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DEPFID Working Papers - 3 / 2011 - Abstract

Investment inflows and sustainable development in a natural resource-dependent economy

Angelo Antoci*, Paolo Russu* and Elisa Ticci**

In the current age of trade and financial openness, remote and poor local economies are becoming increasingly exposed to inflows of external capital. The new investors - enjoying lower credit constraints than local dwellers - might play a propulsive role for the local development. At the same time, inflows of external capitals can produce environmental externalities on local natural resource-dependent activities. We analyze a two-sector model where both sectors damage the environment but only one relies on natural resources. We assess under which conditions the coexistence of the two sectors is compatible with sustainable development and we investigate the effects of environmental regulation and of external capital investment incentives on the welfare of the local populations.

KEYWORDS: foreign direct investments, environmental externalities, poverty

JEL CLASSIFICATION: D62, F21, F43, O41, O44, Q20

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1 Introduction

Processes of global integration of economies, urbanization and industrialization and the growing demand for raw materials and commodities have increased the exposure of rural economies to external influences and investments. External investments may take the form of foreign direct investments (FDI) or domestic capital flows deriving from urban or richer areas. In both cases, the inflow of capital is usually regarded as beneficial for local economic growth and poverty reduction. Indeed, many governments offer significant inducements to attract FDI. UNCTAD [2006] calculates that 2078 out of 2267 national policy changes, introduced between 1992 and 2005 around the world, were favorable to FDI.

This article discusses the impact of external investment inflows on local development with a focus on the role of environmental externalities and of capital market segmentation. These are two recurrent features of many developing countries where local borrowing and investment capacity is often more limited than in other regions or countries, while external investors enjoy a better access to capital markets. Moreover, unlike new incoming activities, local production is usually profoundly dependent on environmental dynamics. For local populations, natural systems represent means of subsistence or valuable economic services and assets.[1] In these contexts, local activities are exposed to multiple sources of externalities: environmental pressure of the local activities themselves and pollution produced by the external investors. Unsustainable management of natural resources in local activities can trigger a vicious circle of poverty and environmental degradation. At the same time, local activities are vulnerable to external environmental damages. Indeed, all over the world increasing struggles of local communities against external agents which threaten their environment suggest that such interaction may not be insignificant. Many grassroots protests are against environmental degradation caused by extractive, fishery and agriculture activities of large firms. Case studies of struggles by poor communities to gain control over natural resources and to deal with injustice and environmental degradation created by big companies, for instance, have been documented, among others, by Lee and So [1999][2], Martines-Alier [2002] [3]. Numerous documents provided by journalists

[1]For example, it has been estimated that in some large devoloping countries ecosystem services and other non-marketed goods account for between 47 percent and 89 percent of the total source of livelihood of rural and forest-dwelling poor households [UNEP, 2010].

[2]Lee and So explore the proliferation of grassroots movements in South Asia against multinational corporations which extract raw materials or move their production plants in this region.

[3]Martines-Alier describes the actions of Oilwatch, a south-south network concerned about the pollution and

and activist organizations describe struggles against mining activities responsible for depletion and contamination of water, air and soil pollution[4]. In some cases, the environmental impacts has provoked worldwide media interest. For example, both international press and international organizations have acknowledged that oil and gas exploration and exploitation, urbanization and industrialization are pushing the Niger Delta towards ecological disaster with dramatic consequences on the life of the indigenous population, nearly 60 per cent of whom depend on the natural environment for their livelihood [UNDP, 2006]. Since the late Eighties, the impact on poverty and deforestation produced by the expansion of large mechanized agriculture, livestock and timber activities has been analyzed by De Janvry and Garcia [1988], by Heath and Binswanger [1996] and, more recently, by Chomitz [2008]. In other cases, local communities are negatively affected by processes of industrialization and urbanization. China provides some of the most symbolic examples of rural communities harmed by the arrival of new manufacturing firms. Heavy damages to agriculture and fishery sectors caused by Chinese industrialization have been documented, amongst others, by Economy [2004] and World Bank [2007]. Other examples are provided by textile activities in India. As shown by Boopathi and Rameshkumar [2011] for Tamil Nadu, promotion of investments in this sector is accompanied by a devastating industrial pollution which is causing increased water and agriculture productivity loss and reduction in cultivable area.

Finally, even if no consensus has been reached in literature, recent works tend to corroborate the "pollution haven hypothesis"[5]. Cole and Fredriksson [2009], Wagner and Timmins [2009], Pao and Tsai [2011] find that the stringency of environmental policy negatively affect FDI inflows, especially in most dirty sectors, while Mulatu et al. [2010] find that environmental regulation is a determinant of industry location. Moreover, empirical evidence (Levinson and Taylor [2008], Ghertner and Fripp [2007]) increasingly suggests that the adoption of cleaner technologies and changes towards less environmentally intensive consumption explain only a

loss of biodiversity, lands and forests 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. In many cases, the expansion of legal or illegal shrimp ponds has caused the eviction of small scale fishermen and the destruction of coastal mangrove forests to the detriment of local communities.

[4]See, for instance, information and documents at the following websites: Earthworks, http://www.earthworksaction.org/. Mines and Communities, http://www.minesandcommunities.org/. No Dirty Gold, http://www.nodirtygold.org/. Observatory for Mining Conflicts in Latin America, http://www.conflictosmineros.net/. Oxfam America, http://www.oxfamamerica.org/.

[5]For a detail explanation and discussion of the "pollution haven hypothesis" refer to Taylor [2004]. For a survey on this topic see Brunnermeier and Levinson [2004].

part of the reduction in the pollution intensity of production systems in Northern countries. In contrast, the growth and composition of imports have also significantly contributed to pollution reductions of high income countries. The flip-side of these processes is the absorption of environmentally intensive industries by the developing countries. In addition, with the fast economic growth of large and intensely populated emerging economies (such as India, China, Brazil), the possibility to rely on changes in level and composition of imports to reduce pollution may be restricted in the future. All these factors suggest that the development process of today's developing countries cannot be viewed in isolation from environmental pressures exerted by external forces. This paper is a step towards the analysis of the role of these forces for poverty reduction.

The article is organized as follows. Section 2 discusses the related literature; sections 3 and 4 present the model; sections 5-6 investigate the basic properties of dynamics that emerge from the model; section 7 highlights the main results on the conditions for sustainable development. Section 8 and 9 contain comparative statics results and examine their implications in terms of welfare; section 10 compares our results with previous work. Finally, section 11 summarizes and draws conclusions.

2 Related literature

Neoclassical and endogenous economic growth theories have highlighted different ways in which external capital inflows can stimulate economic development. Credit constraints may be relaxed via new investments and capital inflows, thus increasing domestic capital stock and facilitating the accumulation of financial capital [Brems, 1970]. Mergers, acquisitions and greenfield investments may generate spill-over effects on local firms (Findlay [1978], Lall [1978], Wang and Blomstrom [1992], de Mello Jr. [1997], Markusen and Venables [1999], Barrios et al. [2003]. Other potentially positive effects produced by FDI include creation of employment, infrastructure development, expansion of tax base, fiscal revenues and foreign exchange earnings (Janeba [2004], Amiti and Wakelin [2003], Li and Liu [2005]). This may result in economic acceleration which, in turn, can sustain a process of poverty reduction. Suitable conditions required to produce such beneficial results for host economies have been discussed at length in economic literature. Empirical findings and theoretical arguments have underscored that institutional and legal contexts, corruption and social capability, the degree of the competition or complementarity with local activities, the technological gap, the level of human capital and development of host economies, the development of financial markets and receptiveness to trade, as well as investment regulation and labor intensity in investment sectors play a key role (Alguacil et al. [2011], Alfaro et al. [2004], citeblomstrometal1994, Balasubramanyam and Sapsford [1996], Borensztein and Lee [1998], Kemeny [2010], Lim [2001], Reiter and Steensma [2010]). In addition, the sectorial composition of FDI has been regarded as a further factor which influences the growth of the host economy. If the impact of FDI on the primary sector is considered to be limited or even negative, more far reaching positive connections and spillovers are expected in the case of capital flow into the manufacturing sector (UNCTAD [2001], Aykut and Sayek [2007], Chakraborty and Nunnenkamp [2008]). All these conditions, identified in economic literature as being relevant in shaping the effects of growth of external capital flows, may explain the considerable degree of heterogeneity in the empirical research with regard to the nexus between FDI, output growth and economic development. Indeed, a meta-analysis by [Wooster and Diebel, 2010]) find that "evidence of intrasectorial spillovers from FDI in developing countries is weak, at best" and the literature review provided by [Reiter and Steensma, 2010] shows that empirical findings on the role of FDI in economic development are still mixed.

Less attention has been dedicated to the potentially negative impacts of external capital investments notwithstanding the findings of some authors that in certain countries foreign investments can harm or crowd-out local firms or have negative effects on economic growth in the short term (Saltz [1992], Aitken and Harrison [1999], Djankov and Hoekman [2000], Damijan et al. [2003], Konings [2001], Agosin and Machado [2005], Herzer et al. [2008], Waldkirch and Ofosu [2010]). Moreover, some studies suggest that there may be a minimum level of absorptive capacity or income-level below which productivity spill-overs from FDI are negligible or negative and that it is only above this threshold that FDI generates positive effects (Barrios et al. [2005], Girma [2005], Mayer-Foulkes and Nunnenkamp [2009]). Most of these studies, anyway, have focused on intra-industry and vertical competition, while the impact of externalities across sectors has been often overlooked.

The objective of this paper is to develop a unified model which focuses on inter-industry linkages between local communities and external investments, including environmental externalities and job effect of capital inflows, but it excludes other positive indirect effects which have already been widely discussed by FDI literature. Firstly, the potential effect of poverty-reduction of external capital flows operates through the labor market by creating new labor opportunities and raising labor demand. Positive spill-overs on host economies are, instead, excluded and local and new activities are not connected by inward or forward linkages. Local and new activities are characterized by different production functions, that is, they belong to different sectors and they are not competitors[6]. In these cases, external investments might be attracted by low labor costs, public incentives, high endowments or the low cost of natural resources rather than by complementarities with local firms. Secondly, we introduce the analysis of a type of externality which has not received much attention in the debate on FDI impact on domestic firms, namely environmental damage. In the proposed model, local activities cause environmental damage but external investors also produce negative externalities on natural resources which are used by local firms for production. Finally, it is worth emphasizing that in this model we use the term "external" to refer not just to foreign investors, but also to national entrepreneurs whose capital derives from a source outside the local economy. Therefore, our model can be considered as complementary to the two-sector models with environmental externalities and intersectorial labor mobility proposed by López [2010] and by Antoci et al. [2009]. Antoci et al. [2009] differentiate the sectors in terms of capital intensity, dependence and degree of pressure on natural resources. In this model, we consider a similar setting, but we allow international capital mobility and physical capital accumulation in both sectors. Thus, the difference across sectors in the evolution of physical capital stock is endogenously determined. Also in Lopez's model, there are two sectors which produce environmental externalities and one of them is represented by harvesting activities which depend on natural resources, but he considers a closed economy. Therefore, pollution causes two opposite effects: it reduces productivity in natural resource-dependent sector and it pushes up the price of the good produced in this sector. In other worlds, the price channel mitigates the negative impact of environmental externalities on the harvesters' welfare. In our model, this compensatory mechanisms does not act because we consider a small open country where prices are set outside the economy. Since most developing countries are small open economies and take prices as given, we reckon that

[6]Note that the main transmission channels of spill-overs are usually expected to be more active within the same industry than across sectors.

the analysis of these dynamics in absence of the price effect is an important extension. Moreover, also López [2010] excludes physical capital accumulation in both sectors and international capital mobility.

3 The model setup

We consider a small open economy with three factors of production: labor, a renewable natural resource and physical capital. In this economy, agents belong to two different communities: "External Investors" (I-agents) and "Local Agents" (L-agents). The I-agents are endowed with physical capital which can be invested in the economy in question or elsewhere. We assume that they do not face credit constraints and their availability of physical capital is "unlimited". Therefore they will continue to invest their capital in the economy as long as the return on capital generated is higher than in other economies. I-agents also hire labor force and undertake all their potential work - represented by a fixed amount of entrepreneurial activity - in what we call "external sector". The asset of the L-agents is labour force and they have to choose how to distribute such asset between two activities: working as employees for External Investors in the external sector or direct exploitation of the natural resource. Let us say that "local sector" denotes production of the Local Agents. Their activities can be represented by harvesting, fishery, forestry or also tourism[7]. Given that L- and I- agents' investments in physical capital follow different mechanisms and rules, we assume that the capital market is completely segmented and it is accessible only by the External Investors, while Local Agents can invest only their savings.

We assume that the production functions of the two sectors satisfy Inada conditions, are concave, increasing and homogenous of degree 1 in their inputs. The production function of the representative L-agent is given by:

$$Y_L = K_L^{\alpha} E^{\beta} L^{1-\alpha-\beta}$$

where:

[7]We could also have distinguished the natural resource-dependent sector between harvesting activities from free access resources and agriculture production which relies on land endowments, but we would complicate the model without making it more realistic. If land frontier is not fixed, physical capital accumulation might also include acquisitions of new lands. If the entire stock of land is completely distributed among the agents, still agricultural productivity depends on environmental services provided by free access natural resources.

E is the stock of a free access environmental resource;

L is the amount of time the representative L-agent spends on local sector production;

K_L is the physical capital accumulated by the representative L-agent;

$\alpha > 0$, $\beta > 0$, $\alpha + \beta < 1$ hold.

The L-agent's total amount of time is normalized to 1 and leisure is excluded, thus $1 - L$ represents the L-agent's labor employed by the representative I-agent as wage work. The production function of the representative External Investor is represented by the Cobb-Douglas function:

$$Y_I = K_I^{\gamma}(1-L)^{1-\gamma} \tag{1}$$

where K_I denotes the stock of physical capital invested by the representative I-agent in the economy. The I-agents choose their labor demand $1 - L$ and the stock of physical capital K_I which they invest in the economy in order to maximize their profits:

$$Y_I - w(1-L) - rK_I$$

where w and r are, respectively, the wage and the interest rate, considered as exogenously determined by each I-agent. However, the wage w is endogenously set in the economy by the labor market equilibrium condition (we exclude the import of labor from other economies), while r is an exogenous parameter. We assume that K_I inflow is potentially unlimited. Therefore the dynamics of the same are not linked to I-agents' savings but only to productivity of K_I (which, in turn, depends on L and K_I).

This is a stylized scenario, but it can represent the main differences between capital accumulation dynamics which have their origin in the choices of local populations and those generated by the choices of external investors who enter small economies dominated by primary activities. The use of labor intensive techniques, employment of family labor and constraints in access to credit markets are often key features of the production activity of local communities[8]. External investors, in contrast, usually manage more capital intensive activities based on

[8] This assumption is consistent with earlier findings on the poverty-environment nexus. Barbier [2010] summarizes his review of empirical literature about the relationship between poverty and natural resource in developing countries by observing that the rural poor are almost "assetless". They depend "critically on the use of common-property and open access resources for their income", they rely on small plots of lands and on selling their labor

employment of wage labor. Their companies or firms are able to gain access to national and international capital markets; they therefore rely on financing sources coming from outside the economy and their ability to accumulate physical capital is in no way comparable to local population's accumulation potential. In addition, we assume that their production is characterized by a higher degree of mobility because it relies on wage labor which is also available in other economies and on physical capital that can be employed elsewhere [9]. Therefore they invest in a economy only if their investment is remunerative and they can defend themselves against a reduction in labor or capital return in the local economy by moving their capital towards other markets. On the other hand, without loss of plausibility, we assume that two productive inputs employed by the local sector, namely labor and the natural resource, constitute capital which is less mobile than physical. Consequently, local producers can rely on fewer strategies than external investors in order to confront reduction in labor or capital productivity. At the same time, they are not completely vulnerable to environmental degradation. Indeed, they can partially substitute natural capital with labor, whose total stock is fixed, but also with physical capital which can be accumulated over time. The local agents can choose the level of their savings and the allocation of their labor between the two sectors. More precisely, we assume that the representative L-agent solves the following maximization problem:

$$\max_{L, C_L} \int_0^{\infty} (\ln C_L)\, e^{-\delta t} dt \tag{2}$$

subject to:

$$\dot{K}_L = K_L^{\alpha} E^{\beta} L^{1-\alpha-\beta} + (1-L)w - C_L$$

where the positive parameter δ represents the subjective interest rate and $\dot{K}$ is the time derivative dK_L/dt of the variable K_L. The representative local agent invests all her savings remaining after financing her consumption C_L in physical capital. Her resources come from self-employment in the local sector ($K_L^{\alpha} E^{\beta} L^{1-\alpha-\beta}$) and from wage labor in the capitalistic sector ($(1-L)w$).

which is their only other asset. López [2010] pushes these assumptions further as he excludes that the poor can accumulate physical capital.

[9]In the real world, capital demobilization faces some constraints and it is often observed that flows of direct productive investment are more stable than portfolio flows and bank lending. However, in this model we compare local and external producers and we consider that the degree of freedom in location choices is much higher for external investors than for local small producers.

We assume that both communities are constituted by a continuum of identical individuals and the size of each community is equal to 1. The dynamics of E are described by a logistic function modified by taking into account of the impact of economic activities:

$$\dot{E} = E(\overline{E} - E) - \epsilon \overline{Y}_L - \eta \overline{Y}_I$$

$\overline{Y}_L$ and $\overline{Y}_I$ are the aggregate values of Y_L and Y_I, respectively and ϵ and η are positive parameters measuring the environmental impact caused, respectively, by the aggregate production of L and I-agents. The positive parameter $\overline{E}$ represents the carrying capacity of the environmental resource and the environmental impacts of economic activities is proportional to their aggregate output. This assumption is usual in models with economic activities depending on open-access resources (see, for example, D'Alessandro [2007], Copeland and Taylor [2009]) or with polluting industries (Ayong Le Kama [2001], Wirl [2004]).

Problem (2) will be analyzed with the following restrictions on variables and parameters: $K, E > 0$; $\alpha, \beta, \gamma, \delta, \epsilon, \eta, r, \overline{E} > 0$; $\alpha + \beta < 1$.

Each economic agent considers to be negligible the effect of her choices on the dynamics of E and does not internalize it. That is, $\overline{Y}_L$ and $\overline{Y}_I$ are considered to be exogenous and this implies that the evolution of E is taken as given in problem (2). As a result, economic agents behave without taking into account of the shadow value of the natural resource and nobody has an incentive to preserve or restore the same. Consequently, the resulting dynamics are not optimal. However, the trajectories under such dynamics are Nash equilibria, in the sense that no agent has an incentive to modify her choices along each trajectory generated by the model for so long as others do not modify theirs.

Working under the assumption that each typology of agents consists of a continuum of identical individuals of size 1, (ex post) aggregate outputs $\overline{Y}_L$ and $\overline{Y}_I$ coincide with pro-capite values Y_L and Y_I, respectively.

4 Dynamics

The dynamics generated by the model are obtained in the Mathematical Appendix A by applying the *Maximum Principle* to the maximization problem (2) of the representative L-agent, under the equilibrium condition in the labor market. According to the results contained in such appendix, we have that the function:

$$L = \Gamma \left(K_L^{\alpha} E^{\beta}\right)^{\frac{1}{\alpha+\beta}} \tag{3}$$

where:

$$\Gamma := \left[\frac{1-\alpha-\beta}{(1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}}\right]^{\frac{1}{\alpha+\beta}}$$

identifies the labor market equilibrium value L^* of L if the right side of (3) is lower than 1; otherwise, the equilibrium value of L is 1, that is:

$$L^* = \min\left\{1, \Gamma \left(K_L^{\alpha} E^{\beta}\right)^{\frac{1}{\alpha+\beta}}\right\} \tag{4}$$

The economy is specialized in the production of the L-sector if $L^* = 1$. The specialization in the production of the external sector is excluded (that is, $L^* > 0$ always holds). Therefore two cases can occur, the case *without specialization* (in the local sector) and the case *with specialization*. It is worth observing that the external sector never completely replaces the local sector, since the productivity of labor employed in the local activities tends to infinity as the workers move away from this sector. That is, the model never reaches the complete specialization in the external sector. In contrast, the economy can fully specialize in the local sector though also the productivity of labor in the external sector tends to infinity as $(1-L) \to 0$. In this case, in fact, external investors withdraw their capitals outside the economy and reduce K, which eventually goes to zero, in that labor becomes increasingly expensive.

4.1 Dynamics without specialization

If K_L and E are such that $\Gamma \left(K_L^{\alpha} E^{\beta}\right)^{\frac{1}{\alpha+\beta}} < 1$ (see (4)), then L-agents spend a positive fraction of their time endowment working in the external sector and equation (3) identifies the equilibrium value of L. Moreover, the following proposition holds:

Proposition 1 *The equilibrium wage rate is constant and is given by* $w = (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}$.

Proof. See the Mathematical Appendix A. ■

The equilibrium wage rate is completely determined by the labor elasticity of production in the external sector (γ) and by the capital cost (r). A change in any other parameter does not affect the equilibrium wage even if it leads to a variation in equilibrium values of L, K_I and of E. We will return later on the implications of this result.

In such a context, the dynamics obtained applying the *Maximum Principle* to problem (2) can be expressed as follows:

$$
\begin{aligned}
\dot{K}_L &= \Gamma\left[T^{-\alpha-\beta} - (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}\right]\left(K_L^{\alpha}E^{\beta}\right)^{\frac{1}{\alpha+\beta}} + (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} - \frac{1}{\lambda} \\
\dot{E} &= E(\overline{E}-E) + \Gamma\left[\eta\left(\frac{r}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} - \epsilon\Gamma^{-\alpha-\beta}\right]\left(K_L^{\alpha}E^{\beta}\right)^{\frac{1}{\alpha+\beta}} - \eta\left(\frac{r}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} \\
\dot{\lambda} &= \lambda\left[\delta - \frac{\alpha\Gamma^{1-\alpha-\beta}\left(K_L^{\alpha}E^{\beta}\right)^{\frac{1}{\alpha+\beta}}}{K_L}\right]
\end{aligned}
\tag{5}
$$

where λ is the co-state variable associated to the state variable K_L, which has the usual interpretation of "price" of K_L.

4.2 Dynamics with specialization

If $\Gamma\left[K_L^{\alpha}E^{\beta}\right]^{\frac{1}{\alpha+\beta}} \geq 1$, then the L-agents spend all their time endowment working in the L-sector, that is $L^* = 1$, and the dynamic system obtained applying the *Maximum Principle* to problem (2) is:

$$
\begin{aligned}
\dot{K}_L &= K_L^{\alpha}E^{\beta} - \frac{1}{\lambda} \\
\dot{E} &= E(\overline{E}-E) - \epsilon K_L^{\alpha}E^{\beta} \\
\dot{\lambda} &= \lambda\left(\delta - \alpha K_L^{\alpha-1}E^{\beta}\right)
\end{aligned}
\tag{6}
$$

5 Stationary states

A stationary state $P^* = (E^*, K_L^*, \lambda^*)$ of the dynamics (5)-(6) is a solution of the system $\dot{K}_L = 0$, $\dot{E} = 0$, $\dot{\lambda} = 0$. From equation $\dot{\lambda} = 0$, in the case without specialization (system (5)), we obtain:

$$(K_L^\alpha E^\beta)^{\frac{1}{\alpha+\beta}} = \frac{\delta K_L}{\alpha \Gamma^{1-\alpha-\beta}} \tag{7}$$

Substituting (7) in (3), we get:

$$L^* = \Gamma \frac{\delta K_L}{\alpha \Gamma^{1-\alpha-\beta}} = \frac{K_L}{\alpha \delta^{-1} \Gamma^{-\alpha-\beta}} \tag{8}$$

Consequently $L^* < 1$ if and only if $K_L < \alpha\delta^{-1}\Gamma^{-\alpha-\beta}$. This implies that the stationary states without specialization lie, in the plane (E, K_L), below the horizontal line:

$$K_L = \overline{K}_L := \alpha\delta^{-1}\Gamma^{-\alpha-\beta} \tag{9}$$

It is easy to check that, below the straight line $K_L = \overline{K}_L$, the stationary states (without specialization) are given by the intersections between the two following curves:

$$K_L = f(E) := \Omega E \tag{10}$$

$$K_L = g(E) := \frac{\eta \left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} - E(\overline{E} - E)}{\Lambda} \tag{11}$$

where:

$$\Omega := \left(\alpha\delta^{-1}\Gamma^{1-\alpha-\beta}\right)^{\frac{\alpha+\beta}{\beta}} \tag{12}$$

$$\Lambda := \frac{\delta\left[\eta(1-\alpha-\beta) - \epsilon(1-\gamma)\right]}{\alpha(1-\gamma)} \tag{13}$$

Notice that $\Omega > 0$ always while:

$$\Lambda > 0 \quad \text{if} \quad \epsilon < \epsilon_\Lambda := \eta\frac{1-\alpha-\beta}{1-\gamma} \tag{14}$$

The existence and stability property of the fixed points without specialization pivot on the sign of the parameter Λ which indicates if the shift of labor force from one sector to the other one will result in an increase or in a decrease of the environmental impact. In particular, according to (14), $\Lambda > 0$ holds if the ratio between ϵ (measuring the environmental impact of the local sector) and η (measuring the environmental impact of the external sector) is lower than the ratio between the elasticities $1-\alpha-\beta$ and $1-\gamma$, with respect to labor, of the production functions in the local sector and in the external one, respectively.

Above $K_L = \overline{K}_L$, the stationary states with specialization (system (6)) are given by the intersections between the following two curves:

$$K_L = f_1(E) := \left(\frac{\alpha}{\delta}\right)^{\frac{1}{1-\alpha}} E^{\frac{\beta}{1-\alpha}} \tag{15}$$

$$K_L = g_1(E) := \frac{\alpha}{\delta\epsilon} E(\overline{E} - E) \tag{16}$$

The following propositions deal with the problem of the existence and numerosity of the stationary states of the dynamics (5)-(6).

Proposition 2 *The dynamic system (5)-(6) admits at most four stationary states:* A *and* B *with* $L^* < 1$*,* A_1 *and* B_1 *with* $L^* = 1$.

Proof. The graph of $g(E)$ is a parabola while the graph of $f(E)$ is a straight line, consequently $f(E)$ and $g(E)$ have at most two intersections. Analogously, both $f_1(E)$ and $g_1(E)$ are concave, however the difference $f_1(E) - g_1(E) = E\left[\left(\frac{\alpha}{\delta}\right)^{\frac{1}{1-\alpha}} E^{\frac{\alpha+\beta-1}{1-\alpha}} + \frac{\alpha}{\delta\epsilon}E - \frac{\alpha}{\delta\epsilon}\overline{E}\right]$ has at most two zeros with $E > 0$. ■

By the symbol A_1 (respectively, B_1) we shall refer to the stationary state $P^* = (E^*, K_L^*, \lambda^*)$ with specialization satisfying the condition $f_1'(E^*) < g_1'(E^*)$ (respectively, $f_1'(E^*) > g_1'(E^*)$); analogously, by the symbol A (respectively, B) we shall refer to the stationary state without specialization satisfying the condition $sign\,(\Lambda) = sign\,[f'(E^*) - g'(E^*)]$ (respectively, $sign\,(\Lambda) = sign\,[g'(E^*) - f'(E^*)]$).

To express the next proposition, we have to define the following threshold values:

$$\begin{aligned}
\overline{E}_1(\epsilon,\eta) &:= 2\sqrt{\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}\eta} - \Omega\frac{\delta(1-\alpha-\beta)}{\alpha(1-\gamma)}\eta + \Omega\frac{\delta}{\alpha}\epsilon && (17)\\
\overline{E}_2(\epsilon) &:= \frac{\overline{K}_L}{\Omega} + \frac{\delta\Omega}{\alpha}\epsilon && (18)\\
\overline{E}_3(\epsilon) &:= \frac{\left(2-\frac{\beta}{1-\alpha}\right)\left(\frac{\alpha}{\delta}\right)^{\frac{\alpha}{1-\alpha}}}{\left(1-\frac{\beta}{1-\alpha}\right)^{\frac{1-\alpha-\beta}{1-\alpha}}}\epsilon^{\frac{1-\alpha}{2(1-\alpha)-\beta}} && (19)\\
\epsilon_T &:= \left(\frac{\delta}{\alpha}\right)^{\frac{2-\beta}{\beta}}\frac{1-\alpha}{1-\alpha-\beta}\overline{K}_L^{\frac{2(1-\alpha)-\beta}{\beta}} && (20)\\
\eta_T &:= \left(\frac{\overline{K}_L}{\Omega}\right)^2\left(\frac{r}{\gamma}\right)^{\frac{\gamma}{1-\gamma}} && (21)
\end{aligned}$$

Proposition 3 *The stationary states of the dynamic system (5)-(6) are (see Figure 1)*[10]*:*

1) A, B, A_1 and B_1 if and only if (iff):

$$\eta < \eta_T, \quad \epsilon > \epsilon_T, \quad \overline{E}_3(\epsilon) < \overline{E} < \overline{E}_2(\epsilon)$$

2) A and B iff:

$$\eta < \eta_T, \quad \epsilon < \epsilon_T, \quad \overline{E}_1(\epsilon,\eta) < \overline{E} < \overline{E}_2(\epsilon)$$

or

$$\eta < \eta_T, \quad \epsilon > \epsilon_T, \quad \overline{E}_1(\epsilon,\eta) < \overline{E} < \overline{E}_3(\epsilon)$$

3) A_1 and B_1 iff:

$$\eta < \frac{1-\gamma}{1-\alpha-\beta}\epsilon_T, \qquad \epsilon > \epsilon_T, \quad \overline{E}_3(\epsilon) < \overline{E} < \overline{E}_1(\epsilon)$$

or

$$\eta > \frac{1-\gamma}{1-\alpha-\beta}\epsilon_T, \qquad \epsilon_T < \epsilon < \epsilon_\Lambda, \quad \overline{E}_3(\epsilon) < \overline{E} < \overline{E}_2(\epsilon)$$

4) A and B_1 iff:

$$\overline{E} > \overline{E}_2(\epsilon)$$

[10] For simplicity, in this classification, we do not take into account the "non robust" cases corresponding to an equality condition on parameter values (for example, the cases in which $\eta = \eta_T$, $\epsilon = \epsilon_T$ or $\overline{E} = \overline{E}_3(\epsilon)$).

No stationary state exists in the remaining cases.

Proof. See the Mathematical Appendix B. ■

Figure 2 shows a numerical example in which four stationary states A, B, A_1 and B_1 exist.

6 Stability properties of stationary states

Let $P^* = (E^*, K_L^*, \lambda^*)$ be a stationary state of the dynamics (5)-(6). The stability properties of P^* depend on the signs of the real parts of the eigenvalues associated to the Jacobian matrix J evaluated at P^*. We shall say that P^* is *saddle-point stable* if J has two eigenvalues with negative real parts, i.e. if P^* has a 2-dimensional stable manifold. As a matter of fact, under the perfect foresight assumption, if the stationary state has a 2-dimensional stable manifold, given the initial values $E(0)$ and $K_L(0)$ of the state variables E and K_L, L-agents are able to fix the initial value $\lambda(0)$ of the (jumping) co-state variable λ so that the growth trajectory starting from $(E(0), K_L(0), \lambda(0))$ approaches P^*. Therefore the stationary state can be reached by growth trajectories. If the stationary state has less than two eigenvalues with negative real parts, then given the initial values $E(0)$ and $K_L(0)$, a value $\lambda(0)$ does not (generically) exist so that the growth trajectory starting from $(K_L(0), E(0), \lambda(0))$ approaches the stationary state.

The following propositions concern the stability properties of the stationary states A_1 and B_1, in the regime with specialization (i.e. $L^* = 1$), and states A and B, in the regime without specialization (i.e. $L^* < 1$). The proofs of such propositions build on the analysis of Wirl [1997]); they require straightforward but tedious calculations; therefore, for space constraints, we omit them[11].

Proposition 4 *In the regime with specialization, we have that:*

1) If $f_1'(E^*) < g_1'(E^*)$ (that is, P^* is of the type A_1), then P^* has two eigenvalues with strictly positive real parts and one with strictly negative real part.

2) If $f_1'(E^*) > g_1'(E^*)$ (that is, P^* is of the type B_1), then P^* is saddle-point stable or it has three eigenvalues with strictly positive real parts; a sufficient condition for saddle-point stability is:

$$E^* > \frac{\overline{E}}{2} - \frac{\delta(1-\alpha)}{2\alpha}$$

[11]Omitted proofs are available from the authors on request.

The following proposition deals with the stability properties of the stationary states A and B in the regime without specialization (i.e. $L^* < 1$).

Proposition 5 *In the regime without specialization, we have that:*

1) If $sign\,(\Lambda) = sign\,[f'(E^*) - g'(E^*)]$ (that is, P^* is of the type A), then P^* has two eigenvalues with strictly positive real parts and one with strictly negative real part.

2) If $sign\,(\Lambda) = sign\,[g'(E^*) - f'(E^*)]$ (that is, P^* is of the type B), then P^* is saddle-point stable or it has three eigenvalues with strictly positive real parts; a sufficient condition for saddle-point stability is:

$$E^* > \frac{\overline{E}}{2} - \frac{\beta\delta}{2\alpha(\alpha+\beta)}$$

7 Conditions for sustainability

This section discusses the conditions for a sustainable development path in the considered economy. We define sustainable an economy which is able to converge to a stationary state characterized by a positive level of the natural resource. That is, the conditions for the existence of equilibria B or B_1 (both characterized by $E > 0$) are conditions for sustainability. In fact, according to Proposition 4, only the stationary states B (without specialization) and B_1 (with specialization) can be saddle-point stable.

Remember that the parameter $\overline{E}$ represents the carrying capacity of the environmental resource E while the parameters ϵ and η measure, respectively, the environmental impact caused by the aggregate production of L-agents and I-agents. Figure 1 shows the regions, in the plane $(\epsilon, \overline{E})$, corresponding to cases 1-4 of Proposition 3.

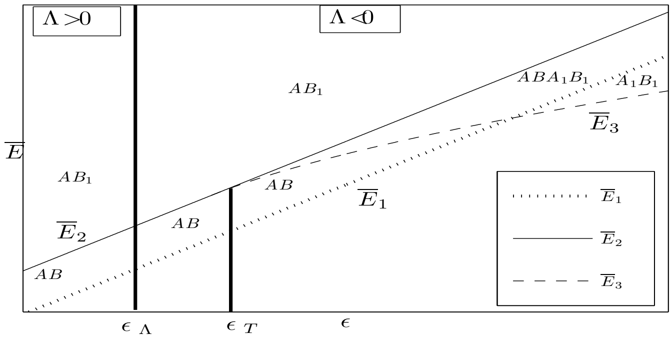
Joining together the results concerning the existence and the stability of the stationary states, we can observe that:

i) A bi-stable regime (case 1 of Proposition 3, where all the stationary states A, B, A_1, B_1 exist) can be observed only for low enough values of η (i.e. $\eta < \eta_T$) and high enough values of ϵ (i.e. $\epsilon > \epsilon_T$), see Figure 1.a; furthermore, the carrying capacity $\overline{E}$ must lie between $\overline{E}_3(\epsilon)$ and $\overline{E}_2(\epsilon)$. In this context, the dynamics is path dependent: if the economy starts near enough to B (respectively, to B_1), then the stationary state B (respectively, B_1) is reached.

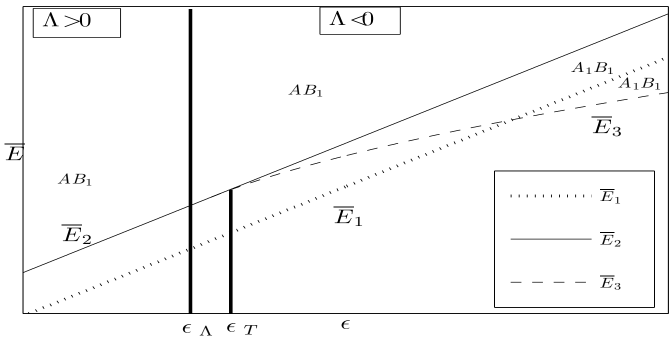
ii) when B and B_1 do not simultaneously exist, then at most one saddle-point stable stationary state can exist. In particular, only B exists if the conditions expressed in case 2 of

Proposition 3 hold while only B_1 exists in the context of cases 3 and 4 of Proposition 3.

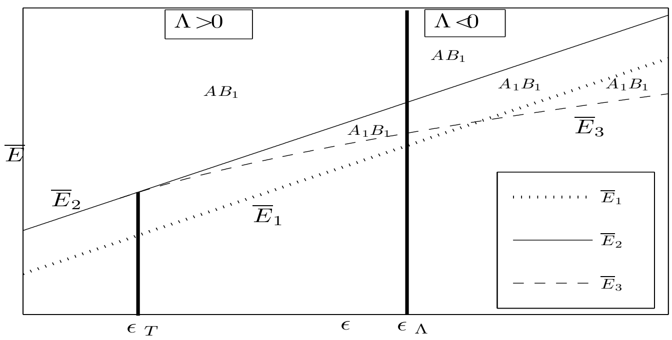
Based on these results, we can answer to three main questions.



(a) $\eta < \eta_T$



(b) $\eta_T < \eta < \overline{\eta} = \dfrac{1-\gamma}{1-\alpha-\beta}\epsilon_T$



(c) $\eta > \overline{\eta}$

Figure 1: Threshold values in the plane $(\epsilon, \overline{E})$ and existing stationary states.

Question 1: When are the arrival of external capital inflows and economic diversification compatible with sustainable development? In other terms, what are the necessary conditions for the sustainable coexistence of the local and external sector?

Answer:

- i) a necessary condition for the existence of a stationary state of the type B is $\eta < \eta_T$ (see Figure 1.a). In this case, a diversified economy with both the local and external sector is sustainable.

- ii) If $\eta > \eta_T$, then only the stationary state with specialization B_1 can exist (see Figures 1.b-1.c). In such a context, the coexistence between the local sector and the external one cannot be observed in a stationary state.

- iii) The coexistence between these sectors is not possible also if (ceteris paribus) the carrying capacity $\overline{E}$ is high enough; in such a case, only the stationary states A and B_1 exist (see Figures 1.a-1.c).

- iv) Finally, no stationary state exists when the carrying capacity $\overline{E}$ is low enough; in such a context, the growth process is not sustainable.

Discussion: In our model, the stock E of the environmental resource affects the labor productivity in the local sector. A reduction of E (ceteris paribus) gives rise to an increase in labor offered to the external investors and to a consequent downward pressure on wages. On the other hand, the labor movement out of the local sector is associated to a rise in labor marginal productivity in such sector (remember that $\frac{\partial^2 Y_L}{\partial L^2} < 0$ and $lim_{L \to 0} \frac{\partial Y_L}{\partial L} = +\infty$) and to upward pressures on wages. According to Proposition 1, in equilibrium these two forces balance each other and wages remain constant. Consequently, the equilibrium allocation of labour force between the two sectors is not determined by variations in wages but rather by variations in the productivity of labor in the two sectors. Local agents defend themselves from environmental degradation (i. e. a reduction of E) by increasing their labor input in the external sector at a fixed (equilibrium) wage rate. In such a context, it is not surprising that when (ceteris paribus) the carrying capacity $\overline{E}$ is high enough (i. e. $\overline{E} > \overline{E}_2(\epsilon)$), then the unique reachable stationary state is B_1, where complete specialization in the local sector occurs, while the sustainable coexistence of the two sectors can be observed only if (see Figure 1.a) $\overline{E}$ is neither “too low” nor “too high” (i.e. $\overline{E}_3(\epsilon) < \overline{E} < \overline{E}_2(\epsilon)$) and if the environmental impact of the external sector is low enough (i.e. $\eta < \eta_T$). If the external sector produces a devastating environmental effect (i.e. $\eta > \eta_T$), then economic diversification is not sustainable, that is, a stationary state of the type B does not exist (see Figures 1.b-1.c); in such case, the expansion of the external sector at the expense of the local one generates an increase in environmental degradation which, in turn, fuels a further expansion of the external sector. This self-enforcing mechanism is incompatible with the sustainable coexistence of the two sectors: external capital inflows may have either a long run negligible effect (i.e. the external sector disappears from the economy, which approaches the stationary state B_1) or a devastating effect (i.e. the growth path of the economy does not approach a stationary state with $E > 0$).

Question 2: When does economic diversification constitute the only way to reach a sustainable development path?

Answer: If B is the unique admissible stationary state, the economy can approach a sustainable path only through a process of diversification towards a sector which does not depend on natural resources and relies on external sources of capitals. This happens when $\eta < \eta_T$ and $\overline{E}_1(\epsilon, \eta) < \overline{E} < \overline{E}_3(\epsilon)$.

Discussion: If η is below the threshold η_T, then the existence and the typology of reachable stationary states depends on the initial endowments of natural resources $\overline{E}$ and on the parameter ϵ (see Figure 1.a). If the economy is well-endowed with natural resources, that is $\overline{E} > \overline{E}_2(\epsilon)$, then economic diversification cannot be observed at a stationary state, since the systems admits only a saddle-point stable stationary state with complete specialization. If $\overline{E} < \overline{E}_2(\epsilon)$, other two scenarios are possible. In relatively resource-poor economies (i.e. $\overline{E}_1(\epsilon, \eta) < \overline{E} < \overline{E}_3(\epsilon)$), the system can reach a sustainable steady state only through economic diversification, since there is a unique saddle-point stable stationary state which is of the type B. If $\overline{E} < \min\left\{\overline{E}_1(\epsilon, \eta), \overline{E}_3(\epsilon)\right\}$), no stationary state exists.

Question 3: When do alternative sustainable development paths coexist?

Answer: A bi-stable regime occurs when $\eta < \eta_T$, $\overline{E}_1(\epsilon, \eta) < \overline{E} < \overline{E}_2(\epsilon)$ and the local sector has a heavy environmental impact (i.e. $\epsilon > \epsilon_T$), see Figure 1.a. In the same context but with $\epsilon < \epsilon_T$, the unique reachable stationary state is of the type B_1, with complete specialization.

Discussion: Under these conditions, both B and B_1 exist; if they are saddle-point stable, then the dynamics are path dependent in that the economy may reach B or B_1 according to the initial values of the state variables K_L and E. As said above, saddle-point stability of a stationary state (E^*, K_L^*, λ^*) means that if the initial values $E(0)$ and $K_L(0)$ are near enough to E^* and K_L^*, respectively, then L-agents are able to fix the initial value $\lambda(0)$ of the (jumping) co-state variable λ so that the growth trajectory starting from $(E(0), K(0), \lambda(0))$ approaches (E^*, K_L^*, λ^*). Therefore, depending on initial conditions, the economy can approaches a sustainable stationary state with or without external investments.

8 Local agents' welfare at the stationary states

The following propositions help to identify the most significant conditions that are verified in correspondence with the stationary states of dynamic system (5)-(6); the asterisk indicates the stationary state values of the variables.

Proposition 6 *The following conditions hold at the stationary states of the dynamic system (5)-(6):*

$$L^* = \min\left\{1,\ \frac{\delta}{\alpha}\Gamma^{\alpha+\beta}K_L^*\right\} \tag{22}$$

$$K_I^* = \max\left\{0,\ \left(\frac{\gamma}{r}\right)^{\frac{1}{1-\gamma}}(1-L^*)\right\} = \max\left\{0,\ \left(\frac{\gamma}{r}\right)^{\frac{1}{1-\gamma}}\left(1-\frac{\delta}{\alpha}\Gamma^{\alpha+\beta}K_L^*\right)\right\} \tag{23}$$

$$C_L^* = \frac{\delta}{\alpha}K_L^* + \frac{r(1-\gamma)}{\gamma}K_I^* \tag{24}$$

Furthermore, in the context $L^* < 1$ (stationary states A and B), the following condition holds:

$$C_L^* = (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} + \delta\left(1+\frac{\beta}{\alpha}\right)K_L^* \tag{25}$$

Proof. See the Mathematical Appendix C ■

We can observe that, according to (25), C_L^* is composed by two addends: the wage rate $(1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}$ (see Proposition 1), namely the return to employment in the capitalistic sector, and $\delta\left(1+\frac{\beta}{\alpha}\right)K_L^*$ which depends positively on the physical capital accumulated by local agents at the stationary state. A variation in parameter γ or r which causes an increase in the wage rate can also rise the local welfare to the extent that the possible negative impact on K_L^* is not too large. In this case, the crowding-out of the local sector is welfare-improving, otherwise the local population might experience a welfare loss even with increased wages.

Notice also that the value of K_L evaluated at the stationary state B_1 is higher than that evaluated at B (when both B_1 and B simultaneously exist) because B_1 lies above the line (see (9)) $K_L = \overline{K}_L := \alpha\delta^{-1}\Gamma^{-\alpha-\beta}$ while B lies below it (see Figure 2). Furthermore, also the value of E in B_1 is higher than in B; therefore, it is easy to check the following proposition[12]:

Proposition 7 *When the stationary states B_1 and B coexist, then L-agents' welfare (measured by C_L), evaluated in B_1, is higher than that evaluated in B* [13]

[12] Notice that the values of C_L^* given by the formulas (24) and (25) coincide for $K_L^* = \overline{K}_L := \alpha\delta^{-1}\Gamma^{-\alpha-\beta}$.

[13] We do not consider the stationary states A_1 and A because they cannot be saddle-point stable.

Proposition 7 entails that, in a bi-stable regime, economies characterized by low initial values of E and K_L (see Figure 2) are more likely to converge to the Pareto-dominated stationary state without specialization than richer economies, which can rely on greater values of $E(0)$ and $K_L(0)$ and, therefore, are located closer to the stationary state B_1. From a policy perspective, in a bi-stable context, incentives for foreign investments may favour undesirable outcomes: the policy maker could produce a greater improvement in local agents' welfare by implementing interventions able to raise the initial endowments of E^* and K_L^*. In this way, the policy maker could help L-agents to select B instead of B_1. Indeed, usually governments introduce inducements for FDIs in order to complement low levels of domestic savings and limited investment capacity.

9 Comparative statics

The following propositions investigate the impact of a change in parameters (in particular, we focus our analysis on $\overline{E}$, ϵ, η, r) on the values of K_L^*, K_I^*, E^*, L^*, Y_I^* and C_L^* evaluated at B, the stationary state without specialization that can be saddle-point stable. By the symbols $x \uparrow$ and $x \downarrow$ we shall indicate, respectively, an increase and a decrease in the parameter or variable x. We carry out some exercises of comparative statics in B in order to assess the impact of various changes in parameters in an economy that can converge to a stationary state with two sectors, namely in a context where inflows of external capital are admissible and, in principle, do not threaten sustainability. Figures 3 and 4 show a graphical representation of the results by some numerical exercises.

9.1 Environmental policies and natural resource abundance

Our model does not include policy variables and policy interventions, but we can study the effect of environmental regulation by analyzing the impact of a change in parameters which represent the environmental pressure of the two sectors (ϵ and η). Regardless of the type of policy instrument, an effective intervention of environmental legislation is expected to result in a decrease in these parameters. Analogously, comparative statistics on $\overline{E}$ can simulate the effect of a variation in natural resource wealth or of a policy intervention which raises the carrying capacity of the economy. The proofs of the following propositions require straightforward but tedious calculations; therefore, for space constraints, we omit them[14].

Proposition 8 *$\overline{E} \uparrow$ (remember that $\overline{E}$ represents the carrying capacity of the environmental resource) implies $E^* \uparrow$, $K_L^* \uparrow$, $L^* \uparrow$, $C_L^* \uparrow$ and $K_I^* \downarrow$.*

Proposition 9 *$\epsilon \uparrow$ or $\eta \uparrow$ (remember that ϵ and η represent, respectively, the environmental impact of L-agents and I-agents) imply $E^* \downarrow$, $K_L^* \downarrow$, $L^* \downarrow$, $C_L^* \downarrow$ and $K_I^* \uparrow$.*

The comparative statics carried out on ϵ and η pinpoints the consequences of considering environmental dynamics. The results show that a lower environmental regulation, which translates into higher levels of ϵ or η, tends to stimulate a labor movement towards the external sector, whose productive performance is not damaged by environmental degradation. The local community faces a reduction in return to self-employed labor and is pushed towards wage employment. In such a context, the expansion of external capital inflows does not help local agents. On the contrary, their welfare declines (i.e. $C_L^* \downarrow$). In policy terms, this scenario implies that permissive environmental policies might attract foreign capitals ($K_I^* \uparrow$) without any positive effects on local populations. These outcomes come out even if the labor market is perfectly competitive and is not segmented, that is a context where a rise in labor demand for external activities produce a pattern of labor reallocation that should raises wages in both sectors. The introduction of environmental externalities, instead, mitigates this channel of transmission resulting into an expansion of output share of the external sector with constant wages and a decrease in local agents' welfare. Indeed, as reported in Proposition 1, the equilibrium wage rate is constant and is not affected by variations in parameters ϵ and η.

A symmetrically opposed effect is produced by an increase in $\overline{E}$, which translates into an increase in the welfare of L-agents and a reduction in the investments of I-agents. In this context, therefore, natural capital abundance is a blessing for the local economy expansion. These results might appear in contrast with the well-established "resource curse" hypothesis. 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 a high $\overline{E}$. In our model, the environmental resources are public goods that all agents have access to. In

[14]Omitted proofs are available from the authors on request.

the empirical literature on resource abundance, instead, resource rich 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), but the use of per capita land as a proxy of resource wealth does not capture distributive aspects, while point resources are more likely to be appropriated by a narrow elite. In these cases, environmental resources are not public but excludible goods that are mainly enjoyed by a minority of wealthier households. Therefore, our model cannot be considered in opposition to the "resource curse" literature as the concept of natural resource abundance here refers to a different context. Paradoxically, extractive sectors can be better represented by the capitalistic activities that are often controlled by external investors, produce environmental impact on surrounding activities and do not depend on renewable natural resources. As mirrored by many protests of local communities against extractive industries, in our model, weak environmental policy (which cause an increase in ϵ or η) leads to an expansion of extractive activities without improving local welfare.

9.2 Capital subsidies or reduction in investors' financing costs

A reduction in r represents a reduction in external agents' opportunity cost of capital investment in the economy. A reduction in r, for example, can represent measures that benefit external investors such as more favorable taxation, regulation, provision of services and infrastructures, political climate and the enforcement of property rights or, more intuitively, a reduction in r can be considered as a subsidy for external investors. The following proposition discusses the effect of a change in r.

Proposition 10 *If* $\Lambda > 0$ *(i.e.* $\epsilon < \epsilon_\Lambda$*; see (14) and Figure 1.a)*[15]*, then* $r \uparrow$ *always implies* $E^* \uparrow$ *and* $K_L^* \uparrow$*. If* $\Lambda < 0$ *(i.e.* $\epsilon > \epsilon_\Lambda$*), then:*

1) $r \uparrow$ *implies* $E^* \uparrow$ *if:*

$$\eta > \frac{\epsilon(1-\gamma)(1-\alpha-\beta)^2}{\beta+(1-\alpha-\beta)^3} \tag{26}$$

[15]According to (14), condition $\epsilon < \epsilon_\Lambda$ can be rewritten as $\epsilon/\eta < (1-\alpha-\beta)/(1-\gamma)$, which requires (ceteris paribus) a low enough ratio between the negative environmental impact of the local sector (measured by ϵ) and of the external sector (measured by η).

2) $r \uparrow$ implies $E^* \downarrow$ if:

$$\eta < \left[-\frac{P}{2} + \frac{1}{2}\sqrt{P^2 + \frac{4(1-\gamma)}{1-\alpha-\beta}} \right]^{\frac{1}{2}}$$

where:

$$P := \frac{\alpha\beta(1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{2(1-\gamma)}}}{\delta\Omega(1-\alpha-\beta)^2}$$

3) $r \uparrow$ implies $K_L^* \uparrow$ if and only if:

$$\frac{1-\alpha-\beta}{\beta} E^*(\overline{E} - 2E^*) - \left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} < 0 \tag{27}$$

Furthermore, (26) is a sufficient condition to have $K_L^* \uparrow$.

Remember that, according to Proposition 6, K_L is positively correlated with L^* and negatively correlated with K_I^*; furthermore:

$$\frac{\partial C_L^*}{\partial r} = \frac{\delta}{\alpha}(\alpha+\beta)\frac{\partial K_L^*}{\partial r} - \left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} \frac{\gamma}{r} \tag{28}$$

This implies that the condition $\frac{\partial K_L^*}{\partial r} > 0$ is necessary but not sufficient to obtain $\frac{\partial C_L^*}{\partial r} > 0$. Our results (see Proposition 3 and formula (28)) predict that a reduction in r surely generates an increase in C_L^* only if $\frac{\partial K_L^*}{\partial r} < 0$; this happens if, in the context $\Lambda < 0$ (i.e. $\epsilon > \epsilon_\Lambda$), the opposite of condition (27) holds. In fact in this case, by formula (28), $\frac{\partial C_L^*}{\partial r} < 0$ holds and so a decline in the opportunity cost of capital for the external investors leads to an increase in K_L^* and in C_L^*. Remember that the condition $\Lambda < 0$ requires (ceteris paribus) a relatively low environmental impact of the external sector in comparison to that of the local activities (see (14)). In the context $\Lambda < 0$, external capital inflows, which attract labor force towards the external sector, alleviate pressure on natural resources because local population has the opportunity to rely more on cleaner activities. In all other cases, a decline in r can have the effect to reduce local agents' welfare. Inflows of external capitals can still have a positive effect even when $\Lambda > 0$, that is when external activities are relatively more polluting than local ones and their expansion is associated with a net negative impact on natural resources. Figures 4.a and 4.c., for instance, show two examples with $\Lambda > 0$ which differ only for the value of η. For a sufficiently low η, a decrease in r leads to a growth of C_L^* though it causes also a decline in E. For high values of η, however, the opposite is true and external investments have a detrimental effect on both the local agents' welfare and the environment. This result indicates that external capital inflows, not only might fail to trigger net positive effects, but they can also produce a net negative impact on local welfare even if they stimulate labor demand.

10 Relations with previous studies

Finally, we discuss the relationship between our analysis and previous work concerning sustainable development in a two-sector context with heterogenous agents, sectorial labor mobility and multiple sources of environmental externalities. Like in López [2010] and in Antoci et al. [2009], in the present model an expansion of physical capital can reduce the stationary state value of natural capital, but its effect on local welfare operates in a different way. In López [2010], it always brings a welfare improvement, regardless of the impact on natural capital, since the effects of the environmental degradation are more than compensated by that on the price of the good produced by the resource-dependent sector. In presence of trade openness, instead, the price channel is not activated and, in fact, the opposite relation holds in Antoci et al. [2009] who focus on a small open economy without international capital mobility and capital accumulation. In such a context, the welfare effect pivots on the environmental dynamics and local welfare increases only if the rise in physical capital has a positive net impact on natural resources. Also in this analysis, we assume trade openness, but we add physical capital accumulation in both sectors. Consequently, the wage rate does not coincide with local population's welfare but it is only one of its components: the effect of external capitals on L-agents' physical capital matters too. Moreover, international capital mobility results in constant equilibrium wages (if parameters γ and r do not vary). If a higher K_I leads to a reduction in E, then part of labour force moves to the external sector. The effects of environmental degradation and of labor shift on labor marginal productivity in such sector offset each other. As a result, the equilibrium wage rate and the equilibrium labor marginal productivity remain constant. The final effect on the expansion of the external sector depends only on the impact of environmental externalities

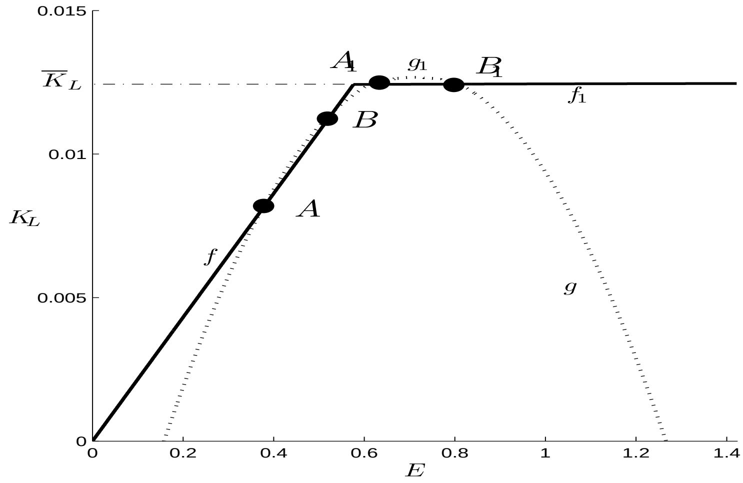
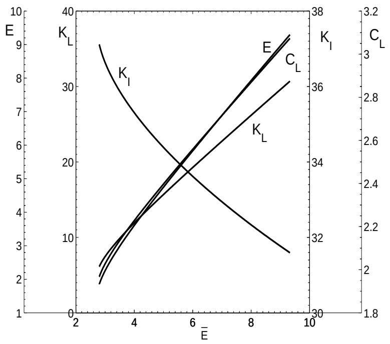
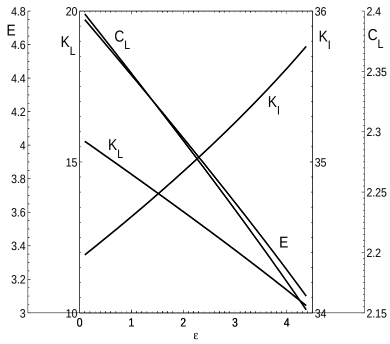


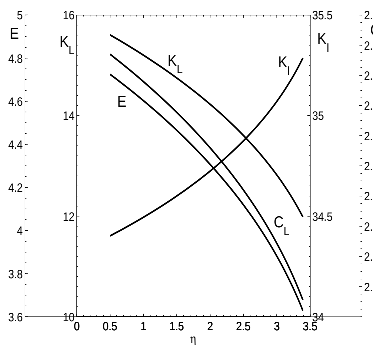
Figure 2: Numerical example in which four stationary states exist; the values of parameters are: $\alpha = 0.25$, $\beta = 0.35$, $\gamma = 0.15$, $\delta = 0.01$, $\epsilon = 2$, $\eta = 0.1$, $r = 0.01$, $\overline{E} = 6.2$.



(a) $\epsilon = 0.1, \eta = 1$



(b) $\overline{E} = 5, \eta = 1$



(c) $\overline{E} = 5, \epsilon = 0.1$

Figure 3: Values of K_L^*, K_I^*, E^*, L^*, Y_I^* and C_L^* evaluated at B, varying the parameters $\overline{E}$, ϵ and η; the other parameters are fixed at the values: $\alpha = 0.1$, $\beta = 0.35$, $\gamma = 0.2$, $\delta = 0.01$, $r = 0.01$.

on productivity of L-agents' physical capital. If a higher K_I is triggered by a change in γ or in r, instead, the welfare impact on local populations is the combination of its impact on wages and on K_L.

11 Concluding remarks

An improvement in the investment climate is one of the main objective of most local and national governments all over the world. The promotion of incentives and of opportunities for firms to invest and to create jobs is regarded as a crucial strategy in order to stimulate economic growth and to reduce poverty. The economic doctrine has underscored both the need to mobilize domestic resources and to attract external capitals and several international organizations[16] have suggested measures for promoting domestic investments and improving investment climate. In poor economies, inflows of external investments are seen by policy makers as the main solution to tackle scarcity of domestic capitals and to escape a poverty trap of low investments - low growth - poverty perpetuation. Expansion of modern activities, prompted by the arrival of external investors, are considered to be the way forward in terms of economic expansion and diversification of the local economy. Many countries, therefore, have focused their efforts on reforms and inducements which aim to promote modern and big companies usually financed by external capitals. The proposed model has enabled us to discuss the effects of these policies and the role of economic diversification for sustainable development in an economy dependent on free access natural resources. Our main findings can be summarized as follows.

1) At most two saddle-point stable stationary states can exist, the state B_1 with complete specialization in the local sector and the state B, where the external sector coexists with the local one (see Figure 2). When B_1 and B simultaneously exist, then the values of E^* and K_L^* in B are lower than the corresponding ones in B_1 (see Figure 2) and consequently local agents' welfare in B is lower than in B_1 (see Proposition 7). When this bi-stable regime occurs, the dynamics is path dependent; economies characterized by low initial values of E and K_L are more likely to converge to the Pareto-dominated stationary state B than richer economies, which can rely on greater initial values of E and K_L and, therefore, are located closer to the stationary

[16] The World Development Report 2005, for example, points out that climate investment improvements are driving factors in boosting economic expansion and combating poverty and it recommends the promotion of domestic investments and support of small and rural firms [World Bank, 2005].

state B_1. From a policy perspective, in a bi-stable context, incentives for foreign investments may favour undesirable outcomes: the policy maker could produce a greater improvement in local agents' welfare by implementing interventions able to raise the initial endowments of E^* and K_L^*. In this way, the policy maker could help L-agents to select B instead of B_1.

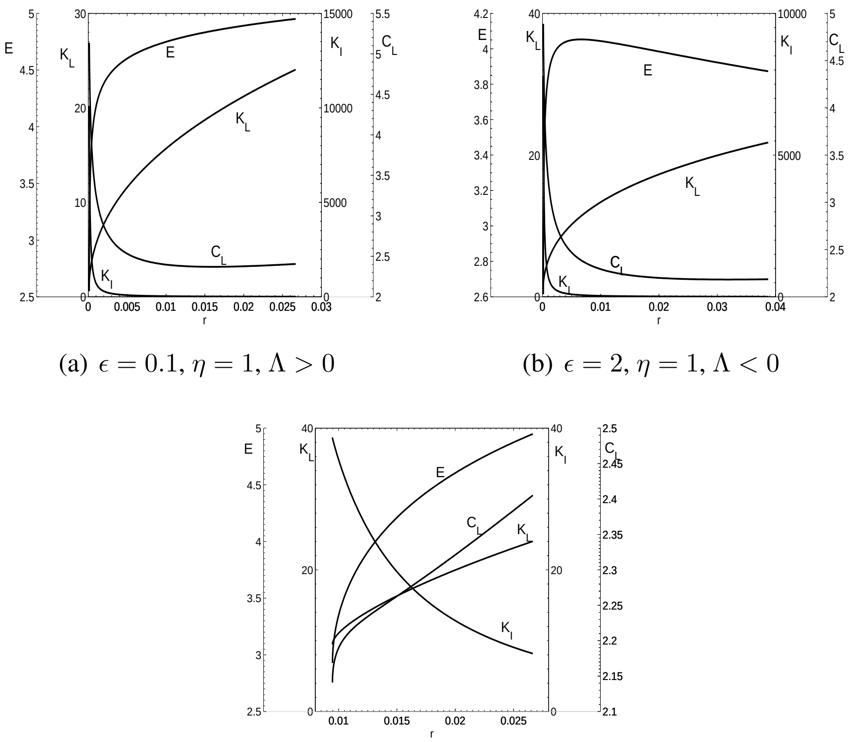
2) The existence of the stationary state without specialization B is possible only if the carrying capacity $\overline{E}$ of the environmental resource is not too high or too low (i.e. $\overline{E}_2 > \overline{E} > \min\left\{\overline{E}_1, \overline{E}_3\right\}$) and if the environmental impact of the external investment (measured by η) does not surpass a certain threshold (i.e. $\eta < \eta_T$).

3) Comparative statics analysis on the stationary state B has shown that two types of interventions can prompt external investments. First, a less strict environmental regulation that increases the values of parameters ϵ and η always leads to an increase of the external investment K_I in equilibrium B. This policy choice always produces a reduction in the stock of natural resource and in local agents' capital accumulation K_L and consumption C_L(see Figures 3b-c). The opposite effect is generated by a policy whose effect is a rise in the carrying capacity of the environmental resource. Alternatively, the policy makers can intervene on the parameter r, the cost of physical capital invested by external investors in the local economy. A decline in r always generates an increase in the external investment (see Figure 3) in B. However, local agents' welfare (measured by C_L) increases only if external agents' economic activity has a sufficiently low negative impact on the natural resource, compared with the impact of the local sector (see Figures 4a-b). Otherwise, scenarios with decreasing C_L cannot be excluded.

4) We found that local welfare evolution is not univocally described by the one of the physical capital, as in López [2010], or of the natural capital, as in Antoci et al. [2009]. In contrast, the pattern of local population's consumption in B can be either positively or negatively correlated with the dynamics of K_I and E depending on the factor which causes the change. If the trigger factor is a variation in the carrying capacity $\overline{E}$ or in the degree of environmental pressure ϵ or η, C_L is positively correlated with E and negatively with K_I. If the trigger factor is a change in r, then C_L is surely positively associated with K_I only if the external sector is not too much polluting and the carrying capacity is within a certain range.

In conclusion, the model shows that conditions for economic development and poverty reduction become stricter when environmental dynamics are included in the discussion on the interaction between local and external producers. In particular, the increasing exposure of local economies to external forces and investments can cause perverse consequences when incoming actors invest in contaminating industries and enter economies characterized by a high dependence on primary activities and, consequently, by an acute vulnerability to environmental degradation or to exclusion from the use of natural resources.

These conclusions, however, have to be evaluated taking into account that, in our model, positive externalities and backward or forward linkages between the two sectors are excluded. The inclusion of these channels of interaction between the two sectors may, in fact, limit or downsize the results obtained by this model. Our objective, however, was to focus on factors that tend to be neglected in the discussion of investment incentives, namely the environmental externalities of human activities and agents' heterogeneity in terms of vulnerability to depletion of natural resources and in access to capital markets.



(a) $\epsilon = 0.1, \eta = 1, \Lambda > 0$

(b) $\epsilon = 2, \eta = 1, \Lambda < 0$

(c) $\epsilon = 0.1, \eta = 5, \Lambda > 0$

Figure 4: Values of K_L^*, K_I^*, E^*,L^*,Y_I^* and C_L^* evaluated at B, varying the parameter r; the other parameters are fixed at the values: $\alpha = 0.1$, $\beta = 0.35$, $\gamma = 0.2$, $\delta = 0.01$, $\overline{E} = 5$.

12 Mathematical appendix

12.1 Appendix A: the dynamics generated by the model

The dynamics generated by the model are obtained by applying the *Maximum Principle* to the maximization problem of the representative L-agent, under the equilibrium condition in the labor market. The current value Hamiltonian function associated to problem (2) is (see Wirl 1997):

$$H = \ln C_L + \lambda \left[K_L^{\alpha} E^{\beta} L^{1-\alpha-\beta} + (1-L)w - C_L\right]$$

where λ is the co-state variable associated to K_L. By applying the Maximum Principle, the dynamics of the economy are described by the equations:

$$\dot{K}_L = \frac{\partial H}{\partial \lambda} = K_L^{\alpha} E^{\beta} L^{1-\alpha-\beta} + (1-L)w - C_L \tag{29}$$

$$\dot{\lambda} = \delta\lambda - \frac{\partial H}{\partial K_L} = \lambda \left[\delta - \alpha K_L^{\alpha-1} E^{\beta} L^{1-\alpha-\beta}\right] \tag{30}$$

with the constraint:

$$\dot{E} = E(\overline{E} - E) - \epsilon \overline{Y}_L - \eta \overline{Y}_I \tag{31}$$

where C_L and L satisfy the following conditions[17]:

$$\frac{\partial H}{\partial C_L} = \frac{1}{C_L} - \lambda = 0 \tag{32}$$

$$\frac{\partial H}{\partial L} = \lambda \left[(1-\alpha-\beta) K_L^{\alpha} E^{\beta} L^{-\alpha-\beta} - w\right] = 0, \text{ i.e. } w = (1-\alpha-\beta) K_L^{\alpha} E^{\beta} L^{-\alpha-\beta} \tag{33}$$

At the same time, the representative I-agent chooses the level of labor demand $1-L$ and physical capital K_I employed in the external production in order to maximize his profit function:

$$\Pi_I = K_I^{\gamma} (1-L)^{1-\gamma} - w(1-L) - rK_I \tag{34}$$

[17]Notice that, in our context, $C_L > 0$ and $1 > L > 0$ always hold.

This gives rise to the following first order conditions:

$$\frac{\partial \Pi_I}{\partial (1-L)} = (1-\gamma) K_I^{\gamma} (1-L)^{-\gamma} - w = 0 \tag{35}$$

$$\frac{\partial \Pi_I}{\partial K_I} = \gamma K_I^{\gamma-1} (1-L)^{1-\gamma} - r = 0 \tag{36}$$

The labor market is perfectly competitive and wages are flexible. I- and L- agents take w as given, but the wage rate and labor allocation between the two sectors continue to change until the labor demand is equal to labor supply. The labor market equilibrium condition is given by:

$$(1-\gamma) K_I^{\gamma} (1-L)^{-\gamma} = (1-\alpha-\beta)\, K_L^{\alpha} E^{\beta} L^{-\alpha-\beta} \tag{37}$$

By equation (36) we have:

$$K_I = \left(\frac{\gamma}{r}\right)^{\frac{1}{1-\gamma}} (1-L) \tag{38}$$

and substituting K_I in (37) we obtain:

$$L = \Gamma \left(K_L^{\alpha} E^{\beta}\right)^{\frac{1}{\alpha+\beta}} \tag{39}$$

where:

$$\Gamma := \left[\frac{1-\alpha-\beta}{(1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}}\right]^{\frac{1}{\alpha+\beta}}$$

Function (39) identifies the labor market equilibrium value L^* of L if the right side of (39) is lower than 1; otherwise, the equilibrium value of L is 1, that is:

$$L^* = \min\left\{1, \Gamma\left(K_L^{\alpha} E^{\beta}\right)^{\frac{1}{\alpha+\beta}}\right\} \tag{40}$$

The economy is specialized in the production of the L-sector if $L^* = 1$. Note that condition (35) excludes the specialization in the production of the external sector (i.e. $L^* > 0$ always). Therefore two cases are distinguished, the case *without specialization* (in the local sector) and the case *with specialization*.

If $\Gamma\left(K_L^{\alpha} E^{\beta}\right)^{\frac{1}{\alpha+\beta}} < 1$, then L-agents spend a positive fraction of their time endowment working in the external sector and condition (39) identifies the equilibrium value of L. The equilibrium wage rate is constant and is given by $w = (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}$ (Proposition 1); to prove such result, let us substitute (39) in (33) obtaining:

$$\begin{aligned} w &= (1-\alpha-\beta) K_L^{\alpha} E^{\beta} L^{-\alpha-\beta} = \\ &= (1-\alpha-\beta) K_L^{\alpha} E^{\beta} \left[\Gamma \left(K_L^{\alpha} E^{\beta}\right)^{\frac{1}{\alpha+\beta}}\right]^{-\alpha-\beta} = \\ &= (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} \end{aligned}$$

In such a context, the dynamic system (29)-(31) can be written in the form (5).

If $\Gamma \left[K_L^{\alpha} E^{\beta}\right]^{\frac{1}{\alpha+\beta}} \geq 1$, then L-agents spend all their time endowment working in the L-sector, that is $L^* = 1$, and the dynamic system (29)-(31) can be written in the form (6).

12.2 Appendix B: proof of Proposition 3

Notice that: a) $f(E)$ and $f_1(E)$ do not depend on the parameter $\overline{E}$ (see (10) and (15)); b) if the value of the parameter $\overline{E}$ increases, the graph of $g(E)$ moves up (in the plane (E, K_L)) in the case $\Lambda < 0$ and moves down in the case $\Lambda > 0$; c) if the value of the parameter $\overline{E}$ increases, the graph of $g_1(E)$ moves up.

The classification given in this Proposition, based on the values of the parameters $\overline{E}$, ϵ, η and represented in the plane $(\epsilon, \overline{E})$ (see Figure 1), can be easily checked considering that the thresholds values defined in formulas (17)-(21) are characterized by the following properties (which can be easily proved):

1) given ϵ and η, the function $\overline{E}_1(\epsilon, \eta)$ (see (17)) indicates the value of the parameter $\overline{E}$ such that the curves $f(E)$ and $g(E)$ are tangent;

2) given ϵ, the function $\overline{E}_2(\epsilon)$ (see (18)) indicates the value of the parameter $\overline{E}$ such that the curves $f(E)$ and $g(E)$ have an intersection point along the horizontal line $K_L = \overline{K}_L$ ($\overline{K}_L$ is defined in (9)[18];

3) given ϵ, the function $\overline{E}_3(\epsilon)$ (see (19)) indicates the value of the parameter $\overline{E}$ such that the curves $f_1(E)$ and $g_1(E)$ are tangent;

4) the tangency point between the curves $f_1(E)$ and $g_1(E)$ lies above the horizontal line $K_L = \overline{K}_L$ if and only if the condition $\epsilon > \epsilon_T$ (see (20)) is satisfied;

[18] Notice that, in such a case, the intersection point between $f(E)$ and $g(E)$ coincides with that between $f_1(E)$ and $g_1(E)$.

5) the tangency point between the curves $f(E)$ and $g(E)$ lies below the horizontal line $K_L = \overline{K}_L$ if and only if the condition $\eta < \eta_T$ (see (21)) is satisfied;

6) $\epsilon_\Lambda < \epsilon_T$ holds (remember that $\Lambda > 0$ iff $\epsilon < \epsilon_\Lambda$, see (14)) if and only if $\eta < \overline{\eta} := \dfrac{1-\gamma}{1-\alpha-\beta}\epsilon_T$, where $\overline{\eta} > \eta_T$ always holds;

7) the graphs of $\overline{E}_1(\epsilon,\eta)$ and $\overline{E}_2(\epsilon)$, in the plane $(\epsilon, \overline{E})$, are two parallel straight lines; they coincide for $\eta = \eta_T$ while $\overline{E}_1(\epsilon,\eta)$ lies below $\overline{E}_2(\epsilon)$ for $\eta \neq \eta_T$;

8) the function $\overline{E}_3(\epsilon)$ is strictly concave in ϵ, its graph lies below the straight line $\overline{E}_2(\epsilon)$ and is always tangent to it for $\epsilon = \epsilon_T$.

12.3 Appendix C: proof of Proposition 6

Formula (22) follows from (4) while formula (23) follows from (38) and (22). To prove (24), let us remember that $\dot{K}_L = 0$ holds for (see (29)):

$$C_L = K_L^\alpha E^\beta L^{1-\alpha-\beta} + w(1-L) \tag{41}$$

and $\dot{\lambda} = 0$ holds for (see (30)):

$$\delta = \alpha K_L^{\alpha-1} E^\beta L^{1-\alpha-\beta} \tag{42}$$

Multiplying both sides of (42) by K_L we get $\frac{\delta}{\alpha} K_L = K_L^\alpha E^\beta L^{1-\alpha-\beta}$; substituting in (41) and taking into account formulas (23) and $w = (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}$, we can write:

$$\begin{aligned} C_L &= \frac{\delta}{\alpha} K_L + (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}}(1-L) = \\ &= \frac{\delta}{\alpha} K_L + \frac{r(1-\gamma)}{\gamma} K_I \end{aligned}$$

Finally, formula (25) is obtained by substituting (23) in (24):

$$C_L^* = (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} + \frac{\delta}{\alpha}\left[1 - (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} \Gamma^{\alpha+\beta}\right] K_L^* = (1-\gamma)\left(\frac{\gamma}{r}\right)^{\frac{\gamma}{1-\gamma}} + \frac{\delta(\alpha+\beta)}{\alpha} K_L^*$$

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