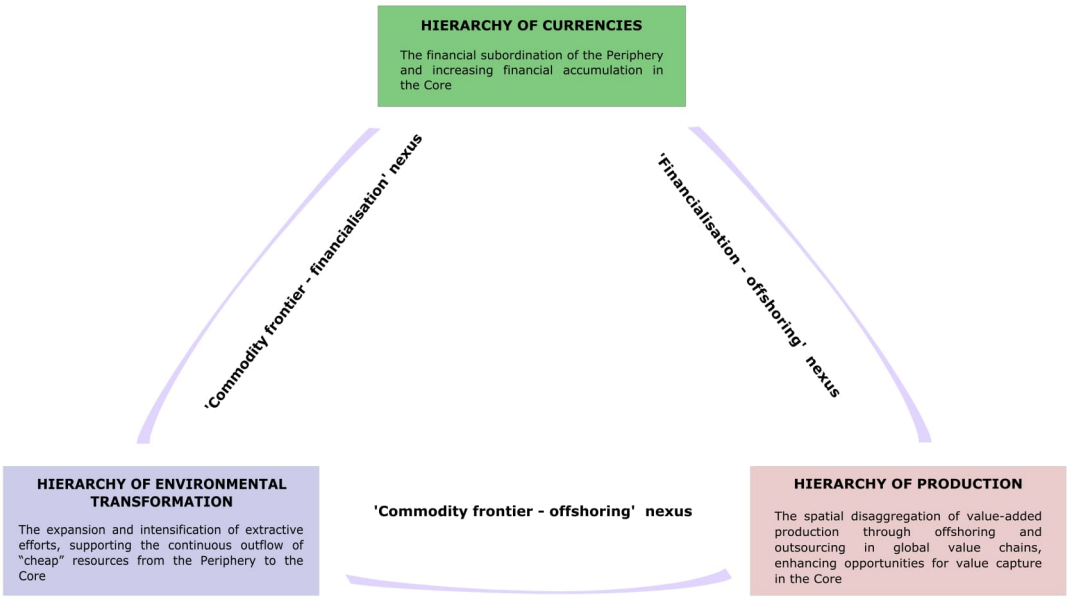

Figure 8: The "Financialization-Offshoring-Commodity Frontier" Nexus

vestment patterns of the Core, while enhancing their relative monetary and productive strength.

The institutional arrangements which support the outflow of cheap resources, material and labor to the Core, however, can be threatened. Commodity booms caused by growth in Asia, geopolitical conflicts over strategic resources, and worsening environmental degradation all challenge the Core's access to cheap resource flows (Moore, 2015), and thus the stability of their hierarchical power. While instability also creates opportunities for accumulation by powerful firms and competing global powers, a steady supply of cheap resources appears fundamental to the pursuit of capital accumulation.

From this perspective, financialized capitalism and the subordination of Peripheral countries illustrate the deeply embedded structures of power within an interconnected world-ecological system. Given the three interdependent hierarchies of financial accumulation explored here, the limited room for policy autonomy in Peripheral countries must be appreciated as playing a 'functional' role within a highly unbalanced geopolitical-material framework. While the Periphery's role as a provider of inexpensive resources and labor is not set in stone, the international monetary and financial system is supported by and promotes continued unequal environmental relations. This finding has important implications for the potential to achieve ecologically sustainable and socially equitable outcomes in the twenty-first century, as discussed next.

5.3.2 *Policy implications - The need for structural financial transformations accompanied by socio-ecological 'sobriety' in the Core*

The foregoing analysis does not imply that the present financialized regime is inescapable, but rather that responding to the urgent need for a global ecological transition should address the regime's various components as a coherent whole. Policies aimed at promoting 'sustainable development' and 'green' industrial upgrading, alongside efforts to 'definancialize' economies - e.g. via capital controls and interventions in the foreign exchange market (Bortz and Kaltenbrunner, 2018)) or via broader reforms of the international monetary and financial system, such as in a "Global Green New Deal" (UNCTAD, 2019a) - should therefore be reappraised in light of the socio-ecological realities of the Core-Periphery system (Ajl, 2021; Mastini, Kallis, and Hickel, 2021; Svartzman, Dron, and Espagne, 2019).

First, proposals to finance 'green' forms of growth in the Periphery overlook the fundamental causes of unsustainable patterns, and may reinforce them (Althouse, Guarini, and Porcile, 2020). Rapid economic growth in emerging economies remains heavily dependent on exploiting domestic and foreign frontiers of commodity extraction. Efforts towards 'greener' forms of accumulation have merely displaced ecological degradation and conflict (Pitron, 2018). Indeed, despite a dramatic increase in green investments in the twenty-first century, the global emissions and material-intensity of production appear to be rising, rather than falling (Krausmann et al., 2018; Schandl et al., 2018). From this perspective, greater policy autonomy and new potential for industrial upgrading in the Periphery would likely threaten the ability of Core countries to access cheap resources. Aside from contributing to financial and monetary instability, this may also result in new efforts by the Core to reaffirm their financial power and restructure global environments.

Second, proposals which perceive the primary obstacle to sustainability as resulting from a lack of sufficient green investments - whether from private or public sources - should be regarded with caution. There may be no quantity of financing that can guarantee the quality of relational care necessary for sustainability or restorative environmental justice (Martínez-Alier et al., 2010). While many beneficial investable projects may exist, approaching sustainability through a financial lens is a decidedly political choice. This choice has undeniable consequences for social and environmental distribution. Perhaps more importantly, it also risks obscuring alternative ways of imagining and valuing the environment, our relationship with it, and our relationships with each other (see Brand and Wissen, 2018; Ouma, Johnson, and Bigger, 2018; Sullivan, 2017). For this reason, Mastini et al. (Mastini, Kallis, and Hickel, 2021, p. 8) contend that 'Green New Deal'-style projects embody a frustrating contradiction: they are at

once the most promising pieces of social and environmental legislation currently on offer while also being a slippery slope that, if not handled correctly "might just result in new rounds of primitive accumulation and commodification of nature".

Finally, there is limited remaining time or space for continued global economic growth, without putting Earth's ecosystems and the future of humanity at risk. There is overwhelming empirical and theoretical evidence that environmentally "efficient" growth is illusory at the global level (Haberl et al., 2020; Hickel and Kallis, 2019; Parrique et al., 2019). Moreover, technology-driven, growth-based solutions are increasingly recognized to heighten the risk of major systemic disruptions (Keyßer and Lenzen, 2021). While some growth-inducing investments may be an inevitable part of any transition in the short term (e.g. massive investments in public transportation), truly 'green' investments would enable more 'sober' lifestyles in the medium term that can potentially reduce material and energetic throughput and be accompanied by divestments elsewhere (e.g. shrinking investment in private automobile transport; placing a moratorium on new extractive efforts).

In light of these findings, it is still possible that significant 'green' reforms of the international monetary system could support a global financial system which relieves environmental pressures on Peripheral countries. In the same way as the principle of stable exchange rates were embedded into Keynes' idea of an International Clearing Union, innovative mechanisms could now be designed into a new system to facilitate socially- and ecologically- fair access to resources across the world-system. This would offer new opportunities to reconsider how to best distribute resources to serve social priorities (Vatn, 2009) through the principle of "common but differentiated responsibilities" (UNFCC, 2015, p. 3) established in international climate negotiations.

Embedding such considerations into a reform of the international monetary and financial systems would mean that social and environmental justice become the cornerstone of a reform of the international financial and monetary system. Inspiration can be found in earlier proposals made to tie global liquidity to a biophysical standard, while improving developing countries' access to their financing needs. For instance, in 1964, Kaldor suggested a commodity reserve currency (CRC), composed of a basket of dozens of commodities, that would be managed at the international level and could benefit from countercyclical mechanisms (Ussher, 2009). Such a plan could provide Peripheral countries with an independent and stable source of growth, without depending on the U.S. as provider of liquidity 'in last resort'. In the context of a socio-ecological transition, it would nevertheless also mean that Core countries should immediately reduce their use of resources so that Peripheral countries have priority access to them.

While this paper cannot delve into the profound changes that such policies would entail, we acknowledge that these may be at least partially incompatible with capitalist modes of living and development (Brand and Wissen, 2018). Reducing the grip of financial power, and the unsustainable subordination of Peripheral countries, will hinge on reforms that would not only imply degrowth in the Core, but also undercut its material and symbolic power. Alternative ontologies of human emancipation and post-development (Escobar, 2015; Kothari et al., 2019) offer important insights for how to improve human health, well-being and the Planetary Commons through local resource governance and economic sovereignty. Proposals along these lines go far beyond the possibilities of the existing institutional framework yet are likely essential components of any realistic effort to promote shared prosperity and planetary health.

5.4 SUMMARY AND CONCLUSIONS

Building jointly on approaches inspired by world-systems and Earth system analysis (Hornborg, 2006; Moore, 2015), this chapter finds that, rather than a detachment of finance from 'real' production, financialization is in fact a way of organising human-nature relations, which reinforces Peripheral subordination and consolidates accumulation in the Core of the world-system. This framework connects three patterns of Peripheral subordination within finance-led capitalism that had previously been assessed in isolation: (1) the hierarchy of currencies (2) the hierarchy of production in global value chains through offshoring and outsourcing; and (3) the hierarchy of environmental transformation, which evolves by developing mechanisms to control the outflow of resources within Peripheral commodity frontiers.

Uniting these, financialization appears as a 'cohesive' (though not inescapable) global socio-ecological regime that links subordinated Peripheries of resource extraction to Cores of accumulation. This suggests that Peripheries are even more vulnerable within financialized capitalism than previous studies have shown (Kaltenbrunner and Painceira, 2015): their role as suppliers of cheap resources and pollution sinks is less a symptom of dysfunctional international monetary and financial relations than a means for the pursuit of capital accumulation in the Core.

Our study has sought to provide a framework to ground studies of financialization within the biophysical realm. While this paper was primarily theoretical, it brings together a wealth of empirical evidence from diverse fields that has yet to be discussed. Transdisciplinary approaches linking the world-system and Earth systems are urgently needed as climate change, biodiversity loss, soil erosion, and all manner of environmental destruction increasingly impinge on the stability of human and natural systems (Ripple et al., 2017). Future research

can further explore the nexus links that we have proposed, while considering the limitations and possibilities for a more socially just and environmentally-coherent global system.

While an assessment of the specific features of a financially- and ecologically-balanced international monetary and financial system is beyond the scope of this paper, a major preliminary lesson can be outlined: the framework presented here significantly undermines the ability of progressive 'green' agendas seeking to manage a win-win-win scenario: Efforts to (1) definancialize Core countries' economies and revive domestic industry and GDP growth, all while (2) providing Peripheral countries with more political autonomy and (3) supporting the transition to a sustainable economic model are well-intentioned, but frequently omit the global interdependencies supporting financialization as a socio-ecological regime. Significant trade-offs exist between these goals. A more balanced international monetary and financial system seems necessary yet may present limits to capital accumulation – and GDP growth – in Core economies.

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6

CONCLUSION

Before you heal someone,
ask him if he's willing to give up the things that make him sick.

— Hippocrates

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In an effort to better comprehend interdependent social, ecological and economic crises, this thesis argued that to "embed" macroeconomic theory within the Earth system requires an understanding of 'nature' as an inherently political terrain. Inspired by dependency theory and Marxist political ecology, this work argued that the nascent field of ecological macroeconomics can develop a more clarified vision of economy-environment dynamics by studying the uneven causes and consequences of socio-ecological change. Human-nature relations evolve through conflicts over how to define, access and organize nature. In a world of profound inequalities of wealth and power, structural inequalities then become reflected and reinforced in the ways that nature is transformed, valued and distributed.

From this perspective, the global 'environmental crisis' can be more effectively understood as a symptom of the uneven structures that generate it. I investigated the implications of this insight at the level of the 'world-ecological system' (Hornborg, 2006; Moore, 2015). More specifically, I re-contextualized (de)growth, rapid 'green' technological innovation, and financial accumulation by inquiring into the structured relationship between the Core and Periphery. I borrowed insights from a large body of theoretical and empirical work which details how the income and geopolitical strength of high-income Core countries has historically relied upon strategies to guarantee a steady flow of "cheap" nature and labor from the Periphery. (Moore, 2000; Patnaik and Patnaik, 2017). Dominant growth patterns have been built through consecutive waves of geographic expansion, extractive intensification and the displacement of environmental risks and burdens. In effect, existing global environmental and social inequalities can be seen as "functional" (or institutionally coherent) to the material dependencies of the present regime of accumulation.

By highlighting the hierarchical organization of global monetary, financial and productive relations, I demonstrated new potential for ecological macroeconomics to apprehend the rapidly unfolding environmental crisis as a crisis of relationship. I also showed how this allows the field to re-evaluate some of its own previous findings. Indeed, it became clear through this work that the possibilities of achieving a 'green' sustainable future within present institutions are far more circumscribed than is generally considered. This work argued that sustainability may be impossible without profound structural changes and global redistribution. Rebalancing the economy towards a more harmonious relationship with the Earth is therefore unlikely to be "smooth and rapid" (Campiglio and Ploeg, 2021, p. 3), but rough, slow and heavily contested by powerful groups who are unlikely to willingly relinquish control.

In order to develop meaningful pathways out of the present predicament, it is therefore necessary to account for the ways that institutionalized asymmetries create a gravitational pull towards an unsustain-

able future. This thesis is part of a growing effort to build towards such a framework:

Chapter 2 presented ecological macroeconomics as an important new field which offers a promising avenue for understanding the macroeconomics of environmental transformation. In this chapter, I reviewed the history of ecological macroeconomics, and brought to the fore five key branches of research through which the field has been expressed: (i) Green Keynesianism, (ii) Financial Stability and Socio-Environmental Change, (iii) Socio-Metabolic Dynamics and Constraints, (iv) Capitalist Growth Imperatives, and (v) Post-growth/ Degrowth Futures. Nearly 60 articles were reviewed and compared to develop a clear understanding of how ecological macroeconomists perceive economy-environment dynamics, how this influences their approach to solving ecological problems, and to what degree this may be limited.

Chapter 3 then followed up with a critical assessment of ecological macroeconomics. It found that while ecological macroeconomics has offered an impressive set of tools for understanding the economy as embedded within the social and biophysical realms, the field suffers from a number of empirical and theoretical deficiencies. By critiquing the methods, objectives and socio-ecological context put forth by ecological macroeconomists, it was found that ecological macroeconomics, is not able to fully grasp the nature and character of the environmental crisis.

I argued that ecological macroeconomists could benefit by integrating insights from the field of 'political ecology'. Political ecology, it was found, provides an ideal set of tools and concepts for analyzing how social institutions determine the ways that environments are defined, accessed, and valued. Nature is (re-)organized and (re-)distributed through competing interests. From this perspective, inequalities of power and vulnerability are essential components for understanding the complex and uneven geography of environmental transformations. I argued that by integrating views from political ecology, ecological macroeconomics can better align with a growing body of work to show how environmental changes are always intertwined with intercountry, and intracountry class, gender, ethnic, or other power struggles.

The rest of the thesis then extended the ecological macroeconomics perspective by integrating insights from political ecology. In particular, I focused on the ways that the asymmetries between high-income (Core) countries and low-income (Peripheral) countries have a distinct ecological component. Chapter 4, for example, developed a post-Keynesian balance-of-payments-constraint (BOPCG) growth model to describe how 'green' structural transformations and industrialization may worsen environmental outcomes globally. Macroeconomic policies which may enhance technological efficiency in Core regions

can displace lower-value pollution- and resource-intensive production to Peripheral countries. Sustainability policy must therefore be contextualized within the global and uneven structures of trade and development that comprise our 'world-ecological system'.

This chapter described four different scenarios: (i) A 'business-as-usual' scenario depicted a situation in which global growth continues unabated, pushing the world collectively past established climate markers. (ii) 'Local sustainability by accumulation' where a 'green new deal'-type strategy in the Core enhances local efficiency at the expense of efficiency in the Periphery, also pushing the globe into carbon overshoot. (iii) 'Global sustainability by accommodation', described a situation in which wealthy countries purposefully reduce growth. This would allow low-income countries the opportunity to improve their material consumption, while global emissions fell. Finally (iv) 'sustainability by cooperation' described an ideal scenario where global sustainability is achieved via a major coordinated international effort. Progress towards global climate goals is made possible by a radical decline in investment within high-income countries, alongside systematic financial and technical aid (particularly technology sharing and patent waivers, etc.) for low-income countries to make up for any loss of export income. From this perspective, sustainable development is best achieved via a radical shift in the structure and goals of production, including systematic efforts to reduce investment growth while enhancing global cooperation.

Chapter 5 then followed up by developing a theoretical approach to understand the development of financialized capitalism as a process that reorganizes environments to serve capital accumulation, primarily in Core countries. Here again, the unevenness of global capitalism was shown to pose a clear stumbling-block to concerted efforts towards more sustainable ways of living and relating.

Financial accumulation in the Core was shown to be made possible through co-dependent and hierarchical relations which subordinate Peripheral countries and their environments. I explored how hierarchies of (i) money, (ii) production, and (iii) environmental transformation are deeply intertwined at the global level. This framework enabled me to connect the growing power of the financial sector to the subordinate position of the Periphery within global monetary institutions, the reorganization of global value production ("offshoring") and the intensification and expansion of capital to new frontiers of resource extraction ("commodity frontiers"). These patterns form what I called the "financialisation-offshoring-commodity frontier" nexus, a self-reinforcing institutional arrangement that guarantees new possibilities for capital accumulation within the Core of the world-system, while accentuating the Periphery's vulnerability to financial instability, uneven development and ecological degradation. This suggests that addressing Core-Periphery structural imbalances and systematic

ecological degradation requires a major overhaul of the international monetary and financial system, in a way that may nevertheless limit capital accumulation and GDP growth in Core economies.

6.1 LESSONS LEARNED: POINTING A WAY TOWARDS MORE SUSTAINABLE SOCIO-ECOLOGICAL RELATIONS

In conducting this research a number of important lessons stand out as salient: First, researchers should proceed with *caution* in regards to efforts to resolve the climate crisis with 'green' investment and efficiency policies, without also calling for more significant social changes. Second, *cooperation* and coordination between countries are essential components of any realistic sustainable future. Third, policies should express our inherent place on Earth by consciously '*coupling*' (as opposed to reactively 'decoupling') the economy within nature.

6.1.1 *Proceeding with Caution: Reconsidering 'green' investment as an inherent solution to sustainability*

Ecological macroeconomists overwhelmingly recognize that 'fundamental' or 'Keynesian' uncertainty rules in environmental issues. The presence of uncertainty is important not just in determining the level of investment demand, it is also a primary reason why ecological macroeconomists have adopted the "Precautionary Principle" (Rezai and Stagl, 2016, p. 182): environmental issues are wildly complex, innovations can fail or have unintended consequences, so caution is necessary. It remains unclear, however "what kind of 'cautious approach' ecological macroeconomics should embrace to deal with ecological, economic and financial uncertainty and instability" (Saes and Romeiro, 2019, p. 397). While a precise answer to this question is perhaps impossible, this thesis has demonstrated that economists and policymakers should be particularly wary of assuming that particular investments, technologies or energy systems have any inherently sustainable qualities.

This thesis argued that the possibilities for combating global climate change within present institutional arrangements are far more restricted than is often suggested in many mainstream and heterodox models. As described in Chapter 3 and 4 investment strategies and technologies that appear sustainable or 'efficient' at one level are frequently 'unsustainable' at another scale (e.g., national vs. global) or along another environmental dimension (e.g., emissions savings vs. biodiversity loss). Green investment programs have tended to neglect the socio-ecological consequences of a high-tech energy transition on vulnerable places and populations, and the kinds of unsustainable patterns they may reinforce (Sovacool, 2021). For example, the scram-

ble for minerals necessary to sustain a low-carbon future, is already the source of violent conflict, land dispossessions, and environmental catastrophe in many Peripheral countries.

From this perspective, a deluge of 'green' investments will not necessarily guarantee a shift into a new post-carbon world of shared wealth and equity. In fact, there may be no quantity of 'clean' technology, 'green' finance or 'renewable' infrastructure that can guarantee the qualities of social and environmental justice necessary to establish a more sustainable relationship with the Earth. Without significant changes to the distribution of wealth and power, even seemingly 'win-win' solutions risk reinforcing historical patterns of unequal and unsustainable resource use. The problem extends far beyond filling in a 'green finance gap' (Chapters 3 and 4). While new 'sustainable' investment strategies and technologies may change the terms around which firms and nation-states compete, they appear unlikely to fundamentally alter the uneven patterns of extraction, exclusion, and environmental degradation, described here

Indeed, even if there were a 'magic bullet' investment strategy, energy source or technology to drastically reduce emissions, there is no guarantee that it would be universally beneficial in the present global configuration. Who will own and maintain the new technologies and energy systems? How will they be accessed and distributed? Who will be allowed access, where, and at what price? What kinds of new social and material patterns will they support?

The COVID-19 pandemic provides an analogous situation. When COVID-19 began spreading throughout the world, massive levels of public and private investment went into R&D to develop a vaccine and then to diffuse it amongst the general populace. Heterodox economists may have felt vindicated in seeing the powers of central governments to mobilize hundreds of billions to meet health needs and sustain businesses, expand unemployment insurance and other social programs and rapidly unroll a mass vaccination program (Byrialsen, Olesen, and Madsen, 2021).

Yet this perhaps misses the larger point: First, it fails to address the causes of the pandemic in the first place.[1] Second, while a vaccine was ultimately rolled out with great success within the Core, the social benefits from the development of a vaccine were restricted to those areas with sufficient funding for testing and vaccination. This was largely the result of the desire to uphold patent rights for major pharmaceutical companies, and was made worse by uneven financial architecture of the global economy.

While the price of testing and vaccination was more easily handled by Core countries with the ability to take on a pile of new debts,

1 For example, the pandemic, alongside other zoonotic diseases, has been linked to an industrial model of intensive agriculture which evolves through new attempts at landgrabbing and deforestation in primary forests whose biodiversity once contained the spread of viruses (Wallace, 2016).

Peripheral countries were practically excluded from doing the same (Stubbs et al., 2021): Peripheries therefore faced depressed demand for their exports, crippling foreign debts and lack of foreign exchange that functionally excluded them from importing vaccines, tests and medical equipment (Elkhishin and Mohieldin, 2021).[2] By excluding access to life-saving vaccines, Core countries prolonged the virus outbreak, increased the risk that new, potentially more dangerous variants would eventually emerge, put a majority of the world's population at risk, and heightened the financial stress of the Periphery.

6.1.2 *Proceeding with Cooperation: Supporting policy coordination and national sovereignty*

Along similar lines, this thesis has also attempted to highlight that an ethical and sustainable economic pathway may be impossible without coordinating efforts to support a global ethic of cooperation, rather than competition. Despite growing recognition of the uneven causes and consequences of environmental degradation, international climate negotiations have failed to catalyze a truly global initiative based on social equity and cooperation. Swift action to redress climate inequalities will have to be conducted through the principle of "common but differentiated responsibilities" (UNFCC, 2015) which recognize the shared but different burdens and adaptive capacities of each country (O'Brien, 2011).

However, in a world led by competitive struggles between firms and nation-states, even ambitious measures that are taken on a piecemeal, country-by-country basis may backfire. For example, some countries may continue to pollute, hoping to "free-ride" on the environmental achievements of others. Alternatively, while strict environmental regulations can be beneficial for some firms or sectors (Guarini, 2020), it is also likely to allow for new lower-cost global market leaders to emerge to capture market-share. More stringent regulations in one area may also incentivize polluting firms to move to other, more permissive jurisdictions to safeguard profits. Furthermore, 'green' structural changes that raise profits, incomes and employment in one area will further enhance access to pollution- and resource-intensive goods from abroad (Chapters 4 and 5). In short, even well-intentioned efforts in the context of inter-firm and inter-state competition may not resolve 'ecological' problems, but merely push them around.

In the absence of cooperation, the socio-ecological vulnerabilities of one group are turned into opportunities for accumulation for another (Bryant and Bailey, 2005). Whereas the recognition of our shared vulnerability could otherwise serve as a basis for greater solidarity, care

2 As of 2019, 45 countries paid more in servicing foreign debts than they did on health care (Khan and Shanks, 2020).

and attentive coordination, a global social system locked into competitive struggle makes vulnerability a liability.

In the presence of vulnerability, competitive pressures tend to drive individuals, firms and nation-states towards self-protective measures that displace risk and uncertainty to rivals. Efforts to increase productivity, capture market share, control valuable assets, and access to key resources become necessary *defensive* survival-strategies in the context of global competition.[3]

From the perspective of this thesis, vulnerabilities within the global battle for financial, productive and monetary power can push countries towards ever-weaker positions within institutional hierarchies. Falling behind competitors brings multiple socio-ecological risks: rising unemployment, falling incomes, taxes and export revenues, financial instability, and rising environmental degradation. At the bottom of global hierarchies, countries compete largely by ensuring the export of domestic resources and by attracting pollution-intensive industries that often bring little long-term socio-economic benefit (Althouse et al., 2022). In short, failure to compete in the hierarchy can create vicious circular and cumulative downward cycles.

As Andersson and Lindroth (2001) describe, this global competition is virtually impossible to escape. In their view,

> it is almost impossible for a country to opt out of this kind of positional competition. In a full world, the rivals may not accept a unilateral withdrawal from the game, and even if they did, it may be technically impossible not to 'export' sink capacity [and domestic natural resources], however unwillingly...(P)ositional competition at best yields no net benefit for the actors as a whole, and usually involves additional resource costs, so that positional competition itself is liable to be a negative-sum game. (Andersson and Lindroth, 2001, p. 117)

In a global system fueled in large part by displacing social and environmental burdens, competition necessarily fuels the logic of growth and drives efforts to capture and transform nature to protect against domination by rival competitors.

Going back to some of the founding texts in ecological economics, it is interesting to note that the logic of infinite growth was maligned less because of any inherent 'physical' limits, but because it forced

3 This impulse to control to avoid vulnerability is intimately linked to the post-Keynesian understanding of uncertainty and the drive to power. According to post-Keynesians, agents in the presence of uncertainty will seek to reduce their own exposure to risks, largely by shaping institutional and contractual conditions to expose their counterparties (Monvoisin and Rochon, 2007). As Lavoie (1992, pp. 99–100) writes, "the firm wants power over its suppliers of materials, over its customers, over the government, over the kind of technology to be put in use...In a world without uncertainty, the notion of power dissolves and loses much of its importance".

nations and classes into an unavoidable rivalry on a *shared* planet. Georgescu-Roegen was particularly clear that continued industrial growth inevitably heightened social conflicts among classes and nations and created a "structural lock" that supported extravagance for some and deprivation for others (Georgescu-Roegen, 1971, p. 314). The social logic of growth could therefore only be understood from "the perspective... of [already] developed (and hence economically and militarily powerful) nations" (Georgescu-Roegen, 1986, p. 8).

Cooperation is then an essential antidote to the hierarchical struggles that engender unsustainable global social relations.[4] Indeed, Georgescu-Roegen argued that major systemic changes will be necessary to instill a cultural ethic of cooperation, alongside values of sufficiency, equality and peace. The task at hand, he said, "requires the cooperation of all nations, a point which reveals that there is a far more dreadful crisis than that of energy, namely, the crisis of the wisdom of homo sapiens sapiens." (Georgescu-Roegen, 1986, p. 18). Global cooperation is then the mirror image of the present global competition for power, resources, and perpetual economic growth.

To that end, this thesis pointed to the need for coordination in order to reconfigure both the structure of global trade (Chapter 4) and global financial and monetary relations (Chapter 5) in order to relieve competitive spirits. The unequal structure of current monetary and financial institutions appear to be a major linchpin holding in place the present unsustainable hierarchy of interstate competition. Keynes (1933, p. 180), for example, wrote about the ways that global financial and economic entanglements have tended to privilege the protection of foreign interests through "the capture of new markets, [and] the progress of economic imperialism", all to the detriment of local sovereignty. Keynes saw policies that aided national self-sufficiency as necessary to reduce geopolitical conflict, alongside "the creation of an environment in which other ideals can be safely and conveniently pursued" (Keynes, 1933, p. 185).

One suggestion that should be taken seriously, already put forward in Chapter 5, is a Commodity Reserve Currency (CRC) as put forward by Nicholas Kaldor in 1964. In much the same spirit, Keynes advocated for an International Clearing Union (ICU) and International Commodities Board (ICB) at the Bretton Woods conference (see Fantacci, 2017; Ussher, 2009). Each of these plans intended to give much more leeway for countries - particularly the Periphery - to decide on

4 Ample empirical and theoretical evidence suggests that hierarchical forms of social organization are necessarily energy- and resource- (Bichler and Nitzan, 2020; Fix, 2019a,b) intensive. Not only do hierarchies generate waste in an attempt to manage and corral subordinates to secure control, they socially and geographically isolate decision-makers from those further down the latter. Top-down decision-making practices are rarely nuanced or responsive, but must become standardized and reactive. As such, hierarchies quickly become "unsustainably removed from both places and people" they are originally meant to protect and serve (M'gonigle, 1999, p. 15).

their own national development strategies, outside of constant productivity improvements, commodity price swings, and fear of foreign competition. By dampening the structural need to raise export earnings, countries would be able to focus on domestic priorities that may have little to do with continuous productivity gains yet raise social welfare, nonetheless. With less pressure to attract foreign currency, for example, countries would be able to implement more stringent environmental and labor standards without fear of retribution by financial markets. By reducing competitive tensions within and between countries the CRC/ICU/ICB could enhance coordination for accomplishing collectively beneficial long term social and environmental goals.

In particular, this thesis argued that an CRC/ICU/ICB plan may be a necessary first step to creating a serious avenue for degrowth. Until now, degrowth and post-growth policies have largely been studied only in the context of high-income countries with no trade or financial obligations. Yet the global monetary, financial and trade systems pose serious constraints any attempt to degrow. On the one hand, it will likely heighten the various potential obstacles already discussed by degrowth scholars (e.g., the potential increase in inequality, employment losses, increase in public debts) (Jackson and Victor, 2015, 2020). On the other hand, it brings new potential risks, including those associated with capital flight, exchange rate risks, currency depreciation, imported inflation, and foreign indebtedness.

Greater cooperation for degrowth is particularly important in the context of a Core-Periphery system. For example, as described in Chapter 4, while a degrowing Core country may help to achieve global climate goals and provide greater operating space for material growth in the Periphery, it can have counterintuitive effects. In particular, the Core serves as a key source of demand for Peripheral firms. Certainly, much of this foreign demand sustains resource- and pollution-intensive production and should be reduced. Nevertheless, degrowth without major cooperation between regions will inadvertently increase unemployment, reduce export earnings, and raise inequality in the Periphery. In sum, while degrowth is perhaps necessary in the Core, untying the current knot of interdependent and uneven economic entanglements likely implies far more radical global changes than are commonly considered.

6.1.3 *Proceeding by Coupling: Identifying how to consciously redirect economic institutions to serve the conditions of life*

Greater cooperation, though, is likely a necessary, but insufficient step towards sustainability. Cooperation at the global level may allow for a more equitable distribution of social power, and enable a more functional, stable and resilient social system. Yet this says little about what,

exactly, should ultimately be sustained and how we would like to sustain it.

From the perspective of this work, any attempt to achieve sustainability by 'decoupling' the economy from environmental impacts is both empirically unfounded and theoretically misguided. First, evidence demonstrates that decoupling has not occurred at the global scale (Haberl et al., 2020; Hickel and Kallis, 2019; Parrique et al., 2019), that energy- and material- intensities are globally rising (Duro, Schaffartzik, and Krausmann, 2018; Schandl et al., 2018; Wiedmann and Lenzen, 2018), and that these are often the result of our very attempts to 'decouple' the economy and the environment (Bonds and Downey, 2012). Second, and perhaps more importantly, the desire to 'decouple' expresses perhaps *the* foundational cultural malaise at root of our ecological crisis: the belief in our separation from nature (Pattberg, 2007).

The language of decoupling appears to be a misguided relic of Enlightenment-era thinking that veils the place of humanity as one of many strands woven into, and out of, 'the web of life' (Moore, 2015). In short, to argue for decoupling - consciously or unconsciously - disavows our actual relationship with the very world within which and through which we live our lives (Medovoi, 2010), and overlooks the vast potential for other ways of being in the world (De Castro, 2019; Descola, 1996; Kothari et al., 2019).

Wealthy societies of the so-called "information age" are no more or less 'decoupled' from the environment than a hunter-gatherer tribe on the other side of the world. The former's impressive control over global resource flows, however, would be impossible without large and environmentally-disconnected institutions (M'gonigle, 1999), backed by a social cosmology which renders much of the non-human world into a pile of resources to be owned, speculated upon, made "cheaply" available (Brand and Wissen, 2018).

Climate change, biodiversity loss, deforestation and water and air pollution are not simply external environmental threats that must be managed. Nor are they reflective of 'humanity's' growing impact on the environment. Rather they are "manifestations of modernity, symptoms of dominant patterns of development, outcomes of social relations, and products of short-sighted visions, which are closely linked to beliefs, values, and world-views." (O'Brien, 2011, p. 542). These world-views have been deeply embedded in social institutions over centuries. Sustainability on a shared planet of human and more-than-human beings will not be possible as long as our institutions and world-views are informed by reductive materialism and a collective denial of our own place within the web of life.

If nature cannot be transcended, it must be embraced. That economic behaviors will 'impact' the environment is undeniable. The question is not how to reduce our impacts, but how to create a society where our impacts are nourishing and serve the conditions for

meaningful and fulfilling lives.[5] Sustainability, then, can only come from a more conscious coupling of our social and economic institutions within and through nature.[6]

Indeed, 'the economy' is little more than an expression of our material relationships with each other and with the Earth (Hickel, 2020, p. 252). Economic institutions both reflect and bring forward particular world-views, ethics, and modes of living and relating (Brand and Wissen, 2018; Svartzman, 2020). Perhaps the most vital questions of our time are: What kind of relationships, attitudes and practices we wish to reproduce? What sort of environments we wish to inhabit?. And how will it be possible to enable "the emergence of a much-needed new ethics of human-nature relationships" (Svartzman, Dron, and Espagne, 2019, p. 117)?

The task of harmonizing economic and social institutions with the web of life, however, will require drastic changes to present modes of living and relating. Indeed, evidence given here suggests that a more sustainable economic system is at least partially at odds with the competitive drive and hierarchical form of capitalist institutions (Brand and Wissen, 2018). For example, reducing the grip of financial power, and the unsustainable subordination of Peripheral countries, will hinge on reforms that would not only imply degrowth in the Core, but also undercut its material and symbolic power. At some point, the

An in-depth analysis of the kinds of changes that would enable such policies to occur, or how to achieve them, goes far beyond the scope of this work. Many of the eco-socialist degrowth policies (working time reductions, universal basic income, moratoriums on extraction, support for public transportation, etc.) already advocated in this thesis and expounded elsewhere (Hickel, 2020) provide some essential steps towards a more sustainable planet. However, reducing growth alone is likely insufficient to achieve the kinds of sweeping changes needed to build a society of human beings which desire to live in communion with the Earth.

Alternative ontologies of human emancipation and post-development (Escobar, 2015; Kothari et al., 2019) offer some potential guidance for how to improve (multi-species) health, and well-being by redirecting human values and world-views towards (re-)integration with nature. These could inform part of a new democratic project that places depth of connection, care and respect for life at the center of insti-

5 Indeed, to sustain comes from the root "sustenance".

6 Bookchin (1990) suggests, for example, individual and collective action can be re-oriented towards greater freedom and creativity by embodying our role as a self-conscious expression of nature. For Bookchin, "by their very own biologically rooted mental power, they [human beings] are literally constituted by evolution to intervene into the biosphere [...] their presence in the world of life marks a crucial change in evolution's direction from one that is mostly adaptive, to one that is, at least, potentially creative and moral." (Bookchin, 1990, p. 72). See also Reclus (1876, 2013) and Leff (2021).

tutions. Projects that support the protection of the Planetary Commons, for example, through improved local resource governance and economic sovereignty, alongside efforts towards decommodification, by reducing protections for private property, would be essential (Ajl, 2021). Proposals along these lines go far beyond the possibilities of the existing institutional framework, yet are likely essential components of any attempt to build a future of shared prosperity and planetary health.

6.2 LIMITATIONS AND AVENUES FOR FUTURE RESEARCH

Despite providing a number of conceptual and methodological innovations to the field of ecological macroeconomics, this work is not without limitations. In particular, this thesis remains predominantly conceptual. The theory and analysis here was, nevertheless, informed by a large breadth of empirical research and case studies detailing in order to "connect the dots" between different streams of literature. For example, studies demonstrating the (lack of) 'decoupling' of economies from environmental impacts (Haberl et al., 2020; Ward et al., 2016; Wiedmann and Lenzen, 2018), the uneven appropriation of nature and labor between Core and Peripheral countries via relationships of "ecologically unequal exchange" (Dorninger et al., 2021; Jorgenson, 2016; Magalhães et al., 2019) allowed me to develop a model which integrated both post-Keynesian ecological macroeconomics and ongoing empirical and theoretical research in political ecology in Chapter 4. Furthermore, the conceptual framework for Chapter 5 was informed by detailed empirical research investigating the ways that the proliferation of global value chains have tended to reinforce environmental inequalities between the Core and Periphery (Duan, Ji, and Yu, 2021) alongside case-studies of how financial dynamics are shaping global commodity markets (Baines and Hager, 2021; Labban, 2010, 2014) and firm behavior in extractive industries (Bowman, 2018; Parker, Cox, and Thompson, 2018).

While borrowing from completed empirical analyses allowed me to develop a stylized interpretation of the relationship between financial globalization and hierarchical monetary, productive and environmental institutions, this research could not test the causal link between these complex structures, on its own. Additional empirical work and case studies would significantly bolster the analytical frameworks put forward in this research. Nevertheless, it should be noted that in the process of making this thesis, some such work (sometimes in collaboration with the author) has been conducted with such a goal in mind. Much of the studies provide further confirmation of what was already discussed in the thesis. For example, Svartzman and Althouse (2020) study the limits of combating climate change within the present international monetary system (IMS). Their paper links the international

dominance of the US dollar to China's coal-powered development to show how the currency hierarchy is supported by an extension and intensification of extractive relations. They gather country-level data to detail how China's rise in the ranks of geopolitical power has gone together with diverse attempts to wield increasing currency power in order to support its own resource-intensive growth.

Following from this, a recent masters' thesis by Olk (2021) developed a novel method for testing the proposed causal link between a hierarchical IMS and the asymmetric transfer of resources from Peripheral to Core countries. The author constructs a piecewise Structural Equation Model (pSEM) and tests it against cross-country data. By linking measures of liquidity premia in the foreign exchange market to observed material and energy balances, he finds some preliminary evidence for the monetary hierarchy's effect on ecologically unequal exchange.

Moreover, a working paper by Althouse et al. (2022) conducts a statistical analysis to specify the link between the degree of participation within global value chains and ecologically unequal exchange (Chapter 5). The authors perform a principal components analysis and a clustering analysis to identify patterns of social, ecological and productive development associated with insertion within GVCs for 133 countries from 1995-2015. The study results affirm that environmental asymmetries are driven in large part by differences in how national production structures are integrated within GVCs. In particular, countries with a higher capacity to capture value from GVC participation ("reproduction of the core") were shown to be uniquely capable of displacing environmental impacts to countries facing a trade-off between the positive socio-economic impacts of rapid GVC integration and ecological degradation ("ecologically perverse upgrading"). Other countries were shown to be marginalized within GVCs ("curse of GVC marginalization"), leaving them uniquely exposed to ecological degradation with few of the potential benefits of social and productive upgrading found in GVCs.

As the present thesis has been predominantly an exploratory, additional work could also improve the quality and explanatory power of some of the findings of this thesis. First, the description of financialization as a 'socio-ecological' regime of accumulation could be extended to other time-periods to understand how hierarchical monetary, productive, and environmental relations have been established and cohered over time. For example, the 'Fordist' regime of accumulation of stable exchange rates, stronger worker protections, less global competition and more on-shore extraction presented a number of different institutional differences that may add a fuller picture to what was described in Chapter 5. Certainly, this could also be applied to earlier periods as well, to determine the degree to which a similar

institutional 'functionality' of hierarchical monetary and financial relations are apparent.

Second, this research opens up a much larger potential project about the relationship between monetary regimes and environmental degradation within capitalism. If money, as Marx says, is a primary instrument by which capital emerges into the world, "dripping from head to toe, from every pore, with blood and dirt" (Marx, 1992, p. 926), then more will have to be done to unearth the socio-ecological foundations of past, present and future monetary orders. Indeed, a wealth of scholarship has argued that there is a clear connection between monetary power, social conflict, and widespread environmental degradation (Di Muzio and Robbins, 2015; Hornborg, 2019; McNally, 2020; Patnaik and Patnaik, 2017; Schoenberger, 2008).[7] If money is a social relation that is "actively created and engineered by societies for collective purposes" (Helleiner, 2017, p. 201), then money can also be seen as a political project that plays a role in organizing human-nature relations to serve particular interests and modes of being (Svartzman et al., 2020).

Third, and related to the above, future research should consider the extent to which the hierarchical arrangement of global currencies creates its own 'growth imperative'. Chapter 2 showed that ecological macroeconomists have already explored whether or not a monetary system based on positive interest-bearing debt results in a growth imperative. Research in Chapter 5 of this thesis points towards an alternative reason that monetary systems may be driving growth. Countries at the bottom of the monetary hierarchy suffer disproportionately from major financial, economic, social and ecological consequences. Unsustainabile growth may then result from an ongoing, and unfortunate, positional competition to maintain sovereignty in system of hierarchical dominance (Andersson and Lindroth, 2001; Svartzman and Althouse, 2020).

Finally, future research could attempt to better integrate the ways that pollution and resource extraction are inextricably linked to social inequalities within existing models already used in ecological macroeconomics. This thesis already demonstrated some potential for integrating such findings, but a number of alternatives are likely possible. Indeed, post-Keynesian models used in ecological macroeconomics generally describe firm profitability as an institutional variable that depends on class power and market structure. From the perspective of this work, firm profitability could also be shown to depend on social-ecological institutions. An institutional variable would then proxy a firm's capacity to offload the costs of pollution and ex-

7 For example, national currency standards among early capitalist states developed primarily as a means to finance and wage war (McNally, 2020). New financial architectures were later developed to insure and charter the first corporations for colonial excursions to capture distant resources, in large part to service national debts and retain currency power (Bhambra, 2020; Di Muzio and Robbins, 2017).

traction to society and nature (Kapp, 1971): their ability to displace burdens geographically (Frey, 2019), their power to 'cheapen' access to resources (Moore, 2000), or their capacity to shape the political conversation to stall meaningful policy intervention and avoid controls, quotas, fines, taxes, or cleanup-efforts (Oreskes and Conway, 2011). This would likely be impacted as much by the structure of markets (e.g. oligopoly), the strength of democratic institutions, as well as the distribution of income.

Similarly, existing models in ecological macroeconomics already identify that income is distributed between classes of workers and capitalists. Given the well-understood relationship between social class, and emissions, and exposure and vulnerability to environmental degradation (see Chancel, 2021; Huber, 2022; Wiedmann et al., 2020), future work should begin by establishing an endogenous link between these elements. Such a move would be a major step to reimagining environmental degradation in current models. By endogenizing the relationship between capital ownership and environmental harm, finding a way out of planetary destruction would no longer be a matter of investment and technology, but a matter of social conflict.

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A

APPENDIX

A.1 DERIVING THE EFFECTIVE RATE OF GROWTH

Aggregate demand is divided in two components, domestic absorption A and net real exports, $X - RM$, where R is the real exchange rate, defined as $R = \frac{P^C r}{P^P}$.

$$Y^P = A + X - RM \tag{14}$$

The demand for exports and imports are given by constant-elasticity demand functions,

$$X = R^{\mu_X}(Y^C)^{\epsilon} \tag{15}$$

$$M = R^{\mu_M}(Y^P)^{\pi} \tag{16}$$

where μ_X and μ_M are price elasticities of exports and imports, respectively, and ϵ and π are income elasticies of exports and imports, respectively. Taking logs and differentiating with respect to time, and representing proportional rates of growth with small letters (e.g., $a = \frac{\dot{A}}{A}$), and assuming a constant exchange rate in the long run we get:

$$y^P = \tilde{\alpha}a + \beta_1 x - \beta_2 m \tag{17}$$

In Equation 9, $\tilde{\alpha} = \frac{A}{Y^P}$, $\beta_1 = \frac{X}{Y^P}$ and $\beta_2 = \frac{M}{Y^P}$. Using Equations 15 and 16 in 17 gives:

$$y^P = \frac{\tilde{\alpha}a + \beta_1 \epsilon y^C}{1 + \beta_2 \pi} \tag{18}$$

Making $\alpha \equiv \frac{\tilde{\alpha}}{1+\beta_2\pi}$ and $\beta \equiv \frac{\beta_1}{(1+\beta_2\pi)}$ renders:

$$y^p = \alpha a + \beta \epsilon y^C \tag{19}$$

Since the rate of growth of exports (x) in the Periphery is given by the income elasticity of exports (ϵ) and the rate of growth of income in the Core (y^C), $x = y^C \epsilon$, Equation 19 can be rewritten as Equation 5 from the main text:

$$y^p = \alpha a + \beta x \tag{20}$$

A.2 ENDOGENIZING THE TECHNOLOGY GAP AND THE "GREEN GAP"

Here we present a simple model of the evolution of the Core-Periphery green technology gap G, and its relationship to endogenous changes in environmental efficiency in and between regions. We follow post-Keynesian and Structuralist literature by assuming that improvements in productive structure in the Periphery result from purposeful investments that decrease the "technology gap" between itself and the technological leader (see Cimoli and Porcile, 2011; Porcile and Spinola, 2018). G is the technology gap, $G = \frac{T^C}{T^P}$, which indicates the relative distance in technological capacity between the Core and the Periphery. As G approaches unity, the Core and Periphery operate under similar technical conditions, and have a rate of accumulation of "sustainable" knowledge, learning-by-doing effects, and industrial synergy on par with each other. When G is high, there is a large (green) technological gap between them, indicating a major discrepancy in efficiency. Closing the technology gap is therefore an important aspect of the sustainability transition. A smaller technology gap is thus consistent with improved green efficiency in the Periphery.

Recalling from Equation 7, that $q^P = f(G, w) - by^C$ (with $f_G > 0, f_w > 0, b > 0$), the evolution of the green gap through time, with an exogenous the rate of growth of green efficiency in the Core, will be:

$$\hat{G} = q^C - q^P = q^C - f[(G, w) - by^C] \tag{21}$$

Assume a linear relationship between the technology gap and green efficiency in the Periphery, $q^P = w + \sigma G - by^P$. In equilibrium the green technology gap will be:

$$\hat{G} = 0 \Rightarrow G = \frac{q^C - w + by^C}{\sigma} \tag{22}$$

Recalling that $y^C = q^C - e$, then Equation 22 can be rewritten as:

$$G = \frac{(1+b)q^C - w - be}{\sigma} \tag{23}$$

The higher the social capabilities in the Periphery w, and the lower the transfer of emissions from the Core (assuming $q^C > e$), the lower the green technology gap in equilibrium. Since climate change is a global existential threat, the degree of pollution transmission is an important variable to consider. Finding a globally sustainable growth path is made exceedingly complicated if the presumed efficiency increases from technological improvements are overcome by "rebound

effects" at the micro, meso, macro and international scales (Rezai, Taylor, and Mechler, 2013; Wei and Liu, 2017).

While b is positive, y^C can be either positive or negative. If positive, economic growth in the Core leads to an increase in pollution emissions in the Periphery. Without sufficient increases in "green efficiency" in developing countries, pollution transmission from the Core raises global emissions. This may happen either *despite* or *as a result of* policies that reduce pollution in the Core. If y^C is negative, the Core has a contracting growth rate and therefore demands less imports of pollution intensive production from the South. In equilibrium, $q^C = q^P$. If the global economy is on the CPEF, then $y^C = y^P = q^C - e$. During the transitional dynamics, the Periphery converges with the Core since $q^P > q^C$ which implies (from Equation 9) that $y^P > y^C$. When G is in equilibrium, the only avenue through which the Periphery can converge is by changing the parameters that define the green technology gap in equilibrium (w, b and q^C).

Note that the above conditions are those required for the world to be upon the CPEF. The technology gap also affects the BP curve, to the extent that it alters the pattern of specialization in the Core and Periphery. While the two schedules (CPEF and BP) co-evolve and are interrelated, there is no automatic mechanism that make them converge. Recall that y^{P*}, the equilibrium rate of growth in the Periphery, is given by Equation 3 and Equation 4. Convergence of the BOP-constrained rate of growth and the rate of growth consistent with the CPEF should be driven by policy interventions which adjust the responses of exports and emissions so that they are convergent. This explains why Scenarios 3 and 4 imply such a major institutional challenge to existing political and economic relations.

A.3 THE CONDITIONS FOR DEGROWTH IN THE CORE AND GROWTH IN THE PERIPHERY

To construct scenarios 3 and 4, in which there is degrowth in the Core and a positive growth rate in the Periphery, it is necessary to explicitly consider international capital flows in the balance of payment constraint, a possibility not addressed before. When capital flows are included in the BOP-constrained growth model (see Thirlwall and Hussain, 1982), Equation 4 becomes:

$$y^{P*} = \frac{\zeta \epsilon y^{C*} + (1-\zeta)n - \hat{P^P}}{\pi} \tag{24}$$

where n is the growth rate of the net capital inflows and $\zeta = \frac{P^P X}{P^P X + N}$, where P^P is the price level in the Periphery, X is the quantity of exports and N are capital inflows. Obviously, Equation 24 equals Equation 4 if $\zeta = 1$. According to Equation 24, the only way to have

degrowth in the Core and a positive growth rate in the Periphery is to assume that the growth rate of real net capital flows is positive and higher than the negative value of $\zeta \epsilon y^{C*}$. This condition highlights how a degrowth scenario in the Core, compatible with positive growth in the Periphery, will place political barriers that would be extremely difficult to overcome. In effect, the Core will face the double burden of transferring capital to the Periphery while their own income is falling.

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MACROÉCONOMIE ÉCOLOGIQUE POUR UNE PLANÈTE PARTAGÉE
VERS UNE ÉCOLOGIE POLITIQUE GLOBALE DE LA MONNAIE, LA FINANCE ET DE LA PRODUCTION

RÉSUMÉ

Cette thèse s'appuie sur le domaine émergent de la « macroéconomie écologique » pour étudier la manière dont les modèles dominants de développement sont la source d'inégalités mondiales et de dégradation de l'environnement tout autant qu'ils en résultent. Le chapitre 2 propose une revue de la littérature sur la macroéconomie écologique, et répertorie cinq thématiques à travers lesquelles elle contribue à la compréhension des dynamiques économie-environnement. Le chapitre 3 procède ensuite à une évaluation critique du cadre de la macroéconomie écologique, fondée sur l'idée qu'une analyse rigoureuse des défis environnementaux requiert d'appréhender la nature comme intrinsèquement *politique* et organisée par des conflits sociaux. Cette approche est mise en pratique dans le chapitre 4, qui utilise un modèle « Centre-Périphérie » (croissance contrainte par la balance des paiements) pour étudier la manière dont les inégalités environnementales mondiales peuvent être renforcées par la transition vers une économie « verte ». En particulier, l'augmentation de l'efficacité énergétique et environnementale au « Centre » (pays à revenu élevé) dépend de la délocalisation des activités à forte intensité de carbone dans la Périphérie (pays à revenu faible). Le chapitre 5 élargit l'analyse en abordant la thématique de la financiarisation via le cadre théorique de cette thèse. La financiarisation peut alors être comprise comme une dynamique mondiale de (ré)organisation environnementale, soutenant l'accumulation dans le Centre au détriment de la stabilité sociale et environnementale dans la Périphérie. Cette dynamique est permise par la subordination des pays de la Périphérie dans l'organisation des relations monétaires, productives et environnementales mondiales. Le chapitre 6 résume et conclut. Les éléments présentés tout au long de la thèse signalent que pour être en mesure de relever les défis actuels, la macroéconomie écologique se doit de développer une vision politique de la nature.

Mots Cléfs: macroéconomie écologique, écologie politique, découplage, échange écologiquement inégal, croissance verte, développement inégal, système monétaire international, décroissance, Centre-Périphérie

Key words: ecological macroeconomics, political ecology, decoupling, ecologically unequal exchange, green growth, uneven development, international monetary system, degrowth, Core-Periphery