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# Working Paper Series

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11/2016

SEEDS Working Paper 11/2016
November 2016
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# The dynamics of foreign direct investments in land and pollution accumulation

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**Abstract**

Following the recent increase of foreign direct investments in land, this paper studies their possible effects on the development of a local economy. To this aim, we use a two-sector model (external and local) with heterogeneous agents: *external investors* and *local land owners*. We assume that both sectors are negatively affected by pollution, but only the external sector is polluting. The local government can tax the external sector's production activities to finance environmental defensive expenditures. We first examine the equilibria that emerge in the model from the dynamics of pollution and physical capital, and then investigate the conditions for the coexistence of the two sectors and the impact of the external sector on the welfare of the local population. Using numerical simulations, we show that a welfare-improving growth path may occur only if the pollution tax is high enough and the impact of the external sector on pollution is low enough. Otherwise, a welfare-reducing growth path may occur, with foreign direct investments decreasing the revenues of local land owners.

*Keywords*: two-sector model, land grabbing, environmental negative externalities, pollution.
*JEL classification*: D62, F21, O15, O41, Q50.

## 1 Introduction

In the last 10 years there was a significant increase of studies on foreign direct investments (FDI) in land, a phenomenon often referred to as *land grabbing*.[1] Some authors consider this phenomenon as an opportunity to improve local physical capital for agricultural production, while others highlight the negative long-term implications for food security (Arezki et al., 2015).

The land rented to foreign investors is used mainly to produce agricultural goods, as food crops and bio-fuel, or to invest in tourism, renewable energy, industry, forestry, conservation.[2] In the case of food production, the FDI in land is equivalent to outsource domestic food production for those countries in which there is a limited availability of water and arable land, such as the Gulf States (Zoomers, 2010). With regard to bio-fuel production, instead, the biggest players are

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[1]By this term, we refer to FDI in land acquisition to produce agricultural goods in developing countries (Saturnino et al., 2011).

[2]See, for further details, http://www.landmatrix.org.

high-income OECD countries and emerging economies, which include some important bio-fuel producers, such as China and South Korea (Cotula et al., 2009). In a recent article on FDI for bio-fuel in Sub-Saharan Africa, Giovannetti and Ticci (2016) have shown that capital is attracted by water abundance, weak institutional framework and ill-defined land property rights. Indeed, the investments in this activity need water, political stability of the local government, and countries where individual land rights do not represent a guarantee against large-scale acquisition.

The debate on the effects of "land grabbing" in developing countries is part of the general debate on the effects of FDI on economic development and on environmental degradation. Some authors emphasize the positive role played by FDI on economic development, while others are more critical. Authors emphasizing the "pros" highlight positive effects of FDI on physical capital accumulation in the host economy due to the introduction of innovative technologies and inputs (Borensztein et al., 1998, Kemeny, 2010; Cipollina et al., 2012), of knowledge and skills through labour and manager training (Liu et al., 2001; Hansen and Rand, 2006), and of industrial competition by overcoming entry barriers and reducing the market power of exiting firms (Chung, 2001; Bitzer and Görg, 2009; Nicolini and Resmini, 2010; Damijan et al., 2013). On the contrary, other authors stress the negative effects on the development of the local economy generated by FDI via the crowding out of local firms (Aitken and Harrison, 1999; Agosin and Machado, 2005; Herzer et al., 2008; Waldkirch and Ofosu, 2010).

There is also no agreement in the empirical literature on the relationship between FDI and environmental degradation, that has been the object of many studies on the so-called *pollution haven hypothesis*. The basic idea underlying this hypothesis is that the polluting firms from developed countries relocate part of their production activities in developing countries, where the environmental regulations are less stringent (Grether and De Melo, 2003). Therefore, some authors argue that the more lenient environmental standards attract polluting FDI (see, e.g., Cole, 2004; He, 2006; Cole and Fredriksson, 2009).[3] However, other economists find no relationship between FDI and environmental regulations (see, e.g., Millimet and List, 2004; Levinson and Taylor, 2008).

The debate so far has mainly focused on empirical controversies and the modelling of the land grabbing phenomenon has been, to our knowledge, very limited. To overcome this drawback of the existing literature, this paper proposes a two-sector model (an *external* and a *local* sector) with heterogeneous agents (*external investors* and *local land owners*) to analyse the effects of FDI in land acquisition on economic development and environmental degradation of the host economy. It investigates the dynamics characterizing a small open economy, in which both sectors are negatively affected by pollution level. Both sectors produce agricultural goods using physical capital and the land endowment of the host economy as inputs.[4]

In such a context, the local land owner can rent her land to the external investors or use it for the local production process. The rent price is set by the land rental market and we assume, for simplicity, instantaneous adjustments in the price level. We suppose that only the external sector has negative effects on the pollution level, and assume that the local government can tax its production activity. The revenues coming from the pollution tax are used to finance

[3] According to some scholars (e.g. Taylor, 2004), this relocation from developed to developing countries might contribute to determine the inverted-U shaped relationship between per capita income and environmental degradation that is observed in several cross-country studies. The curve was named environmental Kuznets curve by Panayotou (1993) due to its similarity with the inequality-income relationship originally observed by Kuznets (1955). See Dinda (2004), Kijima et al. (2010), Pasten et al. (2012), for subsequent and complementary surveys of the literature.

[4] For the sake of simplicity, we suppose that each agent inelastically employs all her labour endowment in the production process, so that the labour input is equal to one in the production function. This simplifying assumption allows to exclude labour from the inputs of the production function and to focus on the land owner's choice between land and capital, which is the object of our analysis.

environmental defensive expenditures. Our model differs in several respects from other similar frameworks proposed by López (2010) and Antoci et al. (2014, 2015a,b) who adopt two-sector models with environmental externalities and heterogeneous agents. While the aforementioned contributions study an industrial sector and a resource-dependent sector, analysing the allocation of labour endowment and the welfare of local workers, here two agricultural sectors are examined, analysing the allocation of land endowment and the welfare of local land owners. Moreover, in López (2010) and Antoci et al. (2014, 2015a,b) local agents can defend themselves from environmental degradation only by working for the polluting sector. In our model, instead, in addition to rent their land to the polluting sector, also the government can defend local agents from environmental degradation by using the revenues raised through the pollution tax. Finally, differently from López (2010) and Antoci et al. (2014, 2015a,b) who measure environmental degradation in terms of depletion of natural resources, here environmental degradation is proxied by the pollution level.

Numerical simulations show that the dynamics may be bi-stable: there are two locally attractive stationary states, one in which the economy is specialized in the local sector and one in which there is coexistence of the external and the local sector, and the basins of attraction of the two attractive stationary states are separated by the stable branch of a saddle point. Moreover, the dynamics with or without specialization in the local sector is determined by the difference between the polluting effect of the external sector and the efficacy of the pollution tax, namely, the pollution abatement brought about by the abating expenditures made possible by the entries raised through the pollution tax.

With regard to the welfare analysis of local agents, it emerges that the revenues of land owners may be greater at the stationary state in which the economy is specialized in the local sector than at the stationary state in which the two sectors coexist. However, if the pollution tax is high enough and the impact of the external sector on pollution is low enough, then the introduction of an external sector may drive the economy along a welfare-improving growth path. Indeed, the revenues of local agents are inversely related to the pollution level. Therefore, an increase in the pollution tax and a decrease in the impact of the external sector on pollution tend to increase the welfare of land owners.[5]

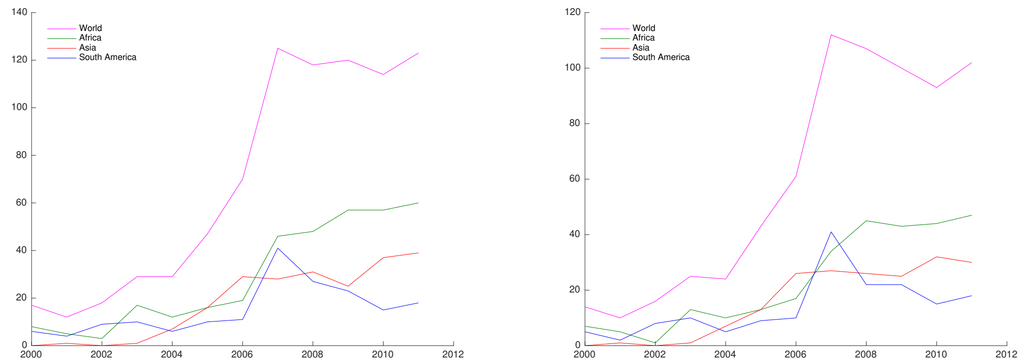
The paper is organized as follows. Section 2 presents a few recent trends in the land grabbing phenomenon that we intend to study with the help of the model introduced in Section 3. Section 4 defines the dynamics of the model, while Section 5 highlights its basic results. Section 6 illustrates, with the help of numerical simulations, some possible dynamic regimes. Section 7 performs the welfare analysis, Section 8 concludes.

## 2 The land grabbing phenomenon: recent trends

The first decade of the millennium has witnessed a surge of investments in land, especially in Africa and Asia (see Figs. 1(a) and 1(b)). The latter two continents account for about 73% of the host economies in which the FDI in land are realized.[6] Investments have been mainly taking

[5] In the rest of the paper we will use the term "welfare analysis" that is commonly used in the literature although we mainly focus on the effects that FDI in land have on the revenues of local land owners. We are fully aware that welfare implies a much broader notion than revenues as it depends on many additional drivers beyond revenues including, among other things, the environmental quality of the local ecosystem. This consideration, however, may actually reinforce some of the main results emerging from the analysis. Indeed, if external investments turn out to be non-convenient for local land owners in the present model, they would be a fortiori welfare-reducing if pollution deriving from such investments was properly taken into account.

[6] Authors' own estimations based on data retrieved from http://www.landmatrix.org




**(a)** All sectors.

**(b)** Agriculture.

**Fig. 1.** International deals by intention of investments.
Source: LAND MATRIX, accessed in September 2016.

place through purchases or long term leases (typically 50 years and some 99 years, see Cotula, 2012). This phenomenon has been particularly evident since the financial crisis of 2007-08, when land started to be acquired not only by investors interested in agriculture of food crops, but also by financial institutions that expected an increase of its value. Indeed, as Deininger et al. (2011) have pointed out, the loss of attractiveness of investing in other assets provoked by the financial crisis contributed to the rapid diffusion of land acquisitions in many continents. According to Deininger et al. (2011), only 20% of announced investments have been followed by agricultural production. In these cases, the crops were particularly water intensive.

The lack of reliable data has mainly hindered the empirical analysis of these phenomena so far. However, the publication in April 2012 of a new integrated dataset - Land Matrix - has contributed to partially fill the gap. Land Matrix has been developed by a net of international research center collecting information about deals from 2000 to 2012 all over the world. This dataset considers signed deals in all the acquisitions of land by domestic and international investors larger than 200 hectares for activities spanning from agricultural production to tourist resorts. Although the new dataset still suffers from a few problems, such as changes of definitions over time and a degree of uncertainty on some deals, it is an important source of information that can open new research strands in the next few years.

Other scholars have recently provided valuable information and useful insights on the empirical dimension of the so-called land grabbing phenomenon.[7] Among them, Rulli et al. (2013) have compiled data on transnational land acquisition. Using that data set, Coscieme et al. (2016) have performed an interesting exercise that allows to account the biocapacity acquired/lost at the global scale. While the aforementioned studies can provide important information for future empirical analysis, little attention has been payed so far to the theoretical foundations of the land grabbing phenomenon. Although the latter has attracted much attention in the public opinion, particularly for its potential consequences on the environmental and economic conditions of the receiving country, the on-going debate has generally lacked sound theoretical basis to support one opinion or the other. The model presented below intends to fill this gap and contribute to this debate by proposing a simple though rigorous theoretical framework that may allow to

[7]See Oya (2013) for a critical methodological discussion on the empirical literature and databases concerning land grabbing.

evaluate the potential effects of the phenomenon described above.

## 3 The model

Let us consider a small open economy with two production factors (land and physical capital) and two groups of agents: "Local land owners" (L-agents) and "External investors" (E-agents). In this context, we will analyse the accumulation of local physical capital and the evolution of pollution, which depends on production activities.

We assume that the production functions of the two sectors satisfy *Inada* conditions, i.e., are concave, increasing and homogeneous of degree 1 in their inputs. Moreover, we assume that the populations of local and external agents are both consisting of a continuum of identical individuals. The model, therefore, focuses on the choice processes of the representative agents of the two populations. The production function of the representative L-agent is given by:

$$Y_L = \widetilde{A} K_L^{\alpha} L^{1-\alpha} \tag{1}$$

where $\widetilde{A} := A/(1+aP)$ is a measure of productivity of the local sector, which negatively depends on the stock of pollution $P$; $K_L$ is the physical capital accumulated by the representative L-agent; $L$ is the land used in the local sector production; $0 < \alpha < 1$ and $A$, $a > 0$.

The L-agent's total endowment of land is normalized to 1. In each instant of time the representative Land owner allocates her land endowment between the two sectors; so $1 - L$ represents the land that the local agent rents to the representative External investor. The production function of the representative External investor is given by:

$$Y_E = \widetilde{B} K_E^{\beta} (1-L)^{1-\beta} \tag{2}$$

where $K_E$ denotes the stock of physical capital invested by the representative E-agent in the economy; $\widetilde{B} := B/(1+bP)$ is a measure of productivity of external sector; $0 < \beta < 1$ and $B$, $b > 0$. The representative E-agent chooses her land demand $1 - L$ and the stock of physical capital $K_E$ in order to maximize her profits, i.e.:

$$\max_{1-L,\, K_E} \left[(1-\tau)\widetilde{B} K_E^{\beta}(1-L)^{1-\beta} - r_L(1-L) - r_K K_E\right] \tag{3}$$

where $\tau \in (0,1)$ is a parameter that measures the environmental taxation, $r_L$ and $r_K$ are, respectively, the land rental price and the cost of capital.[8] We assume that $r_K$ is an exogenous parameter, while $r_L$ is endogenously determined by the land rental market equilibrium condition. We suppose that $K_E$ inflow is potentially unlimited.

The maximization problem of the representative Local agent is instead the following:

$$\max_{L} \left[\widetilde{A} K_L^{\alpha} L^{1-\alpha} + r_L(1-L)\right] \tag{4}$$

Furthermore, we assume that the dynamics of accumulation of $K_L$ is described by the equation

$$\dot{K}_L = s\left[\widetilde{A} K_L^{\alpha} L^{1-\alpha} + r_L(1-L)\right] - \gamma K_L \tag{5}$$

where, $\dot{K}_L$ is the time derivative $dK_L/dt$ of $K_L$, $s \in (0,1)$ is the constant saving rate, and $\gamma > 0$ represents the depreciation of $K_L$. To simplify, we assume that the prices of the goods produced

[8] We can consider $r_K$ as opportunity cost.

in the local and in the external sectors are both equal to unity; moreover, the land rental price $r_L$ is expressed in terms of the output of the external sector. Finally, the dynamics of pollution is described by:

$$\dot{P} = \delta \bar{Y}_E - \varepsilon P - \eta D$$

where, $\dot{P}$ is the time derivative $dP/dt$ of $P$, $\bar{Y}_E$ represents the economy-wide average value of $Y_E$, $\delta > 0$ is a parameter that measures the impact of the external sector on pollution, $\varepsilon > 0$ represents the decay rate of pollution $P$, $D$ are the pollution abatement expenditures financed by taxation of external economic activities ($D = \tau \bar{Y}_E$), and $\eta > 0$ is a parameter that measures the effectiveness of pollution abatement expenditures. Therefore, the dynamics of pollution can be rewritten as:

$$\dot{P} = (\delta - \eta\tau)\bar{Y}_E - \varepsilon P \tag{6}$$

We assume that each economic agent considers as negligible the impact of her choices on $\bar{Y}_E$ and on the time evolution of $P$ (that is, $\bar{Y}_E$ is considered as exogenously determined). Since E-agents are identical, the average output $Y_E$ ex post coincides with the per capita value $Y_E$.

## 4 Dynamics

The dynamics is obtained by solving the maximization problems (3)-(4); the solutions of these problems allow to determine the equilibrium values of $L$ and $K_E$. In particular, the maximization problem of the representative L-agent determines the following first order condition:

$$r_L = (1-\alpha)\, \widetilde{A} K_L^{\alpha} L^{-\alpha} \tag{7}$$

Similarly, the maximization problem of the representative E-agent gives rise to the following first order conditions:

$$r_L = (1-\beta)\,(1-\tau)\, \widetilde{B} K_E^{\beta} (1-L)^{-\beta} \tag{8}$$

$$r_K = \beta\,(1-\tau)\, \widetilde{B} K_E^{\beta-1} (1-L)^{1-\beta} \tag{9}$$

We assume that land rental market is perfectly competitive and land rental prices are flexible. E- and L- agents take $r_L$ as given, but land rental price and land allocation between the two sectors continue to change until land rental demand is equal to land rental supply. The land rental market equilibrium condition is given by:

$$(1-\beta)\,(1-\tau)\, \widetilde{B} K_E^{\beta} (1-L)^{-\beta} = (1-\alpha)\, \widetilde{A} K_L^{\alpha} L^{-\alpha} \tag{10}$$

From Eq. (9), we have:

$$K_E = \left(\frac{\beta}{r_K}\,(1-\tau)\,\widetilde{B}\right)^{\frac{1}{1-\beta}} (1-L) \tag{11}$$

Substituting Eq. (11) in Eq. (10), we obtain:

$$L = \Gamma \left(\widetilde{A} K_L^{\alpha}\right)^{\frac{1}{\alpha}} \tag{12}$$

where:

$$\Gamma := \left[\frac{1-\alpha}{(1-\beta)\left(\widetilde{B}\,(1-\tau)\right)^{\frac{1}{1-\beta}} \left(\frac{\beta}{r_K}\right)^{\frac{\beta}{1-\beta}}}\right]^{\frac{1}{\alpha}}$$

Function (12) identifies the land rental market equilibrium value $\widetilde{L}$ of $L$ if the right side of Eq. (12) is lower than 1; otherwise, $\widetilde{L} = 1$, that is:

$$\widetilde{L} = \min \left\{ 1,\ \Gamma \left(\widetilde{A} K_L^{\alpha}\right)^{\frac{1}{\alpha}} \right\} \tag{13}$$

Consequently, from Eq. (11), the equilibrium value $\widetilde{K_E}$ of $K_E$ is determined by:

$$\widetilde{K}_E = \left( \frac{\beta}{r_K} \left(1-\tau\right) \widetilde{B} \right)^{\frac{1}{1-\beta}} (1-\widetilde{L}) \tag{14}$$

The economy is specialized in the production of the L-sector if $\widetilde{L} = 1$ (and, consequently, $K_E = 0$). The graph of the function (represented in green in Figs. 2(a) and 2(b))

$$K_L := \bar{K}_L = \frac{1}{\Gamma \left(\widetilde{A}\right)^{\frac{1}{\alpha}}} \tag{15}$$

is the separatrix of the plane $(P, K_L)$: it separates the region of the plane $(P, K_L)$ where $\widetilde{L} = 1$ (above it) from the region where $\widetilde{L} < 1$ (below it).[9]

From condition (13) we can distinguish two possible cases: $(a)$ if $K_L = 0$, then the economy specializes in the production of the external sector (that is, $\widetilde{L} = 0$ and $K_E = \left( \frac{\beta}{r_K} \left(1-\tau\right) \widetilde{B} \right)^{\frac{1}{1-\beta}}$ are chosen); and $(b)$ if $K_L > 0$, instead, condition (13) excludes the specialization in the external sector (i.e., $\widetilde{L} > 0$ always holds for $K_L > 0$). In this case, we can distinguish two sub-cases, that is: $(i)$ the case without specialization in the local sector (i.e., $\widetilde{L} \in (0,1)$) and $(ii)$ the case with specialization (i.e., $\widetilde{L} = 1$). When $K_L > 0$, the external sector never completely replaces the local sector since the productivity of land used in the local activities tends to infinity as $L \to 0$. On the contrary, when $K_L > 0$ the economy can fully specialize in the local sector though also the productivity of land in the external sector tends to infinity as $(1-L) \to 0$. In this case, the land rent price becomes increasingly high, therefore, External investors move their capital outside the economy and reduce $K_E$, which eventually goes to zero, so that the economy ends up fully specializing in the local sector.

## 4.1 Dynamics without specialization

If $\Gamma \left(\widetilde{A} K_L^{\alpha}\right)^{\frac{1}{\alpha}} < 1$ (see function (12)), then the representative L-agent rents a positive fraction of her total land endowment to be used by the representative E-agent. Moreover, the following proposition holds:

**Proposition 1** *The equilibrium land rental price is equal to* $r_L = (1-\beta) \left(\widetilde{B}\ (1-\tau)\right)^{\frac{1}{1-\beta}} \left(\frac{\beta}{r_K}\right)^{\frac{\beta}{1-\beta}}$

**Proof.** In the context $\Gamma \left(\widetilde{A} K_L^{\alpha}\right)^{\frac{1}{\alpha}} < 1$, the equilibrium land rental price is given by:

$$\begin{aligned} r_L &= (1-\alpha)\ \widetilde{A} K_L^{\alpha} L^{-\alpha} = (1-\alpha)\ \widetilde{A} K_L^{\alpha} \left[ \Gamma \left(\widetilde{A} K_L^{\alpha}\right)^{\frac{1}{\alpha}} \right]^{-\alpha} = \\ &= (1-\beta) \left( \widetilde{B}\ (1-\tau) \right)^{\frac{1}{1-\beta}} \left( \frac{\beta}{r_K} \right)^{\frac{\beta}{1-\beta}} \end{aligned}$$

□

[9] Recall that $\widetilde{A} = A/(1+aP)$.

When $\Gamma\left(\widetilde{A}K_L^{\alpha}\right)^{\frac{1}{\alpha}} < 1$, the dynamics of the capital invested in the L-sector is given by:

$$\begin{aligned}\dot{K}_L &= s\left[\widetilde{A}K_L^{\alpha}L^{1-\alpha} + r_L(1-L)\right] - \gamma K_L = \\ &= s\left[\alpha\,\Gamma^{1-\alpha}\left(\widetilde{A}K_L^{\alpha}\right)^{\frac{1}{\alpha}} + (1-\beta)\left(\widetilde{B}\,(1-\tau)\right)^{\frac{1}{1-\beta}}\left(\frac{\beta}{r_K}\right)^{\frac{\beta}{1-\beta}}\right] - \gamma K_L\end{aligned} \tag{16}$$

while the time evolution of $P$ is represented by:

$$\begin{aligned}\dot{P} &= (\delta - \eta\tau)\bar{Y}_E - \varepsilon P = \\ &= (\delta - \eta\tau)\,\widetilde{B}^{\frac{1}{1-\beta}}\left(\frac{\beta}{r_K}\,(1-\tau)\right)^{\frac{\beta}{1-\beta}}\left(1 - \Gamma\left(\widetilde{A}K_L^{\alpha}\right)^{\frac{1}{\alpha}}\right) - \varepsilon P\end{aligned} \tag{17}$$

The system of Eqs. (16)-(17), therefore, represents the dynamics of the economy in the case without specialization.

## 4.2 Dynamics with specialization

If $\Gamma\left(\widetilde{A}K_L^{\alpha}\right)^{\frac{1}{\alpha}} \geq 1$ (that is, above the curve (15) in the plane $(P,\, K_L)$), the representative L-agent allocates all her land endowment to the production activity of the L-sector, that is $\widetilde{L} = 1$. The dynamics of the economy in the case with specialization is described by the equations:

$$\dot{K}_L = s\left(\widetilde{A}K_L^{\alpha}\right) - \gamma K_L \tag{18}$$

$$\dot{P} = -\varepsilon P \tag{19}$$

# 5 Stationary states

As it can be easily proved, a stationary state in which the economy is specialized in the external sector does not exist.[10] Therefore, two types of stationary states may be observed:

- the stationary state $A^l = (P, K_L) = \left(0, \left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}\right)$, in which the economy is specialized in the local sector, and the pollution level is equal to zero;
- stationary states in which both sectors coexist.[11]

The following proposition illustrates the conditions for the existence of the stationary state when the economy is specialized in the local sector.

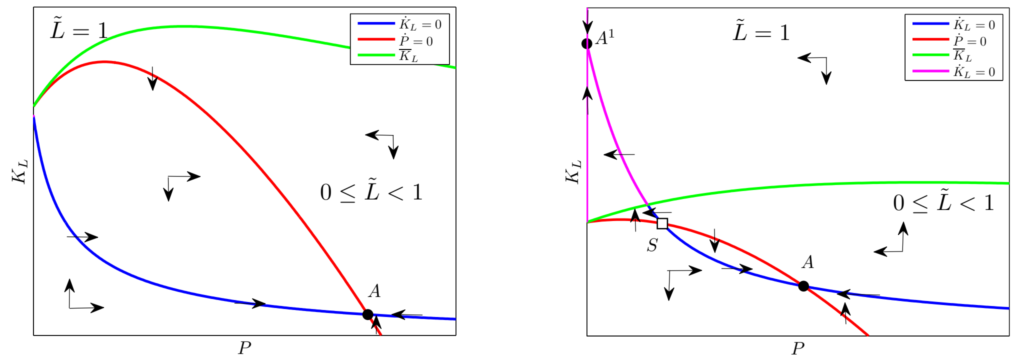
**Proposition 2** *The state* $A^l = \left(0,\ \left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}\right)$ *is a stationary state of the system (18)-(19) if and only if*

$$A \geq \left(\frac{\gamma}{s}\right)^{\alpha}\left[\frac{1-\alpha}{(1-\beta)(B(1-\tau))^{\frac{1}{1-\beta}}(\frac{\beta}{r_K})^{\frac{\beta}{1-\beta}}}\right]^{\alpha-1} \tag{20}$$

*When existing, it is always locally attractive (see Fig. 2(b)).*

[10] Notice that, if the economy specializes in the external sector, then $K_L = 0$ and $L = 1$. If this is the case, from (5) it follows that savings and/or the land rental price would have to be zero at the stationary states, which violates the assumptions underlying the model.

[11] As it will be shown below (see Section 6) through numerical simulations, these stationary states are either attractive or saddle points.




**(a)** $\tau = 0.12$.

**(b)** $\tau = 0.42$.

**Fig. 2.** Isoclines.
*Parameter values:* $A = 1,\ B = 2,\ a = 5,\ b = 2,\ \alpha = 0.65,\ \beta = 0.35,\ \delta = 0.5,\ r = 0.1,\ s = 0.6,\ \eta = 1,\ \varepsilon = 0.55,\ \gamma = 0.19.$

**Proof.** According to the system (18)-(19), it holds that $\dot{K}_L = 0$ for:

$$K_L = \left[\frac{sA}{\gamma(1+aP)}\right]^{\frac{1}{1-\alpha}}$$

The dynamics (18)-(19) admits an unique stationary state $A^l = (P, K_L) = \left(0,\ \left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}\right)$ if and only if $A^l$ lies above the separatrix $K_L = \bar{K}_L$ (see function (15)), i.e, if $\bar{K}_L(0) \leq \left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}$, that is:

$$A \geq \frac{(\frac{\gamma}{s})^{\alpha}}{\Gamma^{\alpha(1-\alpha)}} = \left(\frac{\gamma}{s}\right)^{\alpha}\left[\frac{1-\alpha}{(1-\beta)(B(1-\tau))^{\frac{1}{1-\beta}}(\frac{\beta}{r_K})^{\frac{\beta}{1-\beta}}}\right]^{\alpha-1}$$

While the Jacobian matrix of the system (18)-(19), calculated at the stationary state $A^l$ is:

$$J(A^l) = \begin{pmatrix} -(1-\alpha)s\widetilde{A}K_L^{\alpha-1} & -\alpha sAK_L^{\alpha} \\ 0 & -\varepsilon \end{pmatrix}$$

with strictly negative eigenvalues: $-(1-\alpha)s\widetilde{A}K_L^{\alpha-1} < 0$ and $-\varepsilon < 0$. Therefore, when the stationary state $A^l$ exists, it is always locally attractive. $\square$

As Proposition 2 points out, the stationary state without external sector $A^l$, when existing, lies always above the separatrix $\bar{K}_L$ (where, $\widetilde{L} = 1$) and it is always locally attractive. Numerical simulations show that if the pollution tax is low enough (e.g. $\tau = 0.12$ in Fig. 2(a)), the economy cannot fully specialize in the local sector. However, when the pollution tax gets sufficiently high (e.g. $\tau = 0.42$ in Fig. 2(b)), there exists also the locally attractive stationary state $A^l$ so that the economy can converge to an equilibrium without external sector. This result is rather intuitive: since the pollution tax enters as a cost in the maximization problem (3) of External investors, the higher (lower) the pollution tax, the lower (higher) the incentive for external investors to purchase the local land to establish their production activities in the region.

If the economy is not specialized in the local sector, the stationary states of the system (16)-(17) are given by the solutions of the system of equations:

$$\begin{aligned} 0 &= s\left[\alpha\,\Gamma^{1-\alpha}\left(\widetilde{A}K_L^{\alpha}\right)^{\frac{1}{\alpha}} + (1-\beta)\left(\widetilde{B}\,(1-\tau)\right)^{\frac{1}{1-\beta}}\left(\frac{\beta}{r_K}\right)^{\frac{\beta}{1-\beta}}\right] - \gamma K_L \\ 0 &= (\delta-\eta\tau)\,\widetilde{B}^{\frac{1}{1-\beta}}\left(\frac{\beta}{r_K}\,(1-\tau)\right)^{\frac{\beta}{1-\beta}}\left(1-\Gamma\left(\widetilde{A}K_L^{\alpha}\right)^{\frac{1}{\alpha}}\right) - \varepsilon P \end{aligned} \tag{21}$$

From system (21), we obtain that $\dot{K}_L = 0$ for:

$$K_L = F(P) := \frac{s(1-\alpha)\bar{K}_L}{\gamma\bar{K}_L\Gamma^{\alpha} - \alpha s} \tag{22}$$

and $\dot{P} = 0$ for:

$$K_L = G(P) := \bar{K}_L - \frac{\varepsilon P(1+bP)^{\frac{1}{1-\beta}}\bar{K}_L}{(\delta-\eta)B^{\frac{1}{1-\beta}}\left(\frac{\beta}{r_K}(1-\tau)\right)^{\frac{\beta}{1-\beta}}} \tag{23}$$

Two cases can occur:

i) if $\delta - \eta\tau \leq 0$, i.e., the polluting impact of the external sector ($\delta$) does not overcome the pollution abatement effect ($\eta$) of the defensive expenditures financed by tax entries ($\tau$), then from Eq. (17) it holds that $\dot{P} < 0$ for every $P > 0$, therefore, there are no stationary states with $P > 0$ and the trajectories tend toward the axis $P = 0$.

ii) if $\delta - \eta\tau > 0$, namely, the pollution abatement effort made possible through the pollution tax is insufficient to counterbalance the polluting impact of the external sector, then the curve $K_L = G(P)$ lies always below the separatrix $\bar{K}_L(P)$ and stationary states, in which both sectors coexist in a context with $P > 0$, can exist.

Stated differently, cases i) and ii) above imply that if the pollution tax is high enough (above the ratio between $\delta$ and $\eta$) the economy will converge to an equilibrium without pollution, otherwise it will tend to a coexistence equilibrium in which the pollution level is positive. Moreover, $G(0) = \bar{K}_L(0)$, i.e., the curve $K_L = G(P)$ and the separatrix $K_L = \bar{K}_L(P)$ have the same intercept on the axis $P = 0$ (cf. Fig. 2(b)). It is not possible to compute analytically the number of intersection points that may be observed; however, from the shape of the curves $\dot{P} = 0$ and $\dot{K}_L = 0$ it follows that there may exist at most two stationary states with $P > 0$, i.e., the attraction point $A$ and the saddle point $S$ (see Figs. 2(a) and 2(b)).

Global dynamics of system (5)-(6) is characterized by the following result.

**Proposition 3** *The set:*

$$\Omega = \{(P, K_L) : 0 \leq P \leq P^* \text{ and } 0 \leq K_L \leq K_L^*\}$$

*where*

$$P^* := \frac{\delta-\eta\tau}{\varepsilon}B^{\frac{1}{1-\beta}}\left[\frac{\beta}{r_K}(1-\tau)\right]^{\frac{\beta}{1-\beta}} \quad , \quad K_L^* > \max\left[\left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}},\ \widehat{K}_L\right]$$

*and*

$$\widehat{K}_L$$

*is the maximum of the function (see (15))*

$$K_L = K_L(P) \ ,$$

*is positively invariant under the dynamics (5)-(6); every trajectory starting outside* $\Omega$ *enters it in finite time. When the stationary state with specialization* $A^l = (P, K_L) = \left(0,\ \left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}\right)$ *does not exist, then no sector definitively disappears from the economy (both sectors coexist).*

**Proof.** Considering equation (17), we can write:

$$\dot{P} = (\delta - \eta\tau)\widetilde{B}^{\frac{1}{1-\beta}}\left[\frac{\beta}{r}(1-\tau)\right]^{\frac{\beta}{1-\beta}}\left[1 - \Gamma\left(\widetilde{A}K_L^{\alpha}\right)^{\frac{1}{\alpha}}\right] \ < \ (\delta - \eta\tau)\widetilde{B}^{\frac{1}{1-\beta}}\left[\frac{\beta}{r}(1-\tau)\right] - \varepsilon P \ \leq$$

$$\leq (\delta - \eta\tau)B^{\frac{1}{1-\beta}}\left[\frac{\beta}{r}(1-\tau)\right]^{\frac{\beta}{1-\beta}} - \varepsilon P$$

Since the maximum value that $\widetilde{B}$ can assume is $B$, then it holds $\dot{P} > 0$ for:

$$P \geq P^* := \frac{\delta - \eta\tau}{\varepsilon}B^{\frac{1}{1-\beta}}\left[\frac{\beta}{r_K}(1-\tau)\right]^{\frac{\beta}{1-\beta}}$$

Indicating with $\widehat{K}_L$ the maximum of the function (see (15)) $K_L = \bar{K}_L(P) := \frac{1}{\Gamma(\bar{A})^{\frac{1}{\alpha}}}$ (that always exists), and remembering that the value of $K_L$ in the stationary state $A^l$ is given by $\left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}$, it holds $\dot{K}_L < 0$ for every $K_L > \max\left[\left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}},\ \widehat{K}_L\right]$. □

Proposition 3 implies that coexistence between sectors is possible. Indeed, if the stationary state $A^l$ does not exist (i.e., the economy can not specialize in the local sector), then trajectories that enter the set $\Omega$ can approach either a stationary state or a limit set (e.g. a limit cycle) in which both sectors coexist.

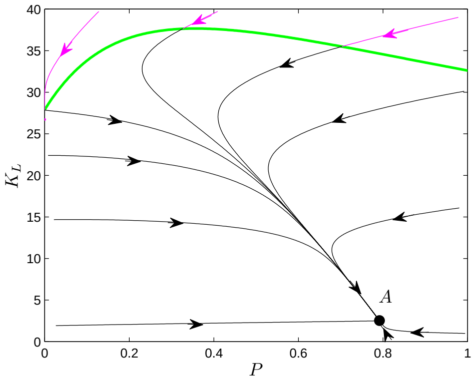
# 6 Simulations

This section presents the results of some numerical simulations of the dynamics of our model. Three types of dynamic regimes may be observed depending on the level of the pollution tax:

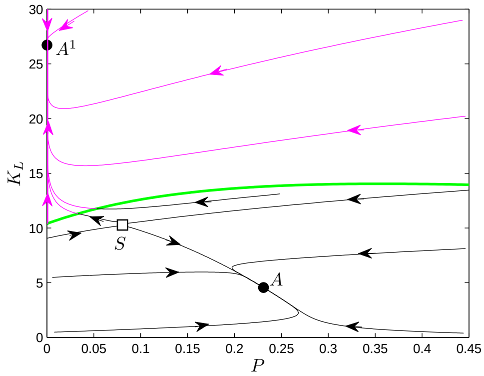
a) if the pollution tax is low enough, then a unique globally attractive stationary state $A$ exists in which both sectors coexist (see Fig. 3(a));

b) for intermediate values of the pollution tax, the dynamics is bi-stable: there are two locally attractive stationary states, $A^l$, in which the economy is specialized in the local sector, and $A$, where both sectors coexist (see Fig. 3(b)); the basins of attraction of $A^l$ and $A$ are separated by the stable branch of the saddle point $S$;

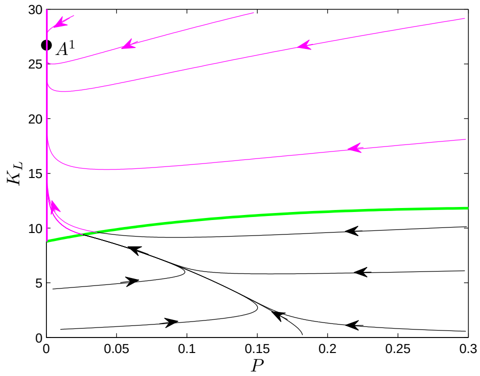
c) if the pollution tax is high enough, then the stationary state $A^l$ becomes globally attractive, and, consequently, the economy always specializes in the local sector (see Fig. 3(c));




**(a)** $\tau = 0.12$.




**(b)** $\tau = 0.42$.




**(c)** $\tau = 0.46$.

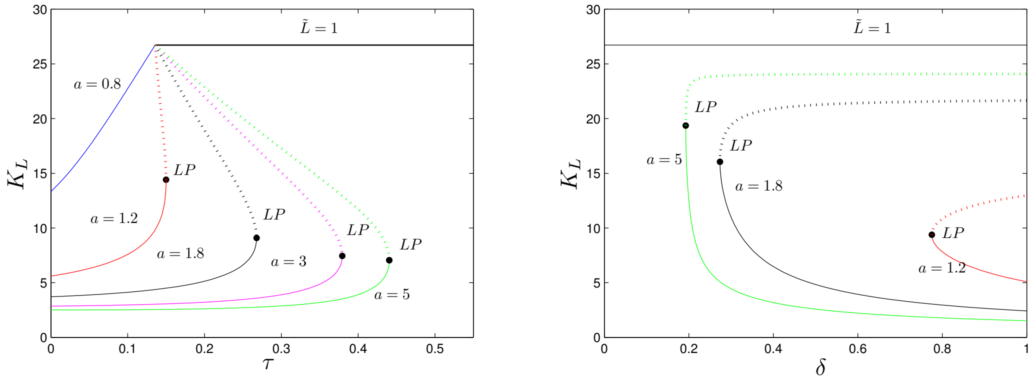
**Fig. 3.** Phase diagrams.
*Parameter values:* $A = 1$, $B = 2$, $a = 5$, $b = 2$, $\alpha = 0.65$, $\beta = 0.35$, $\delta = 0.5$, $r = 0.1$, $s = 0.6$, $\eta = 1$, $\varepsilon = 0.55$, $\gamma = 0.19$.

Figs. 4(a) and 4(b) show bifurcation diagrams obtained, respectively, varying the parameters $\tau$ and $\delta$; the continuous lines represent the stationary state $A$ (except the black line $\widetilde{L}$ that represent the stationary state $A^l$), while the dashed lines represent the stationary state $S$.[12] From Figs. 4(a) and 4(b), we can infer the following main results:

i) a threshold value of the pollution tax exists, such that when $\tau$ is high enough the economy specializes in the local sector (see Fig. 4(a));

ii) a threshold value of the impact of the external sector on pollution exists, such that when $\delta$ is high enough both sectors coexist (see Fig. 4(b)).

[12] As is well known, bifurcation diagrams show qualitative changes (e.g. variation in the number and stability of equilibria) occurring at critical parameter values. In Fig. 4(a), for instance, a unique steady state (denoted $LP$) exists when $a = 5$, $\tau = 0.44$ and $K_L = 7$. However, an infinitesimal fall in $\tau$ below the critical value will give rise to a bi-stable dynamic regime: the stable stationary state $A$ with $K < K_L$ (denoted by the continuous line) and the unstable stationary state $S$ with $K > K_L$ (indicated with a dashed line). A similar interpretation applies to all other curves in Figs. 4(a) and 4(b).




**(a)** $\delta = 0.5$.

**(b)** $\tau = 0.18$.

**Fig. 4.** Bifurcation diagrams; LP represents the limit point.
*Parameter values:* $A = 1$, $B = 2$, $b = 2$, $\alpha = 0.65$, $\beta = 0.35$, $r = 0.1$, $s = 0.6$, $\eta = 1$, $\varepsilon = 0.55$, $\gamma = 0.19$.

These results are rather intuitive, and can be explained by looking at the (relative) values of the pollution tax and of the polluting effect of the external sector. For a given value of $\delta$, a sufficiently low pollution tax attracts foreign direct investments, since it enters as a cost in the maximization problem (3), so that the stationary state with specialization does not exist (see Fig. 4(a)). Mutatis mutandis, for a given value of $\tau$, the same result applies when the polluting effect of the external sector is sufficiently high (see Fig. 4(b)).[13] On the contrary, when the pollution tax is high enough with respect to the polluting impact of the external sector, then for the External investors it is more rewarding to move their capital outside the local economy and reduce $K_E$, which eventually goes to zero, so that the economy ends up fully specializing in the local sector (see Fig. 3(c) and Fig. 4(a)). Finally, recall that the entries coming from the pollution tax are used to finance environmental defensive expenditures (see Eq. (6)). Therefore, if the pollution tax is low enough with respect to the polluting effect of the external sector, then environmental defensive expenditures are insufficient to abate pollution so that at the end of the day the pollution level is relatively high at the stationary state (see Fig. 3(a)). However, if the pollution tax is high enough with respect to the impact of the external sector on pollution, then environmental defensive expenditures can effectively reduce pollution so that the pollution level turns out to be relatively low at the equilibrium (see Fig. 3(b)).

Finally, notice that the threshold levels of $\tau$ and $\delta$ vary with changes in $a$, the impact of pollution on the productivity of the local sector. The higher $a$ the higher the critical value of the pollution tax beyond which external investors stop investing in the land of the host country (Fig. 4(a)). The opposite applies to the critical value of $\delta$ that decreases as $a$ increases (Fig. 4(b)), confirming the opposite trends and roles that $\tau$ and $\delta$ play in the model.

[13] These two results (that can be interpreted as two sides of the same coin) seem to be in line with the pollution haven hypothesis, i.e., external firms relocate part of their production to the countries where the environmental standards are less stringent with respect to their polluting effect.

## 7 Welfare of local land owners

In this section we compare the revenues of L-agents at $A^l$ and at stationary states in which both sectors coexist. The remuneration of capital $K_E$ invested by the representative E-agent is $r_K K_E$ while the revenues of the representative L-agent are given by:

$$\Pi_L(P, K_L) = \bar{A}K_L^{\alpha}L^{1-\alpha} + r_K(1-L) =$$
$$= \begin{cases} \alpha\Gamma^{1-\alpha}\Big(\bar{A}K_L^{\alpha}\Big)^{\frac{1}{\alpha}} + (1-\beta)\Big(\bar{B}(1-\tau)\Big)^{\frac{1}{1-\beta}}\left(\frac{\beta}{r_K}\right)^{\frac{\beta}{1-\beta}} & if \quad K_L < \bar{K}_L(P) \\ \bar{A}K_L^{\alpha} & if \quad K_L \geq \bar{K}_L(P) \end{cases}$$

Therefore, the revenues of the representative L-agent in $A^l = (P, K_L) = \Big(0, \ \left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}\Big)$ are equal to:

$$\Pi_L(A^l) = \Pi_L\left(0, \ \left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}\right) = A^{\frac{1}{1-\alpha}}\left(\frac{s}{\gamma}\right)^{\frac{\alpha}{1-\alpha}}$$

The effects generated by the external investments on welfare of L-agents can be better understood by comparing the dynamics generated by the two-sector model considered in this paper with the one-sector dynamics that would be observed in absence of External investors:

$$\dot{K}_L = sAK_L^{\alpha} - \gamma K_L \tag{24}$$

According to the one-sector dynamics (24), the state $K_L = \left(\frac{sA}{\gamma}\right)^{\frac{1}{1-\alpha}}$ is always a globally attractive stationary state and corresponds to the stationary state $A^l$ of the two-sector model, when existing. We shall compare the revenues of L-agents obtained at the stationary state $A^l$ with those obtained at a generic state $(P, K_L)$ where both sectors coexist. Observe that $\Pi_L(A^l) < \Pi_L(P, K_L)$ holds if and only if the $P$ and the $K_L$ satisfy the condition:

$$A^{\frac{\alpha}{1-\alpha}}\left(\frac{s}{\gamma}\right)^{\frac{\alpha}{1-\alpha}} < \alpha\Gamma^{1-\alpha}\Big(\bar{A}K_L^{\alpha}\Big)^{\frac{1}{\alpha}} + (1+\beta)\Big(\bar{B}(1-\tau)\Big)^{\frac{1}{1-\beta}}\left(\frac{\beta}{r_K}\right) \tag{25}$$

Setting:

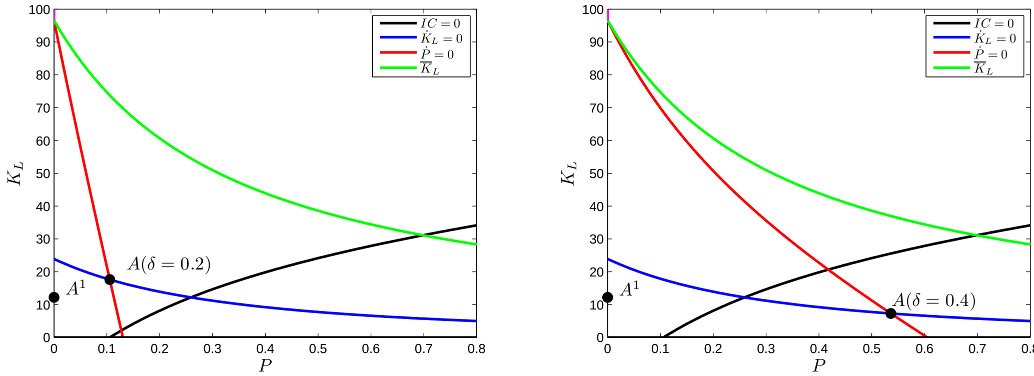
$$A^{\frac{\alpha}{1-\alpha}}\left(\frac{s}{\gamma}\right)^{\frac{\alpha}{1-\alpha}} = \alpha\Gamma^{1-\alpha}\Big(\bar{A}K_L^{\alpha}\Big)^{\frac{1}{\alpha}} + (1+\beta)\Big(\bar{B}(1-\tau)\Big)^{\frac{1}{1-\beta}}\left(\frac{\beta}{r_K}\right)$$

we obtain the indifference curve $(IC)$:

$$\alpha\Gamma^{1-\alpha}(\widetilde{A}K_L^{\alpha})^{\alpha} + (1-\beta)(\widetilde{B}(1-\tau))^{\frac{1}{1-\beta}}\left(\frac{\beta}{1-\beta}\right)^{\frac{\beta}{1-\beta}} - AK_L^{\alpha} = 0 \tag{26}$$

with $\Pi_L(A^l) < \Pi_L(P, K_L)$ (respectively, $\Pi_L(A^l) > \Pi_L(P, K_L)$) if the state $(P, K_L)$ lies above (below) it, in the plane $(P, K_L)$. The following proposition holds.

**Proposition 4** *The revenues of L-agents, evaluated at a generic point $(P, K_L)$ where both sectors coexist, are greater than in $A^l$ (i.e., $\Pi_L(A^l) < \Pi_L(P, K_L)$, see Fig. 5(a)), if the point $(P, K_L)$ lies above the indifference curve (26). Conversely, if the point $A$ lies below the indifference curve (26), then $\Pi_L(A^l) > \Pi_L(P, K_L)$ (see Fig. 5(b)).*




**(a)** $\tau = 0.18$.

**(b)** $\tau = 0.18$.

**Fig. 5.** Indifference Curve.
*Parameter values:* $A = 1$, $B = 2$, $a = 5$, $b = 2$, $\alpha = 0.65$, $\beta = 0.35$, $r = 0.1$, $s = 0.6$, $\eta = 1$, $\varepsilon = 0.55$, $\gamma = 0.19$.

Consistently with Proposition 4, numerical simulations show that if the pollution tax is high enough with respect to the impact of the external sector on pollution, then the introduction of an external sector may lead the economy to a welfare-improving growth path, i.e., $\Pi(A^l) < \Pi(A)$ (see Fig. 6(a) in which the curve $\Pi(A)$ crosses the horizontal line $\Pi(A^l)$ from below, at $\tau = \tau^*$, therefore $\Pi(A^l) < \Pi(A)$) for $\tau > \tau^*$). On the contrary, if the pollution tax is low enough with respect to the impact of the external sector on pollution, then a welfare-reducing growth path (i.e., $\Pi(A^l) > \Pi(A)$) may come along with the external sector (see Fig. 6(a)). Mutatis mutandis, a welfare-reducing growth path may also occur if the impact of the external sector on pollution is high enough with respect to the pollution tax. This can be easily seen from Fig. 6(b)): for a given level of the pollution tax ($\tau = 0.18$) we have $\Pi(A^l) > \Pi(A)$ when $\delta$ is above the threshold level ($\delta = 0.25$).[14]

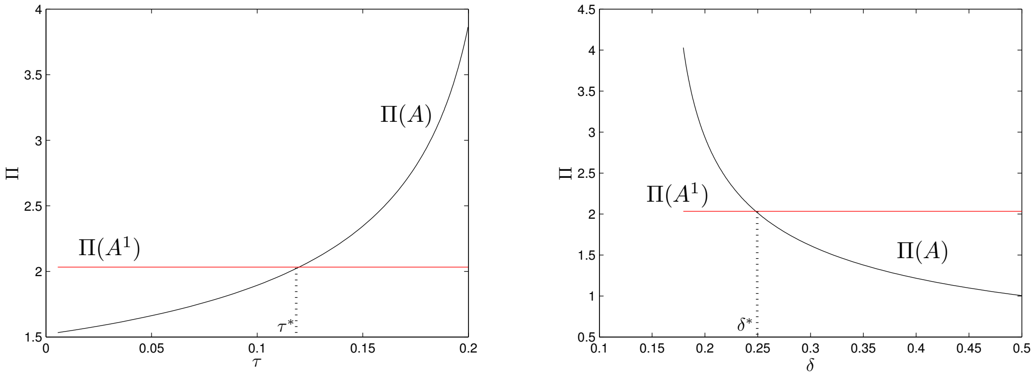
From the numerical simulations shown in Figs. 7(a) and 7(b), and Figs. 8(a) and 8(b), we can infer the following main results:

i) an increase of the pollution tax may have positive effects on $\Pi(A)$ (see Fig. 7(a)) and on both local and external capitals (see Fig. 7(b)), since it decreases the pollution level, which increases the productivities $\widetilde{A}$ and $\widetilde{B}$ of the local and the external sectors, respectively;

ii) an increase of the impact of the external sector on pollution may have negative effects on $\Pi(A)$ (see Fig. 8(a)) and on both local and external capitals (see Fig. 8(b)), since it increases the pollution level, thus decreasing the productivities $\widetilde{A}$ and $\widetilde{B}$ of both sectors.

In summary, if the pollution level is relatively high, then the productivity of both sectors decreases. This has a twofold effect: on the one hand, it reduces the revenues of local land owners,

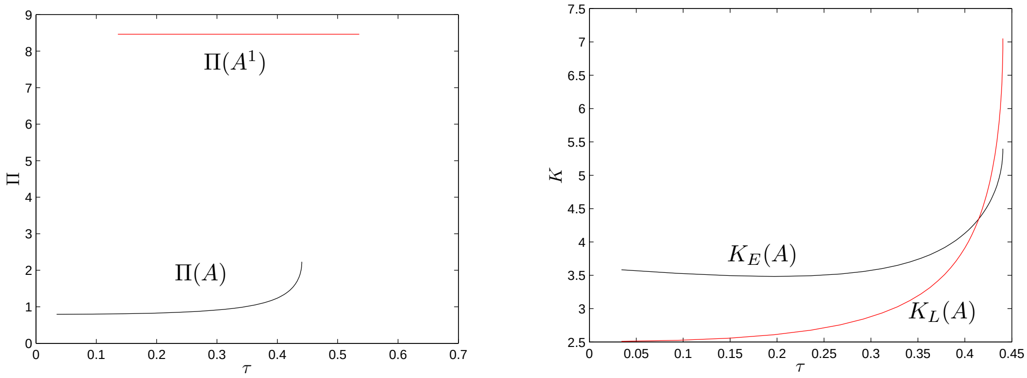
[14] Notice that the revenues of L-agents at stationary state in which the economy is specialized in the local sector ($\Pi(A^l)$) are invariant to an increase of the pollution tax or of the impact of the external sector on pollution (see Fig. 7(a) and Fig. 8(a)).




**(a)** $\delta = 0.2$.

**(b)** $\tau = 0.18$.

**Fig. 6.** Welfare analysis: relationship between revenues of local land owners and pollution tax **(a)**, and impact of the external sector on pollution **(b)**.
*Parameter values:* $A = 1$, $B = 2$, $a = 5$, $b = 2$, $\alpha = 0.65$, $\beta = 0.35$, $r = 0.1$, $s = 0.6$, $\eta = 1$, $\varepsilon = 0.55$, $\gamma = 0.19$.

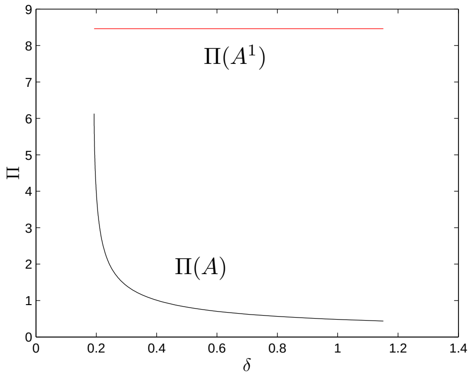



**(a)** $\delta = 0.5$.

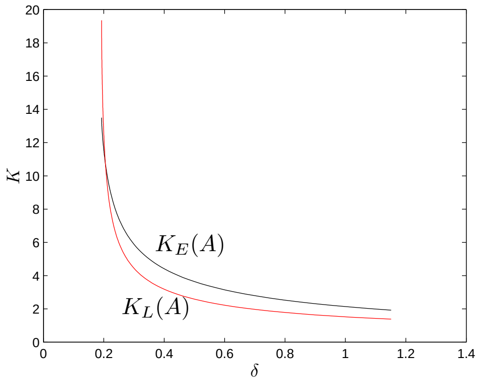
**(b)** $\delta = 0.5$.

**Fig. 7.** Welfare analysis: relationship between pollution tax and revenues of local land owners **(a)**, and capital levels in both sectors **(b)**.
*Parameter values:* $A = 1$, $B = 2$, $a = 5$, $b = 2$, $\alpha = 0.65$, $\beta = 0.35$, $r = 0.1$, $s = 0.6$, $\eta = 1$, $\varepsilon = 0.55$, $\gamma = 0.19$.

on the other hand it induces external investors to move their capital out of the economy, towards other countries in which their capital can be more productive and they can get higher returns. As emerges from the numerical simulations, to avoid that this is the case and ensure that the revenues of local land owners are higher at the coexistence equilibrium than in the absence of external investors, the pollution tax must be high enough and the polluting impact of the external sector low enough (see Figs. 6(a) and 6(b)).




**(a)** $\tau = 0.18$.




**(b)** $\tau = 0.18$.

**Fig. 8.** Welfare analysis: relationship between impact of the external sector on pollution and revenues of local land owners **(a)**, and capital levels in both sectors **(b)**.
*Parameter values:* $A = 1$, $B = 2$, $a = 5$, $b = 2$, $\alpha = 0.65$, $\beta = 0.35$, $r = 0.1$, $s = 0.6$, $\eta = 1$, $\varepsilon = 0.55$, $\gamma = 0.19$.

# 8 Conclusions

Foreign direct investments in land have increased substantially since the beginning of the new millennium, and have recently been the object of several empirical studies. However, to our knowledge, there is not yet a satisfactory theoretical model to investigate their effects on the welfare of local land owners. To fill this gap in the literature, the paper has investigated the possible effects of FDI in land on a small open economy with two sectors, external and local, and heterogeneous agents, external investors and local land owners. Both sectors are negatively affected by pollution, but only the external sector is polluting. We assume the possibility for the local government to tax the production activities of the external sector to finance environmental defensive expenditures that are meant to abate pollution and/or restore the originally cleaner environmental conditions.

Numerical simulations show that the dynamics of the model may be bi-stable. The stationary states in which there is specialization in the local sector and in which both sectors coexist are locally attractive. The basins of attraction of such states are separated by the stable branch of a saddle point. From numerical simulations performed on the model it emerges that if the pollution tax is low enough with respect to the impact of the external sector on pollution, this attracts FDI, so that the economy does not fully specialize in the local sector. On the contrary, if the pollution tax is high enough with respect to the polluting impact of the external sector, then the specialization in the local sector may occur.

As the model shows, FDI in land can increase the revenues of local land owners. This, however, requires a sufficiently low polluting impact of FDI and a sufficiently high pollution tax on their production activity. The former condition is needed to avoid an excessive productivity loss of local land, while the latter allows to finance pollution abatement expenditures that can counterbalance the rise in pollution brought about by the external sector. If these conditions are not satisfied, the land acquisition by foreign investors that has been rapidly spreading at the world level may impoverish local land owners. Moreover, since pollution tends to decrease land productivity in the long run, foreign investors might have an incentive to flee away from the country and move their capital outside the local economy once the productivity of the external sector starts decreasing, leaving the host country worse-off than in the absence of any foreign land acquisition. These results call for a proper regulation of the so-called land grabbing phenomenon from local governments through a sufficiently high pollution tax that may discourage polluting investments and can raise the entries for appropriate environmental policies. This aspect seems of primary importance if we want to pursue a prosperous and sustainable coexistence of the local and the external sectors in those countries.

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