



Analysis

Sustainability in a post-Keynesian growth model for an open economy

Giulio Guarini ^{a,*}, Gabriel Porcile ^b^a Tuscia University, Department of Economics and Management, Viterbo, Italy^b Economic Commission for Latin America and the Caribbean (UN-ECLAC) and Federal University of Parana, Brazil

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ABSTRACT

The paper expands the BOP-constraint growth model and Kaldorian regimes (productivity and demand regimes) in order to include some of the concerns raised by ecological economics in post-Keynesian models for open economies. The demand regime is modified by taking into account Porter's hypothesis, which suggests that environmental innovations, spurred by environmental policies, can foster competitiveness. As a result, the equilibrium BOP-constrained rate of growth increases, leading to a different version of Thirlwall's Law, which opens room for analyzing the impact of environmental innovations on convergence between developing and developed economies. The productivity regime in turn considers the growth and employment implications of innovations in labor productivity (standard innovations) and environmental efficiency (environmental innovations). It is argued that the fiscal policy and composition of public expenditure matter for long run growth, employment and sustainability.

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1. Introduction

In recent years there has been a surge of papers which sought to build bridges between post-Keynesian (PK) and ecological economics (e.g. Gowdy, 1991; Jackson and Victor, 2011; Kronenberg, 2010; Stern, 2006; Victor, 2008, 2012). They stress the convergence and complementarities that exist between these two schools of thought. As highlighted by Kronenberg (2010) and Rezai et al. (2013), areas of convergence are the perception of the production process as one in which there is little room for substitution between factors; a similar view of the consumers' demand function; emphasis on dynamics, particularly on irreversibility and path dependence; the relevance of considering various social actors instead of assuming a single rational actor as in mainstream economics.¹

Along these lines, some contributions have successfully explored environmental themes within a PK framework.² They confirm the potential for a fruitful conversation between ecological and PK economists—combining the concern with sustainability of the former

with the focus on employment and income distribution of the latter.³ These themes have also gained relevance in the policy agenda as international organizations embraced what has been labeled “inclusive green growth”.⁴ In September 2015 the United Nations formally launched the Objectives of Sustainable Development (ODS), which expresses a broad international consensus that should guide cooperation and development policies until 2030. The emerging consensus—based on inclusiveness and sustainability—represents a significant opportunity for PK and ecological economics to inform economic policy with new theoretical insights.⁵

However, there is an important part of the theoretical PK tradition that has so far not been included in this dialog, the Balance-of-Payments-constrained growth (BOPCG) model, which is the workhorse of the PK school for studying long run growth in open economies (Thirlwall, 2011; Blecker, 2013). In particular, the BOPCG model has been extensively used to address the problems of development and

³ See Harris (2013) and Antal (2014). Early contributions are Schefold (1985) and Roncaglia (2003).

⁴ ECLAC (2012) set forth the concept of “structural change for equality” to define a growth path which is sustainable from an economic, social and environmental point of view. See also the work of OECD (2012) and World Bank (2012) on inclusive green growth.

⁵ For instance, ECLAC and the OECD co-organized a Conference at the OECD headquarters in May 2014, *Workshop on New Tools and Methods for Policy-Making*, in which Schumpeterian and Keynesian scholars were invited to discuss how new theoretical perspectives could be used to devise new policy tools.

* Corresponding author.

¹ A discussion of the shortcomings of the neoclassical approach to ecological economics can be found in Gowdy and Erickson (2005).

² Guarini (2015); Guarini et al. (2016); Fontana and Sawyer (2015); Taylor and Foley (2015).

convergence in GDP per capita between advanced and laggard countries in the international economy.⁶ However, there has been almost no attempt to include environmental variables in the BOPCG models. Such absence is particularly unfortunate for three reasons: i) key environmental issues as climate change or the exhaustion of natural resources are by definition long-run issues, which is precisely the time horizon for which these models are valid; ii) economic development and sustainability cannot be separated: developing countries aspire reduce the gap in GDP per capita with respect the developed world and hence for many of them to accelerate growth is a major concern; and iii) the relevance of the environmental impact of globalization and the complex interaction between international competitiveness and sustainability need to be more systematically discussed in open-economy models. It is therefore crucial to discuss paths of world convergence based on absolute decoupling (Jackson, 2009) in order to make development, inclusion and sustainability compatible.

This paper aims to make a contribution to this dialog between PK and ecological economics discussing sustainable convergence and long run growth in open economies, expanding the canonical BOPCG model in order to address the challenges posed by greenhouse emissions and absolute decoupling. The paper does not intend to cover the key contributions of these two fields, but to suggest a way in which environmental variables can be included in the structure of BOPCG models.

The paper consists of 4 sections. Section 1 develops a modified version of the BOPCG model in order to include the effect of environmental innovations on the equilibrium rate of growth. Section 2 expands the analysis of technical change to include both standard and environmental innovations. In Section 3 equilibrium outcomes and policy implications are discussed, focusing on the role of fiscal policy in making compatible growth, employment and sustainability. The conditions that give rise to a pattern of growth consistent with higher levels of employment and lower levels of emissions per unit of output are identified. Section 4 concludes. In order to make the narrative clearer, most technical details are presented in an appendix at the end of the paper.

2. 2. The Modified Kaldorian Demand Regime and the Green PK Model

2.1.1. Export-led Growth and the Equilibrium Rate of Growth

Using the Kaldorian terminology, growth emerges from the interaction between the demand and the productivity regimes. The demand regime is driven by the growth of exports and by the BOP constraint; the productivity regime is driven by static and dynamic economies of scale. The export-led tradition suggests that economic growth (y) depends on the rate of growth of autonomous expenditure (a) plus the rate of growth of exports, weighted by the share of each class of expenditure in total income.⁷ Assuming that the real exchange rate is in equilibrium in the long run (see Appendix), the Kaldorian effective rate of growth is:

$$y = \frac{\alpha a + \beta_1 \varepsilon y^*}{1 + \beta_2 \pi} \quad (1)$$

Small letters are proportional rates of growth. In Eq. (1) a is the rate of growth of autonomous expenditure ($a = \dot{A}/A$), ε is the income elasticity of exports, π is the income elasticity of imports, $\alpha = A/Y$ is the share of autonomous expenditure in total income and β_1, β_2 are the shares of exports and imports respectively, in total income. According to Eq. (1), a Keynesian fiscal policy pursuing full employment (that raises a)

would be effective in raising aggregate demand and the effective rate of economic growth. However, there are different constraints on growth that limit the ability of the government to spur growth in the long run.

The first is the external constraint: the rate of growth of Eq. (1) must be consistent with equilibrium in current account. Otherwise, the external debt would steadily increase and at some point the country's rate of growth would have to fall to correct the external disequilibrium. Other constraints emerge from the supply side. If there is shortage of labor or capital in the economy, demand growth will fail to elicit a response in supply. Another supply-side constraint arises from the carrying capacity of the ecosystem (Arrow et al., 1995), i.e. the capacity of the ecosystem to provide a wide variety of services without degrading and compromising material production in the future. These different types of constraint are discussed in the paper.

The first constraint (external equilibrium) gives rise to the BOP-constrained equilibrium growth rate—the so-called Thirlwall's Law (for a derivation of the equation, see the mathematical Appendix)⁸:

$$y^E = \frac{\varepsilon}{\pi} y^* \quad (2)$$

Eq. (2) is the simplest version of the BOPCG model. The economic intuition of this equation is straightforward: the rate of growth of the developing economy which is consistent with external equilibrium (y^E) depends on the ratio between the income elasticity of exports and the income elasticity of imports (ε/π) and the rate of growth of the world economy (y^*). While Eq. (1) gives the effective rate of growth at a certain point in time (y), Eq. (2) gives the long-run equilibrium rate of growth (y^E). The effective rate must move towards the equilibrium rate; the mechanism that allows for this convergence is discussed later.

For the relative rate of growth of the country with respect the rest of the world (y/y^*) equals the income elasticity ratio (ε/π), convergence requires $y/y^* = \varepsilon/\pi > 1$ (i.e. for the developing economy to grow at a higher rate than the developed economy in equilibrium, the income elasticity ratio should be higher than unity). Otherwise, convergence would bring about a growing deficit in current account as a percentage of GDP—imports will grow faster than exports if the developing economy grows faster than the developed economies—which would then stop the convergence process. The model assumes a North–South economy in which the North issues the international currency and is not BOP-constrained, while the South is the technological laggard which faces a competitiveness challenge, which requires having equilibrium in current account in the long run.

The income elasticity of exports and imports are a function of the pattern of specialization.⁹ More precisely, the income elasticity ratio (ε/π) depends on whether the country produces goods whose demand grows at high rates in the domestic and world markets—the “growth efficiency” of the production pattern (Dosi et al. (1990); see also Ocampo et al., 2009). The pattern of specialization, in turn, depends on technological capabilities.¹⁰ To be able to compete in the long run in sectors with high demand growth, the country should be able to innovate, develop sophisticated technological skills and close the gap with the technological leaders. Technical change is the ultimate driver of competitiveness in a world in which market shares are shaped by leads and lags in innovation and diffusion of technology. Eq. (2) implies that innovation can affect growth by changing the pattern of specialization and the income elasticity ratio (ε/π). The different directions that

⁸ See on this Thirlwall (2011).

⁹ The literature that addresses this point is already large. See for instance Araujo and Lima, 2007; Ciarli et al., 2010; Gouvea and Lima, 2010; Cimoli et al., 2010.

¹⁰ The analysis of the industrial and technological policies driving structural change is beyond the scope of this paper. The reader is referred to the rich literature in this field, in particular Fagerberg and Verspagen (2002); Fagerberg and Srholec (2006); Metcalf (2001) and Narula (2004), who highlight the interplay between economic, political and institutional variables in shaping the pattern of specialization.

⁶ See among others Dosi et al. (1990); Verspagen (1993); Botta (2009); Cimoli and Porcile (2011 and 2014); Lavopa (2014).

⁷ Pioneer works are Kaldor (1966, 1970) and Dixon and Thirlwall (1975). For a recent revision see Blecker (2013).

technical change may follow, and their implications for growth and employment, are addressed in the following section.

2.1.2. The Income Elasticity Ratio, Technology and Environmental Innovations

To analyze the interrelations between technical change, specialization and growth, it is assumed that technical change takes two different forms, namely environmental innovations that reduce greenhouse gases emissions per unit of product; and standard innovations that increase labor productivity (see Ghisetti and Pontoni, 2015). Labor productivity is assumed to depend on two forces: the traditional forces of static and dynamic economies of scale (Kaldor–Verdoorn Law), which states that a higher rate of growth raises productivity growth; and the intensity of standard innovations.

Environmental innovations refer to “the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the firm [or organization] and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives” (Kemp and Pearson, 2007:10). Standard innovations refer to all other innovations.

The goods produced with environmental innovations are considered to be goods of better quality and this have an impact on demand. Because of stricter international standards and/or an increasing awareness of consumers to environmental problems, these greener goods are more demanded than standard goods as income rises in the world economy. As a result, environmental innovations increase the country's income elasticity of the demand for exports; and per Eq. (4), this enhances the BOP-constrained rate of economic growth (a higher income elasticity ratio ε/π).

The previous assumption draws from Porter's Hypothesis, which states that there is a positive relationship between environmental innovations and competitiveness (Porter, 1991). Porter and Van der Linde (1995, p. 104) argue that environmental policies encourage innovations whose benefits offset the initial costs of compliance with regulations: “World demand is moving rapidly in the direction of valuing low-pollution and energy-efficient products, not to mention more resource-efficient products with higher resale or scrap value. Many companies are using innovation to command price premiums for “green” products and open up new market segments”. It is therefore important that the innovation and production systems anticipate the ratification and implementation of international environmental standards in order to gain the “early-mover advantage” in international markets (Porter and Van der Linde, 1995). The green-quality positive effect depends on qualitative changes regarding production, design and related services and support to the consumers (Porter and van der Linde, 1995, p.98). The empirical evidence suggests that consumer preference for environment-friendly goods has recently increased. This happened mainly in developed countries (Sarigollu, 2009), but some case studies point out a similar trend in developing countries, such as Egypt (Mostafa, 2006) and Pakistan (Ali et al., 2011). The main factor supporting this trend is a rise in the awareness of the magnitude of the environmental problems (Diekmann and Franzen, 1999). Other empirical studies underline the role of the capacity of consumers to pay a price premium for greener goods (Laroche et al., 2001; Peattie, 2001), of cultural values (McCarty and Shrum, 1994) and of gender differences (Florenthal and Arling, 2011). Last but not least, it is not just informed consumers that favor the demand of goods produced by sectors and technologies that are more environmentally-friendly. There already exists a significant market for green technologies and equipment. Countries compete to define which one will have the upper hand in these markets—solar panels, wind power equipment, residual waste treatment, electrical vehicles and so on and so forth (Nahm and Steinfeld, 2014; Nahm, 2014). Costantini and Crespi (2008) report that, in OECD countries, environmental innovations (spurred by the regulatory framework) improved

the export performance of the energy sector (1996–2005). Costantini and Mazzanti (2012) verify a positive and significant impact of regulation on environmental innovation and exports in high and medium technology manufacturing sectors in EU15 countries (in the 1996–2007 period). In other words: environmental innovations can generate competitive advantages due to both evolving consumers' preferences and/or changes in the demand of intermediate inputs and equipment in favor of environmentally friendly technologies.¹¹

2.1.3. Expanding the BOPCG Model

To take into account the impact of environmental factors on international competitiveness and demand growth, a green elasticity parameter is introduced in the argument of the demand functions for exports and imports. Environmental innovations increase environmental efficiency, defined as the ratio between value added and total pollutant emissions. A higher environmental efficiency raises the environmental performance of the goods (Rennings et al., 2006), with an impact on demand. The modified function of the demand for exports is thus¹²:

$$X = Q^{\psi_X} (Y^*)^{\varepsilon} Z^{\xi} \quad (3)$$

In Eq. (3) X is the volume of exports, $Q = P^*E/P$ is level of the real exchange rate, Y^* is world GDP, Z is environmental efficiency (the higher Z , the lower are greenhouse gases emissions per unit of output), ψ_X is the elasticity of exports with respect to the real exchange rate, ε is the income elasticity of exports and ξ is the “green elasticity” parameter.

According to the previous discussion (and the abovementioned Porter's Hypothesis), the sign of ξ is positive. This demand equation assumes that environmental innovations elicit a positive response from consumers (more on this later).

The demand for imports is given by:

$$M = Q^{-\psi_M} (Y)^{\pi} (Z^*)^{\xi} \quad (4)$$

In Eq. (4) Y is domestic GDP, Z^* the environmental efficiency of the rest of the world, ψ_M the price elasticity of imports, μ is the environmental elasticity of imports and π is the income elasticity of imports. Taking logs and differentiating Eqs. (3) and (4) with respect to time (and using the result in Eq. (1)) allow for finding the Kaldorian effective rate of growth with a green component (Eq. (5)). It is assumed that the real exchange rate is in equilibrium and hence $q = 0$, where small letters are proportional rates of growth (e.g. $q \equiv \dot{Q}/Q$).¹³ This renders the following effective rate of economic growth:

$$y = \frac{\alpha a + \beta_1 (\varepsilon y^* + \xi z - \mu z^*)}{1 + \beta_2 \pi} \quad (5)$$

¹¹ In the empirical literature there is still a debate on the validity of Porter's Hypothesis. The main empirical criticisms concern mainly the price channel: some empirical studies show green regulations can elevate the production costs reducing exports (the so called, *Pollution haven hypothesis*). From this perspective, environmental improvements are seen only as compliance costs and a burden on price competitiveness: a strong (weak) environmental regulation represents a competitive disadvantage (advantage) (Brunnermeier and Levinson, 2004; Copeland and Taylor, 2003). However, it should be recalled that the role of price competitiveness is not a significant one in the context of the BOPCG model, as it is assumed that in the long run the real exchange rate does not vary. Changes in prices are seen as having just a once and for all effect on growth.

¹² This specification draws from the demand equation suggested by Porcile et al. (2008) in which the quality dimension is included in the argument of the demand function.

¹³ Implicitly, increases in labor productivity are assumed to be translated to a higher mark up, higher wages, or a lower nominal exchange rate (nominal appreciation of the currency). This assumption of imperfect competition and flexible exchange rates help explain why changes in labor productivity do not redefine the real exchange rate in the long run. This assumption also skews the possibility that environment-friendly innovations in the North could change the price of capital and intermediate inputs in the South, reshaping price competitiveness.

In the long run, the current account must be in equilibrium and hence the value of exports and imports must grow at the same rate. When this constraint is imposed, the long run rate of growth with equilibrium in current account is obtained:

$$y^E = \frac{\varepsilon y^* + \xi z - \mu z^*}{\pi} \quad (6)$$

Eq. (6) is a “green Thirlwall’s Law”. The demand for green goods is expected to be higher in developed economies than in developing economies. Concerns with environmental impacts of consumption tend to be higher in affluent countries. For this reasons, it is most likely that $\mu \ll \xi$. To save notation and without loss of generality, it will be assumed $z^* = 0$.¹⁴ The new feature in Eq. (6) as compared to Eq. (2) (Thirlwall’s Law) is that it assumes that environmental innovations do have an impact on the rate of growth of the country’s exports and hence on the equilibrium BOP-constrained rate of economic growth.

An important caveat should be made at this point. The magnitude of the parameter ξ is an empirical matter: it is likely to be rather low at the present moment, but expected to increase in the coming years as a result of higher global awareness of environmental issues by consumers, producers and governments. The December 2015 resolutions of the COP21 in Paris, and the countries’ Intended Nationally Determined Contributions (INDC, which will be periodically monitored and upgraded) are favorable to an increase in ξ . In the same vein, it is likely that environmental innovations will be on the rise in the near future, as the COP21 recommended devoting more resources to R&D in green technologies and green technology transfers to developing economies (UN, 2016). In this sense, the model helps discuss the potential of these policies to sustain growth and convergence, and the conditions required for making convergence compatible with decoupling.¹⁵

As z favors the growth of effective demand but it does not save labor, it has an unambiguously positive effect on employment growth. There are interesting policy implications that can be drawn from this modified specification of the demand equations for exports and imports, particularly as regards the link between environmental innovations and inclusive growth.

3. Transitional Dynamics, Fiscal Policy and the Modified Productivity Regime

3.1. Fiscal Policy and the Adjustment Towards the Equilibrium Rate of Growth

The adjustment between the effective rate of growth y and the equilibrium rate of growth takes places through changes in the rate of autonomous expenditure—more specifically, though expansionary or contractionary changes in fiscal policy.¹⁶ The focus on adjustments through fiscal policy is justified by two reasons. First, because in the Keynesian tradition fiscal policy is the crucial variable used to encourage effective demand and employment. And second, because public investment in R&D, infrastructure and education are crucial for changing the pattern of production towards green growth. Most countries have adopted policies to encourage green growth, and this usually implies a

wide array of public investment and public incentives (Rodrik, 2016; OECD, 2012; ECLAC, 2010, 2012).

The behavioral rule of the government is the following: when the effective rate of growth of the economy exceeds the BOP-constrained rate of growth (i.e. $y > y^E$), and hence a current account deficit emerges, the government reduces the growth of its autonomous expenditure to correct the external deficit (contractionary fiscal policy; see Eq. (8)). The fall in a is associated with a perception that there will be a crisis at some point in the near future if the government fails to curb growth and imports. The signals are growing tensions in BOP, instability in the exchange rate market and outflows of foreign capital. Shortages or rising prices for intermediate import goods, along with weaker “crowding in” effects of government expenditures, may also induce a similar fall in private expenditure. Inversely, if the current account displays a surplus, the government has space for a more expansionary fiscal policy.

Formally:

$$\dot{a} = \psi(y^E - y) \quad (7)$$

Using Eqs. (5) and (6) in Eq. (7) renders (with $q = 0$ and $z^* = 0$):

$$\dot{a} = \left[\frac{\varepsilon y^* + \xi z}{\pi} - \frac{\alpha a + \beta_1(\varepsilon y^* + \xi z)}{1 + \beta_2 \pi} \right] \quad (8)$$

While the income shares α, β_1, β_2 are not constant, it will be assumed that their changes are small enough to be considered negligible and being treated as constants. The behavioral rule above drives the effective rate of growth towards the BOP-constrained rate of growth. Particularly in developing countries, external disequilibrium imposes fiscal austerity to curb an explosive increase in the external debt.

3.2. Productivity Regime: Environmental Innovations and Labor-saving Technical Change

So far the focus has relied on the response of demand patterns to environmental innovations and the ensuing changes in the equilibrium rate of growth. In addition, it was argued that labor productivity was driven by standard innovations and learning by doing. How are the intensity and direction of innovation related to the fiscal policy?

First, it was already argued that public investments in green technologies are crucial for environmental innovations. This assumption is based on evidence that in new, highly uncertain technologies, the government directly or indirectly provides subsidies and financial support to the new industries (Mazzucato, 2013; Cimoli et al., 2015). According to Bergek and Berggren (2014, pp.113–114), environmental policies rely on policy instruments that are economic, regulatory, general or technological-specific. The *economic policy instruments* provide incentives to adopt green technologies by subsidizing actors that make green investments, while punishing the others—for instance, by pricing carbon through a carbon tax and /or a rigorous cap-and trade system. The *regulatory policy instruments* set “technological standards (i.e. prescription of a certain method, equipment or technology), emission standards (an absolute upper emission level), and performance standards, such as a cap on emissions per unit of output”. The *general policy instruments* aim to reduce pollutant emissions without specifying which technology should be adopted (for example the European Union Emissions Trading System). Finally, the *technological-specific policy instruments* encourage the adoption or development of particular green technologies. In any case, all these environmental policies entail a fiscal burden.

To capture the impact of public policy on environmental innovations, a new parameter is introduced in the model, λ , which is the share of the growth of public investment a which goes to environmental R&D and education. The parameter λ reflects the concern of the government with the environment and with competitiveness in green sectors. As environmental innovations and standard innovations compete for

¹⁴ The same result is obtained if it is assumed that $\mu \approx 0$.

¹⁵ The Porter’s Hypothesis focuses on the conditions that can make environmental regulation a driver of competitiveness. Public institutions should be able to identify inefficiencies in pollutant technologies, provide information about potential benefits of environmental innovations, reduce uncertainty in green investments, stimulate an innovative spirit aimed at sustainability, and repress opportunistic strategies to avoid pollution-reducing investments (Porter and van der Linde, 1995, p.99–100). The eventual effects of regulation will depend on the sector, the effectiveness of environmental regulation and the market structure (Mazzanti et al., 2008).

¹⁶ For a discussion of the mechanisms of the adjustment process see Moreno-Brid (2003); Carlin and Soskice (2006) and Blecker (2013). For an empirical analysis which shows that this is the basic adjustment mechanism, particularly in developed economies, see Ocampo et al. (2009).

public funds, the higher is the increase in environmental efficiency and the lower the increase in labor productivity.

The growth of labor productivity (g) therefore depends negatively on λ for less public resources are devoted to labor-saving technical change. On the other hand, labor-saving innovations depend positively on the rate of employment, which captures learning by doing. The higher the employment rate ($E = N/L$ where N are employed workers and L total labor supply), the closer the economy is to full employment, the higher is learning by doing (Kaldor–Verdoorn) and the higher the incentives to invest in labor-saving technology. Formally:

$$g = g((1-\lambda), a, E). \quad (9)$$

In Eq. (9) E is the employment rate and $(1-\lambda)$ is the share of the increase in public autonomous expenditure allocated to standard innovations. As mentioned, $g_a > 0$, $g_E > 0$ and $g_\lambda < 0$.

The change in CO2 efficiency in turn responds to the following motion equation:

$$z = z(\lambda, a) \quad (10)$$

with $z_a > 0$ and $z_\lambda > 0$.

Eqs. (9) and (10) suggest that the intensity and direction of technical change (in either environmental or standard innovations) depend on the increase in public investment in R&D and education, the policy parameter that distributes government investments between green and standard technologies, and the level of employment, which encourages learning and labor-saving innovations. For any rate of growth of public expenditure, the rate of environmental innovations increases with λ . The idea is that the emergence of innovations does not depend on the level of public expenditure, but on the rate of growth of public expenditure and on how it is distributed among the two innovation fields—standard and environmental. A similar assumption is found in some growth models based on human capital in which only changes in (but not the level of) the stock of human capital can affect economic growth (for a discussion of this point in neoclassical growth models, see Sunde and Vischer, (2011)).

4. Growth, Employment and Sustainability in Equilibrium

4.1. The Impact of Green Public Policy

Recalling that $E = N/L$, taking logs and differentiating with respect to time gives $e = \dot{N} - l$, whereas before small letters are proportional rates of growth (e.g. $e = \dot{E}/E$). Assuming a constant supply of labor ($l = 0$), the growth of employment (n) is defined by the difference between the rate of economic growth and the rate of growth of labor productivity, which gives the rate of growth of labor demand. Therefore:

$$e = y - g. \quad (11)$$

Eqs. (8) and (11) should be studied together. While Eq. (8) states that the effective rate of growth must converge with the BOP equilibrium (Thirlwallian) rate of growth (Eq. (7)), Eq. (11) states that effective rate of growth must converge with the rate of growth of productivity (the “natural” rate of growth; see Setterfield, 2009).¹⁷ The latter is a condition for the equality of supply and demand, given the assumption of no increase in labor supply. Eqs. (8) and (11) form a dynamic system with two state variables, y and E (λ is

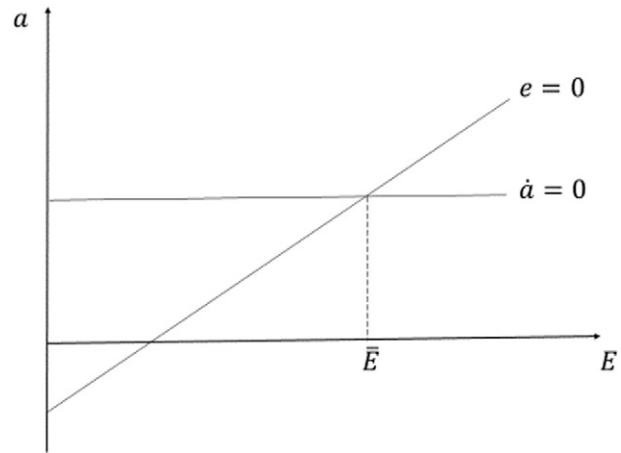


Fig. 1. Phase diagram: the employment rate and the rate of growth of autonomous expenditure in equilibrium.

assumed constant; see the Mathematical Appendix for an analysis of equilibrium and stability). Fig. 1 shows the phase diagram and the equilibrium values of E and a .

The $\dot{a} = 0$ isocline is a horizontal line since per Eq. (8) there is just one value of a that makes this variable constant over time. This happens because E has no effect on the effective and equilibrium rates of growth of the economy. The $e = 0$ isocline, on the other hand, has a positive slope: if E is high, the growth of labor productivity will be high (recall that an economy which is closer to full employment will have more labor-saving innovations). In order to keep the employment rate constant when productivity grows fast, economic growth and labor demand must be high too. For having faster growth, in turn, a more expansionary fiscal policy (higher a) is required. This is why E and a move hand in hand to keep E constant ($e = 0$). The opposite occurs when E is low (lower productivity growth matches a lower a).

What happens if public policy goes greener and λ increases—for instance, out of stronger domestic social pressure or international agreements (such as those entailed by the COP21, see UN (2016)) in favor of green technologies? A rise in the parameter λ leads to a reallocation of resources towards green technical change, from standard innovations to environmental innovations. As a result z increases and so does the BOP-constrained rate of growth, while g falls for any value of a . The increase in z shifts upwards the $\dot{a} = 0$ isocline, from $\dot{a}_1 = 0$ to $\dot{a}_2 = 0$. The fall in g moves the $e = 0$ isocline to the right (from $e_1 = 0$ to $e_2 = 0$): for any value of E , the rate of growth of labor productivity is lower than before, and this requires a lower rate of growth of autonomous expenditure to keep the employment rate constant. Fig. 2 represents the new equilibrium after the change in policy.

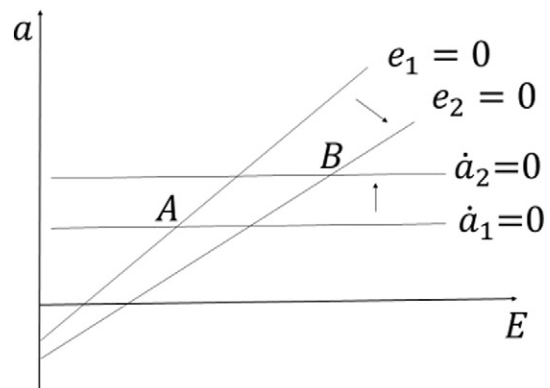


Fig. 2. The effect of green industrial policy.

¹⁷ This specification of Eq. (11) may be altered in different forms. For instance, there may be a delay or friction between the growth of labor demand and the moment in which workers are effectively employed (and hence $e = f(y - g)$); or labor productivity may interact with the employment rate in a nonlinear way (e.g. $e = E[y - g(E)]$). Although the latter case is very interesting and it is likely that this type of non-linearity is relevant empirically (which raises interesting new questions about the links between green growth, employment and income distribution), we leave this possibility as a topic for future research.

The new equilibrium brought about by the change in policy implies a higher rate of growth and a higher rate of employment. The intensity of the effects on growth and employment depends on the relative impact of the reallocation of resources on environmental innovations and standard innovations, and on the impact of environmental innovations on competitiveness in world markets. Note that in the new equilibrium labor productivity will be growing at a lower rate than before. But this will be compensated by the rise in the employment levels and the improvement of the quality of the goods consumed.¹⁸

Finally, for having convergence in the world economy, it is necessary that:

$$\frac{y^E}{y^*} = \frac{\varepsilon y^* + \xi z}{\pi y^*} > 1. \quad (12)$$

This can be rewritten as:

$$z > \frac{y^*(\pi - \varepsilon)}{\xi}. \quad (13)$$

Laggard economies, characterized by weak technological capabilities, will tend to exhibit a large difference between the income elasticity of imports and exports (a high $(\pi - \varepsilon)$). Convergence may either arise from reducing the difference between the income elasticity of imports and exports, or from the acceleration of technical change in favor of environmental innovations (raising z). Both avenues lead to convergence; however, only one of them may lead to sustainable convergence, being compatible with the carrying capacity of the ecosystem, as discussed below.

4.2. Environmental Efficiency and Absolute Decoupling

The model considered demand and supply factors in shaping the evolution of the employment rate and convergence in the world economy. But it has not been yet discussed the problem of the long run sustainability of the growth path. Assume a Leontief production function where the two production factors are energy and labor. This kind of function is coherent with the assumption (set forth by ecological economics) of complementarity among production factors, contrary to the neoclassical assumption of perfect or imperfect substitutability, such as in the Cobb–Douglas function (Rezai et al., 2013). According to Mazzanti and Zoboli (2009), pollutant emissions are directly proportional to the energy consumption, whose proportion is, for simplicity, 1:1. Thus the production function is:

$$Y = \min(ZX, GEL). \quad (14)$$

In Eq. (14) Z is environmental efficiency, X is the level of pollutant emissions, G is labor productivity, E the level of employment and L the total labor supply (assumed constant). Therefore, energy and labor are complementary (non-substitutable) factors in the production function. In equilibrium, E is constant ($e = 0$), which gives:

$$z + x = g. \quad (15)$$

Small letters in Eq. (15) represent proportional rates of growth (hence x is the rate of growth of pollutant emissions). From the previous section it is known that in equilibrium $y^E = g = (\varepsilon y^* + z\xi z)/\pi$. The rate of increase in pollutant emissions is therefore:

$$x = y^E - z = \frac{\varepsilon y^* + \xi z}{\pi} - z. \quad (16)$$

The above equation suggests the following. A policy that aims at decreasing pollutant emissions will increase environmental efficiency, but at the same time increases economic growth. As a result of the latter, the total pollutant emissions might increase rather than decrease after the adoption of the green policy. This is a sort of “green growth rebound” effect¹⁹: environmental innovations increase the BOP-constrained rate of growth and accelerate the depletion of natural resources. The literature points out two kinds of rebound effect: *microeconomic rebound effect*, in which improvements in environmental efficiency reduces prices and increases demand (Sorrell, 2007; Sorrell and Dimitropoulos, 2008); *macroeconomic rebound effect*, according to which green investments increase aggregate demand through the Keynesian multiplier (Barker et al., 2009; Saunders, 2000). In both cases, green efforts indirectly raise pollutant emissions. The conventional macroeconomic rebound effect concerns mechanisms related to domestic demand, while the new rebound effect introduced in this paper works through the BOP constraint. For this reason, it is labeled *macroeconomic rebound effect with a BOP constraint*.

The condition for preventing this rebound effect from happening is the following:

$$\frac{\partial x}{\partial z} = \frac{\xi}{\pi} - 1. \quad (17)$$

If the green-elasticity of exports is lower than the income elasticity of imports, then the macroeconomic rebound effect with a BOP constraint will not happen: the green policy will reduce total pollutant emissions. Inversely, a policy aimed just at increasing the income elasticity of exports would raise total pollutant emissions if $\pi > \xi$. As a result, although there are several possible avenues for convergence in the world economy, there is only one which is sustainable, based on environmental innovations. In this sense, the fruitful combination of ecological economics is not just with PK models but also with the insights provided by the “Keynes meets Schumpeter” type of models (see Dosi et al., 2009), in which the Keynesian tradition and the evolutionary theory of innovation converge. This seems to represent a most promising avenue for further research on sustainability.

5. Concluding Remarks

The paper expanded the BOP-constrained growth (BOPCG) model and the Kaldorian regimes (productivity and demand regimes) in order to include some of the concerns raised by ecological economics in PK models for open economies. The demand regime was modified to take into account Porter's hypothesis, which suggests that emissions-reducing innovations favor competitiveness. As a result, the equilibrium BOP-constrained rate of growth is modified, leading to a different version of Thirlwall's Law, which opens room for the impact of environmental innovations on the growth of exports.

The productivity regime was changed as well in order to consider the employment implications of innovations in both labor productivity (standard innovations) and environmental efficiency (environmental innovations). A crucial assumption is that the country's industrial and technological policy can affect the direction of technical change by reallocating resources from standard to environmental innovation. Fiscal policy is not just an instrument to manage aggregate demand as in the Keynesian models, but also a driver of technical change. The composition of public investment and how much support it gives to R&D and education in green technologies matters for long run growth, employment and sustainability.

The model discusses the conditions for having convergence between developed and developing economies while at the same time reducing total emissions (i.e. the conditions for absolute decoupling). These conditions would not spontaneously emerge from the market process. The

¹⁸ A discussion of the employment effects of green industries can be found in Pollin (2012).

¹⁹ See on this Greening et al. (2000).

values of the parameters of the model are in flux: how they will evolve depends on policy measures adopted by national governments, and on the commitment of the international community to favor trade and investment arrangements that reward a less carbon-intensive growth path. Whether the Paris Agreements of the COP21 translate into binding commitments or not is the crucial policy challenge of the next years.

The paper admittedly adopts highly simplifying assumptions in order to keep the model tractable and highlight the possible mechanisms that link policy, sustainability, growth and employment. Clearly many crucial aspects of this link are not addressed. Just to mention some of them, the paper does not discuss what happens if environmental and standard innovations interact (i.e. whether an increase in environmental efficiency fosters or curbs labor productivity growth). Moreover, all the discussion is referred to a long run in which any change in world demand comes from changes in non-price competitiveness (the green quality of the goods and the income elasticity of demand). Price competitiveness plays no role in the story. This is the standard assumption of the BOPCG model, and it is consistent with assuming that the real exchange rate is constant in equilibrium. However, important questions are left behind. In the transitional dynamics short run disturbances associated with changes in real wages and the real exchange rate may affect the long run equilibrium itself. Hysteresis and path-dependency may play a significant role in the emerging equilibrium, an idea which is important in PK and ecological economics and which is not considered in the paper. These problems are an open invitation to other PK and ecological economists to further advance and improve the canonical model, building a rigorous framework for the analysis of sustainable convergence in open economies.

Appendix A. Mathematical Appendix

A.1. The Canonical Model: Effective Rate of Growth and the Equilibrium Rate of Growth

The point of departure is a Keynesian model in which there are two components of aggregate demand, which are domestic absorption, A , and net real exports, $X-QM$, where Q is the real exchange rate defined as $Q = P^*R/P$ (P^* are international prices, R the nominal exchange rate in units of domestic currency per unit of foreign currency, and P are domestic prices).

$$(i) Y = A + X - QM$$

The demand for exports and imports are given by:

$$(ii) X = Q^{\psi_X} (Y^*)^{\varepsilon}$$

$$(iii) M = Q^{\psi_M} (Y)^{\pi}$$

Where ψ_X and ψ_M are price elasticities of exports and imports, respectively, Y is domestic income, Y^* the rest of the world income, and ε and π are income elasticities of exports and imports, respectively. Taking logs and differentiating (i), (ii) and (iii) with respect to time, and representing proportional rates of growth with small letters (e.g. $a \equiv \dot{A}/A$), give:

$$(iv) y = \alpha a + \beta_1 x - \beta_2 (q + m)$$

$$(v) x = \varepsilon y^* + \gamma_X q$$

$$(vi) m = \pi y - \gamma_M q$$

Where $\alpha \equiv A/Y$ and $\beta_1 \equiv X/Y$ and $\beta_2 \equiv QM/Y$. The rate of growth of the real exchange rate in the long run must be zero ($q = 0$) (McCombie and Thirlwall, 1994). Combining (iv), (v) and (vi), with $q = 0$ gives the Kaldorian effective growth equation (Eq. (1) in Section 2):

$$(vii) y = \frac{\alpha a + \beta_1 \varepsilon y^*}{1 + \beta_2 \pi}$$

Equilibrium in current account requires that exports and imports grow at the same rate. Using equations (v) and (vi), making $x = m$, then:

$$(viii) \pi y^E = \varepsilon y^*.$$

And hence:

$$(ix) y^E = \frac{\varepsilon}{\pi} y^*.$$

In equation (ix), y^E is the long run rate of growth, consistent with equilibrium in current account (Trilwall's Law). Since the domestic economy is a developing economy, convergence requires the domestic economy to grow at higher rates than the rest of the world, i.e. $y^E > y^*$. Therefore, for having convergence the income elasticity ratio should be $(\varepsilon/\pi) > 1$. The income elasticity ratio is a function of the pattern of specialization, which in turn depends on technology gap between the developing economy and the international technological frontier (Cimoli and Porcile, 2014).

A.2. The Dynamic System of the Modified BOPCG Model: Equilibrium and Stability

Combining Eqs. (8), (9) and (10), the dynamic system can be written as follows:

$$(x) \dot{a} = \psi \left[\frac{\varepsilon y^* \xi_Z(a, \lambda)}{\pi} - \frac{\alpha a + \beta_1 [\varepsilon y^* + \xi_Z(a, \lambda)]}{1 + \beta_2 \pi} \right]$$

$$(xi) \dot{e} = \frac{\alpha a + \beta_1 [\varepsilon y^* + \xi_Z(a, \lambda)]}{1 + \beta_2 \pi} - g(\lambda, a, E).$$

The derivatives of equation (x) with respect to a and E are:

$$(xii) \frac{\partial \dot{a}}{\partial a} = \psi \left[\frac{\xi_{Za}}{\pi} - \left(\frac{a + \beta_1 \xi_{Za}}{1 + \beta_2 \pi} \right) \right]$$

$$(xiii) \frac{\partial \dot{a}}{\partial E} = 0.$$

The sign of the partial derivative $\partial \dot{a} / \partial a$ is ambiguous. A negative derivative means that the direct positive effect of an increase in autonomous expenditure on the effective rate of growth $\left(\frac{\alpha + \beta_1 \xi_{Za}}{1 + \beta_2 \pi} \right)$ is higher than the indirect positive effect of such an increase in the equilibrium rate of growth $\left(\frac{\xi_{Za}}{\pi} \right)$, namely (i) $\xi_{Za} (1 + \beta_2 \pi - \beta_1 \pi) - \alpha \pi < 0$. The indirect effect of a rise of a on y^E takes place through the increase in the environmental efficiency produced by higher investments in environmental innovations, which fosters the country's competitiveness. The $(\partial \dot{a} / \partial a < 0)$ result is the most plausible, as assuming otherwise would imply that the government could attain whatever competitiveness and equilibrium rate of growth it wants by just raising the growth of autonomous expenditure. In turn, the derivative $\partial \dot{a} / \partial E$ is always zero, as E is not in the argument in equation (x).

The derivatives of the differential equation (xi) (which gives the motion of the employment rate) with respect to a and e are respectively:

$$(xiv) \frac{\partial \dot{e}}{\partial a} = \frac{a + \beta_1 \xi_{Za}}{1 + \beta_2 \pi} - ga$$

$$(xv) \frac{\partial \dot{e}}{\partial E} = -ge.$$

The sign of the derivative (xiv) is ambiguous. An increase in a increases investments in labor-saving technical change, which reduces the demand for labor at any rate of economic growth (second term of equation xiv). On the other hand, a rise in a directly adds to the growth of effective demand $(\alpha / (1 + \beta_2 \pi))$ in the first term of equation xiv) which increases labor demand. Moreover, a higher a also implies more investment in green innovations $([\beta_1 \xi_{Za} / (1 + \beta_2 \pi)])$ in the first term of equation xiv), which further fosters aggregate demand. If the two positive effects on labor demand (the increase in autonomous expenditure

plus the increase in competitiveness due to higher environmental efficiency) overcome the negative impact of labor-saving innovations, then the employment rate will increase with a , namely $\frac{\alpha + \beta_1 \xi_a}{1 + \beta_2 \pi} > g_a$. This is the most plausible assumption and hence it will be kept in the paper, $\partial e / \partial a > 0$. Lastly, the sign of derivative (xv) is negative without ambiguity, since $g_E > 0$.

The previous analysis indicates that the trace of the Jacobian, which is $\psi[\xi_a \pi^{-1} - (1 + \beta_2 \pi)^{-1}(\alpha + \beta_1 \xi_a)] - g_E$, is negative, while the determinant (which is the product of two negative terms) is positive; hence the system is stable. The isoclines of the system are represented below.

The isocline $\dot{a} = 0$ is a horizontal line in the $a \times E$ plane. There is just one value of a which is consistent with equilibrium in current account, independently of the value of E , which is:

$$(xvi) \quad a = \frac{[\epsilon_Y + \xi_Z(a, \lambda)](1 + \beta_2 \pi)}{\alpha \pi} - \frac{\beta_1 [\epsilon_Y^* + \xi_Z(a, \lambda)]}{a}.$$

To explicitly analyze the slope of the $e = 0$ isocline, assume a linear function for the rate of growth rate labor productivity:

$$(xvii) \quad g = (1 - \lambda)a + \phi \text{ with } (1 - \lambda), \phi > 0.$$

The isocline $\dot{e} = 0$ is given by:

$$(xviii) \quad a = \frac{\beta_1 [\epsilon_Y^* + \xi_Z(a, \lambda)]}{(1 + \beta_2 \pi)(a - (1 - \lambda))} + \frac{\phi}{(1 + \beta_2 \pi)(a - (1 - \lambda))} E.$$

Assuming $(1 + \beta_2 \pi)(\alpha - (1 - \lambda)) > 0$, the isocline $\dot{e} = 0$ is positively inclined. To keep the employment rate constant, a higher a (which implies a higher demand of labor) requires a higher E (which accelerates productivity growth and hence reduces the demand for labor).

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