The Balance-of-Emissions Constraint on Growth: Pathways to Net-Zero Greenhouse Gas Emissions in a Simple Post-Keynesian Model

Ryan Woodgate
Forward College Berlin

Valeria Jiménez
HWR Berlin/ USPN

Demand and Growth Regimes: Expanding the Debate
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Motivation

- Although there is broad consensus regarding the need to decarbonise the global economy, there is less consensus, when it comes to *how* to achieve the established goal of net-zero carbon emissions by 2050.
- Broadly speaking, decarbonization is possible through a reduction in the emission intensity of GDP (green growth) and/or a reduction of output growth (post-growth).

$$I = PAT$$

Impact　Population　Affluence　Technology

Decarbonization and economic growth in three main strands

1. Mainstream Green Growth
   - →With the right incentives, markets can drive the transition to cleaner technologies.
   - →Growth is necessary
2. Heterodox Green Growth
   - →Focus placed on the active role for the government in driving the transition to cleaner technologies. This might include more stringent environmental regulations, direct interventions, and public investment and ownership of key sectors.
   - →At least some growth will be necessary
3. Post Growth
   - →Clear rejection of over-reliance on technological efficiency while emphasizing the need to reduce unnecessary forms of production and transforming consumption patterns to ensure sustainable well-being. Focus also on the insufficient levels of absolute decoupling.
   - →There are constraints on economic growth

Research Questions

What constraints does the goal of net-zero carbon emissions impose on global economic growth and what determines these constraints?

How can public policy influence the “balance-of-emissions constraint” on growth?

Post-Keynesian Literature so far: Three Strands

1. **No explicit presupposition regarding the compatibility of decarbonization and economic growth**
   - This strand within PKE does not actively engage with the previously mentioned debate regarding the compatibility between decarbonization and economic growth. Instead, it focuses on how different policies or policy packages can help tackle different aspects of the climate crisis and the green transition, or the other way around: how the climate crisis will affect macroeconomic aggregates.
   - Onaran (2022), Rezai et al. (2018), Taylor et al. (2016), Dafermos and Nikolaidi (2019)
2. **Zero-growth or degrowth are possible under certain conditions.**
   - This strand, directly informed by the post-growth literature, makes use of a post-Keynesian framework to analyse the macroeconomic implications of zero growth or even de-growth, or the transition toward such a position.
   - Lavoie/Cahen-Fourot (2016), Fontana/Sawyer (2013; 2016; 2022), Monserand (2019), Hein/Jimenez (2022), Jimenez (2023)
3. **Zero-growth is not possible and/or green growth is necessary to achieve decarbonization.**
   - This strand is dubious about the desirability and/or feasibility of zero or de-growth.
   - Priewe (2022), Pollin (2019;2020), Huwe and Rehm (2022), Cahen-Fourot (2022).

Our contribution to Post-Keynesian Economics

- Rather than assuming that there is a net-zero constraint on long-run growth, or no constraint on growth, we aim at offering a formal demonstration of its existence of such constraint and its determinants.
- We show that this balance-of-emissions constraint depends on a number of parameters that may be influenced by policy.
- Hence, we argue that the precise limit on growth implied by the goal of net zero—and whether this limit is negative, zero, or positive—depends partly on public policy around the world and the extent of international coordination.

A Simple Sraffian Supermultiplier Model of Pathways to Global Net Zero Emissions: Assumptions and setup of a basic ***long-run*** macroeconomic model of the global economy

1.	$D = Y = \min(\frac{L}{a}, \frac{K}{v})$	Firms meet demand with output produced using smallest amount of labour and capital required, but do not necessarily minimise emissions
2.	$Y = C + I + G$	Global economy -> No trade
3.	$C = c(1 - \tau)Y$	c: Overall propensity to consume; τ: Overall tax rate
4.	$I = hY$	h: Propensity to invest
5.	$\hat{G} = g$	g: *Autonomous* growth rate of govt expenditure
6.	$Y = \mu^* G$	$\mu^* = 1/(\lambda - h^*)$, long-run supermultiplier depends on $h^* = gv/u_n$ and demand leakage parameter $\lambda = 1 - c(1 - \tau)$. Stability assumed: $\lambda > h^*$
7.	$\hat{Y} = \hat{K} = \hat{L} = g$	Long-run global growth rate is a policy variable

A Simple Sraffian Supermultiplier Model of Pathways to Global Net Zero Emissions: Adding net greenhouse gas (GHG) emissions due to macroeconomic activity, E_N

8.	$E_N = E - A$	Global gross GHG emissions (E) and absorption (A), CO_2-equivalent levels
9.	$E = \epsilon K$	ϵ: Emissions intensity of production capital (endog.)
10.	$A = \alpha N$	N: Natural capital (endog.); α: Absorption capacity per unit of N (exog.)
11.	$E_N = (\epsilon - \alpha\eta)K$	$\eta = N/K$, ratio of natural-production capital

- **Assume 2 techniques of production with identical *a* and *v* but different emissions intensities**: Emission-intensive "brown" technique (ϵ_B) vs low-emission "green" technique (ϵ_G): $\epsilon_G < \epsilon_B$.
- **Inertia**: Firms have no incentive to scrap capital employed using brown tech (K_B) early as it is costly, but can introduce K_G in new gross investment without additional cost. Firms devote a share $0 \leq \phi \leq 1$ of gross investment to green tech.
- **Scope of green tech**: ϕ is affected by policy, but may be limited by technical constraints (i.e. potential for relatively costless decarbonisation may be < 100%, e.g. aviation, steel, cement…)
- **Timing convention:** Introduction of green tech begins at $t = 0$

A Simple Sraffian Supermultiplier Model of Pathways to Global Net Zero Emissions:

(The Pace of) Greening the Capital Stock $E_N = (\epsilon - \alpha\eta)K$

12. $\epsilon = \epsilon_B(1-\kappa) + \kappa\epsilon_G$ — Emissions intensity is average of brown and green emission intensities, weighted by share of green capital $\kappa = K_G/K_B$

13. $\epsilon = \epsilon_B - \epsilon_\Delta\kappa$ — where $\epsilon_\Delta = \epsilon_B - \epsilon_G$

14. $I_G = \phi(I + \delta K) - \delta K_G$ — Net investment into green capital

15. $\hat{\kappa} = \frac{I_G}{K_G} - g = (g+\delta)\left(\frac{\phi}{\kappa} - 1\right)$ — Growth rate of share of green capital stock

16. $\dot{\kappa} = (g+\delta)(\phi - \kappa)$ — Time rate of change of share of green capital stock

17. $\kappa^* = \phi$ — Steady state of the share of green capital in total capital

Expressing κ as a function of time

18. $\kappa(t) = \int \dot{\kappa}\, dt = \phi\left(1 - e^{-(g+\delta)t}\right)$

κ is bound between zero at $t = 0$ and tends to its upper bound of ϕ as $t \to \infty$

A Simple Sraffian Supermultiplier Model of Pathways to Global Net Zero Emissions:

(The Pace of) Restoration of Natural Capital $E_N = (\epsilon - \alpha\eta)K$

19. $\dot{N} = G_N - \rho N$ — G_N: Govt ecological spending; ρ: Maintenance cost per unit N

20. $\hat{\eta} = \hat{N} - g = \frac{\gamma}{\eta}\left(\frac{\lambda u_n}{v} - g\right) - \rho - g$ — $\gamma = G_N/G$

21. $\eta^* = \frac{\gamma}{\rho+g}\left(\frac{\lambda u_n}{v} - g\right)$ — LR ratio of natural-production capital (strictly positive due to Keynesian stability). Clearly, $\eta^* = 0$ if $G_N = 0$.

22. $\dot{\eta} = (\rho + g)(\eta^* - \eta)$ — Time rate of change of natural-production capital ratio

Expressing η as a function of time

23. $\eta(t) = \int \dot{\eta}\, dt = \eta^* - (\eta^* - \eta_0)e^{-(\rho+g)t}$

where η_0 is the ratio of natural to production capital when the green transition begins at $t = 0$

Lastly, we make the level of capital an explicit function of time

24. $K(t) = K_0 e^{gt}$

A Simple Sraffian Supermultiplier Model of Pathways to Global Net Zero Emissions

Putting it all together: Long-run Net GHG Emissions $E_N = (\epsilon - \alpha\eta)K$

25. $E_N(t) = \epsilon_N(t) * K(t)$ $\epsilon_N = \epsilon - \alpha\eta$: *Net* emissions intensity.

26. $\epsilon_N^* = \epsilon_B - \epsilon_\Delta\phi - \alpha\eta^*$ Net zero goal implies $\epsilon_N^* \leq 0$

Level of net emissions at any time t

27. $E_N(t) = \left[\epsilon_N^* + \epsilon_\Delta\phi e^{-(g+\delta)t} + \alpha(\eta^* - \eta_0)e^{-(g+\rho)t}\right]K_0 e^{gt}$

Must be $\epsilon_N^* \leq 0$ for goal of net zero to ever be achieved

Tends to 0 as $t \to \infty$: Partly determines *speed* at which net zero is achieved, if at all

Positive for all t: Partly determines *speed* at which net zero is achieved, if at all

Speed of change in net emissions at any time t

28. $\dot{E}_N(t) = K_0\left[g\epsilon_N^* e^{gt} - \left(\delta\epsilon_\Delta\phi e^{-\delta t} + \alpha\rho(\eta^* - \eta_0)e^{-\rho t}\right)\right]$

Must be $\epsilon_N^* \leq 0$ for goal of net zero to be achieved <u>*quickly*</u>

Negative for all t: The more negative, the faster the fall in net emissions. *Tends to 0 as* $t \to \infty$

$\epsilon_N^* \leq 0$ is doubly important! Determines long-run net emissions and speed at which steady state is brought about

Implications of the Model: Theoretical Insights

$\epsilon_N^* \leq 0$ implies an upper limit to how fast the global economy may grow while respecting net zero

- "Balance-of-emissions" constraint: $g \leq \frac{\alpha\gamma\lambda u_n - \rho v(\epsilon_B - \epsilon_\Delta \phi)}{v(\epsilon_B - \epsilon_\Delta \phi + \alpha\gamma)}$
- Special case of ***technological optimism***: $\phi = 1$***;*** $\epsilon_G = 0 \rightarrow \epsilon_\Delta = \epsilon_B$
  - In this case, $g_{TO} \leq \frac{\lambda u_n}{v}$, which is just the usual Keynesian stability assumption. I.e. *under technological optimism so defined, there is no limitation placed on the growth rate by the goal of net zero*
  - Crucially, however, while techno-optimism implies net zero can be achieved without government intervention such that $\gamma = 0$, net zero will likely be achieved *too slowly*
  - "Laissez-Faire Technological Optimism" is quixotic and simply too slow!
- Clear ecological purpose for govt spending: If $\gamma = 0$, $g \leq 0$ (i.e. societal collapse)
- The (super)multiplier effect also reflects the rebound effect
  - Compare $\mu^* = 1/(\lambda - h^*)$ and $\epsilon_N^* = \epsilon_B - \epsilon_\Delta \phi - \alpha \frac{\gamma}{\rho + g}\left(\frac{\lambda u_n}{v} - g\right)$
  - Policies should aim at high λ (τ high and c low) and h^* low (low g and v, high u_n)

Implications of the Model: Theoretical Insights

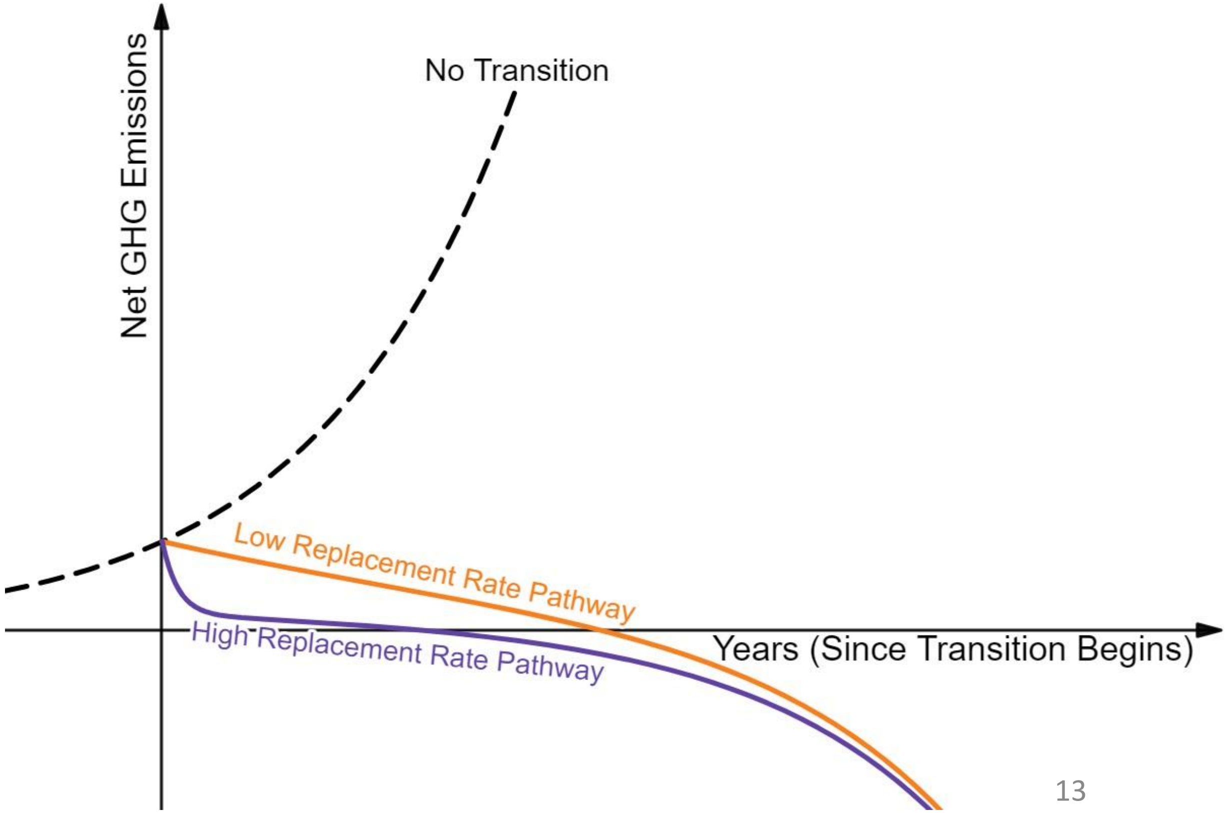
Effect of higher capital replacement rate δ

- $E_N(t) = \left[\epsilon_N^* + \epsilon_\Delta \phi e^{-(g+\delta)t} + \alpha(\eta^* - \eta_0)e^{-(g+\rho)t}\right]K_0 e^{gt}$
- $\epsilon_N^* = \epsilon_B - \epsilon_\Delta \phi - \alpha \frac{\gamma}{\rho+g}\left(\frac{\lambda u_n}{v} - g\right)$

Higher capital replacement rate δ does not effect steady state net emissions, but does effect speed at which LR equilibrium is brought about

Implications for polics (e.g. forced brown capital scrapping)

Figure 2 *Effect of Capital Replacement Rate (δ) on the Speed of Achieving Net Zero*



Implications of the Model: Pathways to Net Zero

Figure 1 *Evolution of Net GHG Emissions over Time in Key Selected Scenarios: Failed (S1), Delayed & Quixotic (S2), and Urgent & Interventionist (S3) Transitions*

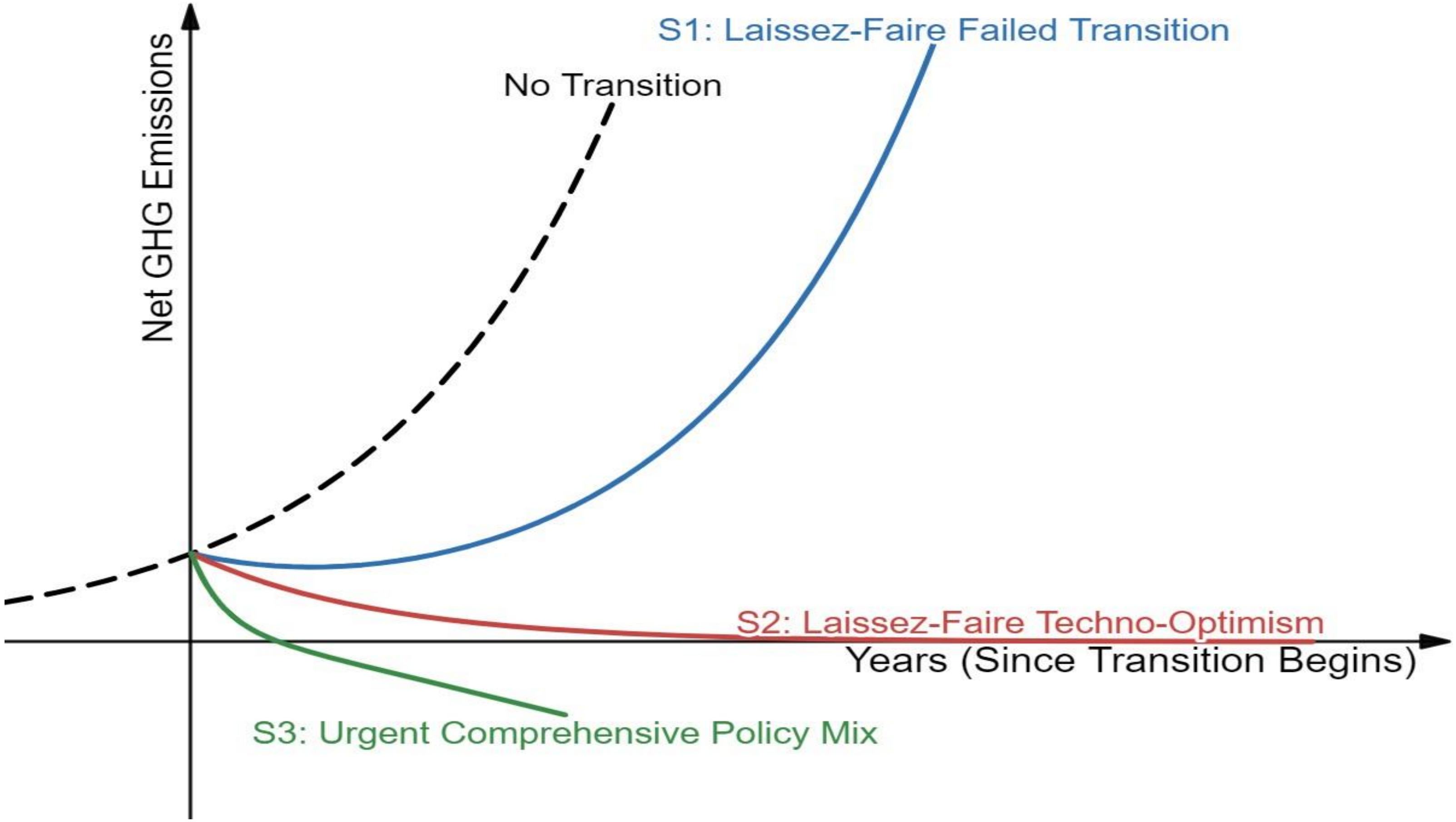


Figure 1 Key	ϵ_G	ϕ	γ	δ	μ	g
Baseline (BL)	$\epsilon_G < \epsilon_B$	0	0	δ_{BL}	μ_{BL}	g_{BL}
S1	$\epsilon_G < \epsilon_B$	< 1	0	δ_{BL}	μ_{BL}	g_{BL}
S2	0	1	0	δ_{BL}	μ_{BL}	g_{BL}
S3	$\epsilon_G < \epsilon_B$	< 1	> 0	$\delta_{S3} > \delta_{BL}$	$\mu_{S3} < \mu_{BL}$	$g_{S3} < g_{BL}$

Conclusion

- The existence of an ecological constraint on growth is often presupposed or loosely inferred in the literature, but controversy abounds and its determinants have yet to be expounded
- In response, we show the existence of a ***balance-of-emissions constraint*** on growth and that the constraint depends on a number of parameters, many of which affected by policy
- Most urgent path to net zero shown to likely involve…
  - high coordinated govt investment in natural capital (γ ↑)
  - regulation to speed up the decarbonisation of production through investment in green techniques (ϕ ↑) and
  - replacement of brown capital (δ ↑)
  - Higher taxation (τ ↑)and discouragement of excessive consumption (e.g. advertising limits) (c ↓)
  - Low rates of growth of autonomous spending ($g \leq g_{BOE}$)
- Limitations and suggestions extensions
  - ϕ and ϵ_G exogenous constants, rather than increasing with innovations over time
  - No endogeneity of the absorption capacity of natural capital (α)
  - g does not affect $\widehat{N}$ and vice versa
  - No monetary policy