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Structural Change, Environment and Well-being: Interactions Between Production and Consumption Choices of the Rich and the Poor in Developing Countries

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Summary

Vulnerability to scarcity or 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 ac- count these elements, this paper argues that environmental degradation may represent a push factor of economic development in an economy polarized into two main classes (the Rich and the Poor) and characterized by the following stylized facts: a) the main income source of the rural poor is self-employment in traditional activities highly depending on natural resources; b) labor remuneration in rural sector represents the basic opportunity cost for (unskilled) labor in the economy. Thus, given that environmental degradation reduces labor productivity of the rural poor, it may depress wages; c) production of the modern sector managed by the rich is less affected by depletion of natural resources because they can adopt defensive strategies that the poor cannot. They are able to defend themselves by partially substituting natural resources with physical capital accumulation and wage labor employment. We will show that, in this context, environmental depletion may benefit the modern sector through an increase in low cost labor supply and, in turn, it may stimulate economic transition. However the structural change is likely to result in an increase in inequality.

Keywords: Production, Consumption Choices, Welfare

JEL Classification: D62, O11, O13, O15, O41, Q20

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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. On the other hand, the environment has been viewed as a limit to economic growth and, therefore, to the expansion of well-being: economic activities based on natural resources 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 [1].

From the perspective of those authors who have pointed out the limited reproducible capacity of the natural resources, structural change, namely a reduction of the traditional primary sector's employment and output share, has been considered a key element in overcoming nature's constraint leading to an expansion of productive possibilities. As observed by López (2007) there is a quite strong consensus on the role of structural change as a cause and consequence of economic development and growth (Lewis 1955, Ranis and Fei 1962, Lucas 2004): primary traditional activities in the rural sector have been seen as limited by the fixity of some productive factors, while expansion of the non-resource sectors may permit an unending process of labor productivity growth because they rely on assets (human and physical capital) that can expand over time. Also Lucas (2004) recently stated that "the origins of modern economic world can be seen, in part, as a transition from a traditional agricultural society to a society of sustained growth in opportunities of human and physical capital accumulation". A part of the literature of "resource curse" can be included in this viewpoint too (see e.g. Matsuyama 1992, Sachs and Warner 1997, Auty 2001): a large endowment of natural resources is likely to delay diversification of economic structure towards more dynamic sectors resulting in low economic growth rates. Finally, such perspective is consistent with many studies finding that access to non-agricultural activities can represent a poverty alleviation

[1] A part of literature focusing on rich countries and on pollution (see e.g. Aghion and Howitt 1998, Antoci and Bartolini 2004, Stockey 1998) considers the environment as a luxury or final good which affects the utility function of people. This idea is neglected in this article because we consider that, in developing countries, the environment and natural resources, especially in rural areas, are, first of all, an input of production.

strategy[2]: rural households that get off-farm jobs can experience a rise in their labor productivity and earnings. It follows that governments should introduce policies helping to diversify the income of households that rely on subsistence primary activities. Looking at the environment as wealth and source of subsistence, environment preservation and access to natural resources has been regarded as a crucial requirement for livelihood defence of rural poor populations. Given that the poor tend to be highly dependent on natural resources and vulnerable to environmental degradation, availability and quality of natural resources can be considered fundamental factors in the struggle against poverty. Indeed, 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). At the same time, dependence on resource-based activities can be seen as a limit: given that the rural poor largely rely on natural capital for their subsistence, they are also prone to entering a vicious circle of further impoverishment and environmental degradation. From this conceptual framework it follows that the measures and changes that provide incentives for investments in modern sectors or that help labor shift to modern sectors have been seen as policies that can stimulate economic growth and from a certain point also reduce poverty. Moreover, economic transition is likely to result in a reduction in pressures of the poor on natural resources with a positive effect on natural ecosystem preservation. Therefore, countries that manage to trigger off a structural change take a path towards sustainable development. Indeed several developing countries, despite their attempts to introduce such interventions, have witnessed a persistence of poverty, especially in rural areas, environmental degradation, an increase in the income inequality associated with different economic performances. Obviously, such results stem from various economic, social and institutional factors; thus, this work will not attempt to provide an extensive and critical assessment of the various explanations found in the literature. The purpose, indeed, is to contribute 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 developing countries. 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

[2]On the role of off-farm (rural or urban) labor 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.

environment or, conversely, minimize its limits in the struggle against poverty. Thus, the work attempts to provide a conceptual and joint framework able to embody both opposing conceptions of the environment. Alternative development paths are distinguished according to the ability of economic systems to preserve the value of the environment as wealth and subsistence basis and to overcome the limits of natural resource dependence. The impact on poverty, distribution, output level and composition is also discussed. Finally, attempts are made to identify the conditions and factors that might determine the type of development path undertaken by a region or by a country. This analysis permits identifying unexpected scenarios different from the positive structural change predicted by the mainstream view. In particular, the work investigates conditions under which there is a theoretical possibility that an expansion of the capitalistic sector can be associated with a process of impoverishment and depletion of natural resources.

2 Well-being, growth and environmental dynamics with heterogenous agents

2.1 Setting of the problem

Most developing countries and advanced economies during their first phases of development present a dual structure with a coexistence of a "traditional" sector and a "modern" sector. The first one is often characterized by the use of labor intensive techniques, employment of family labor and low ability of capital accumulation. A large part of this sector comprises subsistence agriculture, small scale fishery, timber and breeding activities (from now on referred as traditional or subsistence primary activities). Therefore people employed in this sector largely depend on the land on which they live for their livelihood (IFAD 2001a). Besides, as pointed out by Ebkom and Bojo (1999), small-scale farmers often derive additional sources of income from the environment (wild fruits, nuts, berries, herbs, medicinal plants, bushmeat and roots), pastoralists derive essential nutrients from wild flora and fauna in marginal areas and small fishermen rely on marine resources for their subsistence. That is, subsistence primary activities are highly dependent on environmental goods and services: because of a low endowment of physical (and human) capital, the main factors of production are given by self-employed labor and natural resources. At the same

time, households employed in this sector are also among the categories to which segments of poor population usually belong[3]. In addition to this group, another part of the traditional sector is represented by subsistence off-farm activities. People working in this sector are self-employed workers (in non-primary production) who own and operate one-person business and work alone (for example, those who work at home and domestic workers) or with the help of unpaid workers, generally family members and apprentices. Subsistence off-farm activities are less dependent on natural resources (even if some of these activities are linked to agriculture), but are still characterized by labor intensive techniques, low ability of capital accumulation as well as low labor earnings. Therefore the majority of its workforce belongs to the lowest income quintiles. The "modern" sector usually refers to activities with a higher labor productivity, more capital intensive production and employment of wage labor. It includes commercial agriculture, production of exportation commodities, industrial and formal service sector. These firms and economic activities are usually managed or owned by well-off households which are more able to accumulate financial and physical capital. The dependence of this sector on environmental resources varies a lot among countries and it is generally higher in economies with abundance of natural resources. In those countries (almost all developing countries) that have not undertaken a complete transition to industrialization, another urban informal sector has emerged too, increased by a continuous process of urbanization. In advanced economies, the industrial sector has been able to absorb the labor from the traditional agricultural activities, while in many developing countries this sector has not been enough dynamic. Thus, a non-agricultural informal sector has developed and it comprises, not only off-farm subsistence activities already described and ascribed to the traditional sector, but also the universe of micro enterprises which employ a few paid dependent employees (unregistered transportation services, small stores, small firms belonging to construction, textile sector etc). In general, capital intensity and labor productivity are lower than in the modern sector. This factor, associated with the non-adherence to government and labor regulations, leads to low and flexible wages. In the same way, the owner-employers in this sector are usually less rich than the households that hold or manage enterprises of the modern sector, but at the same time, given their higher capital endowment, they are better-off than people working

[3]According to IFAD's Rural Poverty Report, the rural poor in various regions are usually rainfed farmers, smallholder farmers, pastoralists, artisanal fishermen, wage laborers, indigenous people, female headed households, and displaced people (IFAD 2001a).

in the traditional sectors. Three main observations can be drawn from this schematic description of the production systems that characterize many developing countries:

1) The traditional activities, the sector of informal small firms and the modern sector differ for adopted technology and consequently for productivity, dependence on natural resources, vulnerability to environmental degradation as well as their output growth which is not equally subject to external constraints. That is, output composition and sectorial labor allocation are key elements in explicating economic performance of an economy.

2) The sectorial composition of an economic system is strictly linked to income and asset distribution and, at the same time, changes in the sectorial composition of employment and output are likely to cause effects on distribution and poverty.

3) Consequences on economic growth and on distribution produced by a structural change or by an unbalanced growth path (i.e. an expansion of one sector more than proportional to other sectors' growth) are likely to depend not only on the characteristics of each sector, but also on the linkages among the different sectors.

It follows that any work aiming at studying the relationship between poverty, environment and growth in developing countries cannot avoid referring to the theory of structural change, to pluri-sectorial models[4] and to the literature that

[4]The first term of reference for the formulation of a model aiming to describe the relationships among poverty, environment and growth should be the theoretical literature which studies possibility and feasibility of a continuous growth that is also environmentally compatible. Even if it is recognized that sustainability sets a limit to economic growth rates in steady state, namely the economy grows at a slower pace than it would do in absence of environmental problems, authors have identified several conditions for insuring a positive sustainable economic growth. According to Stockey's approach (1998), for example, in economies with exogenous technical progress, sustained growth in capital and continuing tightening of pollution are compatible with a constant rate of return of capital. In other models sustainable growth is obtained also without assuming exogenous positive externalities. In Aghion and Howitt (1998) environmental sustainability is reached through an increase in ratio between human (clean) and physical (dirty) capital in the input composition (Aghion and Howitt 1998); Bevenberg and Smulder (1996) propose a model in which an endogenous progress reduces the intensity of pollution produced by the economic system in a economy where the planner subsides R & D research in abatement technologies. However López and Toman (2005) note that these models need conditions for sustainable development that are quite demanding and are rarely satisfied, especially in developing countries. For example the assumption of a benign social planner able to internalize all environmental effects and to apply an optimal environmental policy or a marginal utility of consumption greater than one (as in Stockey's and Aghion and Howitt's models) are quite unrealistic in contexts where environmental institutions and systems of

studies the links between different sectors. That is the purpose of the next paragraph that reviews the literature on take-off and structural change and discusses the main contributions considering structural or frequent characteristics of developing countries such as environmental externalities, significant dependence of production on natural resources, ill defined property rights and asset inequality. Indications for the formulation of a new model are assessed and proposed.

2.2 Structural change, environment and poverty: a review of the literature

The literature on development theory has identified various factors and mechanisms which may explain a structural change, namely the movement of labor force from the traditional sector to the modern one. The role of structural change in boosting economic take off has been analyzed too. Today, all advanced economies and the most successful emerging economies (mainly from East Asia region) have experienced a complete transition and migration out of traditional agriculture: this sector has almost disappeared and, as noted by Lucas (2004), the agricultural activities that have remained is a part of the modern economy with a sustained productivity growth, while labor share of agriculture has fallen to vary low levels. The development theory has tried to explain this stylized fact (namely economic growth and poverty reduction associated with a structural change) by referring to neo-classical and Keynesian and post-Keynesian models according to which accumulation of physical capital is the key factor for economic growth. Saving and investment in physical capital cause an increase in labor productivity leading to economic expansion. In a dual framework, such vision implies that the capital intensive sector is able to sustain a process of economic growth, while the production of the subsistence sector is constrained and cannot overcome a certain threshold because it relies on limited factors of production such as land and labor. Therefore a labor shift towards the "modern" sector leads to a structural change associated with economic growth.

controls are weak and where a large share of populations enjoy low level of consumption as in many developing countries. Moreover most of models consider the environment as a final good and are quite aggregative in the sense that are based on a unique representative agent or on a unique productive sector. On the contrary in several developing countries asset and income distribution is highly concentrated and therefore agents differ for initial conditions, available strategies and vulnerability, and economic and environmental dynamics are likely to produce effects that are not homogenously distributed. Moreover, in developing countries, natural resources are not only a consumption good, but, and above all, an important factor of production. For all these reasons a large part of the modern sustainable growth theory seems not appropriate for developing countries.

From a certain point, labor remuneration tends to be linked to labor productivity; therefore such transition allows an increase in wages with positive effect on poverty alleviation. In the modern theory, this conceptual framework has been deepened by defining capital in a broader sense to include also accumulation of human capital and public goods as factors for continuous potential for growth (Barro 1990, Lucas 1988 and 2004, Romer 1986). The development doctrine, however, does not agree on mechanisms that are able to trigger off a successful structural change. Some main visions can be identified:

1) Some development theorists attribute to agriculture growth and to agricultural productivity the role of leading the process of industrialization. Kalecky (1971), for example, observes that agriculture provides wage goods therefore growth of agricultural production is essential for limiting wage growth and facilitating industrialization processes. Other authors (Singer 1979, Adelman 1984, De Janvry 1984, Vogel 1994) underscore the potential of agriculture to generate domestic demand to stimulate industrialization. Adelman introduces the idea of "agricultural-demand-led-industrialization" strategy: growth in agriculture sector might stimulate demand of manufacturing goods, via rural income increase, and might expand food supply without rising prices. In the same way, Vogel (1994) identifies agriculture as "leading" sector given its strong backward linkages in developing countries. In short, according to this view, the increase in agricultural output benefits the industrialization process and the growth of the modern sector: a higher agricultural production permits feeding a growing urban population and raises income of rural population stimulating domestic demand for industrial (final and intermediate) goods. Given that agriculture and labor-intensive traditional activities almost coincide during the first phases of the development path, this vision underlines that the traditional sector has to be sustained in order to prompt a virtuous transition.

2) Other theories (Rosenstein - Roden 1943, Rostow 1960, Lewis 1954, Jorgenson 1961, Ranis and Fei 1961, Hirschman 1958) highlight the role of the modern sector as engine of economic growth and stress the need to expand the industrial activities. Presence of previous capital accumulation[5],

[5]Availability of resource that can be invested in capital accumulation can derive from different factors: Adelman and Morris (1988) observe that, in Canada, Australia, New Zeeland and Scandinavian countries, expansion of commodity exportation helped industrialization, Shin

technical progress, international investments and credits, policy interventions that provide support or incentives for investment in the industrial sector, for saving or for human capital formation are seen as factors that can generate a process of structural change. Modern activities constitute the leading sector, even if a stable or growing agricultural production is acknowledged as a necessary condition for successful structural change[6]. Under this perspective, the change in labor allocation is the result of pull forces driving the workforce from low productive (subsistence) activities to the capitalistic sector[7]. On the other hand, the role of agriculture in transforming developing economies is seen as subordinate to acceleration of industrial activities, while the subsistence sector is regarded as a source of labor supply and it is expected to provide abundant "cheap" labor able to feed a successful take off.

3) Other authors make a further step considering that the availability of a reserve of cheap labor provided by traditional sectors has a crucial role in boosting industrialization. Following this approach, also push factors prompting labor expulsion from low productive activities are important determinants of structural changes, while any force that keeps labor force in agriculture sector or slows down labor shift may be an obstacle to industrialization and, consequently, to growth. According to some authors, the experience of industrialized countries might reflect this mechanism. As already noted by Karl Marx, Humpries (1990), for example, highlights that in England parliamentary enclosures of the eighteenth century contributed to proletarianization process of rural population. The exclusion from common land access reduced considerably non wage source of subsistence available to rural classes and left them more dependent on wages. This, in turn, helped the process of industrialization. In the same way, looking at the industrialization experience of some resource-poor countries (such as Belgium, Switzerland, Asian Tigers), Matsuyama (1992) finds a

(1998) underlines that compensation of landlords during the agrarian reform in South Korea was functional to the transfer of capitals, that were inefficiently immobilized in agriculture, towards productive industrial activities.

[6]According to Rostow (1960), for example, the revolutionary changes in agricultural productivity are an essential condition for successful take-off. In the same way, Lewis (1954) writes if the capitalistic sector produces no food, its expansion increases the demand for food, raises the price of food in terms of capitalistic products and so reduces profits. This is one of the ways in which industrialisation is dependent upon agricultural improvement.

[7]Ranis and Fei (1961), for example state that "development consists of the re-allocation of surplus workers, whose contribution to output may have been zero or negligible, to industry".

negative link between labor productivity in the agricultural sector and manufacturing growth. According to the author, a scarce endowment of natural resources implies a low productivity in the rural sector. In this context, the industrial sector can benefit from a large supply of labor at low cost and the economy gains a comparative advantage in manufacturing production. That is, poor resources countries may successfully industrialize by importing primary products and exporting manufacturing goods (Matsuyama, 1992)[8].

All these contributions attempt to identify the main determinants or obstacles of structural changes considered as a cause and consequence of the economic growth process, the first and necessary step towards poverty alleviation too. A different perspective has been recently adopted by López (2003, 2007) who proposes a distinction between two types of economic transition: *benign* and *perverse* structural change. The first one is associated with an increase in investment in modern sector that raises labor productivity in this sector leading to an increase of rural urban migration driven by pull forces. The result is an alleviation of environmental pressures, an increase in share of labor and output of modern sectors, economic growth and, from a certain point, a rise in labor earnings. This is the structural change experienced by industrialized countries and by the most successful emerging economies and it is the typical transition described and explicated by earlier theorists. However, López (2003) observes that in many middle-low income countries[9] the "development" path over the last decades has been characterized by an impressive process of urbanization, growing problems of environmental degradation and low performances in economic growth and in the struggle against poverty. Therefore he detects another type of structural change: a perverse structural change associated with a labor shift from agricultural to non-agricultural sectors driven by push forces. In this case, a decline in productivity of agricultural traditional activities leads to a reduction of labor opportunity cost. The result is labor migration, an increase in non-agricultural share and, in particular, expansion of informal urban activities (instead of economic activities of the modern sector) with declining or stagnant wages and less positive economic trends.

[8]However, it has to be noted that economic openness and the possibility to substitute domestic agricultural products with those imported are the necessary conditions for the existence of this linkage.

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

The main causes that López identifies as responsible for the failure to prompt a benign structural change and for the emergence of perverse structural changes 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. The author blames policies that have focused only on physical capital accumulation neglecting the complementary role of other assets, such as public goods (that, to a certain measure, comprise also natural capital) and human capital, that are affected by higher market failures than capital market. Massive public subsidies for physical capital investment have exacerbated underinvestment in public goods (included environmental protection) and in human capital and have favored natural resource-demanding activities, while most benefits have been captured by the rich, the main owners of physical and financial capital. The results have been environmental destruction and increasing inequality. Finally, to the extent that natural, public and human capital assets constitute factors of production, a physical capital-biased public policy has negatively affect economic performance too.

2.3 Structural change, environment and poverty: a conceptual framework for developing countries

Economic, social and environmental conditions both at national and international levels have changed since the period in which the bulk of the above discussed literature developed and today developing countries are experiencing a process of transition in an economic and social context that profoundly differs from that faced by most industrialized countries during their early phases of development. Therefore it is worth assessing the literature on structural change in the light of the different setting.

2.3.1 Trade openness and heterogeneity of the agriculture sector

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 labor cost[10]. Moreover in many countries, especially in middle income economies of Latin America and Asia, the agriculture sector is not homogeneous and the coincidence between the agriculture and traditional sector no longer works: despite the increasing process of agroindustrialization (Pingali 2001), as already noted, commercial and subsistence activities still coexist. Commercial agriculture is usually practised by medium- and large-size farmers that employ wage labor and use capital intensive and modern technologies. This sector is usually market-oriented and its production is sent to urban national or foreign markets. On the contrary, subsistence agriculture is managed by rural households that adopt poor farming techniques, employ household and, in part, seasonal labor, while the production is used mainly for self-consumption.

In this context the role of the traditional sector for poverty alleviation and economic growth is less likely to operate through the channel of food prices both because the traditional sector cannot be seen as the main supplier of foods and because, as noted by López (2002), in middle income countries characterized by a highly open trade regime and good transportation infrastructures, food prices are mainly determined by foreign market conditions rather than by domestic conditions[11]. Also "backward" and "forward" linkages of agriculture into the input provider sectors, food processing and service sectors are more related to commercial and modern agriculture than to the traditional subsistence sector. For the sake of simplicity, the model we propose does not embody all the relationships between poverty, employment, output sectoral composition, and growth that have been identified in literature. Thus, the model neglects the dynamics which are likely to be less relevant in today developing countries, such as food (as wage good) price channel and effects produced by backward/forward linkage of subsistence sector[12]. However, the introduction of these mechanisms

[10]In this sense, Matsuyama's model (2002) is particularly explicative because it shows how the growth process might be driven by different factors in a open and a closed context: he finds a negative relationship between agricultural productivity and economic growth in open economies, while he detects the inverse links in closed economies.

[11]By using data referring to 1970-2001, Soloaga and Torres (2003), for example, find that in Mexico agricultural growth does not have a significant impact on real food prices, being the real exchange rate movements the main determinant. López and Anriquez (2007) find that in Chile agriculture growth is negatively correlated with real price of non-tradable foods but food price reduction explains only between 10 to 15 % of impact produced by agriculture growth on poverty alleviation.

[12]This is consistent with Vogel's findings (1994) of increasing backward linkages as average income grows. He notes that during the development process, agriculture becomes more capital and input intensive, but it can be added that in middle income countries modern and commercial agriculture is more developed than in low income economies where the traditional

and links represents an interesting extension of the model that may deserve further research.

2.3.2 Traditional sector and opportunity cost of labor

The theories that regard labor surplus as a determinant of structural changes are based on the assumption that wages in the urban sectors are driven by labor supply coming from the traditional sector. Thus, an abundant "cheap" labor supply allows to control growth of urban wages and to foster industrial development. Actually these models seem to be more appropriate to explain the evolution of industrialized economies than that of developing countries where urban sector is segmented and the gap between formal and informal wages is a structural feature because the modern sector is not able to absorb all labor supply. At the same time, López (2003) observes that in developing countries labor remuneration in primary sector (especially traditional primary activities that use labor intensive techniques) is still likely to represent the basic opportunity cost or floor wage for unskilled labor in the whole economy. In fact, the primary sector still absorbs a large share of labor, especially unskilled labor: in 2002, for example, employment in agriculture as percentage of total employment was 3.85 % in high income countries, 14.33 % in upper middle income countries, but it rose to 39.83 % in lower middle income countries (World Development Indicators 2006) and in low income countries is even higher. Therefore this sector can be a key factor in setting the wage rate of unskilled workers and, correcting for skill differentials, of the whole economy[13].

In conclusion, if in developing countries labor 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. In the construction of the model and in the discussions of its results these

agriculture is more widespread. Therefore such linkages can be attributed more to the modern than to traditional agriculture.

[13]For example, López and Anriquez (2006) show that in Chile (1987-2003 period) the main channel through which agriculture growth reduces poverty is the labor market: expansion of agriculture production raises wages and employment of unskilled workers among whom poverty is more predominant, while effects on poverty through food price channel is less relevant. In a study on sectoral composition of growth and poverty in India, Datt and Ravallion (1996) find that output growth in agriculture reduced poverty in both urban and rural areas, while in a successive work (Datt and Ravallion 1998) their analyzes show that growth in farm productivity contributes to poverty alleviation both directly and by inducing a rise in the wage rate as well as a reduction in food prices (although the price effect is lower). Therefore, also in India, poverty reduction impact of agricultural growth might be partially explained by its positive effect on wages of unskilled workers.

observations will be taken into account and labor remuneration in subsistence rural sector will represent the basic opportunity cost for labor in the economy.

2.3.3 Environmental dynamics and heterogeneity of agents

The bulk of literature on structural changes and on links among economic sectors neglects environmental dynamics. As seen above, in general, environmental externalities do not enter theoretical models and when natural resources are included in the analysis they are considered as given and their role is assessed in relation to their abundance/scarcity or to their limited and fixed amount. On the contrary, environmental resources are not fixed, are subject to poor management and over-exploitation (López 2007). Environmental externalities can affect economic activities especially in developing countries where property rights tend to be ill-defined and ill-protected, environmental institutions and regulations are weak and, as noted by López (1997) and by Sachs et al. (2001), natural resources are more fragile than in developed countries that are usually located in temperate areas (on the contrary, most of developing countries are located in tropical and sub-tropical regions).
In order to address this knowledge gap, we refer to works addressing the study of conditions for sustainable economic growth by using two-sector models that include environmental dynamics and consider environmental resources as productive inputs such in López et al. (2005) and Eliasson and Turnovsky (2004). The approach of this work follows these contributions but with some important differences: we are attempting to consider not only sector composition of the economy and factors susceptible to trigger off a structural change but also the distributional dimension. The model intends to distinguish different sectors and agents in terms of their interactions with natural capital to shed light on distributional impact of environmental degradation. In short, the objective is to investigate how the effects of environmental dynamics change in relation to asset endowments and definition of production functions.

Distribution matters: some empirical evidence 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, as seen in the introduction, production function and sectorial structure in the economic systems partially reflects asset and income distribution. At the same time, vul-

nerability 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. Three quarters of the poor live in rural areas and more than half of the rural poor depend on breeding and agricultural activities: cultivation of staple food is the main source of calories, income and job for the rural poor (IFAD 2001). Moreover, it is commonly recognized that rural poor in developing countries significantly rely on common pool resources of the community where they live (Dasgupta 1993, 2001), two-thirds of the world's population live within 100 kms of the coast and they may depend on marine resources for subsistence (Ballance 2004), while according to estimates made by UNDP et al. (2005), around 1 billion of the world's poor rely in some way on forests (indigenous people wholly dependent on forests, smallholder farmers who grow farm trees or manage remnant forests for subsistence and income). Natural assets and common or free access resources provide the poor with other additional services: regulating services for production such as mitigation of floods, drought and erosion, renewal of soil, soil fertility or provision of food, fuelwood and energy, fresh water and genetic material (UNEP 2004). Microeconomic studies confirm the relevance of dependence of rural population on community or free access resources (Jodha 1986, Cavendish 2000, Falconer 1990, Back and Nesmith 2001[14], Fisher 2004, Hecht et al. 1988 cited in Friedman and Rangan 1993, Narain et al. 2005), while the meta-analysis carried out by Vedeld[15] et al. (2004) on a sample of 54 studies finds that average environmental income amounts to 22 percent of total household income, where environmental income is defined as "rent (or valued added) capture through consumption, barter, or sale of natural capital within the first link in a market chain, starting from the point at which the natural capital is extracted or appropriated". Finally, in absence of an insurance market, access to environmental resources may represent a survival strategy to

[14]They estimate that about 12 percent of household income to poor households in India is provided by common pool resource collection. Similar results are found by Nairain et al. (2005) in Jhabua, one of the poorest districts of India.

[15]Vedeld. P., A. Angelsen, E. Sjaastad and G. Kobugabe-Berg (2004), "Counting on the Environment: Forest Incomes and the Rural Poor". Environment Department Paper N. 98, World Bank, Washington, D.C.

cope with adverse shocks[16]. In addition, the poor do not have appropriate tools and means for coping with environmental depletion. Therefore they are more vulnerable than the rich to pollution and to degradation of natural capital while lack well defined property rights, of power, human capital and political linkages make the poor more prone to be deprived of their access on natural resources to advantage of powerful agents (State, large firms or influent people). 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 will be contemplated.

Environmental externalities of economic activities Our model considers a small open economy 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's and Eliasson and Turnovsky's approaches that distinguish between a clean and a dirty sector, the model proposed in this article follows a sector classification based on asset endowment of the two groups (that is reflected in the production function) and contemplates the possibility that both sectors cause an environmental impact. Thus, in this characterization we follow Antoci and Borghesi's (2002) approach[17] which investigates the interactions between two sectors (North and South) by hypothesizing that both harm natural resources. They study a model in which negative externalities may constitute an engine of economic growth through the following mechanism: economic growth produces negative externalities that reduce environmental goods (that is a final

[16]For example, Takasaki et al. (2004) have found that among river peasant households in a region of Peru (Pacaya-Samiria National Reserve) gathering of non timber forest products and fishing are the major strategies to cope with floods, while their subsistence depends mainly on shifting cultivation, foodplain agriculture, hunting, fishing and non timber forest products gathering. In the same way, Dei's study (1992) on natural resources role during recession and drought in 1982 and 1983 in southeastern Ghana showed that the poorest households depended on the "bush" for 20 percent of their food intake, compared to the highest income share, for which the bush provided only 2 percent of the household food intake. Women and children in particular relied on wild products such as roots, fibers, leaves, bark, fruit, seeds, nuts, insects, and sap. Men also hunted and trapped small mammals, reptiles, and birds.

[17]This idea was introduced by Antoci (1996) and Antoci and Bartolini (1997, 1999) and further developed in following works by Antoci (2005), Antoci and Borghesi (2002), Antoci, Galeotti and Russu (2005), Bartolini and Bonatti (2002, 2003). These studies focus on substitution of free goods freely provided by natural or social environment with private costly goods.

good). Agents try to defend themselves from well-being losses by increasing their labor supply in order to raise their consumption of man-made goods. This leads to a growth of output and of negative externalities. Thus, defensive strategies generate a self-enforcing economic growth process but the growth path is likely to be undesirable, that is Pareto dominated in terms of well-being[18]. Our model differs in that we consider natural assets as factors of production, while in Antoci and Borghesi's model environment enters utility function as consumption good. That is in our context a self-reinforcing process of undesirable economic growth might emerge but only under some restrictions because degradation of natural resources can negatively affect production.

Environmental impact of the poor A broad cross-section of the literature considers the poverty as a cause, direct or indirect, of environmental degradation. It is argued that poverty is associated with high discount rates[19]: given that the poor are concerned with day-to-day survival, they are likely to adopt short-term coping strategies and to under-invest in sustainable practices with a long term return (WCED 1987, Durning 1989, World Bank 1992, UNEP 1995). In addition, they might also lack access to productive resources, institutional and credit services, off-farm labor opportunities, technology or knowledge in order to invest in environmental protection and to reduce the pressure on natural resources, even if they are conscious of decrease in the natural resource basis of their livelihood (IFAD 2001b, Pascual and Barbier 2001)[20]. Demographic pressure and the commonly recognized link between poverty and population growth can further worsen environmental depletion (Brown et al. 1998). Finally, given that a large part of rural poor live in fragile areas, they are also more

[18]The idea that there is no coincidence between production and welfare maximization is not new in literature. Indeed, over last years there is a growing debate about the extent to which economic growth and Gross National Product can measure social well-being, while the literature on "genuine saving" points out that the evaluation of the mere man-made capital accumulation, without imputing change in natural capital, can be a biased indicator of economic perspectives and welfare path even under weak sustainability assumption. (See, for example, Vincent 2000, for a review on how national accounts should include environmental depletion). In particular, it has been argued that, if policy makers want to prevent a decrease in social utility, they have to avoid fall in net saving that includes not only physical and human capital, but also natural assets (Hamilton and Clemens 1999, Dasgupta and Maler 2000, Ashem and Weitzam 2001)

[19]Empirical studies are provided by Poulos and Whittington 2000, Cuesta et al. 1997, Holden et al. 1996.

[20]A IFAD's report is particularly emblematic in this sense. It is argued that "environmental degradation in rural areas in many developing countries has little to do with modern farming and intensive agricultural systems. Agriculture practised by poor people often depend on low-intensity systems in marginal areas. In many parts of the developing world there is vicious circle of falling farm incomes and resource depletion" (IFAD 2002).

prone to enter a downward spiral of further impoverishment and environmental degradation (Pichón and Uquillas 1997, UNDP 2005, IFAD 2002).

However, even if poverty is recognised as a possible cause of environmental pressure, in literature there is a consensus that the vision of the poverty as a major cause of environmental degradation is too simplistic (Durahiappah, 1998) because potential environmental impact of poverty is not univocally determined but it can change in relation to a range of factors. Some authors argue that poverty does not necessarily imply short time horizons. (Bromley, 1998, Prakash 1997 (cit. in Lipper and Osgood, 2002), Lumley, 1997). Other observers adhere to the view of the poor as stewards and defenders of environment. Martinez Alier (2001), for example, has collected several examples and episodes of people's protests against the depletion of environmental basis they depend upon for their livelihood. In the same way the neo-Malthusian theory of population growth as cause of environmental distress and increasing poverty is highly debate. Forsyth et al. 1998 note that the poor are often able to adopt local organizational and land management practises that lessen impacts of population growth and environmental degradation or economic changes. Scheer (2000) underlines the heterogeneity in environmental management by the rural poor revealed by the empirical research[21]. Looking at results of research on relationship between rural poverty and environmental degradation carried out in ten different Latin American areas, Swinton et al. (2003) conclude that the case-studies do not permit detecting significant negative links between poverty and sustainable management practices. In particular, they highlight the role of incentives for investment in resource conservation measures and they note that when proper incentives are lacking, the capacity for responsible natural resource management (that is lower for the poor than for the rich) becomes irrelevant. The role of institutional framework in determining the linkages between environmental degradation and poverty has been studied also in India's arid and semiarid regions by Chopra and Gulati (2003). They found that environmental degradation caused by increasing demographic pressure tends to force people to move to urban areas during time of distress, especially during droughts. However their results show that establishment or resurrection of properly constituted common property rights may increase the carrying capacity of resources (i.e. the capacity of environment to support larger populations) reducing migration flows.

[21] Templeton and Scherr (1999), after a review of over 70 empirical studies in poor hill and mountain regions, conclude that effects of population growth on land and forest quality is indeterminate.

These studies show that the effects of demographic growth on natural resources exploitation can be mitigated by other factors such as virtuous institutional dynamics and technological adaptations that may reduce environmental impact caused by economic activities of the poor and population's impact on natural resources. In conclusion, potentiality of the poor 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. As noted by a recent UNDP report (2005), experience of interactions between poverty and environment varies from location to location. Thus, in the model the sector of the poor causes environmental externalities but no assumptions on the degree of such impact are made and alternative scenarios are considered.

Environmental impact of the rich and its consequences on the poor In the model, the sector managed by the rich is represented by capitalistic activities characterized by the employment of wage labor such as the manufacturing, the extractive industries or commercial and mechanized agriculture. It is assumed that these activities harm natural capital stock with negative externalities on the poor. In fact, it is possible to mention many examples of environmental depletion caused by these activities or by policies focusing on the promotion of the capitalistic sector. In addition to classical examples of air and water pollution due to industrial firms and urbanization processes, there is also an increasing concern on some other consequences of industrialization and urbanization. For example, from the analysis of deforestation in Brazil, Guatemala, Cameroon, Malaysia and China, Barraclough and Ghimire (2000) find that in all cases, most forests were cleared for industrial, infrastructural, and urban development, with a smaller area cleared for agricultural expansion and, in particular in Brazil, Malaysia and China, industrialization programs, growing manufacturing sectors, and rapidly expanding urban populations are identified as the main causes of deforestation. Therefore, agricultural expansion in those countries is less about poor peasants clearing land for subsistence production and more about state-directed industrial development. Other emblematic cases of environmental externalities caused by the rich are represented by activities of large-scale commercial enterprises that are often responsible for the unsustainable use of natural resources. Moreover, in many cases the negative effect on natural capital endowments is likely to harm the subsistence basis of the rural poor. A very clear example of this mechanism is given by the overfishing problem. The introduction of new fishing technologies has raised labor productivity

of fishery activities. The modernization of fisheries, the open access nature of fishery, a growing international demand, and, in certain cases, supply of State financial subsidies to encourage investments have been factors contributing to the expansion of capital intensive commercial fishing activities. As a result, seventy percent of the world's commercial fisheries are fully exploited or over-exploited and experience declining yield (World Bank 2003). The impact can be particularly perverse for artisanal fishermen that can not afford mechanized boats and, at the same time, face a decline in productivity because of overfishing[22]. Another example of environmental impact produced by resource-based commercial firms is given by the deforestation problem. Several researchers observe and find that, in many low and middle income countries, deforestation, increased land conversion and soil erosion are associated not only with demographic growth and land inequalities, but also with the expansion of livestock numbers, timber extraction - especially in open access areas - and mechanized agriculture (De Janvry and Garcia 1988, Health and Binswanger 1996, Leonard 1989, López 1992, Markandaya 2001, Stonich 1989). All these activities are usually managed by wealthier households that take advantage of a higher ability to compete for resource use and access because they are well endowed with capital and are more politically linked (Barbier 2006)[23]. These activities produce not only a direct impact through an intensive exploitation of fragile lands and unsustainable use of resources, but they are also responsible for perverse and indirect consequences. People are forced to move into unfamiliar and vulnerable areas in order to allow such activities. Displacement of peasants is likely to lead to the collapse of traditional institutions inducing farmers to destructive practices. In the light of these factors, some authors now acknowledge that the poor are often mere agents of environmental degradation, while the main causes of natural resource exploitation are consumption and production choices of the rich (Durahiappah 1998, Leonard 1989, DFID et al. 2002, Ekbom and Bojo 1999). On the contrary, various empirical works illustrate cases in which the rural poor not only are not responsible for natural resource depletion, but they also claim interventions against environmental degradation caused, directly or indirectly, by activities of large firms and rich households and that threaten the

[22]Kurien (1992), looking at coastal fishery in Kerala, finds that overfishing has dampened the growth of fishery sector, has increased the disparity between working fishermen and non worker owners of mechanized boats and has reduced fish available for local consumers. For other empirical examples see DFID et al. (2002).

[23]In many cases concessions and input or credit subsidies have benefited more than proportional larger producers.

natural resource basis on which they live[24]. 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[25]. Also 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". He describes the actions of Oilwatch that is a south-south network concerned for the loss of biodiversity and forests, soil and water pollution, violations of human rights and indigenous territorial rights caused by oil and gas extraction in tropical countries. He also deals with the growing social resistance against export oriented commercial shrimp farming in several Asian and Latin American countries (especially in Ecuador, Honduras, Guatemala, Colombia, Sri Lanka, Thailand, Indonesia, India, Bangladesh, Philippines and Malaysia). In many cases, the expansion of legal or illegal shrimp ponds has caused the eviction of small fishermen and the destruction of coastal mangrove forests[26] to the detriment of local communities[27]. Moreover, direct pollution from industrial shrimp ponds causes loss of fisheries, reduction of potable water and salinization of fields. Martines-Alier also describes local resistance against conversion of natural forests in plantations in Costa Rica and other countries[28]. Finally he considers struggles against mining activities responsible for depletion and contamination of water, air and soil pollution (Martines-Alier, 2002). Another case of conflict between local poor communities and the capitalistic sector is represented by the constructions of dams. Even the World Bank (2005), one of the main supporters of several dam projects, has recognized that the benefits of dams are mainly enjoyed by the cities and the industries to which they provide electricity (World Bank 2005), while an independent report of the World

[24]According to Broad's study case on Philippines (1994), besides the environmental degradation as threat for livelihood, other necessary conditions for the poor to become environmental activists are the existence of a organized civil society and a sense of permanence, namely belief that their families will likely continue to live in the area affected by depletion.

[25]The study case investigates the action of grassroots movements against trawler owners in Kerala, logging contractors and energy companies in Hymalayan region, and agricultural modernization processes in Mexico.

[26]It is estimated that over the last two decades one third of the world's mangroves have been removed for human activities such as shrimp farming and tourist structures (World Bank 2005).

[27]Mangroves are a source of income, food and wood for poor people, they defend coast against water intrusion and cyclones, and they contribute to combating against salinization and to provide breeding ground for fish.

[28]Poor people complain because, with the conversion of forest in plantations, many ecological and livelihood functions are lost (degradation of soil, loss of fertility and water retention) (Martinez-Alier 2002).

Commission on Dams recognizes that population living in the areas involved in the projects have suffered forced displacement, loss of fishing and of productive agriculture land due to flooding, salinization, and the lack of siltation (Berkamp et al. 2000). Hundreds of protests are still in progress in many parts of the world, in Africa, Asia and Latin America. Finally, to a certain extent, privatization of biological resources and extension of intellectual property rights regimes might be included among the modern "enclosures" that benefit big business to the detriment of small farmer by eroding free access to seeds, plants and other genetic resources as well as by reducing quality of natural resources (genetic variability and biodiversity)[29]. From all these examples it follows that a model aiming at describing interactions between the production choices of the rich and the poor should comprises a sector managed by the rich that produces environmental externalities on the poor. The degree of such externalities will depend on specialization in dirty or clean production and therefore it is likely to vary from one country to another.

2.3.4 Ill-defined property rights

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, as well as very heterogeneous natural resources, but the impossibility to introduce such a complex setting into a theoretical model compels making a choice and assuming 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 analyzed as an extreme case of this type of institutional failure. A comprehen-

[29] Pionetti's study (2006) on dryland farming systems on South India's Deccan Plateau, for example, shows that the seed industry undermines the scope for farmers to save their own seed through a mix of technological, legal and economic strategies: pureline breeding methods or genetically engineered seed sterility; intellectual property rights regimes such as breeders' rights and patents which make it illegal for farmers to reuse seeds; variety registration and seed certification schemes backed by economic rules or subsidies. The result is a reduction of genetic variability, deterioration of social and economic status of women as major autonomous seed producers. Shiva (2005) is more incisive by denouncing the impact of seed multinationals in India on poor farmers: she states that through a deceiving marketing, the help of public subsidies and of patent legislation some multinationals (mainly Cargill and, Monsanto) have transformed the farmers in their main buyers leading to a immiserazing process. Finally, Bolivian quinoa, Amazonian ayahuasca, Peruvian maca and Indian chickpeas are all other examples of resources that have been subject to intellectual property claims and that have been considered a deprivation of knowledge and genetic resources of Indigenous peoples and farming communities.

sive 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 paper. However some observations might be worth underlining. Firstly different property rights regimes have been supposed to produce different environmental impacts, but empirical evidences show a high heterogeneity of outcomes. Given our focus on environmental dynamics, we have preferred to distinguish the various scenarios in terms of environmental impact instead of in terms of property rights regime avoiding any schematic parallelism between the two factors.

Secondly, although with some caveats, depletion of free access renewable natural resources might represent or embody several types of forces that can prompt a negative structural change. The two main direct factors that López identifies as responsible of perverse structural change are natural resource degradation and processes of disenfranchisement of part of the rural poor from access to natural resources. From the examination of poor and rich producers' environmental impact, it follows that natural resource degradation might be caused by different factors:

1) increasing pressures on natural resources because of demographic expansion especially among populations that rely on primary activities;

2) production growth in a sector with environmental externalities in absence of adoption of cleaner technologies or investments in resource preservation;

3) distributional changes in access to natural resources that also lead to environmental externalities (see below).

As seen above, processes of disenfranchisement of part of the rural poor from access to natural resources can be produced by different factors:

1) expulsion of rural communities caused by an expansion in commodities (cattle, mining, logging) activities under a regime of imperfect property rights or under a legislation biased in favor of the commodity sector;

2) large investments in hydroelectric and irrigation projects or other large infrastructures;

3) other types of enclosures of common goods;

4) civil wars and conflicts.

In the model proposed we exclude conflicts. All remaining factors, leading to push forces out of the traditional primary sector, are represented by a decrease in the stock of a free access renewable natural resource. Actually not all phenomena considered are strictly given by a reduction in open renewable resource but we think that this choice can encompass a large part of such mechanisms:

1) In many cases a change in distribution of fixed resources, such as land endowments, can be partially represented by a change in a renewable natural resource, such as land quality: for example expulsion of poor rural population from their lands because of a "beef boom" often translates in migration toward fragile lands, so even if they can cultivate the same amount of land, soil quality has declined. On the other hand, rich cattle owners benefit from a higher land endowment that can be represented by an increase in their total factor productivity. Thus, in this case the dynamics can be represented by an expansion of a capitalistic sector that causes environmental externalities on rural poor dwellers. To the extent that agricultural frontier can be enlarged and property rights are not well defined land is not properly a fixed resource.

2) People displacements often lead not only to distributional changes but also degradation of natural resources. Large investments in mining, logging, hydroelectric projects, irrigation projects are often responsible of severe contaminations or environmental externalities harming also communities that have not been dislocated, while displaced people are often responsible of non-sustainable behaviors and practices because they settle in new and unfamiliar areas, without knowing how long they will stay and because community relations and social capital tend to deteriorate.

In the light of these observations, the choice of focusing on renewable resources in a context of open access can be considered reasonable. The fact remains that the introduction of alternative property right regime might be an interesting extension for further research.

3 The model

We consider a small open economy with three factors of production: labor, 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 accumulate physical capital, hire labor force and employ all their potential work - represented by a fixed amount of entrepreneurial activity - in the capitalistic sector producing a storable private good. We call their production "capitalistic sector" or "market sector". The P-agents are endowed only with labor and they have to choose the distribution of their labor 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. Given that the Poor cannot invest and accumulate physical capital, we assume that the capital market is completely segmented and is accessible only by the Rich.

3.1 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:

1) A non storable good deriving directly from free access renewable natural resources, hereafter referred to as environmental good.

2) A good (hereafter denoted private good) 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 labor force, they satisfy their needs mainly through the consumption of private goods. Each P-agent, in each instant of time, employs all her potential labor (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 inter-sectoral 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 labor 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 function of production in the rural sector is given by

$$Y_R = \alpha N_p E \tag{2}$$

This specification was proposed by Schaeffer (1957) for fishery and since then it has been 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[30]

$$c_p = \frac{Y_p}{N_p} = \alpha E \tag{3}$$

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 and only if

$$c_p = a c_s = a w \tag{4}$$

which can be re-expressed as

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

[30] In the traditional sector the labor payment is not based on marginal product activity, but on income sharing. Thus people that work in this sector receive the average product (Ray, 1998).

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. We assume 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 labor income between the two sectors (from condition (5)) is consistent with the role of rural sector as indicator of the labor opportunity cost[31] in other sectors. In the economy, labor supply is affected by two factors: on one hand, an increase in wage rate (due for example to an augmentation in labor demand) represents a "pull" factor of labor force; on the other one, negative externalities causing environmental depletion constitute a "push" factor of labor force.

3.2 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 labor in the market sector as entrepreneurial activity. Without loss of plausibility, we assume that the marginal product of entrepreneurial labor in the market sector is higher than the marginal product of labor in the subsistence sector. Therefore, the possibility that the Rich work in the subsistence sector is excluded a priori and the production function of the market sector can be specified as follows

$$Y_R = \beta K^{\gamma} E^{\delta} (N^D)^{1-\gamma-\delta} \tag{6}$$

where:
$\gamma > 0$, $\delta \geq 0$ and $\gamma + \delta < 1$ (i.e. the production function satisfies the constant

[31] López (2003) observes that in developing countries labour remuneration in primary sector (especially traditional primary activities that use labour intensive techniques) is likely to represent the basic opportunity cost or floor wage for unskilled labour and, correcting for skill differentials, of the whole economy. López and Anriquez (2007) show that in Chile (1987-2003 period) the main channel through which agriculture growth reduces poverty is the labour market: expansion of agriculture production raises wages and employment of unskilled workers among whom poverty is more predominant, while effects on poverty through food price channel is less relevant. In a study on sectoral composition of growth and poverty in India, Datt and Ravallion (1998) find that growth in farm productivity contributes to poverty alleviation both directly and by inducing a rise in the wage rate as well as a reduction in food prices (although the price effect is lower).

returns to scale assumption);
K: is the physical capital accumulated by the representative R-agent;
N^D: is labor demand by the Rich;
β : is a positive parameter representing (exogenous) technical progress.

The function (6) is increasing in all its inputs, is concave and it satisfies the *Inada conditions* in K and N^D; while, as E approaches zero, its marginal output tends to infinite only if $\delta > 0$. If $\delta = 0$, environmental resources do not enter the production function of the Rich.

3.3 Asset accumulation

P and R-agents consider the effect of their choices on the environment as negligible and they do not internalize it; therefore, in their maximization problems they take the evolution of E as given; that is, they behave without taking into account the shadow value of the natural resource and so 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

$$\dot{E} = E(\overline{E} - E) - \epsilon\alpha N_p E - \eta \overline{Y}_R \tag{7}$$

where:
$\overline{E}$ is 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;
$\epsilon\alpha N_p E^{\chi}$ is the aggregate environmental impact by the rural sector and the parameter $\epsilon > 0$ represents exploitation of the natural resource by P-agents;
$\eta > 0$ is a parameter measuring the environmental deterioration caused by the aggregate production $\overline{Y}_R$ of R-agents. Assuming identical Rich agents, it follows that $\overline{Y}_R = Y_R$.

As there is no investment in natural capital, the R-agent invests in physical capital accumulation all she saves after her consumption expenditures and remuneration of the employed labor force. Therefore the stock of physical capital grows according to the following equation

$$\dot{K} = \beta K^{\gamma} E^{\delta} (N^D)^{1-\gamma-\delta} - wN^D - c_R \tag{8}$$

3.4 The intertemporal maximization problem of the representative R-agent

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

$$U_r(c_R) = \ln c_R \tag{9}$$

Therefore U_R is twice continuously differentiable, strictly increasing and strictly concave, that is $U'_R > 0$ and $U''_R < 0$. The representative R-agent maximizes her utility by choosing c_R and the labor demand N^D, that is she solves the following intertemporal optimization problem

$$\underset{c_R,\, N^D}{Max} \int_0^\infty (\ln c_R) e^{-rt} dt \tag{10}$$

under the constraints (7) and (8), where $r > 0$ is the discount rate. The solution to the R-agent's problem is found considering the following current value Hamiltonian function

$$H = \ln c_R + \lambda(\beta K^\gamma E^\delta (N^D)^{1-\gamma-\delta} - wN^D - c_R) + \theta(E(\overline{E} - E) - \epsilon\alpha N_p E - \eta \overline{Y}_R) \tag{11}$$

where λ and θ are the co-state variables associated to K and E, respectively. It is easy to verify that the dynamics of λ, K and E do not depend on θ. In fact, we have assumed that agents consider $\epsilon\alpha N_p E$ and $\overline{Y}_R$ as given in the maximization problem above and consequently the resulting dynamics are not optimal; however, the trajectories under such dynamics are Nash equilibriums (see Wirl 1997), in the sense that no (Rich or Poor) agent has an incentive to modify her choices along each trajectory generated by the model as long as the others do not modify theirs. The dynamics generated by the model are found by applying the maximum principle

$$\dot{K} = \frac{\partial H}{\partial \lambda} = \beta K^\gamma E^\delta (N^D)^{1-\gamma-\delta} - wN^D - c_R \tag{12}$$

$$\dot{E} = \frac{\partial H}{\partial \theta} = E(\overline{E} - E) - \epsilon\alpha N_p E - \eta \overline{Y}_R \tag{13}$$

$$\dot{\lambda} = r\lambda - \frac{\partial H}{\partial K} = \lambda \left[r - \beta\gamma K^{\gamma-1} E^\delta (N^D)^{1-\gamma-\delta} \right] \tag{14}$$

where c_R, N^D and N_p are determined by the following conditions

$$\frac{\partial H}{\partial c_R} = \frac{1}{c_R} - \lambda = 0 \qquad (\text{i.e. } c_R = \frac{1}{\lambda}) \tag{15}$$

$$\frac{\partial H}{\partial N^D} = \lambda(\beta(1-\gamma-\delta)K^{\gamma}E^{\delta}(N^D)^{-\gamma-\delta} - w) = 0 \qquad (\text{i.e. } \beta(1-\gamma-\delta)K^{\gamma}E^{\delta}(N^D)^{-\gamma-\delta} = w) \tag{16}$$

The labor market is perfectly competitive and wage is flexible. The equilibrium value of N_p is given by the following labor market equilibrium condition (obtained by equalizing left sides of (4) and (16))

$$\frac{\alpha}{a}E = \beta(1-\gamma-\delta)K^{\gamma}E^{\delta}(\overline{N} - N_p)^{-\gamma-\delta} \tag{17}$$

In particular, we obtain

$$N_p = \overline{N} - \left[\frac{a\beta(1-\gamma-\delta)}{\alpha}\right]^{\frac{1}{\gamma+\delta}} E^{-\frac{1-\delta}{\gamma+\delta}} K^{\frac{\gamma}{\gamma+\delta}} \tag{18}$$

if the right side of (18) is not negative, otherwise $N_p = 0$ (i.e. $\overline{N}$ Poor work in the capitalistic sector). By substituting $N_p = 0$ in (18) and solving it with respect to K we get the curve which separates the region where $N_p > 0$ from that where $N_p = 0$ in the plane (E, K)

$$K = L(E) := \left[\frac{\alpha\overline{N}^{\gamma+\delta}}{a\beta(1-\gamma-\delta)}\right]^{\frac{1}{\gamma}} E^{\frac{1-\delta}{\gamma}} \tag{19}$$

where $\dfrac{1-\delta}{\gamma} > 1$.

Along and above the curve (19) it holds $N_p = 0$. By substituting N^D with the equilibrium value of $\overline{N} - N_p$ in (16) the equilibrium wage w is found and it can be used in (12).

Finally, given that (ex-post) $\overline{Y}_R$ is equal to Y_R, the dynamics generated by the model are the following

$$\dot{K} = \beta(\gamma+\delta)K^{\gamma}E^{\delta}(\overline{N} - N_p)^{1-\gamma-\delta} - \frac{1}{\lambda} \tag{20}$$

$$\dot{E} = E(\overline{E} - E) - \epsilon\alpha N_p E - \eta\beta K^{\gamma}E^{\delta}(\overline{N} - N_p)^{1-\gamma-\delta} \tag{21}$$

$$\dot{\lambda} = \lambda(r - \beta\gamma K^{\gamma-1}E^{\delta}(\overline{N} - N_p)^{1-\gamma-\delta}) \tag{22}$$

where $N_p = 0$ for (E, K) above (19) while N_p is given by (18) for (E, K) below the curve (19). The following restrictions on variables and parameters hold: K, E, $\lambda > 0$; a, α, β, γ, ϵ, η, r, $\overline{E}$, $\overline{N} > 0$; $\delta \geq 0$, $\gamma + \delta < 1$.

4 Basic mathematical results

In this section we analyze the existence ad stability of the fixed points (i.e. the stationary states) of the dynamics of the model, obtained by imposing $\dot{E} = 0$, $\dot{K} = 0$, $\dot{\lambda} = 0$ in the system (20)-(22). Note that, for $\lambda > 0$, equations $\dot{E} = 0$ and $\dot{\lambda} = 0$ depend only on E and K and consequently solving them we obtain the fixed point values of E and K. The corresponding value of λ is obtained by solving the equation $\dot{K} = 0$.

4.1 The case without specialization $\overline{N} > N_p > 0$

In the case without specialization (i.e. $\overline{N} > N_p > 0$), the condition $\dot{E} = 0$ is satisfied along the graph of the function

$$K = F(E) := E^{\frac{1-\delta}{\gamma}} \left(\frac{\overline{E} - E - \epsilon\alpha\overline{N}}{M(\beta\eta M^{-\gamma-\delta} - \epsilon\alpha)} \right)^{\frac{\gamma+\delta}{\gamma}}$$

where $M := \left(\frac{a\beta(1-\gamma-\delta)}{\alpha} \right)^{\frac{1}{\gamma+\delta}}$, and the condition $\dot{\lambda} = 0$ is satisfied along the graph of the function

$$K = G(E) := \left(\frac{\beta\gamma}{r} M^{1-\gamma-\delta} \right)^{\frac{\gamma+\delta}{\gamma}} E^{\frac{2\delta+\gamma-1}{\gamma+\delta}}$$

Therefore, the intersections between $F(E)$ and $G(E)$ identify the fixed points under the regime of no specialization. To state the existence and stability results about these fixed points, we define the following threshold values

$$\Omega := \alpha \left(\frac{\eta}{a(1-\gamma-\delta)} - \epsilon \right) \tag{23}$$

$$\Delta := \frac{r}{\beta\gamma \left(\frac{a\beta(1-\gamma-\delta)}{\alpha} \right)^{\frac{1-\gamma}{\gamma}}}$$

$$\overline{N}_1 := \Delta^{\frac{\gamma}{1-\gamma}} \left[\frac{\delta a}{\alpha[\eta - \epsilon a(1-\gamma-\delta)]}\right]^{\frac{1-\gamma-\delta}{1-\gamma}}$$

$$\overline{E}_1 := \frac{\left(1 + \frac{\delta}{1-\gamma-\delta}\right)}{\left[\left(\overline{N}_1\right)^{\delta} \Delta^{\gamma}\right]^{\frac{1}{1-\gamma-\delta}}} + \alpha\epsilon\overline{N}$$

$$\overline{E}_2 := \frac{\alpha\eta\overline{N}}{1-\gamma-\delta} + \left(\frac{1}{\overline{N}^{\delta}\Delta^{\gamma}}\right)^{\frac{1}{1-\gamma-\delta}}$$

According to the sign of the coefficient Ω (see 23), two regimes can be distinguished:

REGIME DCS (Dirty Capitalistic Sector)

We denote regime DCS (Dirty Capitalistic Sector) the scenario in which η, the rate of environmental impact caused by the capitalistic sector, is relatively high (ceteris paribus) in comparison to the environmental impact of the traditional sector, measured by ε. That is, it holds $\Omega > 0$, where $\Omega > 0 \Leftrightarrow \frac{\eta}{\epsilon} > a(1-\gamma-\delta)$.

REGIME DTS (Dirty Traditional Sector)

We denote regime DTS (Dirty Traditional Sector) the scenario in which: $\Omega < 0$.

Now we can state the following proposition. The proof of such proposition requires straightforward but tedious calculations; so, due to space constraints, we omit it.

Proposition 1 *In the regime DCS (i.e. $\Omega > 0$), two fixed points with $\overline{N} > N_p > 0$ at most exist. In particular, if*

$$\overline{N} < \overline{N}_1,\ \overline{E}_1 < \overline{E} < \overline{E}_2$$

then two fixed points exist; if

$$\overline{N} \leq \overline{N}_1,\ \overline{E} \geq \overline{E}_2$$

then one fixed point exists; no fixed point exists in the remaining cases.

In the regime DTS (i.e. $\Omega < 0$), one fixed point with $\overline{N} > N_p > 0$ at most

exists. In particular, if

$$\overline{E} \geq \overline{E}_2$$

then the fixed point exists; no fixed point exists in the remaining cases.

In the regime DCS (i.e. $\Omega > 0$), if there exist two fixed points, in one of these the curve $G(E)$ intersects $F(E)$ from above in the plane (E, K) (we will indicate such point by the letter A) while in the other point (that we shall indicate by B) the opposite holds; in A the value of E is lower than in B. If only one fixed point is admissible, its configuration is like a point B, namely in it $G(E)$ intersects $F(E)$ from below (see **Figure 6** of the mathematical appendix). In the regime DTS (i.e. $\Omega < 0$), in the unique fixed point the curve $G(E)$ intersects $F(E)$ from above.

Proposition 1 highlights that the fixed points with $\overline{N} > N_p > 0$ exist only when the carrying capacity $\overline{E}$overcomes certain thresholds ($\overline{E} > \overline{E}_1$ if $\Omega > 0$ and $\overline{E} > \overline{E}_2$ if $\Omega < 0$). These thresholds are positively correlated to the rate of environmental impact caused by the two sectors (ϵ and η). Thus if the economic activities are too polluting then stationary points with $\overline{N} > N_p > 0$ don't exist.

The Proposition 1 also implies that it can always be found a $\overline{E}$ or $\overline{N}$ so that there exist two fixed points if $\Omega > 0$ and one fixed point if $\Omega < 0$, namely the maximum number of admissible stationary points.

Let (E^*, K^*, λ^*) denotes the fixed point value of the variables. The stability properties of fixed points depend on the signs of the eigenvalues associated to the Jacobian matrix J of the dynamical system (20)-(22) evaluated in (K^*, E^*, λ^*). We define "reachable" a fixed point that has at least two eigenvalues with negative real parts, i.e. with a 2 or 3-dimensional stable manifold. As a matter of fact, under the perfect foresight assumption, if the fixed point has a 2-dimensional stable manifold, given the initial values $K(0)$ and $E(0)$ of the state variables K and E, R-agents are able to fix the initial value $\lambda(0)$ of the jumping variable λ so that the growth trajectory starting from $(E(0), K(0), \lambda(0))$ approaches the fixed point. Therefore the fixed point can be reached by growth trajectories. If the fixed point has a 3-dimensional stable manifold, given the initial values $K(0)$ and $E(0)$ of state variables K and E, a continuum of initial values $\lambda(0)$ exist so that the growth trajectory starting from $(K(0), E(0), \lambda(0))$ approaches the fixed point.

Proposition 2 *The fixed points without specialization ($\overline{N} > N_p > 0$) are characterized by the following stability properties:*

In the regime DCS (i.e. $\Omega > 0$), the fixed point A is always not reachable while the fixed point B is always reachable if $\gamma + 2\delta - 1 < 0$ while, if $\gamma + 2\delta - 1 > 0$, the fixed point can be reachable or repulsive; however, if $E^* > \frac{1}{2}\left(\overline{E} - \epsilon\alpha\overline{N} - \frac{r\delta}{\gamma}\right)$, it is reachable.

In the regime DTS (i.e. $\Omega < 0$), the unique fixed point is always reachable.

Proof. See Appendix. ■

From Proposition 2, it follows that if the gap between the value of the parameter $\overline{E}$ - denoting the carrying capacity - and E^* is not too wide (namely if $E^* > \frac{1}{2}(\overline{E} - \epsilon\alpha\overline{N} - \frac{r\delta}{\gamma})$), the fixed point B is reachable. As we will see in the following sections, this gap depends on demographic pressure and on the environmental impact of the production of the Poor and of the Rich because E^* is decreasing in ϵ, η and $\overline{N}$. As long as the parameters ϵ, η and $\overline{N}$ overcome a certain threshold, the gap is such that the fixed point cannot be reached.

4.2 The case with specialization $N_p = 0$

In this context, the condition $\dot{E} = 0$ is satisfied along the graph of the function

$$K = F_0(E) := \frac{E^{\frac{1-\delta}{\gamma}}(\overline{E} - E)^{\frac{1}{\gamma}}}{(\eta\beta\overline{N}^{1-\gamma-\delta})^{\frac{1}{\gamma}}}$$

while the condition $\dot{\lambda} = 0$ is satisfied along the graph of the function

$$K = G_0(E) := \left(\frac{\beta\gamma}{r}\overline{N}^{\frac{1}{\gamma}}\right)^{\frac{1}{1-\gamma}} E^{\frac{\delta}{1-\gamma}}$$

Therefore the intersections between $F_0(E)$ and $G_0(E)$ identify the fixed points under the regime of perfect specialization in the production of the capitalistic sector.

To state the following proposition, we define

$$\Gamma := \frac{1-\gamma-\delta}{2-2\gamma+\delta}$$

$$\overline{E}_0 := \left(\frac{\overline{N}}{\Gamma}\right)^{\theta} \left(\frac{\left(\frac{\beta\gamma}{r}\right)^{\frac{1}{1-\gamma}}}{\frac{\gamma}{\eta r}(1-\Gamma)} \right)^{\frac{1-\gamma}{2-2\gamma-\delta}}$$

$$\overline{N}_0 := \frac{\eta r}{\gamma}(1-\Gamma)\left(\frac{\beta\gamma}{r}\right)^{\frac{1}{\gamma}} \left(\frac{\alpha\eta\Gamma^{\Gamma}}{a(1-\Gamma)(1-\gamma-\delta)}\right)^{\frac{2\gamma+\delta-1}{1-\gamma}}$$

By straightforward but tedious calculations, we can prove that:

Proposition 3 *Two fixed points with $N_p = 0$ at most exist. In particular, if*

$$\overline{N} < \overline{N}_0,\ \overline{E}_0 < \overline{E} < \overline{E}_2$$

then two fixed point exist; if

$$\overline{E} \geq \overline{E}_2$$

then one fixed point exists; no fixed point exists in the remaining cases.

When two fixed points with specialization exist, in one of these points (the fixed point that we will denote by A_0) the graph of $G_0(E)$ intersects that of $F_0(E)$ from above, viceversa in the other fixed point (which we will indicate by B_0) Furthermore, in A_0 the value of E is lower than in B_0. If only one fixed point exists, its configuration is like a point A_0 namely in this point $G_0(E)$ intersects $F_0(E)$ from above (see **Figure 7** of the mathematical appendix).

We can observe that $\overline{N}_0$ depends on r but not on $\overline{N}$, while $\overline{E}_2$ depends on $\overline{N}$ but not on r. Therefore Proposition 3 implies that, given $\overline{E}$, there always exist $\overline{N}$ and r such that at least one fixed point exists.

Proposition 4 *The fixed point A_0 is always not reachable, while B_0 can be reachable; in particular, it is always the case if*

$$E^* > \frac{1}{2}\left(\overline{E} - \frac{r}{\gamma(1-\gamma)}\right)$$

Proof. See Appendix. ■

It follows that the fixed point with complete specialization can be reached only when two fixed points with specialization exist, namely demographic pressure and carrying capacity do not cross a certain threshold (respectively $\overline{N}_0$ and

$\overline{E}_2$). Moreover, according to Proposition 4, E^* has to be sufficiently high, i.e. $E^* > \frac{1}{2}\left(\overline{E} - \frac{r}{\gamma(1-\gamma)}\right)$. These are sufficient conditions so that the system presents a reachable stationary state with disappearance of the traditional sector and a complete process of "proletarianization" with all the Poor employed in the capitalistic production.

We can also investigate whether the existence of fixed points with $N_p = 0$ is compatible with the existence of fixed points with $N_p > 0$. The following Proposition identifies sufficient conditions for the simultaneous existence of four fixed points A, B, A_0 and B_0.

Proposition 5 *If $\overline{N}_1 < \overline{N} < \overline{N}_0$, $max\{\overline{E}_1, \overline{E}_0\} < \overline{E} < \overline{E}_2$, $\Omega > 0$, then four fixed points exist: A_0 and B_0 with $N_p = 0$, A and B with $N_p > 0$.*

Proof. It follows from Proposition 1 and Proposition 3. ■

For a numerical example, see **Figure 1**. In a context with multiple reachable fixed points, the choice between B and B_0 depends on the initial conditions. This is a typical example of path dependence: the initial value of E and K determine the fixed point (B or B_0) that the growth trajectory will approach.These findings are clearly shown by the numerical simulations showed in **Figures 2-5**. In these Figures, the continuous (dotted) lines indicate values of E^* and K^* corresponding to reachable (respectively, unreachable) fixed points. Note that for some values of η and $\overline{E}$, the conditions set in Proposition 5 are satisfied: four fixed points exist and the initial levels of E and K determine whether B or B_0 will be reached. Moreover, as $\overline{E}(\eta\ )$ overcomes a minimum (maximum) level, only B_0-type fixed points with full specialization are compatible with the dynamic system and are approached. Thus, point B_0 can be generated as a final step of an "excessive" depletion of the stock of environmental resources.

5 Comparative statics

This section studies the role played by the variation of some significant parameters of the model. in determining a structural change, that is a variation of labor allocation between the two sectors of the economy, the traditional sector and the traditional one. To this end, we focus our attention on the variations of the coordinates of the reachable fixed point, in the context $\overline{N} > N_p > 0$. In particular, we are interested to study the impact on R-agent's consumption and accumulation, P-agent's consumption and labor allocation between the two

sectors, as well as natural capital. The following Proposition helps to identify the most significant variables that represent dynamics of the economy.

Proposition 6 *The fixed point value of consumption c_R^* of the Rich is positively proportional to the fixed point value of physical capital K^*. More precisely, it holds: $c_R^* = \frac{(\gamma+\delta)r}{\gamma}K^*$. The fixed point values of consumption c_S^* of the Poor working in the capitalistic sector and of consumption c_P^* of the Poor working in the traditional sector are positively proportional to the fixed point value of natural capital E^*. More precisely, it holds: $c_S^* = \frac{\alpha}{a}E^*$ and $c_P^* = \alpha E^*$.*

This implies that the Rich are able to effectively face environmental degradation through physical capital accumulation. It means that exogenous changes leading to an increase in K^* ensure a growing c_R^*, even if E^* declines. This is not the case for the Poor, whose well-being is positively proportional to E^*.

The above Proposition allows to focus on equilibrium values of N_p^*, E^* and K^*. From these variables, the well-being of Poor and Rich agents can be computed. In order to carry out some exercises of comparative statics, we study how the functions that identify the loci where $\dot{E} = 0$ and $\dot{\lambda} = 0$ move in relation to variations of parameters. The following proposition concerns the impact of a change in the more significant parameters on N_p^*, E^* and K^*; the proof is straightforward but tedious, so we omit it. Results are distinguished according to the relatively more environmental demanding sector DCS (i.e. $\Omega > 0$) and DTS (i.e. $\Omega < 0$) and according to the value of the expression $\gamma + 2\delta - 1$, introduced in Proposition 2, which can be interpreted as an indicator of modern sector dependency on natural capital. It holds $\gamma + 2\delta - 1 > 0$ if $\delta > \frac{1-\gamma}{2}$, where δ is the natural capital elasticity of the production function of the modern sector. So a positive value of $\gamma+2\delta-1$ indicates a "high" importance of natural resources in the production process of the modern sector. We will indicate by the symbol $x \uparrow$ (respectively, $x \downarrow$) an increase (respectively, a reduction) of x.

Proposition 7 *1) If $\overline{E} \uparrow$, then $N_P^* \uparrow$, $E^* \uparrow$ and $K^* \uparrow$ when $\gamma+2\delta-1>0$ while $N_P^* \uparrow$, $E^* \uparrow$ and $K^* \downarrow$ when $\gamma + 2\delta - 1 < 0$.*

2) If $\epsilon \uparrow$ or $\eta \uparrow$, then $N_P^* \downarrow$, $E^* \downarrow$ and $K^* \downarrow$ when $\gamma+2\delta-1>0$ while $N_P^* \downarrow$, $E^* \downarrow$ and $K^* \uparrow$ when $\gamma + 2\delta - 1 < 0$.

3) If $\beta \uparrow$, then:

3.1) $N_P^* \downarrow$, $E^* \downarrow$ and $K^* \downarrow$ or $K^* \uparrow$ when $\gamma + 2\delta - 1 > 0$ and $\Omega > 0$.

3.2) $N_P^* \downarrow$, $E^* \uparrow$ and $K^* \uparrow$ when $\gamma + 2\delta - 1 > 0$ and $\Omega < 0$.

3.3) $N_P^* \downarrow$, $E^* \downarrow$ and $K^* \uparrow$ when $\gamma + 2\delta - 1 < 0$ and $\Omega > 0$.

3.4) $N_P^* \downarrow$, $E^* \uparrow$ *and* $K^* \downarrow$ *or* $K^* \uparrow$ *when* $\gamma + 2\delta - 1 < 0$ *and* $\Omega < 0$.

The following sections discuss these comparative statics results.

6 Classification of structural changes

Comparative statics in the regime without specialization $\overline{N} > N_p > 0$ has shown that a change in some parameters of the model causes an impact on the fixed point value of N_p^*; that is, the economy reaches an equilibrium characterized by a different labor allocation between the two sectors. Thus a structural change comes out. The analysis focuses on structural changes in which labor shifts from the traditional to the modern sector (namely with $N_p^* \downarrow$). These transitions can be classified in four different typologies:

1) **Immiserizing structural change (ISC)** $N_p^* \downarrow$, $E^* \downarrow$, $K^* \uparrow$*: labor moves out from the subsistence sector, the stationary value of environmental stock declines as well as Poor agents' consumption, while the equilibrium physical capital and the Rich agent's consumption grow. Thus, the structural change is characterized by environmental degradation and increase in inequality. Rich is not negatively affected by environmental stress because they partially substitute natural capital with physical capital and wage labor employment.*

2) **Pro-poor Structural Change (PpSC)** $N_p^* \downarrow$, $E^* \uparrow$, $K^* \downarrow$*: labor shift is associated with a growth in the stationary value of natural capital and with a decrease in physical capital. That is, structural change benefits the Poor to detrimental of the Rich.*

3) **Positive Structural Change (PSC)** $N_p^* \downarrow$, $E^* \uparrow$, $K^* \uparrow$*: in this case, the structural change leads to a Pareto improvement. Both the Rich and the Poor are benefited and environment is preserved.*

4) **Negative Structural Change (NSC)** $N_p^* \downarrow$, $E^* \downarrow$, $K^* \downarrow$*: in this case, environmental degradation push labor force to the capitalistic sector but both the Rich and the Poor are harmed by the reduction in natural capital endowment.*

Comparative statics results of our model have shown that alternative scenarios can emerge. Table 1 and 2 associate to variations of parameters the corresponding structural change type.

Parameter	$\Omega > 0$			Typology	$\Omega < 0$			Typology
	N_p^*	E^*	K^*		N_p^*	ΔE^*	K^*	
$\overline{E} \downarrow$	$\downarrow$	$\downarrow$	$\uparrow$	ISC	$\downarrow$	$\downarrow$	$\uparrow$	ISC
$\beta \uparrow$	$\downarrow$	$\downarrow$	$\uparrow$	ISC	$\downarrow$	$\uparrow$	$\updownarrow$	PpSC / PSC
$\eta \uparrow$ or $\epsilon \uparrow$	$\downarrow$	$\downarrow$	$\uparrow$	ISC	$\downarrow$	$\downarrow$	$\uparrow$	ISC

Table 1: Comparative statics if $\gamma + 2\delta - 1 < 0$

Parameter	$\Omega > 0$			Typology	$\Omega < 0$			Typology
	N_p^*	E^*	K^*		N_p^*	E^*	K^*	
$\overline{E} \downarrow$	$\downarrow$	$\downarrow$	$\uparrow$	ISC	$\downarrow$	$\downarrow$	$\downarrow$	ISC
$\beta \uparrow$	$\downarrow$	$\downarrow$	$\updownarrow$	ISC /NSC	$\downarrow$	$\uparrow$	$\uparrow$	PSC
$\eta \uparrow$ or $\epsilon \uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	NSC	$\downarrow$	$\downarrow$	$\downarrow$	NSC

Table 2: Comparative statics if $\gamma + 2\delta - 1 > 0$

The following section attempts to schematize, highlight and discuss our findings.

7 Interpretation of results

7.1 Classical context

As seen in the introduction, the bulk of contributions on structural change neglects environmental dynamics. That is, environmental externalities of economic activities are assumed to be equal to zero. Therefore, as technical progress in the modern sector grows, the modern sector expands over time, population is pulled by labor demand and no impact affects the environment. The result is that the ecosystem is preserved, labor remuneration initially remains stable and inequality increases but, when labor surplus is completely absorbed, labor earnings start to grow too. In our model this scenario is represented by the effect of an increase of β with $\eta = 0$ and $\epsilon = 0$. In such context, the coordinates of the

fixed point are

$$K^* = \left(\frac{\beta\gamma \overline{E}^{\delta} (\overline{N} - N_p^*)^{1-\gamma-\delta}}{r} \right)^{\frac{1}{1-\gamma}}$$

$$E^* = \overline{E}$$

$$\lambda^* = \left(\frac{r}{\gamma} \right)^{\frac{\gamma}{1-\gamma}} \frac{1}{\gamma+\delta} \left(\beta \overline{E}^{\delta} (\overline{N} - N_p^*)^{1-\gamma-\delta} \right)^{\frac{1}{1-\gamma}}$$

where

$$(\overline{N} - N_p^*) = \left(\frac{a}{\alpha} 1 - \gamma - \delta \right)^{\frac{1-\gamma}{\delta}} \left(\frac{\gamma}{r} \right)^{\frac{\gamma}{r}} \beta^{\frac{1}{\delta}} \overline{E}^{\frac{\gamma+\delta-1}{\delta}}$$

Moreover the wage is given by

$$w = (1 - \gamma - \delta) \left(\frac{\gamma}{r} \beta^{\frac{1}{\gamma}} \right)^{\frac{\gamma}{1-\gamma}} \left(\frac{\overline{E}}{\overline{N} - N_p^*} \right)^{\frac{\delta}{1-\gamma}}$$

It follows that an increase in β causes a rise in K^*, namely an improvement in well-being of the Rich, while the natural capital is not affected by human activities and it is equal to its carrying capacity $\overline{E}$. Therefore the stationary value of Poor agents' welfare does not change. However, if the growth of β is sufficiently high to lead to a full specialization in the capitalistic sector the wage rate will be defined as follows

$$w = (1 - \gamma - \delta) \left(\frac{\gamma}{r} \beta^{\frac{1}{\gamma}} \right)^{\frac{\gamma}{1-\gamma}} \left(\frac{\overline{E}}{\overline{N}} \right)^{\frac{\delta}{1-\gamma}}$$

That is, w is positively linked to β. Consequently as β grows, labor remuneration increases too.

7.2 Dual context

Most of two-sectors models with environmental externalities (e.g. Eliasson and Turnovsky 2004, López et al. 2007) distinguish between a clean and non-

resource sector (it comprises activities that do not employ natural capital neither pollute) and a dirty resource sector (i.e. activities that use natural resources as input of production and that cause an environmental impact). Under some assumptions on the values of parameters, our model can reflect these characterizations. Given that the traditional sector tends to be more dependent on natural resources, in our model this case occurs when $\eta = \delta = 0$ (where η and δ are respectively the environmental impact and natural capital elasticity of the capitalistic sector production) and consequently $\Omega < 0$ and $\gamma+2\delta-1 = \gamma-1 < 0$. However, differently from Eliasson and Turnovsky's and López's models, in our context this specification is not neutral from a distributional point of view. Indeed, it implies that the production of the Poor represents the dirty sector, while the R-agent is involved in clean production. In this context, consistently with other models, an increase in β leads to a positive structural change and the economy tends to a fixed point with a higher level of natural and physical capital, so well-being of the Poor and the Rich agents increases. However, if the movement of labor is caused by an increase in environmental pressures (for example $\epsilon \uparrow$ - i.e. the environmental impact of the traditional sector rises- or $\overline{E} \downarrow$ - i.e. carrying capacity decreases), the final result is an immiserizing structural change: the traditional sector is affected by the reduction in natural capital, while the Rich are not harmed. Indeed, the capitalistic sector is benefited by the access to labor at low cost and this, in turn, produces incentives for investment in physical capital. Both structural changes are positive for the representative Rich agent but the results in terms of the capitalistic sector output are different. Note that labor productivity in the modern sector is equal to $\beta(1-\gamma-\delta)K^{\gamma}(\overline{N}-N_p)^{-\gamma-\delta}$. Thus, even if $\beta \uparrow$, $\epsilon \uparrow$ or $\overline{E} \downarrow$ lead to the same labor shift, in the first scenario labor productivity grows more than in the other cases. Therefore, the immiserizing structural change leads to an expansion of the capitalistic sector associated with a lower labor productivity than in the positive structural change.

7.3 Interdependent context

The economy represented by our model is characterized by a more complex context: both sectors produce and are affected by natural resource degradation. The analytical study of our model has shown that alternative scenarios can emerge.

7.3.1 How much the environment matters for the Poor and for the Rich

The basic hypothesis of this work is the non-homogenous distribution of assets. The model analyzes a stylized case in which physical capital is completely concentrated in the endowments of a social class (the upper class), while all agents have access to environmental capital. Although this is a highly stylized fact, it reflects the ways in which different assets (natural, physical, social, human capital) are typically distributed. Physical capital tends to have a low dispersion across the population because of financial market failures. In absence of perfect information and competition, the wealthier individuals and large firms have a privileged access to capital market, because they are more endowed with collateral and they have a higher ability to exploit scale economies. Conversely, the services coming from environmental resources may be more dispersed and tend to have characteristics of public goods (in our model all agents have access to environmental capital). In this context, economic agents also differ in feed-back mechanisms and interactions between their choices of production (consumption) and environmental dynamics. The case with $\gamma + 2\delta - 1 < 0$ (namely the modern sector has a relatively low dependence on natural resources) sheds light on the consequences determined by the initial hypothesis of physical asset concentration and free access environmental capital. From Proposition 7 it follows that in this context the model tends to be a zero-sum game. Physical capital endowments allow the Rich to employ wage labor too and this possibility lies at the roots of a conflict between the Rich (labor employers), and the Poor (labor force providers). The Rich are more able to defend themselves from environmental degradation because they can partially substitute natural capital with physical capital or wage labor 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 labor supply from the traditional sector to the modern one. Therefore they take advantage of the possibility to exploit labor at a lower cost. This, in turn, generates incentives to physical capital accumulation. On the other hand, the poor are harmed because they face a reduction in productivity of their labor, namely of their major mean of subsistence. In this context a reduction of the environmental impact of the economic activities (i.e. a reduction of ϵ or η) or an increase in the carrying capacity $\overline{E}$ not only help preservation of environment

(equilibrium stock of natural capital grows), but they have a distributive impact too.

7.3.2 Conditions for positive structural change

The comparative statics of an increase in β pinpoints the consequences of considering environmental dynamics. 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, our model shows that this scenario can occur only if the modern sector has a relatively low environmental impact in comparison to the traditional one (i.e. $\Omega < 0$). In this case, a rise in β determines an increase in labor productivity in the market sector leading to a growth in wage of workers employed by the Rich as well as an augmentation of c_R^*. At the same time, the movement of labor caused by an increase in labor demand reduces the demographic pressures on natural resources with positive effect on labor productivity in the subsistence sector too. In particular, the following result holds:

Proposition 8 *$\beta \uparrow$ and $\Omega < 0$ are necessary conditions for a positive structural change, that is a labor transition to the capitalistic sector associated with an increase in well-being for the Poor and the Rich agents. In all other cases, a parameter variation that causes a labor shift to the capitalistic sector leads to an immiserizing or a negative transition driven by push forces.*

Other variations of the parameters (for example an increase in carrying capacity or a reduction in rates of environmental impact ϵ or η) lead to higher level of natural and physical capital but they are not accompanied by a process of proletarianization. Proposition 8 highlights a novel requirement for positive structural changes: labor reallocation towards the non subsistence sector can lead to poverty reduction only if the capitalistic sector is not too polluting, namely it produces relatively low environmental externalities in comparison to the traditional activities. The positive structural change also represents the labor transition associated with the highest level of labor 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 SC. Looking at policy implications, we can conclude that, in a country with high income and asset concentration and where the capitalistic

sector is quite polluting or environment demanding, measures for controlling environmental externalities of the capitalistic sector are necessary not only for sustainability, but also for economic growth and poverty alleviation. Therefore policies aiming at promoting a positive structural change require that government support to capitalistic sector productivity (such as incentives, direct and indirect subsidies for capital accumulation, financial grants, tax exemptions, public credit, favorable regulations, financing of infrastructures and so on) does not include measures too permissive in terms of environmental externalities[32].

7.3.3 Undesirable economic growth

Not only an increase in β might fail to trigger off positive structural change, but it can also cause an immiserizing structural change (refer to Propositions 7 and 8). In particular, we focus on effects of an increase in β in a DCS regime. This case clearly shows that, 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 economic growth is a not a sufficient condition for reducing poverty, but distributional dynamics play a decisive role in shaping effects of economic growth on poverty rates. A stylized fact commonly accepted is that negative rates of economic growth tend to disproportionately hit lower income quintiles, but at the same time a positive performance may neglect the poorest. However, in practice, economic growth remains one of the main goals pursued by national governments and international institutions. Although a positive trend in GDP growth does not insure per se an increase in well-being of the Poor, it is seen as a necessary condition. 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 β when $\Omega > 0$ raise doubts about this expected virtuous relationship between economic growth, poverty reduction and preservation of ecosystems. Indeed, in this scenario the environmental externalities may contribute to generating an undesirable and self-reinforcing path of expansion of the modern sector associated with a process of impoverishment[33]: the capitalistic sector grows producing push forces on

[32]Environmental externalities can be represented by resource contamination or depletion but also, adopting a broader definition, by expulsion of other users from the access to natural resources.

[33]Models that predict scenarios with undesirable economic processes are not new in literature. Actually, Antoci (1996), Antoci and Bartolini (1999, 2004), Antoci (2008) and Antoci

the Poor due to the environmental pressures, labor moves out the subsistence sector and the capitalistic sector further expands. This unexpected result may be explained by the fact that positive impact of a growing β 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 β may reduce well-being of the Poor if it is not accompanied by counterbalancing factors such as a rise in α (i.e. total factor productivity of the traditional sector) or a reduction in η (i.e. environmental impact of the capitalistic sector). The parameters α and β can be affected by public investments. 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 [34].

7.3.4 Consequences of a high dependence on natural resources

From Proposition 7 it follows that if the modern sector is more resource-based (i.e. $\gamma + 2\delta - 1 > 0$) the Rich are more vulnerable to environmental degradation.

et al. (2005, 2008) propose models in which negative externalities may constitute an engine of economic growth. In their models, economic growth produces negative externalities that reduce the capacity of natural or social environment to provide free goods. Agents try to defend themselves from well-being losses by increasing their labor supply in order to rise their consumption of private goods that are substitute of free access goods. This, in turn, leads to economic growth. As result, defensive strategies generate a growth path that is Pareto dominated in terms of well-being.

[34] Claims of representatives of organisations of peasants, fisher peoples, victims of tsunami (Via Campesina, World Forum of Fisher Peoples) can be interpreted also in the light of these findings. In the final declaration of Regional Conference on Rebuilding Peasants' and Fisherfolk's Livelihoods After the Earthquake and Tsunami Catastrophes (Medan-Indonesia, 17-19 February 2005) the following statements can be read: After the terrible destruction caused by the quake-induced tsunami, hundreds of thousands of victims have had to flee their homes, their fishing grounds and farmlands and shift to relief camps, leading to a great sense of despair and despondency in having to depend on charity and others for their living. This condition has only been worsened by the attempts of governments in some tsunami-hit countries to clear the beaches and coastal areas in the name of tsunami-preparedness, preventing coastal communities from exercising control of, and access to, traditional sources of beach-based economic activities, while simultaneously planning to hand them over to corporate and business interests in the tourism, industrial fisheries and aquaculture, and maritime industries..... Rehabilitation and reconstruction activities in the affected coastal areas should give utmost priority to traditional, artisanal, small-scale communities relying on beach-based fishing activities, and not to large scale mechanized fishing vessels or industrial aquaculture farms.....We reject aid for the affected coastal fishing communities that are not locally appropriate or designed to suit the needs of beach-based labor-intensive fishing practised by most coastal fishing communities in the affected regions, in contrast to the harbour-based fishing prevalent in the donor countries (www.viacampesina.org).

In this context, a variation in parameters produces an impact with the same sign to the Rich and the Poor, namely their utility are positively correlated. Thus, a reduction of E, due to a decrease in the carrying capacity or to an increase in η or ϵ, leads the economy to stationary states associated with lower level of well-being both for the Poor and for the Rich because natural resources are relevant for their production activity. Therefore, in the long run, 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, but they require similar interventions (such as measures for raising carrying capacity or legislation, controls and incentives for adoption of sustainable practices or technologies that reduces η or ϵ).

7.3.5 Effects of resource abundance and environmental preservation

Proposition 7 provides information on the relationship between resource abundance and structural change. According to these findings, in all scenarios we have that $\overline{E} \uparrow$, $\epsilon \downarrow$ or $\eta \downarrow$ lead to $E^* \uparrow$ and $N_p^* \uparrow$. Thus, scarcity of natural resources represents a push force of labor factor towards the capitalistic sector, while natural capital abundance (given by a high endowment of natural capital stock or a low environmental impact of human action) tends to delay labor shift to the modern sector and physical capital accumulation while at the same time reducing poverty. If the modern sector is seen as engine of growth, our results are consistent with the "resource curse hypothesis". At the same time, unlike this literature, in our model agents' well-being and economic growth are not always coincident: natural capital abundance is not a curse but a resource against processes of impoverishment even if it can be an obstacle to economic growth. However, though our findings recall this literature, some differences have to be considered. Studies on "resource curse" have focused on settings that are not likely to be represented by high $\overline{E}$. In our model, the environmental resources are public goods that all agents have access to, while well resource endowed countries have been identified according to per capita land (Wood and Berge 1997), primary export share (Sachs and Warner 1997) or abundance of point resources (mining, oil and, in a certain measure, plantations)[35]. However the use of per capita land as a proxy of resource wealth does not capture dis-

[35]Mineral resources, oil, plantations which require immediate processing can be considered examples of "point" resources because their rents and sources are not diffuse, but they are concentrated. These sectors are typically characterized by concentrate ownership and capital intensive production processes.

tributive aspects, while point resources are more likely to be appropriated by a narrow elite and export oriented primary activities can be assimilated to what we have called "modern" sector: they often adopt capital intensive techniques of production, employ wage workers and are managed by the rich. In these cases environmental resources are not public but excludible goods that are mainly enjoyed by the rich. Therefore it can be concluded that, even if our results are not tested by the studies on performance of resource-rich countries in terms of poverty and inequality, they are not in opposition to this literature. Moving to change in labor allocation, we observe that the positive (negative) relationship between ϵ and η (respectively, $\overline{E}$) and "proletarianization" is consistent with the empirical evidences in many countries. Chopra and Gulati (2001) show that, in India's arid and semiarid regions, environmental degradation tends to force people to move to urban areas during time of distress, especially during droughts, while measures reducing environmental pressures lead to a decrease in migration flows. In Nepal, out-migration to seek wage employment is one of the strategies adopted by farmers in the hills to cope with soil erosion and land degradation that is due to bad land use practices and to natural factors (World Bank, 1995). The investigations on environmental degradation and migration between the US and Mexico (Schwartz and Notini 1994) confirmed that the inability to make living from the land due to dry conditions and processes of soil erosion contribute to the decision of rural people to migrate. Similar evidences are found also in Africa where climate variability, climate change and unsustainable human activities (overcultivation, overgrazing, deforestation, and poor irrigation practices) lead to an increasing process of desertification that forces people to emigrate both in other rural and urban areas (UNCCD, 2005). Finally, a cross-country analysis, conducted by Shandra et al. (2003) on a panel of fifty-eight developing countries, finds that deforestation exerts a positive effect on over-urbanization whereas environmental sustainability produces a negative impact on over-urbanization. According to these results, developing countries suffering environmental degradation would be prone to over-urbanization. Environmental pressures of the poor might be worsened by the fact that rises in η and ϵ are likely to occur at the same time. As already noted, environmental stress caused by the Rich may lead to the disruption of sustainable traditional institution, a process of migration of the Poor in fragile areas, further impoverishment which induces short-sighted choices and higher environmental pressures (López 1998). If $\gamma + 2\delta - 1 < 0$, this may exacerbate the increase in income distribution inequality produced directly by the environmental impact of the

market sector. In fact, c_p declines, while the consumption level of the Rich is not negatively affected by environmental pressures because they can rely on physical capital accumulation and employment of wage labor.

8 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)In the model the capitalistic sector is interpreted as the combination of the modern activities and what we have called the sector of informal small enterprises. The labor 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 labor surplus would emerge and would lead to a better sectorial diversification between the modern and the informal urban activities. In this case, it would be interesting to analyze 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). However, it has been noted that several countries have undertaken trade liberalization reforms and, consequently, the importance of the domestic market has diminished, at least for the traded sectors. In open economies, a factor for export-led economic growth is production competitiveness that is partially represented in the model

through labor costs. As already underscored, 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 common or private property (for example land) could be investigated in order to assess whether other property right regimes are likely to lead to different findings. 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. A great attention has been devoted to the theoretical and empirical analysis of the impact of property or tenure right regime on incentives for environmental preservation, short- or long-run strategies, free-riding or collective actions. However we believe that it is not possible to classify the regimes according to the environmental degradation that are likely to produce. Bromley (2006), for example, demonstrates the plausibility of the degradation of Africa commons arising from factors outside the commons (namely market forces, isolation and general institutional arrangements at nation-state level) rather than arising from standard accounts of selfish behavior within the commons. At the same time, the relationship between privatization of common property resources (or the formalization of individual titles) and investment in land has been challenged by many authors[36] (Atwood 1990, Carter and Olinto 2003, de Janvry et al. 2001, Deininger and Feder 2001, Fitzpatrick 2005, Migot-Adholla et al. 1991, Place and Hazell 1993, Sjaastad and Bromley 1997 and 2000), while the literature has emphasized that a community's ability to properly manage environmental resources might depend on

[36]According to Baland and Platteau (1996), to be efficient, privatization programs have to ensure well defined property rights, all markets have to exist and to be competitive, and transaction costs for the enforcement of property rights must be absent. Most of developing countries fail to verify these conditions: input and capital markets are imperfect and segmented, the dismantling of traditional systems can increase the transaction costs and lead to conflicts over resources and to violent reactions by those who are excluded, the State is often not able to assign clear and defined titles, while privatization tends to privilege the political and economic elites who may use resources for non-productive purposes (rent-seeking activities, hedge against inflation, speculative or privilege purposes etc). For a review of the studies on the relationship between titling and land investment incentives see Bromley (2007).

several conditions[37]. Therefore we have preferred to focus the analysis on a open-access regime and to successively analyze different scenarios according to the exogenous rate of environmental impacts (ϵ and η) instead of endogenously deriving incentives for investment in ecosystem preservation. 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.

9 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, global warming effects and ocean acidification) 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 labor 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 on the basis of distributive, environmental and economic impact and we have attempted to identify under which

[37]For a review of literature on itra-community governance issues see Agrawal (2001), while for the role of external forces refer to Engel and López (2004) and Bromley (2006a).

conditions each SC can occur. Firstly, the work has identified new requirements for prompting positive structural changes, i.e. a movement of labor 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.

10 Appendix

10.1 Proof Proposition 2

Recalling the definition of M and noticing that $N_p = \overline{N} - MK^{\frac{\gamma}{\gamma+\delta}}E^{\frac{\delta-1}{\gamma+\delta}}$ the dynamic system becomes

$$\dot{K} = \beta(\gamma+\delta)K^{\frac{\gamma}{\gamma+\delta}}E^{\frac{2\delta+\gamma-1}{\gamma+\delta}}M^{1-\gamma-\delta} - \frac{1}{\lambda} \tag{24}$$

$$\dot{E} = E(\overline{E}-E) - \epsilon\alpha\overline{N} + K^{\frac{\gamma}{\gamma+\delta}}E^{\frac{\delta-1}{\gamma+\delta}}M(\epsilon\alpha - \eta\beta M^{-\gamma-\delta}) \tag{25}$$

$$\dot{\lambda} = \lambda\left(r - \beta\gamma K^{-\frac{\delta}{\gamma+\delta}}E^{\frac{2\delta+\gamma-1}{\gamma+\delta}}M^{1-\gamma-\delta}\right) \tag{26}$$

Let (K^*, E^*, λ^*) denotes the fixed point values of (K, E, λ). Remember that fixed points of our sistem correspond to the intersections between the graphs of the functions $K = F(E)$ and $K = G(E)$ occurring below the curve $K = L(E)$ in the plane (E, K) (see **Figure 6**) It is easy to check that **Figure 6** shows all possible configurations of curves $K = F(E)$ and $K = G(E)$; in such figure,

$E_1 := \dfrac{1-\delta}{1+\gamma}(\overline{E}-\epsilon\alpha\overline{N})$ indicates the value of E maximizing $F(E)$; furtheremore, when the curve $K = L(E)$ is not drawn, this means that both the intersections between $K = F(E)$ and $K = G(E)$ occur below $K = L(E)$; that is, both intersections give rise to fixed points in the regime $\overline{N} > N_p > 0$.

Before calculating the Jacobian matrix, we note that from (25) and (26) it follows that in the fixed point it holds

$$\frac{1}{\lambda} = \frac{r(\gamma+\delta}{\gamma}K^* \tag{27}$$

and

$$\overline{N} - N_p^* = \frac{\overline{E} - E^* - \epsilon\alpha\overline{N}}{\Omega}$$

By straightforward calculations we now find the Jacobian matrix evaluated at the steady state (J^*)

$$J^* = \begin{pmatrix} h_K^* & h_E^* & h_\lambda^* \\ f_K^* & f_E^* & f_\lambda^* \\ g_K^* & g_E^* & g_\lambda^* \end{pmatrix}$$

where

$h_K^* = r$

$h_E^* = \dfrac{r(\gamma+2\delta-1)K^*}{\gamma E^*}$

$h_\lambda^* = \dfrac{1}{\lambda^2} = \left(\dfrac{r(\gamma+\delta)K^*}{\gamma}\right)^2$

$f_K^* = -\dfrac{\gamma}{\gamma+\delta}\dfrac{E^*(\overline{N}-N_p^*)\Omega}{K^*}$

$f_E^* = (1+\gamma)\dfrac{E_1 - E^*}{\gamma+\delta}$

$f_\lambda^* = 0$

$g_K^* = \dfrac{\gamma\delta}{(K^*)^2(\gamma+\delta)^2}$

$g_E^* = -\dfrac{\gamma}{(\gamma+\delta)^2}\dfrac{\gamma+2\delta-1}{E^*K^*}$

$g_\lambda^* = 0$

Therefore, h_K^*, h_λ^* and g_K^* are always positive, h_E^* and $\rho := \gamma + 2\delta - 1$ have the same sign, g_E^* and ρ have opposite sign, f_K^* and $E_1 - E^*$ have the same sign, f_K^* and Ω have the opposite sign.

In order to study the stability properties of fixed points, we apply the methodology proposed by Wirl (1997). The eingenvalues of the system are

the roots of the following characteristic polynomial

$$P(z) = z^3 - z^2 tr(J^*) + zM_2 - |J^*|$$

where

$$tr(J^*) = k_k^* + f_E^* + g_\lambda^* \qquad |J^*| = h_\lambda^*(f_K^* g_E^* - f_E^* g_K^*) \qquad M_2 = -h_\lambda^* g_K^* + h_K^* f_E^* - h_E^* f_K^*$$

Therefore, the following results can be easily proved.

Lemma 1 *If $E^* < E_1$, then $tr(J^*) > 0$.*

Lemma 2 *If $\Omega > 0$, then $|J^*| < 0$ in A and $|J^*| > 0$ in B.*
If $\Omega < 0$, in the unique admissible fixed point it holds $|J^*| > 0$.

Lemma 3 *If $\rho < 0$, then $M_2 < 0$.*
If $\rho > 0$ and $\Omega < 0$, then $M_2 < 0$.
If $\rho > 0$ and $\Omega > 0$, a sufficient condition for $M_2 < 0$ is $E^* > \frac{1}{2}\left(\overline{E} - \epsilon\alpha\overline{N} - \frac{r\delta}{\gamma}\right)$.

It is now possible to discuss stability properties of A and B, in the regime $\Omega > 0$, and of the unique admissible point in the regime $\Omega < 0$. As explained in the main text, we define "reachable" those fixed points with at least two eigenvalues with negative real parts, i.e. with a 2 or 3-dimensional stable manifold.

10.1.1 Stability analysis of A

In A, it holds $|J^*| < 0$; therefore, such fixed point may be unreachable (a saddle point with two positive eingenvalues) or locally attractive (i.e. a sink). Conditions for local attractivity are (Wirl, 1997): $tr(J*) < 0$, $|J^*| < 0$ and $M_2 < 0$. **Figure 6** shows that the fixed point A can assume two possible configurations. In the cases (a) and (b), it holds $\rho < 0$; thus, from Lemma 3, it follows that $M_2 < 0$, therefore A cannot be attractive. This implies that A is unreachable. In the cases (e) and (f), in A it holds $E^* < E_1$; this implies, by Lemma 1, that $tr(J*) > 0$. Thus A cannot be attractive and it is unreachable. In short, the fixed point A is always not reachable.

10.1.2 Stability analysis of B and of the fixed point in the regime $\Omega < 0$

In B and in the fixed point in the regime $\Omega < 0$ it holds $|J^*| > 0$; therefore, such fixed points can be repulsive or reachable (Wirl 1997). Wirl finds that a

positive determinant and a negative coefficient M_2 are sufficient conditions for saddle point stability (i.e. for reachability). Given Lemma 2 and Lemma 3, this happens when $\rho < 0$ (**Figure 6**, cases a-d) or when $\rho > 0$ and $\Omega < 0$ (**Figure 6**, case h). If $\rho > 0$ and $\Omega > 0$, the sign of M_2 is not univocally determined. Consequently, in this case, B can be repulsive or reachable. However, by Lemma 3, $E^* > \frac{1}{2}\left(\overline{E} - \epsilon\alpha\overline{N} - \frac{r\delta}{\gamma}\right)$ is a sufficient condition for saddle point stability (**Figure 6**, cases e-g); this completes the proof of Proposition 2.

10.2 Proof of Proposition 4

In order to study the stability proprieties of fixed points in the reime $N_p = 0$, we calculate the Jacobian matrix J_0^* evaluated at a fixed point (K^*, E^*, λ^*) with $N_p = 0$

$$J_0^* = \begin{pmatrix} h_{0K}^* & h_{0E}^* & h_{0\lambda}^* \\ f_{0K}^* & f_{0E}^* & f_{0\lambda}^* \\ g_{0K}^* & g_{0E}^* & g_{0\lambda}^* \end{pmatrix}$$

Remembering that $r - \beta\gamma K^{\gamma-1}E^{\delta}\overline{N}^{1-\gamma-\delta} = 0$, we have

$h_{0E}^* = \dfrac{r\delta(\gamma+\delta)K^*}{\gamma E^*} > 0$

$h_{0K}^* = (\gamma+\delta)r > 0$

$h_{0\lambda}^* = \dfrac{r^2(\gamma+\delta)^2(K^*)^2}{\gamma^2} > 0$

$f_{0E}^* = \overline{E}(1-\delta) - (2-\delta)E^* > 0$, if $E^* < E_M := \dfrac{\overline{E}(1-\delta)}{2-\delta}$

$f_{0K}^* = -\eta r < 0$

$f_{0\lambda}^* = 0$

$g_{0E}^* = -\dfrac{\gamma\delta}{(\gamma+\delta)K^*E^*} < 0$

$g_{0K}^* = \dfrac{\gamma(1-\gamma)}{(\gamma+\delta)(K^*)^2} > 0$

$g_{0\lambda}^* = 0$

Let us first consider $tr(J_0^*) = h_{0K}^* + f_{0E}^*$.

Figure 7 shows all possible configurations of the fixed points with $N_p = 0$. Remember that fixed points correspond to the intersections between the graphs of the functions $K = F_0(E)$ and $K = G_0(E)$ occurring above the curve $K = L(E)$ in the plane (E, K). In such figure, E_M indicates the value of E maximizing $F_0(E)$; furtheremore, when the curve $K = L(E)$ is not drawn, this means that both the intersections between $K = F_0(E)$ and $K = G_0(E)$ occur

above $K = L(E)$; that is, both intersections give rise to fixed points in the regime $N_p = 0$.

Note that in A_0 it holds $E^* < E_M$; therefore $f^*_{0E} > 0$ and $tr(J^*_0) > 0$ (see cases a-b in **Figure 7**).
In **Figure 7a**, in B_0 it holds $E^* < E_M$; therefore $f^*_{0E} > 0$ and $tr(J^*_0) > 0$.
In **Figure 7b**, in B_0 it holds $E^* > E_M$; therefore $f^*_{0E} < 0$ and the sign of $tr(J^*_0)$ is not univocally determined.

Let us now analyze the sign of $|J^*_0| = h^*_{0K}(f^*_{0K}g^*_{0E} - f^*_{0E}g^*_{0K})$. We can observe that in A_0 it holds $F_{0E} > G_{0E}$, while in B_0 it holds $F_{0E} < G_{0E}$, where $F_{0E} = -\dfrac{f_{0E}}{g_{0K}}$ and $G_{0E} = -\dfrac{g_{0E}}{g_{0K}}$. It follows that $|J^*_0| < 0$ in A_0 while $|J^*_0| > 0$ in B_0. If only one fixed point exists (**Figure 7c**), then in such point it holds $F_{0E} < G_{0E}$ and consequently $|J^*_0| > 0$.

Let us consider

$$M_{02} = -h^*_{0\lambda}g^*_{0K} + h^*_{0K}f^*_{0E}f^*_{0K} = -\frac{r^2(\gamma+\delta)}{\gamma(1-\gamma)} + r(\gamma+\delta)(\overline{E}(1-\delta) - (2-\delta)E^*) + \frac{\delta\eta r^2(\gamma+\delta)K^*}{\gamma E^*}$$

Replacing $K^* = \dfrac{\gamma(\overline{E} - E^*)}{r\eta}$, we obtain

$$M_{02} = -\frac{r^2(\gamma+\delta)}{\gamma(1-\gamma) + (\overline{E}(1-\delta) - (2-\delta)E^*) + \delta(\overline{E} - E^*)} > 0$$

if $E^* > \dfrac{1}{2}\left(\overline{E} - \dfrac{r}{\gamma(1-\gamma)}\right)$.

10.2.1 Stability analysis of A_0

Since in A_0 it holds $|J^*_0| < 0$, such fixed point can be a saddle point with two positive eingenvalues or a sink. Given that $tr(J^*_0) > 0$, local attractivity is excluded and the fixed point A_0 is always not reachable.

10.2.2 Stability analysis of B_0

In B_0 we have $|J^*_0| > 0$; therefore such fixed point can be repulsive or reachable (Wirl 1997). If $E^* > \dfrac{1}{2}(\overline{E} - \dfrac{r}{\gamma(1-\gamma)})$ then $M_{02} < 0$ and the fixed point cannot be repulsive. That is $E^* > \dfrac{1}{2}\left(\overline{E} - \dfrac{r}{\gamma(1-\gamma)}\right)$ is a sufficient condition for saddle point stability.

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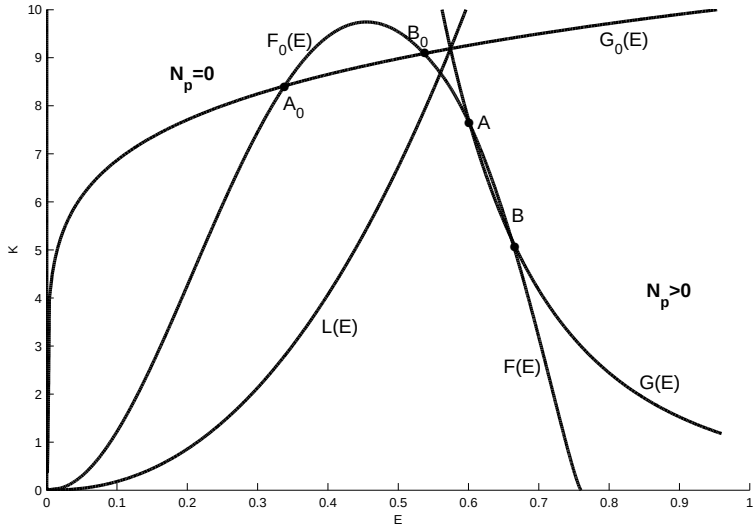


Figure 1: Four fixed points: A_0 and B_0 with $N_p = 0$, A and B with $N_p > 0$. The parameters' values are: $\alpha = 2$, $\beta = 1$, $\gamma = 0.4$, $\delta = 0.1$, $\epsilon = 0.1$, $\eta = 0.1$, $a = 1$, $r = 0.1$, $\overline{E} = 0.96$, $\overline{N} = 1$.

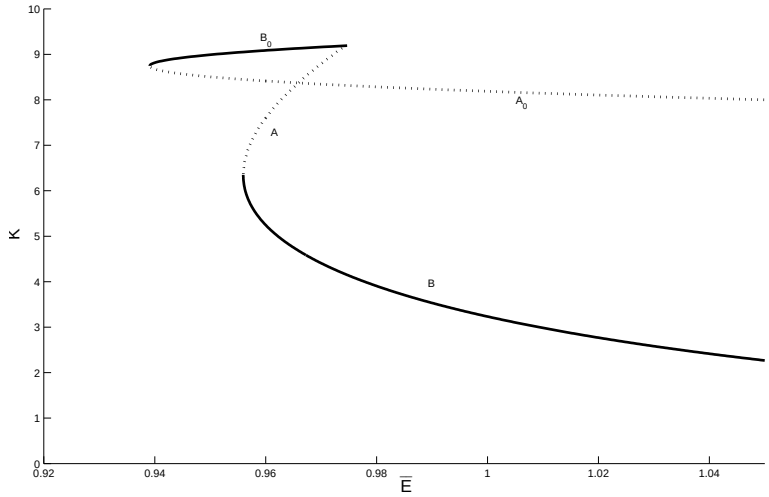


Figure 2: The value of K, evaluated at the fixed points with $N_p > 0$ and $N_p = 0$ varying $\overline{E}$. The dotted lines represent the unreachable fixed points, while the continuous lines represent the reachable fixed points.

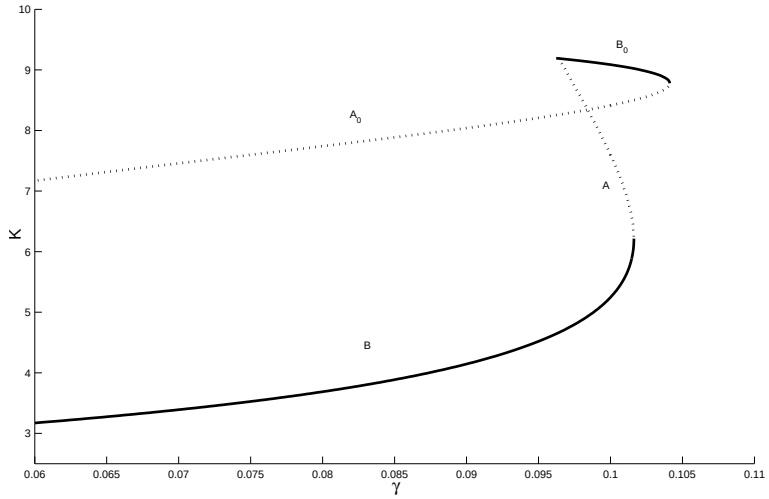


Figure 3: The value of K, evaluated at the fixed points with $N_p > 0$ and $N_p = 0$ varying η. The dotted lines represent the unreachable fixed points, while the continuous lines represent the reachable fixed points.

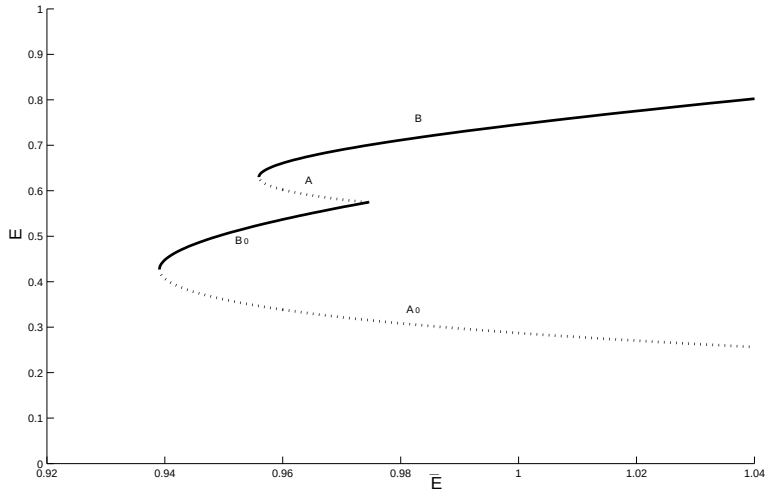


Figure 4: The value of E, evaluated at the fixed points with $N_p > 0$ and $N_p = 0$ varying $\overline{E}$. The dotted lines represent the unreachable fixed points, while the continuous lines represent the reachable fixed points.

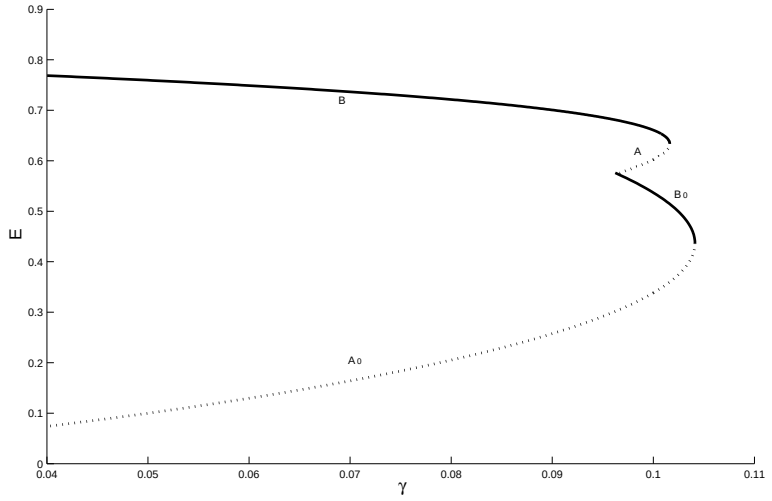
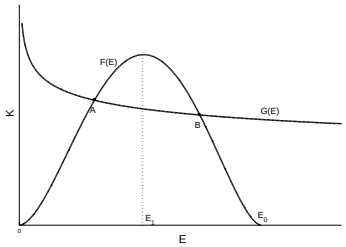
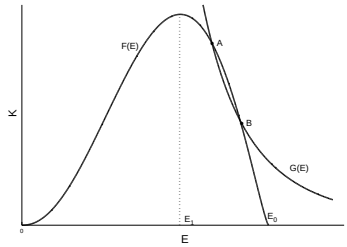


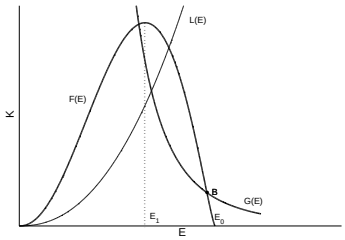
Figure 5: The value of E, evaluated at the fixed points with $N_p > 0$ and $N_p = 0$ varying η. The dotted lines represent the unreachable fixed points, while the continuous lines represent the reachable fixed points.



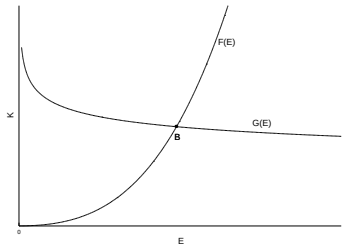
(a) $\rho < 0$, $\Omega > 0$



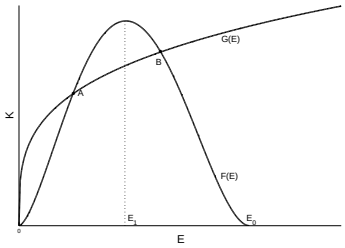
(b) $\gamma + 2\delta - 1 < 0$, $\Omega > 0$



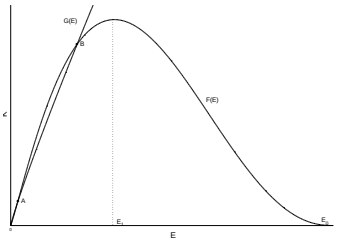
(c) $\rho < 0$, $\Omega > 0$



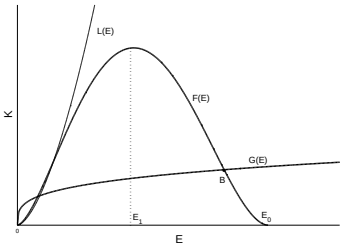
(d) $\gamma + 2\delta - 1 < 0$, $\Omega < 0$



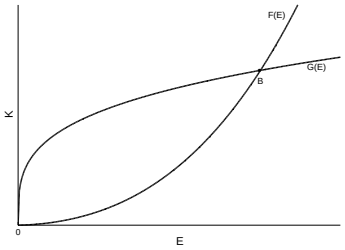
(e) $\gamma + 2\delta - 1 > 0$, $\Omega > 0$



(f) $\gamma + 2\delta - 1 > 0$, $\Omega > 0$

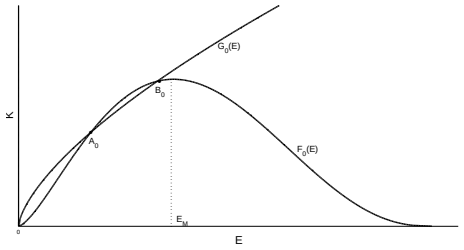


(g) $\gamma + 2\delta - 1 > 0$, $\Omega > 0$

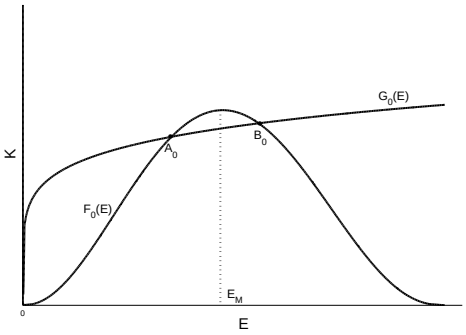


(h) $\gamma + 2\delta - 1 > 0$, $\Omega < 0$

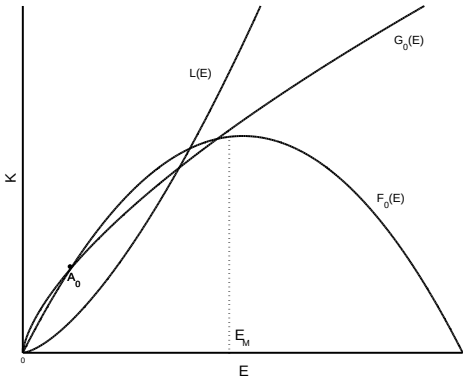
Figure 6: Fixed points with $N_p > 0$.



(a)



(b)



(c)

Figure 7: Fixed points with $N_p = 0$.

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