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A Classical-Post Keynesian critique on neoclassical environmentally-adjusted multifactor productivity*

Uma crítica pós-keynesiana clássica à produtividade multifatorial ajustada ao meio ambiente

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RESUMO: O objetivo do artigo é analisar criticamente a Produtividade Multifatorial Ajustada ao Meio Ambiente (PMAMA), considerando o aspecto ambiental clássico-pós-keynesiano, integrado à Economia Ambiental Evolucionária. O artigo apresenta a PMAMA enraizada na economia neoclássica e derivada da função Cobb-Douglas com recursos naturais construída por Solow (1974). Apresento críticas teóricas aos pressupostos neoclássicos da PMAMA desenvolvendo perspetivas da literatura heterodoxa da Macroeconomia Ecológica. Por fim, discuto as deficiências da estrutura conceitual da PMAMA fazendo referência específica ao debate político sobre a Hipótese de Porter. O artigo evidencia como as premissas de retornos constantes de escala, concorrência perfeita e substitutibilidade perfeita de insumos alteram seriamente o significado e a promessa da política de sustentabilidade. A análise indica que a PMAMA é um instrumento pobre para estudar questões complexas sobre a promoção e eficácia das inovações verdes e, portanto, deve ser abandonado para enfrentar os grandes desafios do processo de transformação ecológica.
PALAVRAS-CHAVE: Economia clássico-pós-keynesiana; produtividade multifatorial ajustada ao meio ambiente; ecoinovação.

ABSTRACT: The aim of the article is to critically analyze Environmentally-Adjusted Multifactor Productivity (EAMP), by considering the Classical-Post-keynesian environmental framework Ecological Macroeconomics, integrated with the Evolutionary Environmental Economics. The paper introduces EAMP as rooted in in neoclassical economics and derived from Cobb-Douglas function with natural resources built by Solow (1974). I present theoretical critiques of EAMP's neoclassical assumptions by developing perspectives from heterodox Ecological Macroconomics literature. Finally, I discuss the shortcomings of EAMP's conceptual framework, making specific reference to the policy debate on Porter Hypothesis. The article puts in evidence how the assumptions of constant returns to scale, perfect competition and perfect input substitutability seriously alter the meaning and promise of sustainability policy. The analysis indicates that EAMP is a poor instrument

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to study complex issues regarding the promotion and effectiveness of green innovations and should therefore be abandoned to face the great challenges regarding the process of ecological transformation.
KEYWORDS: Classical-Post-Keynesian economics; environmentally-adjusted multifactor productivity; eco-innovation.
JEL Classification: B12; Q55; O13.

INTRODUCTION

The aim of this paper is to critically analyze the concept of Environmentally-Adjusted Multifactor Productivity (EAMP). Following the new and growing field of Ecological Macroeconomics (Hardt and O'Neil, 2017), I integrate Classical-Post-Keynesian (CPK) and Evolutionary Environmental Economics framework (Gilli et al., 2013) to coherently blend classical, Keynesian and Schumpeterian elements (Sylos Labini, 1984) for our critique. In the neoclassical environmental economics literature, two main approaches have been utilized to measure environmental efficiency: frontier analysis such as Data Envelopment Analysis (Jaraitė and Di Maria, 2012) or stochastic frontier and green growth indicators. There are many indicators concerning green growth used by international institutions and developed also in literature (Casadio Tarabusi and Guarini, 2018). The EAMP is one of the main green productivity indicators used in growth accounting approaches; it is used in neoclassical models, and it is also promoted by institutions, such as OECD, for empirical studies (Cárdenas et al., 2018). The interest for this critical analysis is twofold: it contributes to reinforcing the theoretical bases for a Classical-Post-Keynesian contribution to ecological issues by underlining the theoretical flaws within mainstream environmental economics; on the other hand, it puts in evidence the theoretical and policy implications of the EAMP conceptual framework, which have not been seriously considered in many empirical studies that use this indicator.

The structure of the article is the following: in the first section the neoclassical roots of EAMP will be illustrated, based on neoclassical Cobb-Douglas function with natural resources built by Solow (1974). In the second section, the theoretical criticisms of EAMP's neoclassical assumptions will be discussed from the environmental sustainability point of view in the light of the heterodox environmental literature. Finally, the shortcomings of EAMP's conceptual framework are outlined concerning the policy debate on the Porter Hypothesis.

1. THE NEOCLASSICAL ROOTS OF THE ENVIRONMENTALLY-ADJUSTED MULTIFACTOR PRODUCTIVITY

The EAMP is usually expressed in terms of growth rates in two different versions (Koźluk and Zipperer, 2015; Brandt et al., 2017; Cárdenas et al., 2018):

$$\hat{A} = \hat{Y} - \alpha\hat{K} - \beta\hat{L} - \gamma\hat{E} \qquad (1)$$

$$\widehat{A'} = \hat{Y} - \delta\hat{H} - \alpha\hat{K} - \beta\hat{L} - \gamma\hat{E} \qquad (2)$$

Parameters A and A' indicate the EAMP. Variables *Y*, *K*, *L* are GDP, physical capital and labor, respectively. Variable *E* stands generically for "environment" that can represent, according to different empirical applications, various concepts such as "natural capital", "environmental services", "intermediate inputs", "land", "energy", "raw materials", and variable *H* stands for pollutant emissions. The symbol "^" indicates the growth rate. Parameters $\delta, \alpha, \beta, \gamma$ represent the elasticity of *Y* with respect to $\frac{\partial Y}{\partial H}\frac{H_t}{Y_t}$, $K, \frac{\partial Y}{\partial K}\frac{K_t}{Y_t}$, $L, \frac{\partial Y}{\partial L}\frac{L_t}{Y_t}$, and $E, \frac{\partial Y}{\partial E}\frac{E_t}{Y_t}$, respectively. To calculate the elasticities, two kinds of approaches are used: inputs elasticities are found by calculating neoclassical profit maximization, while the elasticity δ in equation (2) is found using econometric methods. This estimation still includes neoclassical elements, as one of the regressors considered to estimate δ is the elasticity-weighted growth rate of inputs, that contains the inputs elasticities α, β, γ calculated in the former case (Cárdenas et al., 2018; Brandt et al., 2013). To better understand the theoretical characteristics of EAMP it is necessary to focus on the Environmentally-Adjusted Cobb-Douglas Function proposed by Solow (1974) and Stiglitz (1974). These authors were spurred to carry out environmental analyses by discussing the limits of growth due to oil crises in the seventies (Meadows et al., 1972). The function is expressed by the following equation:

$$Y_t = AK_t^{\alpha}L_t^{\beta}E_t^{\gamma} \quad \text{with} \quad \alpha + \beta + \gamma = 1. \qquad (3)$$

Parameter A with $\gamma = 0$, becomes the traditional "Solow residual" or Total Factor Productivity (or Multifactor Productivity). Moreover, putting $\widehat{Y_h} = \hat{Y} - \delta\hat{H}$ in equation (2), variable Y_h represents the Environmentally-Adjusted GDP, thereby equation (3) can be considered the theoretical reference for the two versions of EAMP expressed in equations (1) and (2). Equation (3) is a function *F(K,L,E)* continuous, two times continuously differentiable for $K,L,E \geq 0$ with $F(0,0,0)= F(K,L,0)=F(K,0,E)=F(0,L,E)=0$ That function has the following properties

(i) $F_K, F_L, F_E > 0, F_{KK}, F_{LL}, F_{EE} < 0, F(\theta K, \theta L, \theta E) = \theta F(K, L, E)$

with $\theta > 0$ where F_K, F_L, F_E, represent the first partial derivative of *K*, *L*, *E* respectively; and F_{KK}, F_{LL}, F_{EE}, stand for the second partial derivatives of *K*, *L*, *E*, respectively. Thus, the function *F(K, L, E)* is increasing, it presents decreasing marginal returns of physical capital, labor and environment, it is homogenous of degree one and finally, it presents constant returns to scale. With both the neoclassical profit maximization and assumption of perfect competition we have

(ii) $F_K = r, F_L = w, F_E = u$

where *r*, *w* and *u* are the input costs and specifically the unit cost of labor (wage), the user cost of produced capital and the user cost of natural capital, respectively.

Combing properties (i) and (ii) derive the inverse relation between each production factor and its corresponding price. It is beyond this article to deal with the Cambridge critique to the neoclassical theory of Capital (Kurz and Salvadori, 1995; Petri, 2004; Corsi and Guarini, 2007) concerning the concept of physical capital and the inverse relation between factors and prices traditionally applied to the Total Factor Productivity. It is obviously extendable to the EAMP. The abovementioned critique becomes even more decisive because the relationship between the input and its price are even more complex and indefinable *a priori* firstly due to the increasing heterogeneity of non-labor inputs given the multidimensional concept of variable E, "environment", secondly, due to the increasing numbers of inputs (from two-*K* and *L*- to three -*K*, *L* and *E*) and thirdly, due to the numerous measurement problems concerning natural capital and to its user costs (Brandt et al., 2013). Furthermore, the identity problem (Felipe and McCombie, 2003) according to which it is demonstrable that given the national income identity, TFP results to be related not to the technological progress, but to the profit and wage shares, can be extended to EAMP where environmental input becomes part of the functional distribution by considering rents.

2. THE THEORETICAL IMPLICATIONS OF EAMP REGARDING ENVIRONMENTAL SUSTAINABILITY

The main theoretical assumptions of EAMP included in the previous analysis are the following:

(a) constant returns to scale

(b) perfect competition

(c) perfect input substitutability.

Constant returns to scale. The assumption of constant returns to scale has important conceptual implications for sustainable development issues. The concept is heavily criticized in heterodox literature and contradicted by numerous empirical studies. CPK economics is founded on the idea of that increasing returns dominate manufacturing and service sectors as unit costs tend to fall due to the static and dynamic economies of scale (Kaldor, 1970). Environmental evolutionary economists have also considered the characteristics of green innovation concerning this phenomenon, citing two important particularities for developing sustainable technologies. The first one is "double externalities": green innovations generate a reduction of pollution (negative externality) as well as stimulate the formation of new knowledge (positive externality). Externalities and spill-overs are extremely important for green innovations (Horbach et al., 2013).[1] Whereas in the neoclassical approach externalities represent an obstacle for market mechanisms, in the CPK paradigm

[1] Exist also international negative externalities involved in the production of green technologies linked to the "ecologically unequal exchange" (Althouse et al., 2020).

they represent an opportunity of collaborations and interaction across agents. Indeed, another relevant factor for green innovation are networks: as underlined in Ghisetti et al., (2015), the Eco-Open Innovation Mode is central for ecological transformation because green innovation implies a multidisciplinary approach (firm needs for green normative, green management, green technicalities, green management), a transfer of external knowledge (usually green knowledge is new knowledge with respect to the core business) and a combination of the scientific and technologically-based innovation mode (STI) and the mode based on learning-by-doing, by-using, and by-interacting (DUI) (Jensen et al., 2007). These aspects represent the peculiarities of green innovation, and, at the same time, they generate increasing returns (Arthur, 1994; Katz and Shapiro, 1985). If networks are important for standard innovations, they are indispensable for green innovations due to their peculiar nature.

Perfect competition. The assumption of perfect competition is central in mainstream environmental economics. In their view, perfect competition permits prices to orient the ecological transformation. The decreasing availability of natural capital is signaled by increasing prices that change the choices of firms and consumers in favor of sustainability. The seminal concept of sustainable development as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987) is based on the intertemporal equity, that according to neoclassical view, can be governed by market price mechanisms., By contrast, the CPK approach views perfect competition as an exception to the rule: prices reflect market power not scarcity. The main example is the oil market that is dominated by trilateral oligopoly: producing countries, oil companies and consuming countries (Roncaglia, 2015). Moreover, the assumption of perfect competition does not allow for environmental issues to be considered as internal to the mechanisms of the production system, as is possible by assuming imperfect competition. Indeed, in this latter case, the Kaleckian price equation, which in its original version entails raw materials and energy, can be applied (Kalecki, 1954 and 1971; Sylos Labini, 1979). It can be represented by the following equation:

$$p = (1 + \mu)\left(\frac{w}{\pi} + \frac{p_e}{\epsilon}\right) \qquad (4)$$

where $p, \mu, w, \pi, p_e, \epsilon$ represent the price level, mark-up, wages, labor productivity, prices of raw materials and energy, and intermediate inputs productivity (Taylor, 1991), that is composed of what Kalecki calls "raw material per unit of final output and energy per unit of final output". Equation (4) permits green innovation to be linked with numerous market phenomena: price competition, for the impact of intermediate inputs productivity on prices; functional income distribution (Galindo et al., 2020), because from equation (4) derives a distribution of GDP that includes not only profits, wages but also intermediate inputs; international competition, if we consider that intermediate inputs can be imported and thus their price is strictly linked with the exchange rate.

Perfect inputs substitutability. According to the Cobb-Douglas function, the use of partial derivative implies the assumption of perfect input substitutability. This assumption entails a "weak sustainability" approach, according to which physical capital (called man-made capital) and natural capital are perfect substitutes. Natural capital can therefore be used until exhaustion if intertemporal utility does not decrease. For this reason, Solow (1974, p. 11) proposed that there was no limit to economic growth as long as sufficient man-made capital existed to replace nature.[2] The opposite assumption is that these inputs are complementary (Limburg et al., 2002; Brand, 2009; Costanza et al., 2014) and, therefore interdependent. As such, natural capital should be preserved in the short as well as in the long run. Ecological macroeconomic models often assume a "strong sustainability" approach and assume that physical capital cannot replace natural capital. Consequently, the typical production function used is the following

$$Y = min\,(K, L, E) \qquad (5)$$

An intermediate approach between weak and strong sustainability is represented by the Critical Natural Capital (CNC) theory (Turner, 1993; Ekins, 2003), according to which only the part of natural capital (the critical part) that provides essential environmental services cannot be substituted by made-man capital. Obviously, there is an important debate about the "criticality" and in which terms it should be evaluated: socio-cultural, ecological, sustainability, ethical, economic, or/and human survival. CNC theory and the strong sustainability approach underline the heterogenous nature of physical capital. According to both approaches with non-weak sustainability it is stressed that natural capital is a heterogenous system both of renewables and non- renewable natural resources, and of the provision of ecosystem services with life-support functions (De Groot, 1992; MacDonald et al., 1999; Daly and Farley, 2004). The assumption of perfect input substitutability assumption denies ecological resilience, strictly linked with the CNC concept, defined as the "capacity of an ecosystem to maintain desirable ecosystem services in the face of human use and a fluctuating environment" (Brand, 2009; Carpenter et al., 2001). Ecological resilience is a multidimensional concept concerning the links between environment and social factors in a way that converts an engineering view of resilience with only a return to an equilibrium to a socio-ecological view characterized by adaptation, learning process, innovation based on complementarities, new dynamics, and social networks (Folke, 2006). In the perspectives of strong sustainability and CNC theory, there are important complementarities: those between physical capital and natural capital, those across the elements constitutive of natural capital and finally those between labor input and non-labor inputs. This socio-ecological perspective entails unpredictability, uncertainty, change, dynamic interaction among elements, and a need of governance (multilevel international, national and local): all aspects typical of the Classical-Post-Keyensian tradition.

[2] Solow (1974, p. 11) wrote that "The world can, in effect, get al., ng without natural resources, so exhaustion is just an event, not a catastrophe."

The interconnection of social, economic and environmental elements entailing multilevel governance and unpredictable results of interactions is typical of various approaches such as panarchy (Holling et al., 2001), integral ecology (Esbjörn-Hargens, and Zimmerman, 2009; O'Brien, 2010; O'Neill, 2016), social ecology (Stokols et al., 2003, 2013) where key concepts are transformation and interconnection. According to the fourth law of thermodynamics of Georgescu-Roegen (1971, 1976, 1979a, 1979b) technology can reduce the generation of waste, but it is not possible to eliminate it by recycling. Meanwhile, according to the neoclassical assumption of perfect input substitutability, the potential for a completely circular economy is infinite. Perfect input substitutability also implies that technology is mainly disembodied from inputs: the typical critique about this aspect comes from the neo-schumpeterian approach (integrated in the CPK for many authors such as Sylos Labini (1984) where the sources of technological advances cannot be divided across organizations improvement, labor input and machineries: the innovation entails all these aspects (Nelson, 1973, 1981, 1987; Nelson and Winter, 1989). In the eco-innovation literature, complementarities are found between green technology and standard technology as well as between labor productivity and environmental efficiency and between green process innovation and green organization innovation (Guarini, 2015). Specifically, performances of product and process innovations are positively influenced by environmental management systems (Rave et al., 2011).

3. THE POLICY IMPLICATIONS OF EAMP REGARDING ENVIRONMENTAL SUSTAINABILITY.

The theoretical characteristics of EAMP greatly influence the environmental policy debate. We take into consideration the Porter Hypothesis (PH), which is the most studied contribution on green policies (Porter and Van der Linde, 1995; Guarini, 2020). According to PH, an appropriately implemented environmental policy can provoke the so called "double dividend": it can generate positive performances of firms in terms not only of sustainability but also innovation. In particular, the weak version of PH concerns the policy impact on environmental innovation, while the strong version of PH is related to the impact of green policies on labor productivity and competitiveness. The conceptual framework of PH is different from that of EAMP. EAMP considers profit-maximizing individuals, according to which every institutional intervention can impede his/her optimization choices. Consequently, environmental policies represent costs to be minimized. PH, on the other hand, assumes that a policy can transform environmental sustainability from a cost to an opportunity, by setting the grounds for unexpected new ways of doing business, and improve their environmental performance. A serious methodological shortcoming exists in the studies using EAMP for analyzing PH. EAMP is generally applied without properly considering that its assumptions condition the evaluation of the effectiveness of PH. This results in findings which seem to contradict PH theory and undercut its transformative potential.

The weak version of PH. The use of EAMP does not permit to take into account some channels through which policy tools can affect eco-innovation: for instance, the weak version of PH is strictly linked with networks across public and private sector (Fabrizi and Meliciani, 2018) by generating economies of scale that are denied by EAMP conceptual framework. Furthermore, some studies underline that green policies can better stimulate green innovations if firms focus on clean technology instead of end-of pipe technologies (Van Leeuwen and Hohnen, 2017): the clean technologies inform the entire production process entailing complementarities across all inputs and between embodied and disembodied technical progress; while the end-of pipe technologies are applied at the end of the process to minimize the pollution without influencing the internal mechanisms of production. The implementation of the clean technologies makes the policies more effective, but at the same time they are resized by using EAMP, because they are not compatible with perfect input substitution.

The strong version of PH. The assumption of perfect input substitutability within EAMP tends to orient analyses towards a negative impact of environmental policies on productivity. Total factor productivity growth rate B can be derived from EAMP in the following form:

$$\hat{B} = \hat{A} + \gamma\left[\hat{E} - \left(\frac{1}{\alpha+\beta}\right)(\alpha\hat{L} + \beta\hat{K})\right] \qquad (6)$$

With reference to equation (6) an environmental policy which increases prices of input E for the properties (i) and (ii) can generate a decrease of E and consequently, for the perfect input substitutability, it can increase L and/or K. The final effect can be a decrease of traditional total factor productivity, B (Kozluk and Zipperer (2015). Furthermore, some contributions argue that environmental policies can diminish total factor productivity because green standards can become barriers to entry that reduce competition and weaken incentives to innovate and increase economic efficiency (Albrizio et al., 2014; Rubashkina et al., 2015). However, these models apply total factor productivity, which is fundamentally incompatible with all market regimes other than perfect competition.

CONCLUDING REMARKS

This article has critically illustrated the theoretical characteristics of Environmentally-Adjusted Multifactor Productivity (EAMP) that is one of the main indicators of green innovation. The article puts in evidence how its assumptions of constant returns to scale, perfect competition and perfect input substitutability have a relevant impact on the analysis of environmental sustainability and of related policies. From the analysis, EAMP is found to be a poor instrument to study the main complex issues regarding green innovations, and to face the great challenges regarding the process of ecological transformation. As such, other green innovation indicators are likely to be significantly more effective to evaluate sustainability policy, including those related to R&D activity, patents, intermediate productivity (namely the ratio between income/GDP/value-added and raw materials/energy consumption) or environmental productivity (namely the ratio between income/GDP/value-added and environmental impact measure such as pollutant emissions). This brief note has demonstrated that it is important to bring out the differences between mainstream economics and Classical-Post-Keynesian economics in the field of environmental sustainability and that there is room for the latter approach to carry out an original contribution to the theoretical, empirical and policy debates concerning an ecological transition.

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