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Integrando a sustentabilidade ambiental nas estruturas macroeconômicas: A cruz Eco-Keynesiana

Integrating environmental sustainability into macroeconomic frameworks: The Eco-Keynesian cross

Integrando la sostenibilidad ambiental en las estructuras macroeconómicas: La Cruz Eco-Keynesiana

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Resumo: A transição ecológica depende de uma mudança estrutural ecológica, o que necessita de políticas macroeconômicas inteligentes. A incorporação de considerações ecológicas na modelagem macroeconômica constitui uma área pivotal de investigação que examina o nexo entre a sustentabilidade ambiental e a expansão econômica. Este artigo propõe uma modelagem macroeconômica para estabelecer uma estrutura analítica fundamental para enfrentar esse desafio. Contribuindo para o campo da Macroeconomia Ecológica Pós-Keynesiana, este trabalho propõe uma cruz eco-keynesiana devido à sua

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simplicidade e ampla utilização no ensino de macroeconomia para ilustrar a perspectiva macroeconômica das estratégias de metas verdes em uma economia fechada. Investimentos públicos e privados verdes têm o potencial de aumentar a produção por meio do efeito multiplicador e melhorar a eficiência ambiental. No entanto, esses investimentos também podem induzir efeitos rebote, resultando em um aumento líquido da intensidade da poluição dentro da economia. O modelo destaca a potencial compensação entre objetivos sociais e ambientais, que uma perspectiva ecológica busca superar, defendendo o desenvolvimento industrial sustentável e inclusivo.

Palavras-chave: Macroeconomia ecológica, cruz eco-keynesiana, políticas macroeconômicas ecológicas, efeito rebote

Abstract: The ecological transition hinges on ecological structural change, necessitating smart macroeconomic policies. Incorporating ecological considerations into macroeconomic modelling constitutes a pivotal area of inquiry that examines the nexus between environmental sustainability and economic expansion. This article proposes a macroeconomic modelling to establish a foundational analytical framework to address this challenge. Incorporating ecological considerations into macroeconomic modelling constitutes a pivotal area of inquiry that examines the nexus between environmental sustainability and economic expansion. Contributing to the post-Keynesian Ecological Macroeconomics field, this paper proposes an eco-Keynesian cross due to its simplicity and widespreadness for teaching macroeconomics to illustrate the macroeconomic perspective of green targets strategies in a closed economy. Green public and private investments have the potential to enhance output through the multiplier effect and improve environmental efficiency. However, these investments may also induce rebound effects, resulting in a net increase in pollution intensity within the economy. The model underscores the potential trade-off between social and environmental objectives, which an ecological perspective seeks to surmount by advocating for sustainable and inclusive industrial development.

Keywords: Ecological Macroeconomics, eco-Keynesian cross, ecological macroeconomic policies, rebound effect

Resumen: La transición ecológica depende de un cambio estructural ecológico, lo que requiere políticas macroeconómicas inteligentes. Incorporar consideraciones ecológicas en la modelización macroeconómica constituye un área de investigación fundamental que examina el nexo entre la sostenibilidad ambiental y la expansión económica. Este artículo propone una modelización macroeconómica para establecer un marco analítico fundamental para abordar este desafío. Contribuyendo al campo de la Macroeconomía Ecológica Post-keynesiana, este trabajo propone una cruz eco-keynesiana debido a su simplicidad y uso generalizado en la enseñanza de la macroeconomía para ilustrar la perspectiva macroeconómica de las estrategias de objetivos verdes en una economía cerrada. Las inversiones públicas y privadas verdes tienen el potencial de aumentar la producción a través del efecto multiplicador y mejorar la eficiencia ambiental. Sin embargo, estas inversiones también pueden inducir efectos rebote, lo que resulta en un aumento neto de la intensidad de la contaminación dentro de la economía. El modelo subraya la potencial disyuntiva entre los objetivos sociales y ambientales, que una perspectiva ecológica busca superar, abogando por un desarrollo industrial sostenible e inclusivo.

Palabras clave: Macroeconomía Ecológica, cruz eco-keynesiana, políticas macroeconómicas ecológicas, efecto rebote

Introduction

Since the publication of the Bruntal Report by the United Nations in 1987, persisting poverty and environmental degradation have been considered the most significant threats confronting humanity, and we can only act by promoting new strategies for sustainable development. While the United Nations suggested sustainable growth driven by policies that could balance economic and social systems and ecological conditions, much of the literature has focused on environmental technical solutions, underestimating the importance of other dimensions of sustainability. It is imperative to attain an equilibrium among ecological, economic, and social sustainability dimensions while effectively managing potential trade-offs, which is possible only through integrating policies that are expressly designed to ensure continuous economic expansion, environmental health, and inclusive social progress. To sustain a just ecological transition, governments and institutions, such as central banks and development banks, should strategically coordinate a variety of policy instruments that function across distinct domains over time (Andreoni & Chang, 2019). Consequently, there is a burgeoning discourse on the governance, promotion, and coordination of this type of change.

Integrating ecological issues into macroeconomic modelling is a critical area of research that addresses the intersection of environmental sustainability and economic growth. Addressing this challenge is formidable due to the absence of macroeconomic frameworks and modelling tools capable of evaluating the feasibility of a stable transition through proposed post-growth policies and their viability as alternatives to economic growth (Jackson et al., 2015). Consequently, there is a pressing requirement to either develop novel macroeconomic modelling approaches or modify existing ones to explore potential futures under post-growth conditions (Hardt & O'Neill, 2017). Whereas post-Keynesian economics predominantly focuses on issues related to demand, distribution, and unemployment and generally overlooks environmental dimensions, ecological economics is primarily engaged with the ecological underpinnings of economic production, yet it exhibits a deficiency in macroeconomic analysis (Fontana & Sawyer, 2013; Spash & Schandl, 2009). However, the growing awareness of environmental limits and the need for sustainable development has led to ecological macroeconomics, which aims to incorporate environmental constraints and considerations into macroeconomic analysis.

The integration of Ecological Macroeconomics has predominantly involved the contributions of post-Keynesian scholars, given that post-Keynesian and ecological economics share numerous foundational assumptions (Hardt & O'Neill, 2017). Fontana & Sawyer (2013, 2016) proposed one of the primary analytical ecological macroeconomic models, reconsidering macroeconomic analysis, integrating environmental limits as crucial constraints on growth and advocating for "*a complex and multifaceted set of public policies*" to steer economies towards sustainable development. Just as Rezai et al. (2013) propose a demand-driven ecological macroeconomic model that integrates a systems perspective on natural and socio-economic interdependencies. This model incorporates Keynesian concerns like involuntary unemployment, environmental issues, sustainable consumption, and green investment. They suggest incorporating environmental variables into post-Keynesian analysis yields counterintuitive crucial insights for informing economic and ecological policies (Saes & Romeiro, 2019). Utilizing a closed economy model, Guarini (2020) highlights how adopting a post-Keynesian macroeconomic perspective on environmental sustainability provides analytical tools to devise an ecological conversion of the economic system. While recent endeavours by post-Keynesian scholars to integrate ecological considerations into their models have predominantly neglected open-economy dynamics, Guarini & Porcile (2016) incorporate ecological economics concerns into post-Keynesian models for open economies, suggesting environmental policies can foster competitiveness through environmental innovations, increasing the BOPCG equilibrium rate. Althouse et al. (2020) propose a Keynesian environmental coordination game for evaluating the role of international policy cooperation in achieving social and environmental sustainability. Moreover, Guarini & Oreiro (2023) developed a Post-Keynesian/Structuralist-New Developmentalist model to elucidate the relationship between ecological transition and structural change, and to examine the impact of Ecological Structural Change (ESC) on the Middle-Income Trap (MIT) induced by Dutch disease. According to this perspective, we build an eco-Keynesian cross as an example of how environmental issues can be inserted into a macroeconomic traditional Keynesian framework, highlighting the critical role of policy coordination in promoting sustainable and inclusive industrial development.

2. The eco-Keynesian cross

Ecological structural change considers environmental and social innovations to push for a reallocation of resources and employment from brown sectors characterised by a high

pollution intensity to green ones with greater environmental efficiency (Guarini & Oreiro, 2022). While policies aimed at decarbonization that effectively disentangle ecological degradation from economic activities may not significantly influence the business cycle, they can potentially exert extensive ramifications across the macroeconomic landscape. The incremental costs associated with the transition to a low-carbon economy can directly and indirectly impact households and businesses, modifying their incentive frameworks and potentially influencing their reactions to uncertainty and economic perturbations (Annicchiarico & Di Dio, 2015). Given that policies predicated only on technological advancements may prove inadequate, the ecological transition calls for a coordinated policy strategy that harmonizes an array of policy instruments, including environmental regulations, subsidies, incentives, and infrastructural developments (Jimenez & Mercado, 2014).

We propose an eco-Keynesian cross due to its simplicity and widespreadness for teaching macroeconomics to analyse the critical role of policy coordination for sustainable development in a closed economy. This last assumption is employed in other post-Keynesian ecological models (Guarini, 2020). As shown in Figure 1, the eco-Keynesian cross is composed of two different graphs. Figure 1.a corresponds to the conventional AD-Y graph with the AD curve where AD is equal to the sum of autonomous investment (I), autonomous public expenditure (G) and private consumption (C) that is equal to $\bar{C} + c(Y - T)$, where $\bar{C}$ is the autonomous component of consumption, c is the propensity to consume, and T is Taxes. In particular, I, G and $\bar{C}$ are exogenous variables. For simplicity, the aggregate demand can be expressed by the following equation:

$$AD = I + G + C \quad (1)$$

The 45° line, instead, reflects the market equilibrium between aggregate demand (AD) and real income (Y), expressed by the following condition $AD = Y$.

The second graph 1.b represents the sustainability identity derived from the IPAT identity (Commoner, 1972) that explains the technological relationship between the output and the related environmental pressure, which we represent with the pollution concentration, namely the most evident environmental impact of human activities (Ukaogo et al., 2020). According to this identity, the environmental impact (EI) depends on the Population (P), per capita Affluence (A) represented by per capita GDP, and Technologies (TECH) (Fischer-Kowalski & Amann, 2001):

$$EI = P * A * TECH \quad (2)$$

In the light of the IPAT Identity, defining the variables H and Y respectively as the greenhouse emissions level and GDP, and assuming that the population is constant, the sustainability criterion can be rewritten as follows:

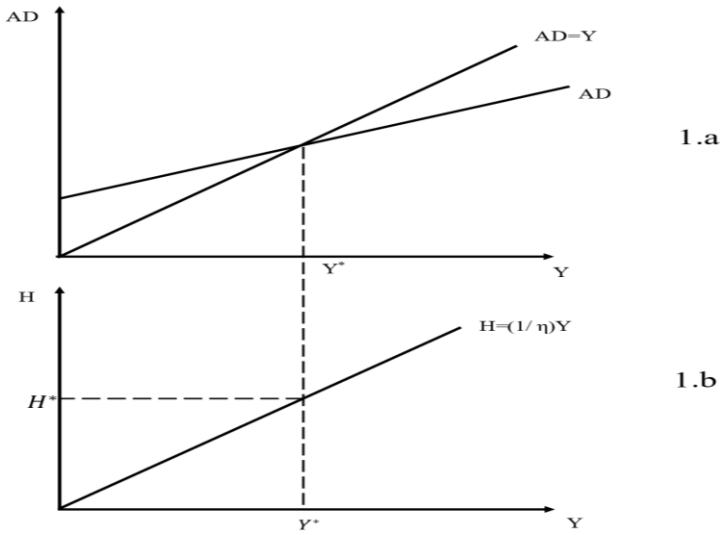
$$H = (H/Y) * Y \quad (3)$$

Defining the environmental efficiency as the inverse of the pollution intensity, i.e. $Y/H = \eta$, we obtain that:

$$H = \left(\frac{1}{\eta}\right) * Y \quad (4)$$

Combining the conventional AD-Y graph and that representing the sustainability criterion as in Figure 1, we identify the starting situation of the economy, where Y^* and H^* indicating the equilibrium values of output and the corresponding level of greenhouse gas emissions, respectively.

Figure 1. The Eco-Keynesian cross.



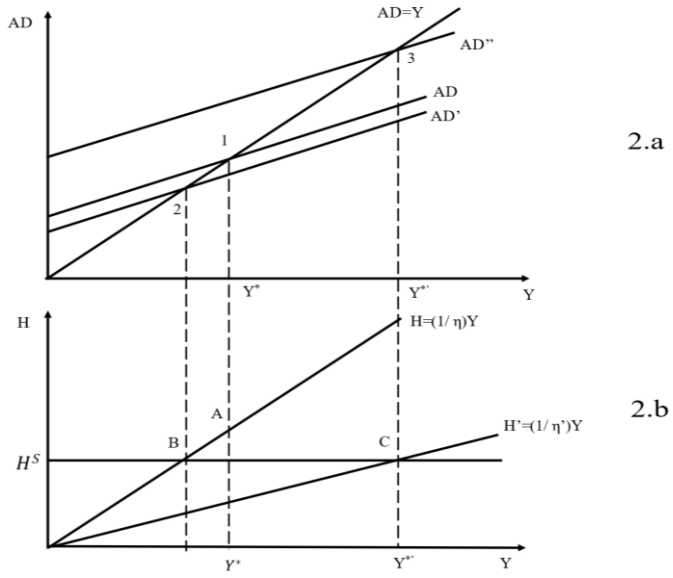
2.1. Ecological macroeconomic policies

Recognizing the unsustainability of the actual economic development, policymakers have expressly set out the goal of constraining the global temperature increase to a maximum of 1.5°C above the pre-industrial level (Huang et al., 2017). To represent this international objective, we introduce in the model a more stringent sustainable target ($H^S < H^*$), as represented in Figure 2.

According to Victor (2012), it is impossible to reduce greenhouse emissions without reducing the size of the economy or simply substituting fossil fuels with renewable energy sources. Schneider et al. (2010, p. 512) define sustainable de-growth as "*an equitable downscaling of production and consumption that increases human well-being and enhances*

ecological conditions at the local and global level, in the short and long term. Sustainable de-growth will involve a decrease in GDP as currently measured, because of a reduction in the large-scale, resource-intensive productive and consumptive activities that constitute a big portion of GDP". This strategy improves ecological sustainability and social equity at the cost of a significant reduction in GDP (Victor, 2012). Reducing the production and consumption allows to satisfy the target immediately: the AD curve goes down to AD', the equilibrium moves from point 1 to point 2 in Figure 2.a and the economy moves from point A to point B in Figure 2.b, where there is greater environmental sustainability and less economic sustainability. The de-growth strategy prioritizes the objective of reducing economic activity with the expectation that environmental outcomes will subsequently improve. Nevertheless, de-growth only reduces pollution intensity in the short term due to decreasing aggregate production, while growth could support employment, reduce debt, and fund public services (Kallis et al., 2018; Van den Bergh, 2011).

Figure 2. Introduction of a sustainable target in the Eco-Keynesian cross.



Globally, the path toward a zero-carbon economy by 2050 requires more significant public commitment and funding (Meckling et al., 2022). Therefore, ecological transition necessitates systemic structural changes and enabling investments in green infrastructure, housing, and environmental efficiency across production processes. Public authority intervention is essential because their extensive nature and policy coordination is required. As shown in Figure 2, a more sustainable strategy is increasing the environmental efficiency of the production system to reduce its pollution intensity throughout the implementation of

ecological macroeconomic policies, which contribute to enhancing environmental sustainability by reducing CO_2 emissions, decreasing reliance on fossil fuels, promoting industrial competitiveness through lower energy expenditure and operational costs, and boosting productivity and economic growth (Nawaz et al., 2021; Wenlong et al., 2023). Governments are responsible for directing their policies toward low-carbon energy systems to protect the environment through investments in energy technology research and development budgets (Kassouri et al., 2022). Considering green regulation or state-led investment schemes (Mazzucato, 2015), '*an exogenous allocation of "green" public R&D can enable a substitution away from a Labor-saving investment towards a Resource-saving investment*' (Naqvi & Stockhammer, 2018, p. 178). Increasing G in equation 1, the AD curve moves up in Figure 2.a.

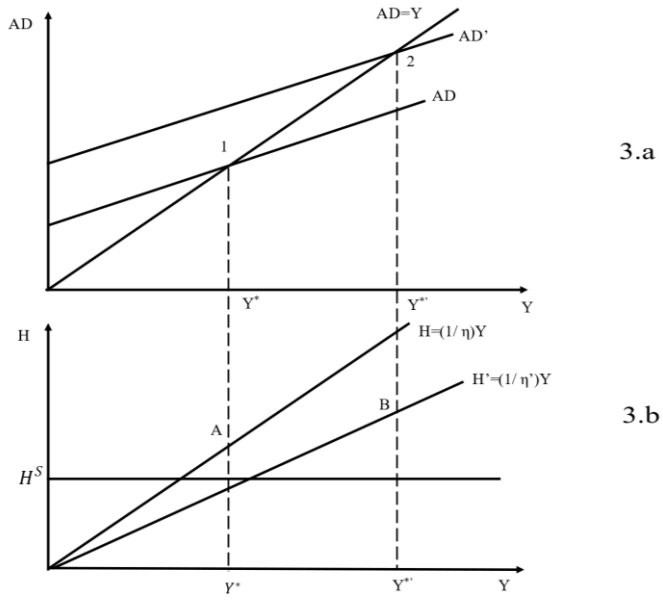
Public expenditure is considered a crucial tool for sustaining economic growth, favoured owing to its prospective amplified multiplier effects relative to consumer spending. It also facilitates economic revival and its aptitude for augmenting production levels and efficiency over an extended temporal horizon (Saccone et al., 2022). In particular, an augmentation in governmental expenditure on investment amplifies aggregate demand via the multiplier effect, akin to other components of government spending. Increased public expenditure initially influences economies within existing constraints, but surging demand may prompt private firms to enhance production capacity, leading to further increases in output, known as "accelerative effects" (Schreiner & Madlener, 2021). Therefore, government investment engenders positive externalities that accrue to the private sector. It occurs as public expenditures in sectors like infrastructure, research and development, and sustainable energy initiatives lead to beneficial spillovers that private entities can leverage (Deleidi et al., 2023). Empirically, Batini et al. (2022) verify that each dollar invested (encompassing both private and public funds) in carbon neutral or carbon sink activities has the potential to stimulate economic activity exceeding the value of the initial investment: the aggregate growth in Gross Domestic Product (GDP) surpasses the initial augmentation in green expenditure. These economic impacts are significantly more substantial and enduring than non-environmentally friendly investments because green expenditures tend to demand a higher labor input and possess a more significant domestic component than no-green expenditures. For the above effects, the AD curve moves to AD" in Figure 2.a due to increased autonomous, green public spending, expressed by G in equation 1, and its accelerating effect on green private investment, represented by I in equation 1, so the equilibrium shifts from point 1 to point 3.

Green investments improve environmental efficiency by enhancing energy conservation and emission reduction efficiencies, broadening technological innovation capacities, and advancing industrial structures. These investments contribute to reducing greenhouse gas emissions and environmental degradation and foster the adoption of sustainable technologies and processes (Ren et al., 2022). Environmental efficiency improvements enable the production of a greater volume of goods with reduced resource consumption. Under these premises, it is plausible to increase output while continuously decreasing resource extraction and pollution (OECD, 2011). From equation 4, the increase in environmental efficiency (from η to η') reduces the slope of the H curve, which moves from H to H', representin a lower current level of CO_2 emissions. Due to the increase in the AD curve from AD to AD' and the enhancement of environmental efficiency, the final equilibrium of the economy moves from point A to point C, as shown in Figure 2.b. Therefore, higher green public investments increase the environmental efficiency of the economy, allowing for satisfying the sustainability target (H^s).

2.2. The risk of rebound effect

However, policy coordination is also essential for avoiding possible green rebound effects: "In the macro-economic level, the main concern of most authors is not the rebound effect arising from energy savings taken back in the form of increased welfare (the direct rebound), but the income effect arising from introduction of efficiency improvements in energy services that are close to saturation. This income gain will stimulate consumption and energy demand" (Dimitropoulos, 2007, p. 6355). Environmentally friendly investments could increase output by the income multiplier and increase environmental efficiency, but they could lead to a net increase in pollution (Rezai et al., 2013). According to Barker et al. (2009), the improvement of energy efficiency could produce three different types of rebound effect: direct one, when the reduction of the good's price induces an increase in its consumption; indirect one due to the first impact influences the demand for other goods and services; the economy-wide effect, when a decline in the real price of energy services triggers a ripple effect throughout the economy, resulting in lower prices of intermediate and final goods leading to a series of adjustments in terms of price and quantity favouring energy-intensive sectors. Let us consider the case of the rebound effect generated by green public expenditure.

Figure 3. The rebound effect.



As described in the previous section, green government expenditure as an autonomous component of aggregate demand shifts the AD curve from AD to AD' in Figure 3.a, so the economy moves from point 1 to point 2. By stimulating green private investment, green public spending improves the economic system's innovative capacity and environmental and economic performance. As a result, enhanced environmental efficiency reduces the slope of the H curve in Figure 3.b. Thus, we can see that green public improves environmental efficiency (η) as well as increases income (Y) through the multiplier principle and, in turn, employment following the environmental identity.

However, the rebound effect may originate from backstop technologies, which facilitate the substitution of renewable for non-renewable resources. As non-renewable resources diminish, investment shifts towards renewable alternatives like photovoltaics, reducing costs and increasing aggregate demand (Chenavaz et al., 2021). This demand surge encourages further investments, initiating a cycle where renewable resources gradually supplant non-renewable ones, thereby perpetuating a sequence of investments, demand escalation, cost reduction, and enhanced investment and demand. Therefore, the improvement in environmental efficiency could be partially compensated by the increase in final and intermediate consumption induced by the rebound effect, so the slope of the H curve is lower than in the previous case. As shown in Figure 3, if the latter effect is higher than the multiplier effect of green public expenditure, the final net impact will be an increase in CO_2 concentration, creating a contradiction between means and ends. The improvement of

environmental efficiency shifts the H curve to H' in Figure 3, but its extent is not sufficient to generate a significant reduction in emissions or satisfy the sustainability target.

Final remarks

Adopting a standard macroeconomic model, this paper shows the complexity of the ecological transition and the required ecological structural change. In particular, the eco-Keynesian cross highlights the potential trade-off between social and environmental goals that an ecological perspective aims to overcome by promoting sustainable and inclusive industrial development (UNIDO, 2013) through a "*structural change for equality*" where social and green instances are integrated (ECLAC, 2012). To improve environmental sustainability immediately, the most straightforward ecological de-growth strategy could be implemented but imposing a substantial economic cost by placing the economy in a position to compromise sustainability's social and environmental dimensions. At the macroeconomic level, green public and private investment could increase output per multiplier and increase environmental efficiency. However, they could generate rebound effects, determining a net increase in pollution intensity in the economy.

The ecological structural change requires implementing ecological policies designed to catalyse structural transformations that enhance green productivity by expanding the proportion of green sectors and augmenting green productivity across all sectors, while simultaneously incorporating green principles into the components of aggregate demand. In light of this policy complexity, it depends strictly upon the coordination between public and private sectors and between public institutions and the positive interaction between technological, social, and economic development factors (Costantini & Crespi, 2013). To avoid the adverse effects of environmental improvements, policies that have a financial impact (fiscal and distributive policies) thanks to the multiplier, but at the same time should have an ecological effect (ecological industrial policies): the improvements in social inclusion make the pursuit of green targets socially and politically practicable (Baland et al., 2007). Therefore, promoting sustainable and inclusive ecological macroeconomic policies could overcome this potential trade-off to avoid possible rebound effects.

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