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Distributive impact of structural change: does environmental degradation matter?*

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Abstract

Vulnerability to reduction of natural capital depends on defensive substitution possibilities that, in turn, are affected by the availability of other productive factors. However in several developing countries asset distribution tends to be highly skewed. Taking into account these elements, this paper proposes a model considering an economy polarized into two classes (the rich and the poor) and characterized by the following stylized facts: income and productivity of the rural poor is highly dependent on natural resources; labour remuneration in rural sector represents the opportunity cost for wage labour; the rich can partially substitute natural capital with physical capital accumulation and wage labour employment. In this context, agents differ for feed back mechanisms and interactions between their choices of production and environmental dynamics. Moreover environmental depletion may trigger economic transition, but the structural change is likely to result regressive.

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Keywords: structural change, environmental externalities, economic development, poverty alleviation.

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1 Introduction

In the economic literature the environment has been studied from opposing perspectives and as a bivalent concept. It has been seen as a "source" of value and wealth: water, land and the other natural resources are the basis of our subsistence and, at the same time, they are assets that can be used in economic activities for generating income or self-consumed goods. Thus, environment preservation and access to natural resources has been regarded as a crucial requirement especially for livelihood defence of rural poor populations that tend to be highly dependent on natural resources and vulnerable to environmental degradation. In fact, it is commonly recognized that no long-term strategy of poverty alleviation can succeed in the face of forces that promote the persistent erosion of the resources upon which poor people depend (Leonard 1989, UNDP 2005).

On the other hand, economic doctrine views the environment as a limit to economic growth and, therefore, to the expansion of well-being: economic activities based on natural capital exploitation are subject to the bounds of their productive inputs. Land is considered a fixed and non-reproducible asset; non-renewable resources are prone to exhaustion, while reproduction of renewable resources cannot surpass their carrying capacity. Dependence on resource-based activities, for example, has been regarded as an obstacle to escape from poverty: given that the rural poor largely rely on natural capital for their subsistence, they depend on low-income generating activities and they are also prone to entering a vicious circle of further impoverishment and environmental degradation. On the contrary, many studies find that access to non-agricultural activities can represent a poverty alleviation strategy[1] : rural households that get off-farm jobs can experience a rise in their labour productivity and earnings.

Such perspective is also consistent with the hypothesis that the evolution of an economic system towards less resource-dependent productions is a successful way to expand productive possibilities and to drive the economy to higher level of economic production and well-being while at the same time overcoming nature's constraint. As observed by López (2007) there is a quite strong consensus on the role of structural change (i.e. a labour shift from traditional agricultural sectors) as a cause and consequence of economic development and growth (Lewis

[1] On the role of off-farm (rural or urban) labour in raising household income, see: Weiming et al. (2004) for China, Escobal (2002) for Peru, De Janvry and Sadoulet (2000) for Mexico and Central America, Reardon et al. (1998) for Latin America.

1955, Ranis and Fei 1962, Lucas 2004): expansion of the non-resource sectors may permit an unending process of labour productivity growth because they rely on assets (human capital and physical capital) that can expand over time. On the other hand, Lopez (2003, 2007) notes that many middle-low income countries[2] experienced a structural change associated with growing problems of environmental degradation in addition to low performances in the struggle against poverty. In this case, environmental pressures can have a role in triggering off what he refers as "perverse structural change", namely a labour migration from agricultural sector pushed by a decline in productivity of agricultural traditional activities and the consequent reduction of labour opportunity cost[3]. The result is an expansion of informal urban activities (instead of economic activities of the modern sector) with declining or stagnant wages and less positive economic trends. Two direct factors[4] that López identifies as responsible for the emergence of perverse structural changes are natural resource degradation and processes of disenfranchisement of part of the rural poor from access to natural resources. In turn, these factors can be caused by demographic expansion, environmental externalities of economic production, expulsion of rural communities due to an expansion in commodities or manufacturing activities, large investments in hydroelectric and irrigation projects, other infrastructures or other types of enclosures of natural common goods.

Our model follows Lopez's approach in that we try to embody the role of environmental externalities in shaping a process of structural change by focusing on the channel of labour costs and labour productivity, but we will attempt to adopt a distributive perspective too.

The purpose is to present a theoretical model aiming at contributing to the analysis of the role that the environment may play in the relationship between growth, poverty and distribution in the light of some peculiarities of several

[2]In particular he refers to Latin America, but the observation is valid for many other countries too.

[3]López (2003) observes that in developing countries labour remuneration in primary sector (especially traditional primary activities that use labour intensive techniques) is still likely to represent the basic opportunity cost or floor wage for unskilled labour and, correcting for skill differentials, of the whole economy. In fact, the primary sector still absorbs a large share of labour, especially unskilled labour. In conclusion, if in developing countries labour remuneration in traditional agriculture is not always directly associated with economic growth, it is likely to be linked to wages in the other sectors and, through this channel, to poverty.

[4]Lopez points out that indirect factors capable to trigger a perverse structural change are inadequate policies aiming at fostering productivity in the modern sector in addition to a complete neglect of traditional subsistence sector of the rural poor.

developing countries[5]. Understanding the conditions and factors related to the environmental dynamics that influence distributional, poverty and economic outcomes may give us a clue about how to maximize benefits from the environment or, conversely, minimize its limits in the struggle against poverty. We aim to shed light on the distributional impact of environmental degradation and to investigate how the effects of environmental dynamics change in relation to asset endowments and definition of production functions. Indeed, in many developing countries, asset distribution is highly concentrated. Differences in asset endowment and composition determine differences in terms of constraints and opportunities in the choices of income generating strategies. Thus, production functions and sectoral structure in the economic systems partially reflects asset and income distribution. At the same time, vulnerability to environmental degradation is linked to the degree of dependency on natural resources (i.e. on production function) and on ability to adopt defensive strategies, namely the ability to substitute environmental resources with other productive assets. That is, in the societies where there is a polarization in the asset distribution, agents differ not only for their income, but also for their vulnerability to environmental depletion. Thus the poor, especially in rural areas, tend to be more dependent on natural resources and more vulnerable to ecosystem degradation[6] (IFAD 2001a-b, 2002; Dasgupta 1993 and 2001; UNDP et al., 2005, UNEP 2004). On the other hand, the rich have a higher ability to substitute private goods for public ones. Thus, they are able to self-protect themselves from pollution and to face depletion of natural capital (UNEP 2004). Besides, the rich may have the power to access to natural resources at a lower cost because of their power and lack of well defined and enforceable property rights.

In the light of these elements, the model will consider different production functions for the rich and the poor, while a different grade of resource dependence

[5]In the model natural resources are represented by a free access renewable resource. Actually different property right regimes (open, private, public, and communitarian) usually coexist, but the impossibility to introduce such a complex setting into a theoretical model compels making a choice and the assumption of stable institutions is made: property right regime does not change along the process of structural change. Given that many developing countries are affected by ill-defined property rights (and it is particularly valid for the resource endowments of the poor), open access is analysed as an extreme case of this type of institutional failure.

A comprehensive review of the empirical and theoretical literature on the effects of different property right regimes in terms of distribution and sustainability is beyond the scope of this article.

[6]Microeconomic studies and meta-analyses confirm the relevance of dependence of rural population on community or free access resources (Jodha 1986, Cavendish 2000, Falconer 1990, Back and Nesmith 2001, Fisher 2004, Hecht et al. 1988 cited in Friedman and Rangan 1993, Narain et al. 2005, Vedeld et al. 2004).

will be contemplated. Our model considers a small open economy[7] with two sectors: a traditional resource-based sector that rely on self-employment of poor households and a sector managed by the rich. Unlike López (2007) and Eliasson and Turnovsky (2004), that distinguish between a clean and a dirty sector, the model proposed in this work follows a sector classification based on asset endowment of the two groups and contemplates the possibility that both sectors cause environmental externalities but no assumptions on relative difference in the degree of such impact are made and alternative scenarios are considered. Potentiality of poor and rich producers to cause environmental depletion and degradation can be considered an empirical issue changing according to the institutional, natural and economic settings and their dynamics. The empirical research finds many examples of unsustainable use of natural resources perpetrated by the poor and by the rich, while, as noted by a recent UNDP report (2005), experience of interactions between poverty and environment varies from location to location[8]. At the same time, the empirical literature shows many examples of erosion of the subsistence basis of the rural poor caused by manufacturing, extractive industries, and mechanized agriculture or by policies focusing on the promotion of the capitalistic sector[9]. More recently, the World Bank (2007) has studied the negative effects of Chinese economic boom, industralization and urbanization on productivity of agriculture and fishery, while according to the 2005 Human Development Report it has been estimated that between 1987 and 2001, non agricultural projects caused the legally or illegaly land expropriation of 40-50 millions of farmers. RIF: World Bank (2007).
Therefore a model aiming at describing interactions between the production choices of the rich and the poor should comprise a sector managed by the rich that produces environmental externalities on the poor. The degree of such exter-

[7]The majority of developing countries are little open economies. In the last two decades, several countries have undertaken trade liberalization reforms and, consequently, the importance of the domestic demand in sustaining economic growth has diminished (at least for trade sectors) because economies are less constrained by a limited national demand. On the contrary in open economies, a fundamental factor for economic growth is productive competitiveness that depends, among other important factors, on labour cost .

[8]An extensive review of the debate on poverty-environment linkages is provided by Opschoor (2007).

[9]Ghai and Vivian (1992) collected studies on struggles by poor communities to gain control over natural resources and to face iniquities and environmental degradation caused by capitalists interests often with state support. Also Stonich (1989) and Friedman and Rangan (1993) review episodes of "enclosures" that have affected poor populations. In the same way, Martines-Alier (2002) reports other cases of what he calls "environmentalism of the poor". The impact on poverty and deforestation induced by mechanized agriculture and expansion of livestock numbers and timber extraction is analysed by De Janvry and Garcia 1988, Health and Binswanger 1996, Leonard 1989, López 1992, Markandaya 2001.

nalities will depend on specialisation in dirty or clean production and therefore it is likely to vary from one country to another.
The remainder of the article is organized as follows. Section 2 presents the model. Section 3 analyses the model and investigates the dynamics that may emerge from the model, their implications in terms of well-being and the conditions for their existence. Section 4 draws conclusions and gives some suggestions for future research.

2 The model

We consider a small open economy with three factors of production: labour, a free access renewable natural resource (E) and physical capital (K). In this economy agents belong to two different populations: the "Rich" (R-agents) and the "Poor" (P-agents). The R-agents own physical capital, hire labour force and employ all their potential work - represented by a fixed amount of entrepreneurial activity - in the capitalistic sector producing a private good (Y_R). We call their production "capitalistic sector" or "market sector". The P-agents are endowed only with labour and they have to choose the allocation of their labour between two activities: working as employee for the Rich in the capitalistic sector or directly exploiting natural resources to produce a non storable good. Let "subsistence sector" or "rural sector" denote production of the Poor.

2.1 The maximization problem of the Poor and the production in the traditional sector

The population of the Poor is constituted by a continuum of identical individuals and the size of the population is represented by the positive parameter $\overline{N}$. The P-population well-being depends on two goods:

- A good deriving directly from free access renewable natural resources, hereafter referred to as environmental good.
- A good (hereafter denoted private good) produced in the capitalistic sector which can be consumed as a substitute for the services coming from the environmental good.

We assume that the instantaneous utility function of each P-agent is the following

$$U_P(c_P, c_s) = \ln(c_P + ac_s) \tag{1}$$

where:

c_s : is the consumption of the produced good as a substitute for the environmental good.

c_P : is the consumption deriving from the exploitation of the environmental resource. According to (1), c_s and c_P are perfect substitutes, with a (constant) rate of substitution equal to $a > 0$. That is, the private good produced by the Rich is able to substitute completely c_P. This is a stylized fact, but it can represent the main components of Poor people's well-being: if they work in the subsistence sector in rural areas (fishing, forestry, agriculture or breeding) their standard of living strictly depends on access to and exploitation of E; while if they move to urban zones or they become wage labour force, they satisfy their needs mainly through the consumption of private goods. Each P-agent, in each instant of time, employs all her potential labour (that we normalize to unity) in the subsistence sector or in the sector of the Rich. Thus, she cannot rely on alternative income sources at the same time. However, in the absence of intersectorial moving costs, significant divergences from the case with employment diversification are not a priori expected. Therefore, for the sake of analytical simplicity, the hypothesis of indivisible labour allocation will be kept.

Let us indicate with N_P and N_R the number of the Poor that work, respectively, in the rural subsistence sector and in the capitalist sector. Consequently we have $N_P + N_R = \overline{N}$. The aggregate production function in the rural sector is given by

$$Y_P = \alpha N_P E \tag{2}$$

This specification was proposed by Schaeffer (1957) for fishery and since then it has widely adopted in literature in modelling natural resources (Munro and Scott 1993, Conrad 1995, Brander and Taylor 1998a and 1998b, McAusland 2005, López et al. 2007).

We have assumed that the Poor cannot save and that production is completely exhausted by their consumption. From equation 2, it follows that per capita

output and consumption for the Poor working in this sector is equal to [10]

$$c_P = \frac{Y_P}{N_P} = \alpha E \tag{3}$$

The Poor that are hired in the sector of market goods receive a real wage equals to w (in terms of the private good produced by the Rich) that is considered as exogenously given. By (3) the Poor are indifferent between the work in the traditional sector and that in the capitalistic one if it holds

$$c_P = ac_s = aw \tag{4}$$

which can be re-expressed as

$$\frac{1}{a}\alpha E = w \tag{5}$$

If $\frac{1}{a}\alpha E > w$ (respectively $\frac{1}{a}\alpha E < w$), then no Poor (respectively all Poor, i.e. $\overline{N}$) would like to work in the capitalistic sector. It is to note that E is taken as exogenously given by the Poor, that is they do not internalize the impact of their production on natural resources. However we will return to this issue later. In equation 5 the parameter a determines the difference between the wage in the capitalistic sector and the average output in the rural sector that allow for the same level of utility. The alignment of labour income between the two sectors (from condition (5)) is consistent with the role of rural sector as indicator of the labour opportunity cost [11] in other sectors. In the economy labour supply is affected by two factors: on one hand, an increase in wage rate (due for example to an augmentation in labour demand) represents a "pull" factor of labour force; on the other one, environmental depletion constitutes a "push" factor of labour force. Natural resource stock degradation causes a decline in labour productivity in the rural sector (for example the rural Poor have to move to other zones from polluted rivers or from eroded areas, they have to walk for longer distance to collect potable water etc.). This leads to a decrease in the opportunity cost of the labour force and to a movement of labour to the market sector. In turn, as we will see below, the labour supply increase may depress wages in the economy providing the Rich with cheap labour.

[10] In the traditional sector the labour payment tend to be not based on marginal product activity, but on income sharing. Thus people that work in this sector receive the average product (Ray, 1998).

[11] The alignment should be corrected for skill differentials, but in this model we have neglected the distinction between skilled and unskilled workers

2.2 The production in the capitalistic sector

The population of the Rich is constituted by a continuum of identical individuals and the size of the population is represented by the positive parameter $\overline{M}$. We normalize the size of the R-population by assuming $\overline{M} = 1$. As said, the representative R-agent employs all her fixed potential labour in market sector as entrepreneurial activity. Without loss of plausibility, we assume that the marginal product of entrepreneur labour in the market sector is higher than marginal product of labour in the subsistence sector. Therefore the possibility that the Rich work in subsistence sector is excluded a priori and the production function of the market sector can be specified as follows

$$Y_R = K^{\epsilon} E^{\phi} (N_R)^{1-\epsilon-\phi} \tag{6}$$

where:
$\epsilon > 0$, $\phi \geq 0$ and $\epsilon + \phi < 1$ (the production function satisfies the constant returns to scale assumption); K is the physical capital accumulated by the representative R-agent. We consider the value of K as exogenously given an we analyse the effects that an increase in K produces on E, on P-agents' labour allocation and on well-being of P and R-agents. In companion paper (Antoci, Russu and Ticci 2008) we have introduced, in the same context, the dynamics of K generated by R-agents' intertemporal optimization choices obtaining very similar results, but at the expenses of analytical simplicity.
Function (6) is increasing in all its inputs, is concave and it satisfies the *Inada conditions* in K and N_R, while, as E approaches to zero, its marginal output tends to infinitive only if $\phi > 0$. If $\phi = 0$, environmental resources do not enter into the production function of the Rich.

2.3 Dynamics of natural capital

P and R-agents consider the effect of their choices on environment as negligible and they do not internalize it, therefore in their maximization problems they take the evolution of E as given. They behave without taking into account of the shadow value of the natural resource and, as a result, nobody has an incentive to preserve or restore natural resources. Thus, investment in natural capital does not affect the environmental stock and the dynamics of E can be

described by the usual logistic function modified for human intervention

$$\dot{E} = E(\overline{E} - E) - \beta\alpha N_P E - \gamma \overline{Y}_R \tag{7}$$

where the parameter $\overline{E}$ represents the carrying capacity of the environmental resource, that is the maximum stock at which E stabilizes in absence of negative impacts due to P and R-agents' economic activities; $\beta\alpha N_P E^{\chi}$ is the aggregate environmental impact by the rural sector and the parameter $0 < \beta < 1$ represents exploitation of natural resource by P-agents;
$0 < \gamma < 1$ is a parameter measuring the environmental deterioration caused by the average production $\overline{Y}_R$ of R-agents. Assuming identical Rich agents, it follows that $\overline{Y}_R = Y_R$.

2.4 The maximization problem of the representative R-agent

Preferences of the Rich are assumed to be representable by an utility function defined over consumption of the private good. Let the R-agent's instantaneous utility be:

$$U_r(c_R) = \ln c_R \tag{8}$$

Therefore U_R is twice continuously differentiable, strictly increasing and strictly concave, i.e. $U'_R > 0$ and $U''_R < 0$. The representative R-agent maximizes her utility by choosing the labour demand N_R to maximize

$$Y_R - wN_R = K^{\epsilon} E^{\phi} (N_R)^{1-\epsilon-\phi} - wN_R \tag{9}$$

where w is taken as given; since there is not accumulation, it holds $c_R = Y_R - wN_R$. The solution to the R-agent's problem is found maximizing (9) with respect to N_R

$$(1 - \epsilon - \phi) K^{\epsilon} E^{\phi} (N_R)^{-\epsilon-\phi} = w \tag{10}$$

Equation (10) gives the R-agent's choice of N_R for every w.

2.5 Labour market equilibrium

We assume that the labour market is perfectly competitive and wage is flexible. We will come back later on the implications of these assumption. The equilib-

rium value of N_P (and, consequently, of $N_R = \overline{N} - N_P$) is given by the solution of the following labour market equilibrium condition (obtained by equalizing left sides of (5) and (10))

$$\frac{\alpha}{a}E = (1-\epsilon-\phi)K^{\epsilon}E^{\phi}(\overline{N}-N_P)^{-\epsilon-\phi} \tag{11}$$

that is

$$N_P = \overline{N} - \left[\frac{a(1-\epsilon-\phi)K^{\epsilon}}{\alpha E^{1-\phi}}\right]^{\frac{1}{\epsilon+\phi}} \tag{12}$$

if the right side (12) is not negative, otherwise $N_P = 0$ (i.e. $\overline{N}$ Poor work in the capitalistic sector). Notice that, by (12), N_P is increasing in E and decreasing in K.

By substituting $N_P = 0$ in (12) and solving it with respect to E we get

$$E = E^* := \left[\frac{a(1-\epsilon-\phi)K^{\epsilon}}{\alpha\overline{N}^{\epsilon+\phi}}\right]^{\frac{1}{1-\phi}} \tag{13}$$

where $E^*$is the threshold value of E that separates the region $(E > E^*)$ where $N_P > 0$ from that $(E \leq E^*)$ where $N_P = 0$.

By substituting N_R with the equilibrium value of $\overline{N} - N_P$ in (10) the equilibrium wage is found and it can be used in (9) to obtain the R-agent's consumption level c_R.

2.6 Dynamics

Substituting the equilibrium value of N_P in (7) and taking into account that (ex-post) $\overline{Y}_R$ is equal to Y_R, the dynamics generated by the model are given by the following equation

$$\dot{E} = E(\overline{E}-E) - \beta\alpha N_P E - \gamma\delta K^{\epsilon}E^{\phi}(\overline{N}-N_P)^{1-\epsilon-\phi} \tag{14}$$

where $N_P = 0$ for $E \leq E^*$ while N_P is given by (12) for $E > E^*$.

3 Mathematical results

Fixed points of dynamics (14) are given by the values of $E \geq 0$ satisfying the equation

$$\dot{E} = E(\overline{E} - E) - \beta\alpha N_P E - \gamma\delta K^{\epsilon} E^{\phi} (\overline{N} - N_P)^{1-\epsilon-\phi} = 0 \tag{15}$$

Figure 1 shows the complete classification of possible cases. The graph of the function

$$l(E) := M^{-\frac{1}{\epsilon}} \cdot \overline{N}^{\frac{\epsilon+\phi}{\epsilon}} \cdot E^{\frac{1-\phi}{\epsilon}}$$

where $M := \dfrac{a(1-\epsilon-\phi)}{\alpha}$, separates, in the plane (E, K), the regions in which $1 > N_P > 0$ (on the right of the graph of $l(E)$) and in which $N_P = 0$ (on the left)[12]. In the region where $1 > N_P > 0$, the graph of the function

$$f(E) := \left[\frac{\overline{E} - \alpha\beta\overline{N} - E}{M^{\frac{1}{\epsilon+\phi}} \left(\dfrac{\gamma\delta}{M} - \alpha\beta \right)} \right]^{\frac{\epsilon+\phi}{\epsilon}} \cdot E^{\frac{1-\phi}{\epsilon}}$$

gives the fixed point values of E which correspond to every (fixed) value of the parameter K. In the regime $N_P = 0$, $E = 0$ is always a fixed point; the values of E corresponding to the other fixed points are given by the graph of the function

$$g(E) := \left(\gamma\delta \overline{N}^{1-\epsilon-\phi} \right)^{-\frac{1}{\epsilon}} \cdot E^{\frac{1-\phi}{\epsilon}} \cdot (\overline{E} - E)^{\frac{1}{\epsilon}}$$

for every fixed value of K.
The threshold values E_0, $\overline{E}_{01}$ and $\overline{E}_{02}$, in figure 1, are given by

$$E_0 := \overline{E} - \frac{\alpha\gamma\delta\overline{N}}{a(1-\epsilon-\phi)}$$

[12] Inada conditions exclude the case $N_P = 1$ and $N_R = 0$.

$$\overline{E}_{01} := \frac{\alpha\gamma\delta(1+\epsilon)\overline{N}}{a(\phi+\epsilon)(1-\epsilon-\phi)} - \frac{\alpha\beta(1-\phi)\overline{N}}{\phi+\epsilon}$$

$$\overline{E}_{02} := \frac{\alpha\gamma\delta(2-\phi)\overline{N}}{a(1-\epsilon-\phi)}$$

Straightforward computations show that the fixed point $E = 0$ is always locally attractive; the other fixed points in the regime $N_P = 0$ are attractive (respectively, repulsive) when corresponding to the decreasing (increasing) portion of the graph of $g(E)$. In Figures 1.a-1.e, the fixed points in the regime $1 > N_P > 0$ are attractive (respectively, repulsive) when corresponding to the decreasing (increasing) portion of the graph of $f(E)$; in Figures 1.f-1.g, they are always attractive.

From figure 1 we can observe that four fixed points with $E > 0$ may simultaneosly exist. Figure 2 shows an example in which this happens for some values of the parameter K belonging to the interval $(200, 250)$; in such case, there exist three attracting fixed points, as figure 3 shows (the attracting fixed points are indicated by full dots); in the attracting fixed points $E = 0$ and E_{B0}, it holds $N_P = 0$ while in the attracting fixed point E_B we have $N_P > 0$. Figure 4 shows dynamics corresponding to the specification of parameters in figure 2 and with $K = 100$. In such case, we observe a bi-stable regime where only two fixed points are attracting, $E = 0$ and E_B, where $N_P = 0$ and $N_P > 0$, respectively. Figure 5 shows how fixed point values of E are affected by an increase of the parameters β, γ and K (the other parameters are fixed as in the exaMple showed in figure 2).

Continuous and dotted lines represent, respectively, attracting and repulsive fixed points; furthermore, in the fixed points A and B it holds $1 > N_P > 0$, while in A_0 and B_0 it holds $N_P = 0$.

4 Classification of structural changes

Identifying a structural change whit a reduction of N_P, in our model a structural change occurs every time the economy follows a trajectory with a decreasing value of E (see by (12)).

By (3) and (4), Poor's consumption and the equilibrium wage w are positively correlated to the value of the stock E. Therefore, well-being of the Poor decreases (increases) every time the economy follow a trajectory along which the value of E decreases (decreases).
The consumption of the Rich is given by

$$c_R = TK^{\frac{\epsilon}{\epsilon+\phi}}E^{-\frac{1-\epsilon-2\phi}{\epsilon+\phi}} \tag{16}$$

if $N_P > 0$ and by

$$c_R = (\epsilon+\phi)K^{\epsilon}E^{\phi}\overline{N}$$

if $N_P = 0$, where

$$T := (\epsilon+\phi)\left[\frac{a(1-\epsilon-\phi)}{\alpha}\right]^{\frac{1-\epsilon-\phi}{\epsilon+\phi}}$$

Therefore, in the context $N_P > 0$, the effect on c_R generated by a reduction of E depends on the sign of the exponent $-\frac{1-\epsilon-2\phi}{\epsilon+\phi}$; in particular, if $\phi > \frac{1-\epsilon}{2}$ (respectively, if $\phi < \frac{1-\epsilon}{2}$) there exists a positive (negative) correlation between c_R and E.
Notice that the parameter ϕ measures the "importance" of the input E in the production process of the capitalistic sector; if it is "low" (i.e. if $\phi < \frac{1-\epsilon}{2}$) then the Rich are able to compensate the negative effects of environmental deterioration by the reduction of equilibrium wages.
With K constant, structural changes occur every time the economy follows a trajectory along which E is decreasing and are driven by push forces in that N_P decreases as a consequence of environmental degradation and the consequent reduction of P-agents' labour opportunity cost. Furthermore, they always lead to a reduction of P-agents' well-being; as said above, this reduction is accompanied by an increase of R-agents' well-being if $\phi < \frac{1-\epsilon}{2}$ (in such case, we have a "zero sum game" structure) or by a reduction of their well-being in the case $\phi > \frac{1-\epsilon}{2}$. Therefore, structural changes are always associated to a reduction of P-agents' well-being.
Now, it is interesting to see what happens to P and R-agents' well-being when an exogenous increase of K occurs; in such case, we may expect to observe

structural changes generating an improvement of P-agents' well-being. In fact, this may be the case if the environmental impact of the capitalistic sector is low enough, as we shall see.

Our analysis will focus on the (unique) attracting fixed point without specialization, i.e. where $1 > N_P > 0$, when existing (let us indicate it by the symbol B). Figure 1 shows how the value of E, evaluated at B, varies acconding to an increase of the parameter K. Notice in the cases represented in Figures 1.a-1.e, an increase of K generates a reduction of the value of E in B; the opposite holds in cases represented in Figures 1.f and 1.g[13]. So, in Figures 1.a-1.e, starting from B, an increase of K leads to a structural change (by (12)) which generates a reduction of P-agents' well-being (by (1)-(3)); the opposite holds in Figures 1.f-1.g, where the increase of E rises the opportunity cost of labour and consequently the equilibrium wage w.

Note that the cases in Figures 1.f-1.g are characterized by a relatively high negative inpact on E by the traditional sector (with respect to that of the modern sector).

Let us now consider the effects of an increase of K on R-agents' well-being. Observe that, in Figures 1.f-1.g, K and E (evaluated at the fixed point B) are positively correlated; consequently, by (16), c_R increases when K increases. In Figures 1.a-1.e, K and E are negatively correlated; to evaluate the effects of an increase of K on R-agents' well-being, we write (16) as follows

$$c_R = T \cdot \frac{\overline{E} - \alpha\beta\overline{N} - E}{M^{\frac{1}{\varepsilon+\phi}}\left(\frac{\gamma\delta}{M} - \alpha\beta\right)}$$

with

$$\frac{dc_R}{dE} = -\frac{T}{M^{\frac{1}{\varepsilon+\phi}}\left(\frac{\gamma\delta}{M} - \alpha\beta\right)} > 0$$

if and only if

$$\frac{\gamma\delta}{M} - \alpha\beta > 0$$

[13]Remember that, in Figures 1.a-1.e (respectively, Figures 1.f-1.g), the value of E in B is given by the intersection between the horizontal line $K = \overline{K}$ (where $\overline{K}$ is the accumulation level of the economy) and the decreasing (respectively, increasing) portion of the graph of $f(E)$.

that is (being $M = a(1 - \varepsilon - \phi)/\alpha$)

$$\beta > \frac{\gamma\delta}{a(1 - \varepsilon - \phi)} \tag{17}$$

It is easy to check that (17) is never satisfied in cases in Figures 1.a-1.e and,

consequently, c_R always increases when K increases (even if E decreases).
Figures 6.a-6.b represent numerical simulations of cases showed in Figures 2 and 1.f, respectively, and show how the values of c_R and E change, evaluated at the attracting fixed points B_0 (where $N_P = 0$) and B (where $1 > N_P > 0$), when K increases. The arrows indicate the path followed when K increases. Note that, in both Figures, c_R and K are positively correlated; the same holds for c_P and K in figure 1.b (remember that c_P and E are positively correlated) while a negative correlation is observed between c_P and K in figure 1.a.
To summing up, the structural changes that may occur in our model can be classified in three different typologies:
Pro-Rich structural change: Labour moves out from the subsistence sector, the environmental stock declines as well as Poor agents' consumption, while the Rich agent's consumption grows. Thus, this structural change is characterized by *environmental degradation and increase in inequality.*
Positive structural change: In this case, the structural change leads to a Pareto improvement. Both the Rich and the Poor are benefited and environment is preserved (this type of structural change may occur only if K increases).
Perverse structural change: In this case, environmental degradation push labour force to the capitalistic sector but both the Rich and the Poor are harmed by the reduction in natural capital endowment, i.e. both c_R and c_P decrease.
Pro-Rich structural change tipically occurs in a context in which the modern sector has a relatively low dependence on natural resources (i.e. $\phi < \frac{1-\epsilon}{2}$) and the negative environmental impact γ of the capitalistic sector is relatively high. In such context, the model tends to be a zero-sum game. Physical capital endowments allow the Rich to employ wage labour and this possibility lies at the roots of a conflict between the Rich (labour employers), and the Poor (labour force providers). The Rich are more able to defend themselves from environmental degradation because they can partially substitute natural capital with physical capital and wage labour employment. Thus, the Rich are not disadvantaged by the environmental degradation because they can rely on substitution possibilities as a defensive strategy. On the contrary, they may benefit

from the role played by the natural capital scarcity in accelerating human resources mobilization and shift of labour supply from the traditional sector to the modern one. Therefore they take advantage of the possibility to exploit labour at a lower cost. On the other hand, the Poor are harmed because they face a reduction in productivity of their labour, namely of their major mean of subsistence.

Positive structural change may be observed in a context in which the modern sector has a relatively low negative impact γ on the environmental resource and so the structural change is driven by pull forces (i.e. by an increase of K rather than a reduction of E). Furthermore, the dependence of the modern sector on E is not negligible (i.e. ϕ is not too low) so that the increase of equilibrium wages is counterbalanced by an increase of E, this produces an increase of c_R.

Perverse structural change may happen in a context in which the modern sector has a relatively high dependence on natural resources (i.e. $\phi > \frac{1-\epsilon}{2}$) and the negative environmental impact γ of the capitalistic sector is relatively high. In such context, R-agents are not able to compensate the reduction of E by the mobilization of human resources due to environmental degradation (in a context of decreasing equilibrium wages). Therefore, the Rich are more vulnerable to environmental degradation, which produces an impact with the same sign to the Rich and the Poor. Therefore, environmental policies may be win-win strategies; in this context, there is not a trade-off between goals of poverty alleviation, economic growth and environmental preservation.

According to the mainstream view, a growth in total factor productivity of the modern sector is always seen as a positive factor leading to growth and, at least in the long term, poverty reduction. On the contrary, the model shows that this scenario might occur only if the modern sector has a relatively low environmental impact in comparison to the traditional one. In this case, a rise in K determines an increase in wage of workers employed by the Rich as well as an augmentation of E. At the same time the movement of labour caused by an increase in labour demand reduces the demographic pressures on natural resources with positive effect on labour productivity in the subsistence sector too.

Our model highlights a novel requirement for positive structural changes: labour ri-allocation towards the non subsistence sector can be associated with poverty reduction only if the capitalistic sector is not too polluting, namely it produces relatively low environmental externalities in comparison to the traditional ac-

tivities. The positive structural change also represents the labour transition associated with the highest level of labour productivity because it occurs when there is a growth of total factor productivity as well as of all productive inputs. Therefore the positive structural change also insures the best economic performances of the capitalistic sector in comparison to the other typologies of structural changes. Looking at policy implications, we can conclude that policies aiming at promoting a positive structural change require that government support to capitalistic sector productivity does not include measures too permissive in terms of environmental externalities.

5 Undesirable economic growth

When we consider distributive and environmental dynamics in a joint framework, some scenarios neglected by the literature can emerge. The economic literature in general agrees that, although economic growth does not insure per se an increase in well-being of the Poor, positive economic performance is a necessary condition for poverty alleviation. This entails that policies aiming at stimulating economic growth are consistent with objectives of poverty reduction that, in turn, is likely to result in relieving pressures on natural resources and in helping environmental conservation. On the contrary, the consequences of an increase in K when the modern sector is too polluting raise doubts about this expected virtuous relationship between economic growth, poverty reduction and preservation of ecosystems and about capitalistic sector expansion as panacea for poverty reduction. Indeed, in this scenario the environmental externalities may contribute generating an undesirable and self-reinforcing path of expansion of the modern sector associated with a process of impoverishment: the capitalistic sector grows producing push forces on the Poor due to the environmental pressures, labour moves out the subsistence sector and the capitalistic sector further expands[14]. This unexpected result may be explained by the fact that positive impact of a growing on the wage is overcome by down pressures on w because of the environmental degradation caused by the modern sector's expansion. Thus, an increase in K may reduce well-being of the Poor if it is not associated with counterbalancing factors such as a rise in α (namely total factor productivity of the traditional sector) or a reduction in γ (i.e. environmental

[14] Analogous results about the indesiderability of economic growth are obtained in Antoci (1996), Antoci and Bartolini (1999, 2004), Antoci et al. (2005), where environmental goods are considered as final goods rather than inputs.

impact of the capitalistic sector). The values of α, γ and K can be affected by public choices. Therefore, looking at the policy implications of these findings, it could be argued that governments should take into account the possibility of such perverse mechanisms in their decisions about allocation of public expenditure. If the public funds focus only on the modern sector neglecting productivity of the subsistence sector the result may be an immiserizing growth, namely an output growth that worsens income distribution.

6 Possible extensions of the model

The model examines a simplified economy and a perfect polarization between the representative agents. The purpose was to identify and focus to some links between asset distribution, well-being and environmental dynamics that are likely to be relevant in developing countries, but implications drawn from this analysis cannot be considered exhaustive. Indeed, some important aspects that might deserve further attention in future extensions of the model can be cited:

1) Under a more realistic perspective, the capitalistic sector can be interpreted as the combination of the (primary and non primary) modern activities and the non primary sector of informal small enterprises. In the model the labour market is perfectly competitive with flexible wages and full employment. Labour supply is determined by conditions in the subsistence rural sector and it is completely absorbed by the sector of the Rich. Conversely, if wages were rigid or they could not decrease below a minimum level, a labour surplus would emerge and would lead to a better sectoral diversification between the modern and the informal urban activities. In this case it would be interesting to analyse changes in dynamics generated by our model in terms of distributional and environmental impact. Under the assumption of wage rigidity or the existence of minimum wages, the linkage between the negative externalities and production in the modern sector may weaken and it should be possible to highlight wage differentials and, in particular, between the agents working in the subsistence or informal sectors and employees in the modern sector.

2) This is a model of supply-led growth and well-being, and the role of private demand is neglected. In fact, an increase in income inequality and a further impoverishment of the working class may depress demand and

inhibit economic growth. It would be interesting to develop the present model including the impact of inequality and poverty on growth through the channel of domestic demand (forward and backward linkages between the sectors). The model also neglects the role of the traditional sector as supplier of food (i.e. wage goods), but in open middle-income countries the channel of food prices in boosting industrialization and economic growth is less likely to operate.

3) Given that many developing countries are affected by ill-defined property rights, open access has been studied as an extreme case of this institutional failure. Moreover many environmental services or goods are public goods: some examples are the mitigation of floods and drought, soil renewal, provision of fuels, energy, fresh water and biodiversity, and marine resources. Anyway, the introduction of another type of natural asset characterized by communitarian or private property (for example land) could be investigated in order to assess whether other property right regimes are likely to lead to different results. Final results can be expected to depend on the assumptions related to the initial distribution of natural resources, while the choice of the property regime typology might be less informative in terms of environmental outcomes. Nevertheless the comparison with other tenure right arrangements could provide interesting suggestions.

4) In this model, natural capital has two main peculiarities: firstly, it is a public free access resource whose services are used by the whole population, Poor people included; secondly, it is subject to underinvestment and overexploitation problems because it produces positive externalities and it is affected by negative externalities. The present model could be modified by including other public goods (R&D, infrastructures, development and strengthening of institutions etc) whose benefits are distributed across all the population or other assets with characteristics of semi-public goods such as human capital.

7 Conclusions

Nowadays no development strategy can avoid considering environmental dynamics, externalities of human activities under a distributive perspective. Environmental problems (the depletion of marine stocks, soil erosion, land degradation, lost of forests and biodiversity, air contamination and global warming effects)

have become a major concern in the international agenda, while the Poor, not only tend to rely more than the Rich on natural resources but they also are less able to defend themselves from environmental degradation.

This article has attempted to study the linkage between environmental resources and labour and output composition by taking into account two main factors that have been partially neglected by the economic development literature: the environmental externalities of human activities and agent's heterogeneity in terms of asset endowment and, consequently, in terms of income source and vulnerability to depletion of natural resources.

The proposed model have shown that the introduction of these factors adds new elements in the analysis of these link and permits to shed light on agents' differences in feed-back mechanisms and interactions between their choices and environmental dynamics.

We have proposed a taxonomy of structural changes typologies on the basis of distributive, environmental and economic impact and we have attempted to identify under which conditions each structural change regime can occur. Firstly, the work has identified new requirements for prompting positive structural changes, i.e. a movement of labour to capitalistic activities associated with poverty reduction and the alleviation of environmental pressures. In particular, the capitalistic sector has to produce a relatively low impact on natural resources. Secondly, we have found that the existence of counter-intuitive results cannot be excluded: an increase in total factor productivity of the capitalistic sector (or other factors leading to the growth of this sector) might stimulate a self-reinforcing and immiserizing growth, namely an output growth that results in a further impoverishment of the Poor and in a worsening of income distribution. This finding suggests that proper caution is to be adopted in designing government measures which emphasize only physical capital accumulation or expansion of the market sector with the purpose of alleviating poverty via economic growth. Indeed, some "collateral" effects may jeopardize the benefits of economic growth causing environmental degradation and impoverishment processes.

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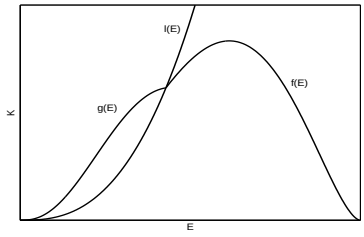
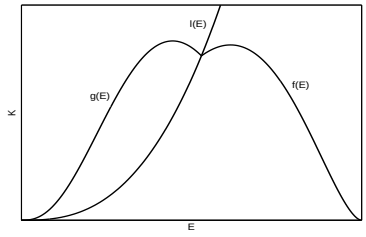
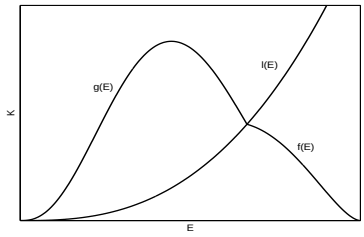


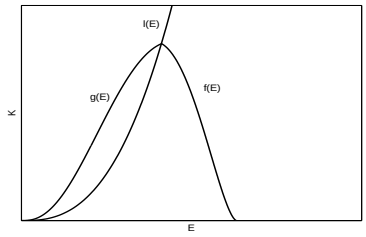
(a) $E_0 < \overline{E} < \overline{E}_{02}$, $\frac{\gamma\delta}{a} < \beta < \frac{\gamma\delta}{\alpha M}$



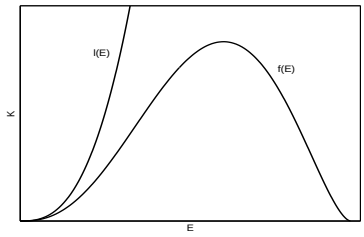
(b) $\overline{E}_{02} < \overline{E} < \overline{E}_{01}$, $\beta < \frac{\gamma\delta}{a}$



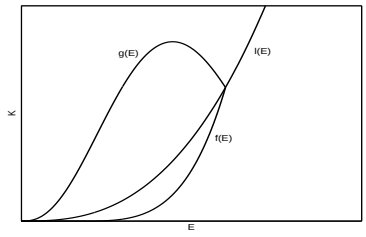
(c) $\overline{E} > \overline{E}_{02}$, $\frac{\gamma\delta}{a} < \beta < \frac{\gamma\delta}{\alpha M}$



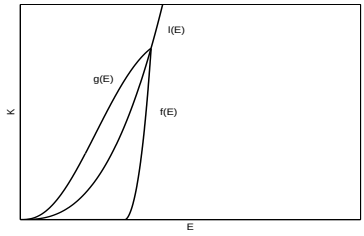
(d) $\overline{E}_{01} < \overline{E} < \overline{E}_{02}$, $\frac{\gamma\delta}{a} < \beta < \frac{\gamma\delta}{\alpha M}$



(e) $\beta\alpha\overline{N} < \overline{E} < \frac{\alpha\gamma\overline{N}\delta}{a(1-\epsilon-\phi)}$



(f) $\overline{E} > \overline{E}_{02}$, $\beta > \frac{\gamma\delta}{\alpha M}$



(g) $\overline{E}_{01} < \overline{E} < \overline{E}_{02}$, $\beta > \frac{\gamma\delta}{\alpha M}$

Figure 1: Fixed points configurations varying the value of the parameter K.

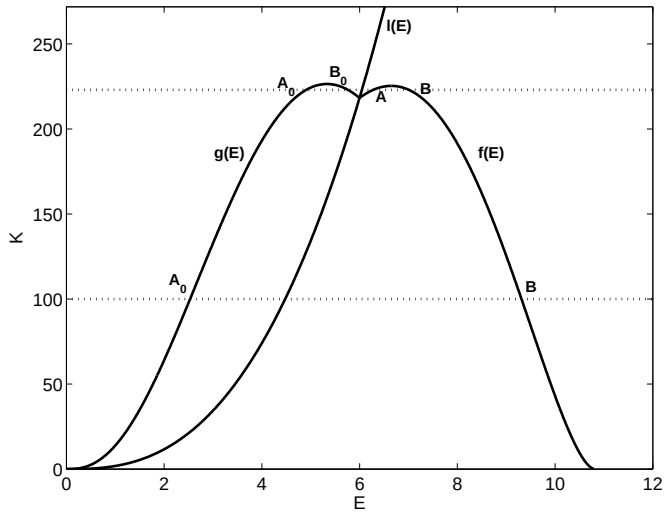


Figure 2: A numerical example in which four fixed points (A_0 and B_0 with $N_P = 0$, A and B with $N_P > 0$) with $E > 0$ exist. The parameters are: $\alpha = 0.12$, $\beta = 0.1$, $\gamma = 0.5$, $\delta = 1$, $\epsilon = 0.3$, $\phi = 0.2$, $a = 2$, $\overline{E} = 12$, $\overline{N} = 100$

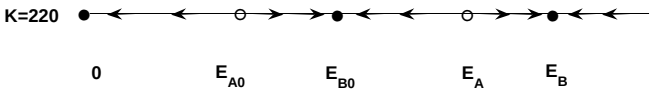


Figure 3: Dynamic regime corresponding to the example of Figure 2, with $K = 220$

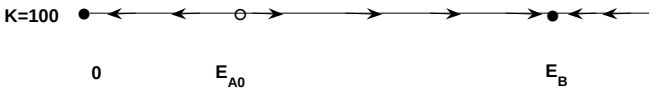
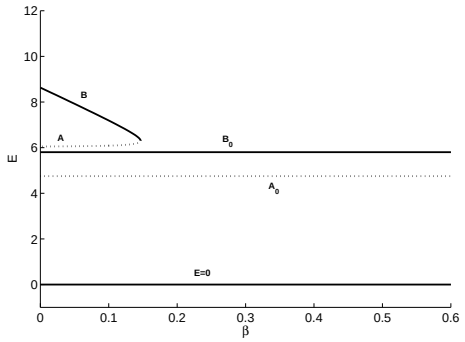
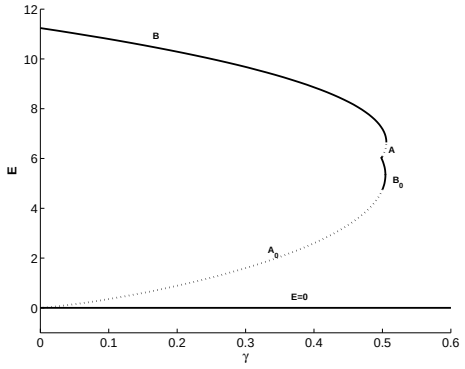


Figure 4: Dynamic regime corresponding to the example of Figure 2, with $K = 100$



(a)



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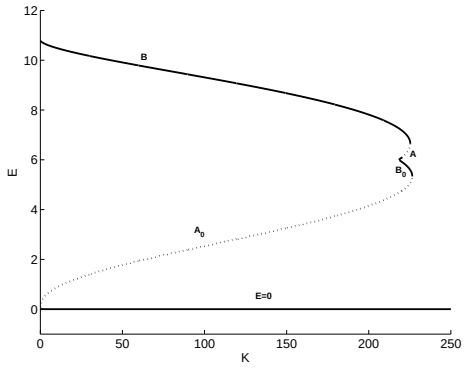
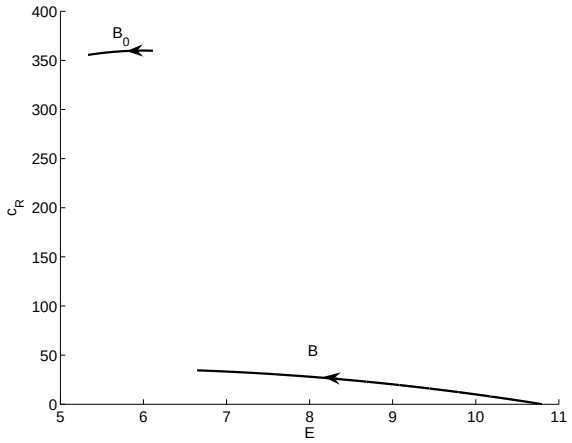
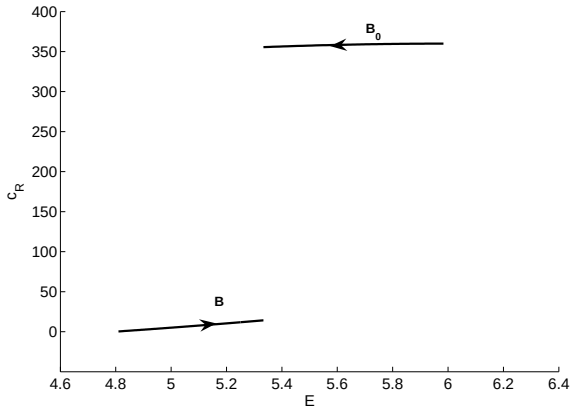


(c)

Figure 5: A numerical example showing how the environmental stock E, evaluated at the fixed points A and B with $N_P > 0$, A_0 and B_0 with $N_P = 0$, changes varying the parameter β, γ, and K. The dotted (continuous) lines represent repulsive (attractive) fixed points.



(a)



(b)

Figure 6: A numerical example showing how the values of c_R and E, evaluated at the attracting fixed points B_0 (with $N_P = 0$) and B (with $N_P > 0$), change varying the parameter K. The arrows indicate the path followed when K increase. Remember that c_P and E are positively correlated.