PSL Quarterly Review

vol. 71 n. 285 (June 2018)

Original article

Environment, effective demand, and cyclical growth in surplus labor economies

GUILHERME DE OLIVEIRA*

Abstract:

The study presents a simple extension of a Harrodian model, that explores, the relationship between the environment and economic growth in a hypothetical dual low-income economy with relatively low levels of environmental quality. It is supposed that the rise in effective demand increases the flow of negative externalities on the environment, which, in turn, would affect output expansion negatively in the capitalist sector through the occurrence of environmental adjustment costs. From such conflictual dynamics, the model shows that perpetual vicious circles may characterize the pattern of fluctuations in economic activity in this economy.

* Federal University of Santa Catarina, Brazil, email: oliveira.guilherme@ufsc.br

How to cite this article:
De Oliveira G. (2018), “Environment, effective demand, and cyclical growth in surplus labor economies”, *PSL Quarterly Review*, 71(285): 183-201.

DOI: http://dx.doi.org/10.13133/2037-3643_71.285_5

JEL codes:
O11, O44, Q50

Keywords:
environmental quality, effective demand, cyclical growth, dual low-income economies

Journal homepage:
http: //www.pslquarterlyreview.info

Theoretical and empirical advances in environmental and ecological economics pose new challenges for economic growth and development theory, suggesting that limits to growth may not arise from the limited capacity of nature to provide resources, but instead from the planet’s limited ability to act as a disposal for capitalist waste.[1]

Neoclassical answers to these challenges are typically optimistic, relying on the assumption that the capitalist system may achieve a stable, sustainable growth path endogenously. Hence, under certain conditions, environmental constraints would not prevent the economy from achieving a full employment growth trajectory, with diminishing negative impacts on the environment. In general, the argument is justified by using controversial

---

* I wish to thank Gilberto Tadeu Lima, Peter Skott, Gustavo Serra, and the two anonymous referees for their helpful comments on early versions of this paper. The usual disclaimer applies.

[1] See, for example, Brock and Taylor (2005) and Foley (2012) for some reflections on these new challenges.

empirical evidence about the environmental Kuznets curve (EKC), which first appeared in Grossman and Krueger (1995).[2]

Concretely, the EKC hypothesis proposes that an inverted U-shaped relationship exists between the flow of negative externalities on the environment and levels of per capita income. In the first stage of development, environmental degradation grows relatively quickly because financial resources to invest in pollution abatement are relatively low, and capital accumulation is the primary concern. With this ongoing development process, an income threshold exists, above which the economy starts to invest in pollution abatement and mitigation so that eventually growth begins to reduce the negative environmental impact of economic activity. In the words of Stokey (1998, p. 1), "while the early stages of economic growth cause the problem, later ones bring the remedy."

Several objections can be raised against the EKC's theoretical foundations. Its concept depends mostly on an economic model in which no feedback exists from environmental quality to economic growth, i.e., in the absence of environmental regulation, growth can expand at no environmental cost.[3] The heart of the critique is simply that neoclassical optimism is implicitly based on the assumption that countries in the early stages of development have relatively high levels of environmental quality and may sacrifice some of this quality to grow quickly (Stern, 2004). However, in some dual low-income economies (including much of Asia and Africa), such a growth strategy can result in an unsustainable increase in environmental degradation before the maximum range of pollution illustrated by the EKC is reached (Dasgupta et al., 2002) – precisely because they have relatively low levels of environmental quality in the first place.

As a theoretical experiment, we will assume a hypothetical dual economy in which environmental degradation is relatively high. In this context, the main feature of this economy may be the occurrence of environmental adjustment costs that are already binding in the short run. Any expansion of economic activity comes with even more negative effects on the environment, which, if strong enough, may compromise output expansion in the capitalist sector. It is the corresponding lowering in economic growth toward the medium run that reduces negative pressures on the environment. In fact, in a significant chunk of extant literature, the possible existence of developing countries with relatively low levels of environmental quality offers empirical evidence against the arguments based on the EKC and the prediction of a well-behaved growth trajectory (Dasgupta et al., 2002).[4]

International development actor such as the World Bank have highlighted empirical evidence that illustrates this point on a small scale concerning developing countries such as Rwanda, where the cost of land degradation has been negatively affecting gross domestic product .[5] Rwanda has experienced particularly perverse Malthusian dynamics: an increase in economic growth has stimulated agricultural consumption, which, given the rudimentary techniques adopted by low-skilled workers, accelerates soil degradation and reduces productivity, thereby lowering GDP. Furthermore, in some regions of China, especially in the

---

[2] Stokey (1998) and Brock and Taylor (2010), for instance, formulated models in which the EKC standard prediction plays an important role in generating such a sustainable growth path in mature economies.

[3] The feedback effect from environmental quality to economic growth also has serious implications for the assumption of strict exogeneity in econometric models seeking to empirically test the EKC. See Stern (2004), Carson (2010), and Stern (2015) for empirical analyses of the EKC. See Bulte and van Soest (2001) for an evidence on reverse causality.

[4] In the long-run effect, of course, this will depend on how absolute poverty responds to slower economic growth.

[5] See, for example, Downing et al. (2009) and part of the environment-poverty literature: Bôjo et al. (2002) and Dasgupta et al. (2005).

metropolises, industrial pollution has led to emissions of harmful pollutants in the form of ambient fine particulate matter (PM2.5). As discussed by Tanaka (2015), these emissions have been tied to infant mortality and health problems, including respiratory diseases, with possible adverse consequences for labor productivity (Graff Zivin and Neidell, 2013). In turn, unhealthy and less productive workers may constrain the growth rate of industrial production (Chang et al., 2014).[6] Both cases illustrate the occurrence of distinct types of environmental adjustment costs, operating as a feedback mechanism from environmental quality to output expansion.

A major question in this context is how these developing countries, or at least some of them, are likely to behave in a hypothetical trajectory of this type as far as their macroeconomy is concerned. The first step in addressing this concern would be to establish a formal model that explores the macroeconomic implications, in one of its several relevant aspects, of such a conflictive relationship between environmental quality and economic growth in a surplus labor low-income economy.

Far from full employment, dual low-income economies are characterized by hidden unemployment and the presence of a relatively large capitalist sector coexisting with a larger subsistence sector. In this context, effective demand plays a key role in generating a long run path that, according to Harrod (1939), is likely to be unstable. In the medium run, in addition to driving output expansion, effective demand generates negative externalities on the environment that reduce environmental quality. In turn, such an effect raises firms' environmental adjustment costs, thereby exerting downward pressure on economic growth. Hence, instead of suggesting a stable, sustainable growth path, as proposed by most neoclassical constructions, this aspect of the relationship between environmental quality and economic growth may result in a medium run vicious circle, in which the level of environmental quality operates as a potential taming mechanism for the Harrodian instability.

Such a theoretical description requires that we shift focus from a well-behaved trajectory of long run stable growth to the description of endogenous cyclical fluctuations. A theoretical framework that quite naturally accommodates this possibility is the Harrodian one, in which effective demand plays a pivotal role. However, cycles arise in a standard version of this model only in mature economies, in which capital accumulation endogenously affects the labor market's structure. In the surplus labor case, instead, the theoretical explanatory power of the framework is extended to include environmental considerations, with which another source of cyclical growth arises as a new accommodation mechanism of instability.

Ironically, the post-Keynesian literature is not immune to criticism that it largely ignores sustainable development issues. However, the tide is turning, and the present study is related to a few attempts to model environmental and ecological issues in a post-Keynesian framework, as was done by Guarini (2015), Fontana and Sawyer (2016), Taylor et al. (2016), and Guarini and Porcile (2016).[7] The main distinguishing feature and contribution of the present, simple model is that it provides a plausible explanation for a possible new source of cyclical growth in surplus labor economies. The model set forth herein provides insights that should be considered in an evaluation of the conflictive relationship between environmental quality and economic growth in low-income developing economies with relatively low levels of environmental quality.

---

[6] The channels through which pollution affects labor productivity and thus economic growth, are explored in the next section.

[7] For early efforts and other non-theoretical contributions, see Schefold (1997), Roncaglia (2003), Harris (2013), and Kronenberg (2010).

1. The model

Let us consider a hypothetical surplus labor developing economy with relatively low levels of environmental quality that is closed to exchanges with the rest of the world and has no public sector. The relatively low level of environmental quality is caused by a local effect (to be described later). Dualism is represented by the coexistence of capitalist and backward sectors, the latter being a repository of hidden unemployment. The capitalist sector produces according to a production function with fixed coefficients that combine capital, K, and labor, L, in which it is supposed that there is no labor hoarding, and an excess of capital capacity is the normal state of affairs. To focus on the relationship between economic growth and pollution, it is assumed that land, energy, and other raw materials are not directly used in the production process (even if they make a relevant environmental impact). These assumptions imply that the output, X, is given by the following:

$$X = xL \leq \rho^{max} K, \tag{1}$$

in which x is labor productivity and ρ^{max} is capital productivity at the full-capacity level. Since capital stock is subject to lagging adjustments, firms may want to maintain excess of capacity to deter new entry and respond to fluctuations in demand (Steindl, 1952).

One of the crucial aspects of the Harrodian benchmark is related to the investment sensitivity to capital capacity utilization in the short and long run, the equality of desired (ρ^*), and actual output-capital ratio (ρ) in the steady state. Hence, a standard Harrodian investment function relates the change in the rate of accumulation, $d\widehat{K}/dt$, to the difference between the actual output-capital ratio and the desired ratio (Skott, 2010):[8]

$$\frac{d}{dt}\widehat{K} = \lambda(\rho - \rho^*), \ \lambda > 0. \tag{2}$$

Following classical economists and the Cambridge (UK) tradition, it is supposed that workers as a class spend all their income, whereas capitalists save a constant fraction, s, of gross profits, Π (Kaldor, 1966):

$$S = s\Pi. \tag{3}$$

Regarding gross investment, the following provides a standard specification:

$$I = \frac{dK}{dt} + \delta K, \tag{4}$$

in which δ is an exogenous depreciation rate. The capital stock, the rate of capital accumulation, and the output are predetermined in the ultra-short run.[9] These past production decisions are governed by demand expectations that sometimes are not fulfilled. Unlike most Keynesian and Kaleckian approaches, it is supposed here that output cannot adjust to a demand shock instantaneously. The Keynesian equilibrium condition, $S = I$, is thereby elicited through changes in prices (in both directions). Therefore, it is supposed that firms may respond to

---

[8] This function is a continuous approximation for a discrete investment function that only considers the output-capital ratio as affecting investment for purposes of simplicity. See Skott (2010).

[9] According to Skott (1989b), the ultra-short-run notion of the Harrodian model follows the Marshallian analysis of individual markets for which investment and output are exogenously given (predetermined). Hence, an increase in investment must be accompanied by an identical reduction in consumption. In contrast, in the short run, it is assumed that firms' short-term expectations are not fulfilled and individual firms have an incentive to change their level of production and employment. In the short run, firms choose the rate of change in output to accommodate variations in demand.

unexpected shocks in aggregate demand by adjusting prices, and considering that the profit share, π, is determined by a mark-up pricing equation, profits increase. This approach also finds support in Keynes' *Treatise on Mon*ey ([1930]1976).[10]

The causality channel is as follows: the output level is predetermined in the ultra-short run, and a rise in demand leads to an increase in the output price. Money wages are fixed, as there is no perfect foresight and instantaneous feedback from prices to money-wage rates. Thus, real wages and the profit share respond to unanticipated movements in prices, and a positive demand shock increases the profit share. Normalizing (3) and (4) by K and using the definition of the profit rate, $r = \pi\rho$, for a given profit share the investment and savings equilibrium condition, generates the following solution for the output-capital ratio, ρ, in the ultra-short run:

$$\rho = \frac{\hat{K}+\delta}{s\pi}. \tag{5}$$

Therefore, the Keynesian equilibrium condition, $S = I$, defines a sort of Marshallian ultra-short run equilibrium: a market-clearing price vector is defined, but it may give firms an incentive to change their production directly after this.

When the system moves over time, using (5) in (2), the change in the rate of accumulation becomes the following:

$$\frac{d}{dt}\hat{K} = \lambda\left(\frac{\hat{K}+\delta}{s\pi} - \rho^*\right), \tag{6}$$

which in equilibrium defines the warranted growth rate, g_W:

$$\hat{K}^* = s\pi\rho^* - \delta = g_W. \tag{7}$$

This solution for the rate of accumulation at the stationary level is warranted because on average firms achieve precisely the desired rate of utilization in the long run, ρ^*, a rational expectations equilibrium (Nakatani and Skott, 2007) that can be seen by using (7) in (5). However, it gives rise to the well-known instability mechanism described in Harrod (1939), as well as the likely inequality between g_W and the natural growth rate – the growth that an economy requires to maintain full employment, which Harrod sees as an intrinsic characteristic of capitalist societies.

Skott (1989b) reconciles the warranted and natural growth rate without leaving aside the endogenous fluctuations of capitalist economies. This mechanism operates through the interaction between effective demand and employment rate, which evolves over time, according to predator-prey dynamics. However, in a surplus-labor economy, the employment rate carries little information for the capitalist sector. As a result, the labor market may not change endogenously in response to variations in capital accumulation. In this case, the cyclical pattern of Harrodian models may not arise unless another containment mechanism is in operation. As described in what follows, environmental quality can serve as a channel for such a mechanism.

---

[10] As argued by Skott (2015), perfect, flexible prices are not as problematic an assumption as imagined, because in his approach cyclical growth can arise with or without flexible prices.

1.1. The output expansion function and the environmental dynamics

The Harrodian framework supposes that firms respond to shocks in aggregate demand in the ultra-short run via price adjustments because production is subject to adjustment costs and takes place after some time. To accommodate this assumption, it is supposed that profit-maximizing firms choose the rate of production expansion instead of the output level, which balances the costs and benefits of moving toward a desired level of utilization. This rate of expansion is selected subject to effective demand, technical, and cost constraints.

In the present surplus-labor case, demand signs come from the profit share and cost signs come from the level of environmental quality, ϵ. To model the feedback effect from the level of environmental quality to economic growth, it is supposed that a relatively low level of environmental quality is associated with a relatively high amount of environmental adjustment costs of production. The effect will be modeled through its negative effects on labor productivity. Hence, the Harrodian rate of growth of production is algebraically defined as follows:

$$\hat{X} = h(\pi, \epsilon), \quad h_{\pi},\ h_{\epsilon} > 0, \tag{8}$$

which assumes that the environmental adjustment costs, whose effects are captured by the level of environmental quality, are convex; thus, $\hat{X}$ can be modeled in continuous time. The model leaves aside the possibility that relatively strong changes in the environment can cause discrete changes in environmental adjustment costs (non-convexities). In a climate-change scenario, these discrete effects may be important for firms' cost structure, but I ignore this possibility here.

In a Harrodian framework, a certain degree of capitalists' inability to respond to demand shocks is supposed, but in the present case, this inability also assumes the presence of an environmental dimension. The inability to instantly adjust to a change in environmental quality arises because the representative agent does not perfectly observe the negative externalities on the environment (Kelly et al., 2005). An agent in this hypothetical developing country with a relatively low level of environmental quality only slowly realizes that the environment has changed.

However, if a negative change in environmental quality is persistent, firms know that it lowers labor productivity, given the negative effects of pollution on factory workers' health and cognitive abilities. To counterbalance reductions in environmental quality, firms increase investments in occupational health and training of the labor force to maintain labor productivity levels, which I shall refer to as environmental adjustment costs. It is supposed that firms always achieve such goal at any level of ϵ. Note that there is an inverse relationship between the level of environmental quality and environmental adjustment costs; thus, we can model output expansion dynamics as described in (8).

The recognition that the level of environmental quality can affect human health is not new, but economic research only recently expanded the focus of analysis beyond direct health outcomes. Many health effects can affect human capital and labor productivity both in the short run (Currie and Stabile, 2006) and the long run (Cunha and Heckman, 2007). A recent and growing body of literature has begun to make this link more explicit, providing empirical evidence that justifies the functional relationship between environmental quality (or pollution, its inverse) and labor productivity, as well as cognitive outcomes.[11]

---

[11] See Graff Zivin and Neidell (2013) for a summary of this literature.

Analyzing the effects of negative changes in ozone concentration, Graff Zivin and Neidell (2012) found robust evidence that ozone levels well below federal air quality standards significantly impact labor productivity negatively. The impact's magnitude is large, as they found that a decrease of 10 ppb (parts per billion) in ozone concentration increases labor productivity by 5.5 percent. The authors argued that investment in environmental protection could be viewed as an investment in human capital as well. Similarly, Chang et al. (2014) estimated the effect of outdoor air pollution on indoor workers' labor productivity at a pear-packing factory. They found that an increase in particulate matter less than 2.5 micrometers in diameter (PM2.5) from a harmful pollutant outdoors, which easily penetrates indoor settings, led to a statistically and economically significant decrease in packing speeds inside the factory.

The level of environmental quality modeled as environmental adjustment costs is also compatible with short-term adjustments in the Harrodian perspective. Graff Zivin et al. (2015) provided the first estimates of the potential impact of climate change on human capital, focusing on the impacts from both short-run weather and long-run climate. Exploiting the longitudinal structure of the National Survey of Youth (NLSY 79) and random fluctuations in weather across interviews, they identified the effect of temperature in models with child-specific fixed effects, finding that short-run changes in temperature led to statistically significant decreases in cognitive performance in math.[12] In contrast, a long-run analysis revealed no statistically significant relationship between climate and human capital. According to the authors, this finding is consistent with the notion that adaptation, particularly compensatory behavior, plays a significant role in limiting long-run impacts from short-run weather shocks. In the present approach, it may be consistent that in the long run, firms move to a desired level of utilization via adaptation, even when facing environmental constraints on the labor force.

One may ask, however, whether these environmental-adjustment costs are economically relevant. In the climate-change literature, this is a controversial point. In fact, most old quantitative estimates of the cost from environmental damages in mature economies are modest. This is a different cost perspective from the empirical evidence reviewed by Graff Zivin and Neidell (2013), who argue that most recent estimates in extant literature have found economically relevant parameters related to environmental damage. However, for low-income developing economies with relatively low levels of environmental quality, a conclusion that such a cost is relatively small intuitively seems misguided. Of course, in the real world, the ways in which the capitalist sector captures signals of environmental quality are diverse and difficult to generalize; thus, I have focused on the effects on labor productivity following recent, robust, economically relevant empirical evidence (Graff Zivin and Neidell, 2013).

The level of environmental quality, ϵ, endogenously changes in time according to its natural growth rate and with the growth rate of pollution released into the environment. Regarding the pollution effect, as the present model is a one-sector model and abstracts from technical change, it is assumed that the level of pollution, Ω, changes solely according to the economy's size, as measured by gross domestic output, X.[13] Hence, the flow of pollution is defined according to the following:

---

[12] The NLSY79 cohort is a longitudinal project that follows the lives of a sample of US youth born between 1957 and 1964.

[13] According to Brock and Taylor (2005), from an empirical perspective, three channels exist through which an economy generates pollution: the scale effect, in which pollution rises or falls in proportion to the size of economic activity as measured by real GDP; the composition effect, in which pollution decreases if an economy moves toward producing a set of goods that are cleaner on average than what had been produced before; and the technical effect,

$$\Omega = \vartheta(X),\ \vartheta > 0, \tag{9}$$

in which the higher the scale of the economy, the higher the flow of pollution will be. Thus, the output-expansion function (8) solely governs the growth rate of pollution, $\hat{\Omega} = (d\Omega/dt)/\Omega$, i.e.,

$$\hat{\Omega} = \omega[h(\pi, \epsilon)], \tag{10}$$

in which ω measures the intensity of the output expansion's negative impact on the environment.

In turn, a logistic function, perhaps the simplest plausible functional form for biological growth in a constrained environment, describes the natural growth rate of environmental quality. The reason is that the level of environmental quality is treated as a renewable resource, whose essential feature is that its stock is not fixed. It can be increased or decreased, even without pollution activities. Nonetheless, there is a maximum stock level at which no environment can regenerate its quality to levels above a certain carrying capacity in the ecosystem. The logistic function shows that, even in the absence of economic activity, at low stock levels, environmental quality grows. However, as stock levels increase, the growth rate slows. Eventually, the stock increases to a maximum level, which is a general behavioral pattern in ecosystems (Pearce and Turner, 1990). Hence, the natural growth rate of environmental quality, $G(\epsilon)$, is defined as follows:

$$G(\epsilon) = \beta(E - \epsilon)\epsilon, \tag{11}$$

in which E, the maximum carrying capacity point, is the maximum possible level of environmental quality, so that when $\epsilon = E$, further growth cannot occur, $G(\epsilon) = 0$, and β is an exogenously given natural capacity of regeneration of the environment in time.

Therefore, using (10) and (11), the proportional rate of change in environmental quality can be defined as being equal to:

$$\hat{\epsilon} = \beta(E - \epsilon) - \omega[h(\pi, \epsilon)]. \tag{12}$$

Note that the growth rate of pollution flow negatively affects the growth rate of environmental quality, thereby creating an inverse relationship with the output-expansion function. Thus, a stationary solution for ϵ requires a balance between effective demand and its polluting dynamics with natural environmental regeneration capacity.

For the present study's purposes, it is inconvenient to link this description of the environmental quality to climate change. In all the analyses that follow, the negative externalities from the capitalist sector are local, as they are in many models within extant literature.[14] It is more convenient to think of environmental quality as an ecological complex consisting of forests, soil, water, and air quality, so that "the environment" assumes this particular meaning. However, a substantive assumption is necessary. The level of environmental quality must respond in a sufficiently positive amount to negative oscillations in production to capture the diminishing pressures on environmental adjustment costs. All environmental externalities are suitable for this medium run perspective of the model, as some

---

in which pollution decreases when production techniques become cleaner, even though output and its composition remain constant. The present model concentrates only on scale effects since it is a one-sector model that abstracts from the occurrence of technical change.

[14] For the purposes of the present study, an open macroeconomic model of climate change will just increase negative environmental effects. See for example Copland and Taylor (2005) for some open macromodels along neoclassical lines. A recent and elegant structuralist formalization of open ecological macroeconomic issues can be found in Razmi (2016).

negative impacts on the environment are permanent, or take a very long time for significant regeneration, thereby exerting continuous negative effects on the labor force.

Before analyzing the mathematical properties of the model, it may be useful to compare it with other attempts to model similar environmental and ecological dynamics in macromodels, especially the attempt to model how environmental quality affects labor productivity and economic growth, with which the present model shares inspiration.

Oliveira and Lima (2015) use a labor-augmenting process of technical change to model the negative effect of pollution on labor productivity in a Lewis dual-economy framework. Interestingly, they find that a developing dual economy that must comply with a pollution-abatement requirement may fall into an "ecological development trap" and thereby fail to mature. Moreover, once caught in such a trap, a developing dual economy either already is experiencing, or eventually will experience, a Kaldor-Myrdal circular and cumulative causation process of decline in capital intensity and environmental quality. The specific source of the environmental toll comes from a profit-reducing pollution abatement rule, which is endogenous to the level of environmental quality. However, effective demand issues affecting economic growth are ignored. The present model considers that even without environmental regulation, similar conflictive behavior may arise in a context in which the role of effective demand in generating an unstable and warranted growth path is considered explicitly.

In Taylor et al. (2016), a large set of variables affects labor productivity. They particularly claim that greenhouse-gas emissions may decrease labor productivity since they also cut "profitability and destroy the stock of capital" (Taylor et al., 2016, p. 4). However, the channel through which environmental quality (or pollution) affects labor productivity is not explained in detail. They also establish an interesting link between energy and productivity through which important growth and distribution outcomes are analyzed. In contrast, the present model adopts a more parsimonious specification, examining the role of environmental-adjustment costs, which arise through firms' actions to prevent losses in labor productivity through health shocks in generating cyclical growth.

2. Demand-driven economic growth and (in)stability

At any moment in time, the output level, X, the capital stock, K, the level of environmental quality, ϵ, and the output-capital ratio, ρ, are given. The equilibrium in the goods market determines income distribution, π. Therefore, output expansion and the investment function determine the growth rate of output and capital accumulation, which, in turn, will determine the level of environmental quality.

In a simple Harrodian benchmark, the output-capital ratio is constant and equal to ρ^* along a steady-state path. As argued before, a key element is the distinction between a weak short-run and strong long-run sensitivity of investment to variations in aggregate demand. With capacity utilization being a state variable, this distinction is captured through a static relationship between the accumulation rate and capacity utilization (Skott, 2010), i.e.,

$$\widehat{K} = \varphi(\rho), \tag{13}$$

in which φ measures the relationship between accumulation and the output-capital ratio.

As the profit share is determined by the equilibrium condition for the goods market, we can use (13) in (5) to determine the long run relationship given by the following equation:

$$\pi = \frac{\varphi(\rho)+\delta}{s\pi} = \mu(\rho), \tag{14}$$

in which the strong, long run sensitivity of the rate of accumulation to changes in the output-capital ratio implies that $\mu' > 0$.

Using (8), (12), (13), and (14), the two-dimensional system can be algebraically written as follows:

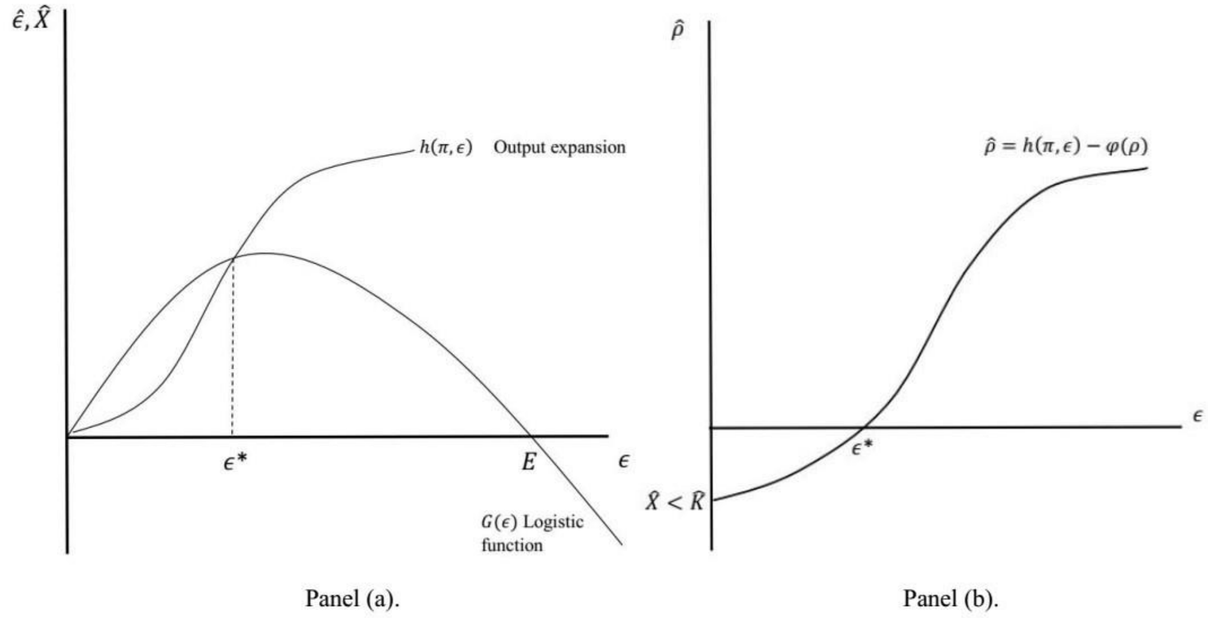
$$\hat{\rho} = \hat{X} - \hat{K} = h[\mu(\rho), \epsilon] - \varphi(\rho), \tag{15}$$

$$\hat{\epsilon} = \beta(E - \epsilon) - \omega\{h[\mu(\rho), \epsilon]\}. \tag{16}$$

The system given by (15) and (16) will have a steady-state solution if $\dot{\epsilon} \equiv d\epsilon/dt$ and $\dot{\rho} \equiv d\rho/dt$ simultaneously equal zero, so that reconciliation between the warranted and natural growth rate is environmentally constrained in this surplus-labor economy. This simple model exhibits four steady states: three corner solutions – $(\epsilon^*, \rho^*) = (0,0), (E, 0), (0, \rho^{*\prime})$ – and one interior solution, which is the unique equilibrium that is economically relevant and will be explored in the (in)stability analysis that follows.

Figure 1 illustrates a possible steady-state configuration using the output expansion (8) and the logistic-growth function of environmental quality (10) in panel (a). The equilibrium level of environmental quality, ϵ^*, implies that $\dot{X} = h(\pi, \epsilon^*)X$ just matches the growth of environmental quality, $G(\epsilon)$, at $\epsilon = \epsilon^*$. Hence, ϵ^* is an equilibrium point, if we explicitly treat ρ as fixed. However, ρ varies over time, which is pictured in panel (b) in figure 1. The illustrative discussion of figure 1 implicitly assumes so far that the effects of ϵ on the output-expansion function are nonlinear, but focus only on the relevant, positive domain.

Figure 1 – *Environmental quality, effective demand, and economic growth*



Panel (a). Panel (b).

The nonlinearity of output expansion illustrates that, for a relatively high level of environmental quality, the growth rate of output is relatively insensitive to variations in ϵ. The same remains true for the growth rate of the output-capital ratio.

To compute the interior solution of the dynamical system given by (15) and (16), set $\hat{\epsilon} = 0$ to obtain the following:

$$\frac{\beta(E-\epsilon)}{\omega} = h[\mu(\rho), \epsilon]. \tag{17}$$

And, substituting (17) in (15) with $\hat{\rho} = 0$, the following is true:

$$\varphi(\rho) = \frac{\beta(E-\epsilon)}{\omega}. \tag{18}$$

Isolating ρ under the equilibrium for the profit share in the long run, (14), we can use the corresponding result in (17) to obtain the equilibrium level of environmental quality, ϵ^*. Intuitively, such a level will be in the relevant positive domain if and only if the impact of economic activity on the environment is not too high. Such a corresponding solution for (17) can be substituted in (18) to obtain the unique, relevant, positive equilibrium value for the output-capital ratio.

The system (15)-(16) is qualitatively analyzed around the interior steady-state solution, in which local stability properties are determined by the corresponding Jacobian matrix:

$$J = \begin{bmatrix} (h_\pi \mu' - \varphi')\rho & h_\epsilon \rho \\ -\omega h_\pi \mu' \epsilon & -(\beta + \omega) h_\epsilon \epsilon \end{bmatrix}.$$

In a standard Harrodian model, J_{11}, the effect of the output-capital ratio on $\dot{\rho}$, is positive, as the short-run macroeconomic multiplier ensures that $d\hat{X}/d\hat{K} - 1 > 0$ (under the supposition that adjustment variations in output are fast, relative to any movement in the capital stock; see Skott, 1989a, for a detailed discussion).[15] In the present model, the marginal effect of the level of environmental quality on $\dot{\rho}$, J_{12}, is positive. A rise in the level of environmental quality raises the growth rate of output because it reduces environmental adjustment costs related to health and training expenditures required to maintain labor productivity levels unchanged.

In turn, an increase in the output-capital ratio lowers the growth rate of the level of environmental quality in the economy, $J_{21} < 0$, given its positive effects on output expansion. J_{22} measures the negative impact on its rate of change, which is negative, as expected, in a logistic specification for the level of environmental quality when the effects of output are given.

Consequently, the corresponding determinant and trace are respectively given by the following:

$$Det(J) = \varphi' \beta \rho \epsilon > 0, \tag{19}$$

$$Tr(J) = (h_\pi \mu' - \varphi')\rho - (\beta + \omega) h_\epsilon \epsilon. \tag{20}$$

The determinant is unambiguously positive; however, the trace is ambiguous. A result with a negative trace (a locally asymptotically stable equilibrium point) will require strong negative feedback effects from environmental quality on its rate of change, J_{22}, in a sufficient amount that yields $h_\pi \mu' \rho < \varphi' \rho + (\beta + \omega) h_\epsilon \epsilon$.

A positive trace (a locally asymptotically unstable – or repeller – equilibrium point) requires that J_{11} be greater than J_{22}. In such a case, as the determinant is positive, the neighborhood of the equilibrium may be characterized by a limit cycle. However, what are the

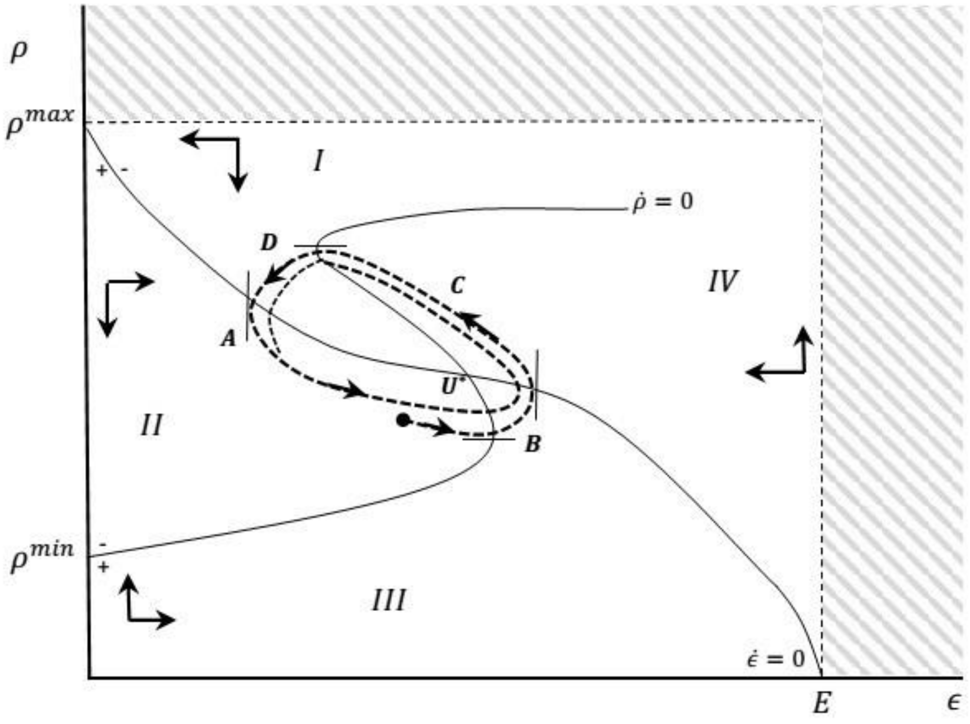
---

[15] The symbol x' denotes a partial derivative.

system’s global stability properties (15)-(16)? To examine the system’s global behavior and the possible existence of a limit cycle as a global property, a sufficient condition is to show that a closed and bounded subset of the positive domain exists with the property, that if the initial value of the state variables starts in this region, the trajectories represented with (15) and (16) will not exit this subset (a trapping region). If such condition is satisfied, the Poincaré-Bendixson theorem guarantees that all trajectories in the subset will converge into a closed orbit, thereby exhibiting perceptual, cyclical behavior (Lima, 2004).

First, note that, based on Bendixson criteria, we cannot rule out that $Div\vec{F} \equiv \frac{dp}{dt} + \frac{d\epsilon}{dt} = 0$; thus, we cannot rule out the non-existence of a closed orbit within the economically relevant domain and, thus, the non-existence of a limit cycle. Figure 2 provides a qualitative illustration of a possible trapping region in the state space of the dynamical system represented by (15) and (16) with a positive trace.

Figure 2 – *A possible limit cycle in the surplus labor economy*



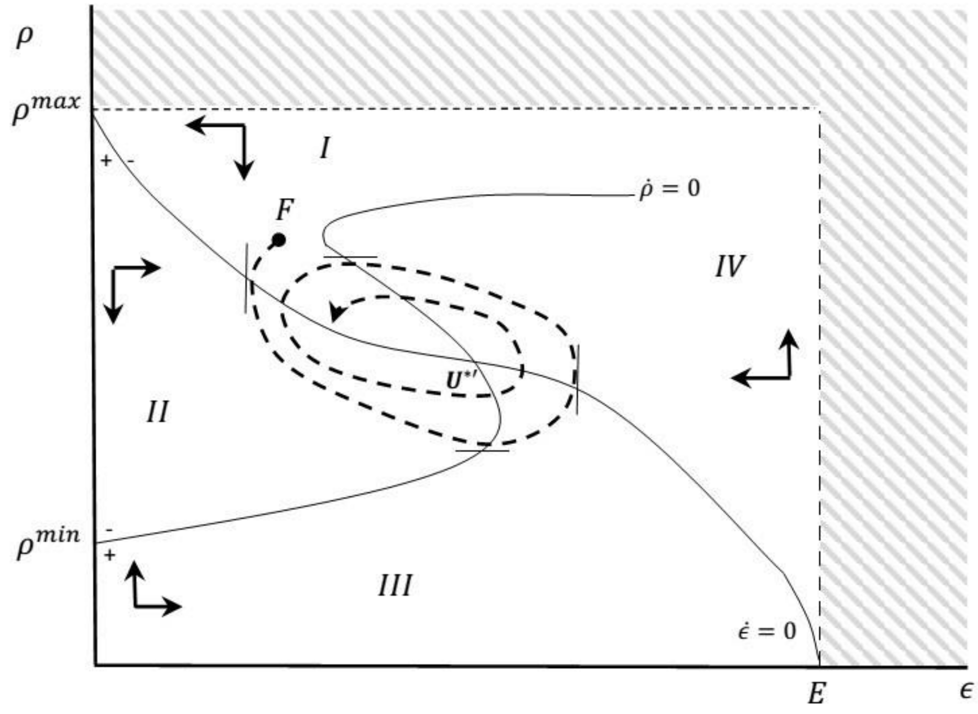
The rationale for the construction of this trapping region is as follows. Both isoclines, $\dot{\epsilon} = 0$ and $\dot{\rho} = 0$, are negatively sloped in the neighborhood of the unique equilibrium point, U^*. The $\dot{\epsilon} = 0$ isocline is negatively sloped in the positive domain. Around U^*, as $J_{22} < 0$, when the level of environmental quality is increasing, its rate of change is steadily decreasing so that the signals of $\dot{\epsilon}$ are positive (negative) below (above) the $\dot{\epsilon} = 0$ isocline. In turn, in the neighborhood of U^*, a rise in the output-capital ratio raises its rate of change so that $\dot{\rho}$ is increasing (decreasing) above (below) $\dot{\rho} = 0$. The full configuration of $\dot{\rho} = 0$ is depicted under the following assumptions: (i) there is a minimum level of output-capital ratio in the economy,

ρ_{min}, at which I suppose that $\widehat{X} > \widehat{K}$; (ii) for high values of ρ, $\widehat{X} < \widehat{K}$; and (iii) for high levels of environmental quality, the locus, $\dot{\rho} = 0$, is flatter.

The first assumption is important for generating a floor for the cyclical fluctuations, which are now bounded from below, and to guarantee that for relatively low levels of output-capital ratio, ρ is increasing. This is consistent with the notion that firms pursue a minimum margin of profits so that below this point, the output-capital ratio increases to maintain at least the minimum profit share. The second assumption is important to ensure that the fixed-coefficient assumption, $\rho < \rho_{max}$, holds for relatively high values of ρ (i.e., far from the neighborhood of U^*). The third assumption is related to the lower sensitivity of output-capital ratio for relatively high levels of environmental quality because, at such a level, the influence of environmental-adjustment costs on output expansion is lower.

To check the consistency of the bounded subset, note that if these assumptions are satisfied, for very large values of output-capital ratio, $\dot{\rho}$ is decreasing. Note also that the system is naturally bounded from above by the maximum carrying capacity, E, so that for very large values of ϵ, the rate of change of the level of environmental quality is also decreasing. Both are represented by the hatched silver area. In addition, for very large values of ρ and ϵ (the northeast region in figure 2), the sensitivity of the output expansion to a change in the output-capital ratio (capacity utilization), and the level of environmental quality is zero; thus, $\dot{\rho} = -\varphi(\rho)$ and $\dot{\epsilon} = -\infty$, so that $d\rho/d\epsilon \approx 0$. Such conditions form a possible trapping region that does not contain an equilibrium point (except in the closed orbit), so that the Poincaré-Bendixson theorem guarantees the existence of a limit cycle within such a region.

Figure 3 – *A locally asymptotically stable equilibrium point in the surplus labor economy*



As the stability of the unique, economically relevant equilibrium solution cannot be ruled out, figure 3 depicts this possibility. The main difference between this and the previous analysis is that instead of exhibiting perpetual oscillatory behavior, the economy moves cyclically to the stable focus, $U^{*\prime}$, which is likely much different from U^* in figure 2. Whether this equilibrium is higher or lower than the one represented in figure 2 depends, of course, on the parameter values.

One may wonder: in what situations is the response of the rate of change of the level of environmental quality to changes in ϵ strong enough to produce such a result? This depends on the type of negative externality in each low-income developing economy. It is plausible to think, as suggested by Perman (2003), that the natural rate of environmental regeneration is relatively lower in response to externalities related to land degradation, poisoned water, deforestation, and atmospheric pollution concentration than for indoor pollution (burning of biomass). Hence, while stability might be a regular feature of indoor pollution cases, a lower β should be expected in the most common environmental problems of soil, water, atmospheric, and forest degradation.

The sensitivity of the level of environmental quality to output expansion is also important. It can be argued, however, that in the absence of discrete effects, ω is relatively small. It is only under anthropogenic environmental disasters that a relatively high ω should be expected.[16]

At the same time, it is difficult to assume that the environmental adjustment costs related to different externalities are relatively homogenous. Intuitively, what matters most for the argument is how rapidly output expansion responds to a change in the level of environmental quality and, thus, to environmental adjustment costs, $dX/d\epsilon = h_\epsilon$. To treat the possibility of stability as a special case in the interaction between economic growth and environmental quality, I suppose that this sensitivity is relatively low compared with the adjustment process in the capital-output ratio over the cycle.

2.1 An economic interpretation of the cycles

This section provides an economic interpretation of the vicious circle. A limit cycle need not be unique, as it is sensitive to initial economic conditions. Figure 2 presents one of the possible branches covered in the system. Note that the set of trajectories must exhibit the same oscillatory behavior; thus, the economy is represented without loss of generality.[17]

Consider that the economy is at point A, in a situation with a relatively high level of output-capital ratio and of the share of profits in income, but a relatively low level of environmental quality. The adjustment costs corresponding to environmental quality signals are relatively high, given the negative pressure that economic activity exerts on the environment. This negative effect helps compress the rate of output expansion below the rate of capital accumulation. Therefore, the output-capital ratio is falling at A. As ρ is falling, investment level and effective demand also are falling; thus, equilibrium in the goods market is maintained by a reduction in the profit share. In contrast, environmental quality is increasing, given the

---

[16] As an example of the destructive potential of capitalist activities, the recent collapse of a mining dam in the Brazilian state of Minas Gerais in 2015 is worth noting. It was one of the biggest environmental disasters in the history of Brazil and of Latin America (see Massarani, 2015).

[17] For illustrative purposes, the reader may think of negative environmental externality as local emissions of toxic industrial pollutants, which in such cases are clearly pro-cyclical. As the health effects are sensitive to the atmospheric flow of this pollutant, the growth rate of environmental quality also varies with the business cycle.

diminishing negative scale effects on the environment, and the economy moves toward region *II*.

At *B*, the output-capital ratio and profit share are relatively low, but with average levels of ϵ. The smaller ρ compresses capital accumulation, which then drops below the rate of output expansion, thereby increasing ρ. Investment increases, and the effective demand changes raise π, which restores the equilibrium in the goods market. As the profit share increases, and adjustment costs that come from the level of environmental quality decrease, the output grows at a rate that does not compromise the expansion in the level of environmental quality, with the economy moving toward region *III*. However, when the system enters region *IV*, output expansion starts to compromise environmental quality as the negative effects of the economy's scale are greater than the natural growth rate (the environmental capacity of regeneration, thereby decreasing labor productivity). Such an effect is represented by point *C*.

After a while, the corresponding decrease in the level of environmental quality, given environmental deterioration, begins to exert a stronger pressure on adjustment costs that, in turn, start compressing output expansion, with the economy moving toward region *I*. At point *D*, the output-capital ratio and profit share are relatively high, and the capital-accumulation rate is above the growth rate of output. The corresponding negative changes in effective demand are accommodated by reductions in the profit share, thereby exerting further downward pressure on $\hat{X}$. Even with such a decrease, the level of environmental quality is relatively low so that ϵ and ρ are both declining.

Without exogenous intervention, such cyclical counter-clockwise behavior will go on perceptually in this dual low-income economy. Note that this oscillatory behavior is possible under the assumption of free utilization of environmental quality in the sense that no vector of prices clears the 'environmental market'. What prevents the economy from achieving complete environmental decline is the rise in adjustment costs when the level of environmental quality is relatively low. Regarding the possibility of stability, presented in figure 3, the properties of the oscillatory behavior are similar, but the economy converges to the stable focus, U^*. In such case, if the sensitivity of environmental quality to output expansion is relatively high, and the natural rate of regeneration of the environment is relatively low, the economy eventually experiences a decline.

The present model is related to (and inspired by) an interesting environmental macromodel of economic growth: the Brander and Taylor (1998) Ricardo-Malthus general equilibrium model of renewable-resource use. They model population dynamics in a framework related to the Lotka-Volterra predator-prey model, with humans as the predator and environmental resources as the prey, offering a possible explanation for the rise and fall of past civilizations such as in Easter Island. In the model, it is population growth that degrades the resource base. In turn, the reduction in resource stocks exerts a downward effect on the population's fertility rate. Such dynamics also result in an oscillatory behavior within the system. Locally stable cycles arise because the resource base has a slow rate of regeneration.

Our results have some similarities with the work of Brander and Taylor (1998) in the sense that a low natural growth rate (a low rate of regeneration in environmental quality) may eventually compromise economic activity. This can happen only in the setting illustrated in figure 3, in which a strong negative labor productivity effect generates stability. However, I extended the results in several directions. I combined environmental and effective demand issues via the relationship between capital-output ratio and environmental quality in a medium-term vicious circle. More importantly, capital accumulation is included in the model, in which the role of the capitalist sector is analyzed explicitly. It is this conflictive relationship that creates conditions for perpetual oscillation in the medium run, instead of asymptotically stable behavior in the long run.

This paper also shares some views of the long run with a study by Taylor et al. (2016). As discussed earlier, the authors developed a demand-driven model to explore stabilization of greenhouse-gas (GHG) emissions in a Kaleckian economy. The dynamical analysis suggests that the interaction between emissions and economic growth is likely to involve cyclical boom-bust periods in output, which are the result of several feedback effects from the interaction between energy intensity, GHG emissions, and output. In addition, the model predicts the stabilization of GHG emissions at elevated levels to maintain capital accumulation at a growing pace. However, in the present study, the focus is on a Harrodian economy of which cyclical growth arises quite naturally in the presence of negative environmental feedback toward production. While in Taylor et al. (2016) several variables such as energy intensity and GHG emissions affect labor productivity, in the present study the negative effect of pollution on labor productivity is explored as another taming mechanism for Harrodian instability. Finally, their model presents a more general prediction that extends to mature economies, while the results of the present study may at best be related to an abstract, low-income surplus labor economy.

To sum up, a brief political economy discussion is in order. One may wonder whether the behavior of the system described in this paper underestimates the power of institutional change, since we should expect the possible creation of efficiency-resource arrangements through market solutions or institutional evolution, even in low-income developing economies. Note that a market solution (a price vector for negative externalities) only magnifies the output expansion's sensitivity to changes in the level of environmental quality through more direct environmental adjustment costs. It is only if these costs create incentives for adopting clean technologies that an eventual market solution helps the economy break, or at least weaken, the vicious circle. However, it seems unlikely that a low-income developing economy, if left to the free play of its structural forces while facing poverty, and education and health development problems, can generate, or even adopt, clean technologies to reduce its negative externalities on the environment.

Meanwhile, even without market or governmental (taxation) solutions, it is also possible that the population of agents endogenously can learn to solve their common-pool problem through institutional co-evolution (Bowles, 2004). This argument brings me to the seminal work of Elinor Ostrom (see Ostrom, 1990, and Ostrom et al., 1994), which shows that primitive and advanced communities can eventually resolve the common-pool problem through cooperative arrangements, but this does not mean that all of them will do so. As described in Ostrom (1990), in the end, this is an empirical question, and she collected evidence to determine which factors favor the survival of efficient institutions. Brander and Taylor (1998) point out that the most important favorable factor is an agreed-upon and correct understanding of the problem. They use a modern example, explaining that it was not possible to settle on an effective response to ozone deterioration until there was substantial agreement that the problem existed and that the mechanism causing the problem was anthropogenic. Ostrom (1990) also points out several other important factors: resource-stock size, the group's size and homogeneity; existence of leadership; and likelihood of punishment if deviations from the cooperative equilibrium occur.

Therefore, it is not clear whether, in the event of widespread environmental degradation scenarios in dual low-income economies, all these countries can promote a cooperative outcome, thereby reducing negative externalities on the environment and decreasing output-expansion sensitivity to corresponding environmental adjustment costs. From an empirical perspective, however, certain development agencies are carrying out initiatives to promote such changes in developing countries, such as Rwanda. As mentioned in the introduction, Rwanda has serious problems with land degradation that may compromise its GDP. The Poverty-Environment Initiative of the United Nations Development Program (UNDP) and the United Nations Environment Program (UNEP) in the country, for instance, focuses on enhancing sound environmental management to reduce poverty, nurture sustainable economic growth, and achieve, Sustainable Development Goals.[18] Parallel to our results, this is an important political attempt to reduce the occurrence of vicious circles in low-income developing economies.

3. Final remarks

The present study explores the issue of reverse causality in the environmental Kuznets curve, arguing that when environmental adjustment costs are binding already in the medium run in low-income developing economies with relatively low levels of environmental quality, we should consider turning the focus from a long run well-behaved trajectory of economic growth to a possible new channel of endogenous cyclical fluctuations. One of this study's contributions is being a blueprint for such possibilities through a simple Harrodian macrodynamic model of economic growth that explores, in one of its relevant aspects, the conflictive interaction between environmental quality and economic growth.

From a methodological perspective, our results extend the theoretical explanatory power of the Harrodian models, showing that the environmental dynamics may operate as another taming mechanism for the instability raised by effective demand issues. Essentially, this occurs through the interaction between environmental adjustment costs in the production process and its negative scale effects, which endogenously change the level of environmental quality in the whole economy, weakening the health of the labor force, as well as factory workers' productivity.

The same mechanism that 'stabilizes' Harrodian instability may eventually create a region of perpetual vicious cycles from which a dual low-income economy may never escape without first resolving its exploitative relationship with the environment. A 'dirty' growth strategy, one based on EKC, is environmentally unsustainable in the medium run because the effective demand that expands investment also exerts downward pressure on environmental quality. In turn, a reduction in environmental quality raises the environmental adjustment costs of production. In this sense, the conflictive relationship between effective demand (economic growth) and the environment (environmental quality) illustrates a Keynesian perspective on an endogenous relationship between the environment and economic growth in some low-income developing economies.

Thus, the model creates an innovative link between effective demand and environmental quality. A rise in effective demand is associated with a fall in the level of environmental quality. In addition, according to the Harrodian instability 'problem', effective demand is endogenously linked to the environment's natural growth rate. Such an apparently naive result holds

---

[18] Sustainable Development Goals, an initiative launched by the United Nations, comprises 17 international development goals, including the reduction of poverty, hunger, gender inequality, and strategies for mitigating climate change.

important implications for ecological and environmental macroeconomics. If environmental adjustment costs are considered, the model indicates that a long-run trajectory exists, linking economic growth (the warranted growth rate) with the behavior of the environment (the natural growth rate). What the model emphasizes, in line with its Harrodian specifications, is that this trajectory is cyclically unstable and not well behaved, as explained by most neoclassical models based on the unidirectional (and endogenous) prediction of the environmental Kuznets curve.

Possible theoretical extensions of the present model could incorporate the role of abatement efforts from a Keynesian perspective, which should include an explicit abatement function affecting investment decisions. In addition, the adoption of clean technology could exert a powerful role in avoiding the emergence of such endogenous cyclical fluctuations.

References

Bôjo J., Bucknall J., Hamilton K., Kishor N., Kraus C. and Pillai P. (2002), "Environment", in Klugman J. (ed.), *A Sourcebook for Poverty Reduction Strategies*, vol. 1, *Core Techniques and Cross-Cutting Issues* (pp. 375-401), Washington (DC): The International Bank for Reconstruction and Development/The World Bank, available at: http://documents.worldbank.org/curated/en/156931468138883186/pdf/298000182131497813.pdf

Bowles S. (2004), *Microeconomics: Behavior, Institutions and Evolution*, Princeton (NJ): Princeton University Press.

Brander J.A. and Taylor M.S. (1998), "The Simple Economics of Easter Island: A Ricardo-Malthus Model of Renewable Resource Use", *American Economic Review*, 88 (1), pp. 119-138.

Brock W.A. and Taylor M.S. (2005), "Economic Growth and the Environment: A Review of Theory and Empirics", in Aghion P. and Durlauf S.N. (eds.), *Handbook of Economic Growth*, vol. 1, Part B, of *Handbook of Economic Growth* (pp. 1749-1821), Amsterdam: Elsevier.

Brock W.A. and Taylor M.S. (2010), "The Green Solow Model", *Journal of Economic Growth*, 15 (2), pp. 127-153.

Bulte E.H. and van Soest D.P. (2001), "Environmental Degradation in Developing Countries: Households and the (Reverse) Environmental Kuznets Curve", *Journal of Development Economics*, 65 (1), pp. 225-235.

Carson R.T. (2010), "The Environmental Kuznets Curve: Seeking Empirical Regularity and Theoretical Structure", *Review of Environmental Economics and Policy*, 4 (1), pp. 3-23.

Chang T., Zivin J.S.G., Gross T. and Neidell M.J. (2014), "Particulate Pollution and the Productivity of Pear Packers", *NBER Working Paper*, no. 19944, Cambridge (MA): National Bureau of Economic Research, available at: http://www.nber.org/papers/w19944.pdf

Copland B.R. and Taylor M.S. (2005), *Trade and the Environment: Theory and evidence*, Princeton (NJ): Princeton University Press.

Cunha F. and Heckman J. (2007), "The Technology of Skill Formation", *American Economic Review*, 97 (2) pp. 31-47.

Currie J. and Stabile M. (2006), "Child Mental Health and Human capital Accumulation: The Case of ADHD", *Journal of Health Economics*, 25 (6), pp. 1094-1118.

Dasgupta S., Laplante B., Wang H. and Wheeler D. (2002), "Confronting the Environmental Kuznets Curve", *Journal of Economic Perspectives*, 16 (1), pp. 147-168.

Dasgupta S., Deichmann U., Meisner C. and Wheeler D. (2005), "Where Is the Poverty Environment Nexus? Evidence from Cambodia, Lao Pdr, and Vietnam", *World Development*, 33 (4), pp. 617-638.

Downing T., Watkiss P., Dyszynski J. et al. (2009), *Economics of Climate Change in Rwanda*, Oxford: Stockholm Environment Institute, available at: https://www.sei.org/mediamanager/documents/Publications/Climate/cc_economics_rwanda.pdf

Foley D.K. (2012), "Dilemmas of Economic Growth", *Eastern Economic Journal*, 38, pp. 283-295.

Fontana G. and Sawyer M. (2016), "Towards Post-Keynesian Ecological Macroeconomics", *Ecological Economics*, 121 (Jan), pp. 186-195.

Graff Zivin J. and Neidell M.J. (2012), "The Impact of Pollution on Worker Productivity", *American Economic Review*, 102 (7), pp. 3652-73.

Graff Zivin J. and Neidell M.J. (2013), "Environment, Health, and Human Capital", *Journal of Economic Literature*, 51 (3), pp. 689-730.

Graff Zivin J., Hsiang S.M. and Neidel M.J. (2015), "Temperature and Human Capital in the Short- and Long-Run", *NBER Working Paper*, no. 21157, Cambridge (MA): National Bureau of Economic Research, available at: http://www.nber.org/papers/w21157.pdf

Grossman G.M. and Krueger A.B. (1995), "Economic Growth and the Environment", *Quarterly Journal of Economics*, 110 (2), pp. 353-377.

Guarini G. (2015), "Complementarity between Environmental Efficiency and Labor Productivity in a Cumulative Growth Process", *PSL Quarterly Review*, 68 (272), pp. 41-56.

Guarini G. and Porcile G. (2016), "Sustainability in a Post-Keynesian Growth Model for an Open Economy", *Ecological Economics*, 126 (Jun), pp. 14-22.

Harris J. (2013), "Green Keynesianism: Beyond Standard Growth Paradigms", *GDAE Working Papers*, no. 13-02, Medford (MA): Tufts University, Global Development and Environment Institute, available at: http://www.ase.tufts.edu/gdae/Pubs/wp/13-02HarrisGreenKeynesianism.pdf

Harrod R.F. (1939), "An Essay in Dynamic Theory", *Economic Journal*, 49 (193), pp. 14-33.

Kaldor N. (1966), "Marginal Productivity and the Macro-Economic Theories of Distribution: Comment on Samuelsson and Modigliani", *Review of Economic Studies*, 33 (4), pp. 309-319.

Kelly D.L., Kolstad C.D. and Mitchell G.T. (2005), "Adjustment Costs from Environmental Change", *Journal of Environmental Economics and Management*, 50 (3), pp. 468-495.

Keynes J.M. (1976 [1930]), *A Treatise on Money*, vol. 1, New York: AMS Press.

Kronenberg T. (2010), "Finding Common Ground between Ecological Economics and Post Keynesian Economics", *Ecological Economics*, 69 (7), pp. 1488-1494. Special Section: Ecosystem Services Valuation in China.

Lima G.T. (2004), "Endogenous Technological Innovation, Capital Accumulation and Distribution Dynamics", *Metroeconomica*, 55 (4), pp. 386-408.

Massarani L. (2015), "Brazil Mine Disaster Floods Area with Toxic Substances", *Scientific American*, 25 November, available at: https://www.scientificamerican.com/article/brazil-mine-disaster-floods-area-with-toxic-substances/

Nakatani T. and Skott P. (2007), "Japanese Growth and Stagnation: A Keynesian Perspective", *Structural Change and Economic Dynamics*, 18 (3), pp. 306-332.

Oliveira G. and Lima G.T. (2015), "A Green *Lewis* Development Model", *FEA-USP Working Paper*, no. 2015-49, São Paulo (BR): Department of Economics, University of São Paulo, available at: http://www.repec.eae.fea.usp.br/documentos/Oliveira_Lima_49WP.pdf

Ostrom E. (1990), *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge (UK): Cambridge University Press.

Ostrom E., Gardner R. and Walker J. (1994), *Rules, Games and Common Pool Resources*, Ann Arbor (MI): The University of Michigan Press.

Pearce D. and Turner R. (1990), *Economics of Natural Resources and the Environment*, Baltimore (MD): Johns Hopkins University Press.

Perman R. (2003), *Natural Resource and Environmental Economics*, Harlow (UK): Pearson Education.

Razmi A. (2016), "North-South Interactions in the Presence of Trade in Environmental Permits: A Structuralist Investigation", *Cambridge Journal of Economics*, 40 (2), pp. 541-574.

Roncaglia A. (2003), "Energy and Market Power: An Alternative Approach to the Economics of Oil", *Journal of Post Keynesian Economics*, 25 (4), pp. 641-659.

Schefold B. (1997), "Ecological Problems as a Challenge to Classical and Keynesian Economics", in *Normal Prices, Technical Change and Accumulation* (pp. 525-549), London: Palgrave Macmillan.

Skott P. (1989a), *Conflict and Effective Demand in Economic Growth*, Cambridge (UK): Cambridge University Press.

Skott P. (1989b), "Effective demand, class struggle and cyclical growth", *International Economic Review*, 30 (1), pp. 231-247.

Skott P. (2010), "Growth, Instability and Cycles: Harrodian and Kaleckian Models of Accumulation and Income Distribution", in Setterfield M. (ed.), *Handbook of Alternative Theories of Economic Growth* (pp. 108-131), Cheltenham (UK) and Northampton (MA): Edward Elgar.

Skott P. (2015), "Growth Cycles with or without Price Flexibility", *Review of Keynesian Economics*, 3 (3), pp. 374-386.

Steindl J. (1952), *Maturity and Stagnation in American Capitalism*, London: Monthly Review Press.

Stern D.I. (2004), "The Rise and Fall of the Environmental Kuznets Curve", *World Development*, 32 (8), pp. 1419-1439.

Stern D.I. (2015), "The Environmental Kuznets Curve after 25 Years", *CCEP Working Papers*, no. 1514, Canberra: Centre for Climate Economics & Policy, Crawford School of Public Policy, The Australian National University.

Stokey N.L. (1998), "Are There Limits to Growth?", *International Economic Review*, 39 (1), pp. 1-31.

Tanaka S. (2015), "Environmental Regulations on Air Pollution in China and Their Impact on Infant Mortality", *Journal of Health Economics*, 42, pp. 90-103.

Taylor L., Rezai A. and Foley D.K. (2016), "An Integrated Approach to Climate Change, Income Distribution, Employment, and Economic Growth", *Ecological Economics*, 121 (Jan), pp. 196-205.