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PAYMENTS FOR ENVIRONMENTAL SERVICES AND ECONOMIC GROWTH: A THEORETICAL MODEL

Abstract

Given the global climate emergency and the complex financing problems facing developing countries, some economists are advocating the introduction of payments for environmental services. The question is whether payments for environmental services will enable developing countries to make the ecological transition compatible with the economic growth they need to develop. This study presents a theoretical analysis of the economic and ecological efficiency of such a mechanism, and aims to determine whether it has any recessionary or disincentive effects. In other words, it determines whether, from a theoretical point of view, the environmental services provided by developing countries are compatible with continued growth. The study introduces a "payments for environmental services" procedure into a general equilibrium model (with involuntary unemployment) composed of multinational firms in developed and developing economies. This theoretical model yields the following results. Firstly, higher ecological taxes can directly increase environmental services without any recessionary effect. The system of payments for environmental services means that green investment is not necessarily incompatible with growth and development in developing countries. On the other hand, services in return for environmental payments can lead to a rebound effect from polluting activities, which is why such programs need to be accompanied by more radical environmental policies. In conclusion, while payments for environmental services can promote both ecological transition and growth in developing countries, it is necessary to control the rebound effect arising from the development of economic activity.

Keywords carbon tax, developing countries, ecological transition, general equilibrium, global warming, greenhouse gas emissions, green sector, rebound effect

JEL Classification Q52, Q54, D50, O10

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INTRODUCTION

Despite the political will of governments, the commitment of international organizations and civil society, and the involvement of private-sector players, one thing is clear: the environment is deteriorating fast. One major challenge is how to design public policies that integrate environmental issues and economic concerns within a single framework with several players who sometimes have diverging objectives. The problem is that developing countries prefer to implement economic policies to ensure the growth and development of their economies rather than ecological transition policies that can hinder economic growth and development. In this context, it is appropriate to ask whether payments for environmental services (PES) are compatible with the objectives of ensuring growth while enabling the ecological transition.

Developed countries finance payments for environmental services. This type of funding is based on taxes and charges, which can discourage economic activity. Furthermore, the development of the green sector in developing countries is likely to detriment their economic growth. This raises the question of whether payments for envi-

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ronmental services can override the disadvantages. However, this issue has not yet been clarified by a theoretical approach. While there are many microeconomic models, the question remains to be studied from a macroeconomic point of view. For this purpose, it is appropriate to use a theoretical general equilibrium model in which all markets are interdependent. Within this framework, it is possible to analyze the impact of the development of the green sector on other sectors of activity that meet the needs of the population.

1. THEORETICAL BASIS

Payments for environmental services (PES) are the subject of growing interest from the scientific community from a theoretical (Wunder, 2005, 2015; Sommerville et al., 2009; Muradian et al., 2010; Tacconi, 2012; Karsenty & Ezzine de Blas, 2014) and a practical point of view (Muradian et al., 2010; Karsenty et al., 2017). Wunder (2005) defines payment for environmental services as a voluntary transaction in which one or more environmental service buyer(s) purchases a well-defined environmental service (or a land use likely to secure that service) from one or more environmental service provider(s) under the condition that the environmental service provider shall deliver the service. According to this mechanism, individuals, communities, or landowners receive compensation or financial reward in exchange for the preservation, restoration, or sustainable management of ecosystems. PES are granted to provide environmental services beneficial to society, e.g., carbon sequestration, protection of water resources, biodiversity conservation, or preservation of natural habitats.

This definition does not meet with the unanimous approval of researchers, as in practice PES are mobilized to achieve different objectives (Sommerville et al., 2010; Farley & Costanza, 2010). However, it remains a benchmark and supports the idea that PES have similar characteristics to economic incentive-based instruments, such as taxes and subsidies.

Understood as such, PES are not based on the polluter-pays principle but rather on the beneficiary-pays rationale. Thus, PES schemes have the potential to transform the externalities and non-market values of the environment into genuine financial incentives for local communities while also inducing them to provide environmental services (Engel et al., 2008).

However, local stakeholders might often receive fewer benefits from ecosystem conservation than they could derive from alternative use of their land, such as conversion to agricultural activities. This poses a real problem for assessing the opportunity cost of PES and their environmental effectiveness that guarantees the sustainability of such schemes.

This evaluation of PES has been the subject of numerous studies focusing on the criteria of environmental effectiveness (Sills et al., 2008; Wunder & Albán, 2008; Cole, 2010; Pattanayak et al., 2010; Scullion et al., 2011; Arriagada et al., 2012; Yang et al., 2013) and socio-economic efficiency (Uchida et al., 2007; Locatelli et al., 2008; Richards, 2008; Jagger et al., 2010; Hegde & Bull, 2011; Arriagada et al., 2012; Tacconi et al., 2013). According to Coase's theorem (Coase, 1960), the PES mechanism is theoretically based on the idea that problems of externalities can be solved by coordination between two economic agents, for example, between the beneficiaries (buyers) of environmental services and the suppliers (providers) of these services. However, the conditions advocated in Coase's theorem are not found in reality, notably because of high transaction costs and poorly defined or undefined property rights in developing countries. Such a configuration does not necessarily guarantee the effectiveness of PES. On the other hand, it is surprising that hardly any studies use economic modeling to analyze the effects of implementing a PES scheme on economic activity. Most of the literature is either concerned with qualitative case studies or empirical analyses using econometric approaches. A theoretical analysis should identify the general conditions for the effectiveness of PES.

Using the general equilibrium model, it is possible to shed more light on the macroeconomic plan of Graff-Zivin and Lipper (2008), Alix-Garcia et al. (2012), Mason and Plantinga (2013), Pates and Hendricks (2020), and Krautkraemer and

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Schwartz (2021). Therefore, to gain a macroeconomic perspective on the economic implications of payment for environmental services, the present study considers a global economy made up of two countries: developed and developing. Within the economies considered in this study, there are two representative multinational firms. One produces a green good (quantity Y) that reduces greenhouse gas emissions (e.g., a CO2 capture good), while the other produces a final consumer good (quantity X) that meets a basic need of the population but whose production method causes various forms of pollution (pesticides or CO2 emissions). Companies, employees, and public authorities are assumed to be price takers. The formal distinction between the two types of countries is that the developing country is financially dependent on the developed country for the provision of environmental services. As a result, the developed country decides the quantity of environmental services that the developing country must produce on its own territory in return for funding.

The model assumptions are as follows. The utility function of a developed market economy $U(Y_R, X_R)$ uses two arguments:

1) the quantity of an environmental good Y_R (or a green good) that helps the fight against global warming, and

2) the quantity of a polluting good X_R that the state distributes as collective aid to households. The quantity of green goods is partly supplied by the developing country to the developed country's government as part of a payment-for-environmental-services mechanism.

The developing country must arbitrate between the quantity of the environmental good (part of which corresponds to an order placed with the developing country) and the distribution of the good within its community under a budgetary constraint defined by the tax levy (T). This corresponds to a uniform worldwide tax on the profits of the polluting company. The environmental good is useful for the countries because its production reduces global warming, while the distribution of the polluting good to the final consumer is useful for the countries because it raises the population's standard of living.

Thus, the solution to the problem is obtained as follows by maximizing the utility function in the developed country:

$$Max\,U\left(Y_R, X_R\right) = Y_R \cdot X_R, \tag{1}$$

under constraint

$$\varpi T = PY_R + P_x X_R, \tag{2}$$

where ϖ is the proportion of global tax revenues T allocated to the state of the developed country. P is the price of the green good and P_x is the price of the polluting good for the final consumer. Tax revenues are a tax levied on part of the profit of the firm producing the polluting good (X).

The result of the maximization program is expressed by the following function:

$$Y_R = \frac{\varpi T}{2P}, \text{ and } X_R = \frac{\varpi T}{2P_x}. \tag{3}$$

The demand for green and brown sector goods expressed by the government of the developed country is an increasing function of the tax revenues allocated to it and a decreasing function of the respective price of each good. Demand for the green good Y_R is partly met by local production in the developing country in exchange for payment from the developed country.

The developing country has a utility function $U(\rho Y_R, X_p)$ with the same arguments as those used by the developed country (quantities of green good Y_R and polluting good X_p). However, the utility function is partly under the control of the developed country, which decides unilaterally the quantity of green goods to be produced through the environmental services payment scheme. ρ represents the proportion of the developed country's demand for the green goods (Y_R) to be met by local production in the developing country. The quantity of green goods produced is useful to the developing country's state, as the fight against global warming benefits both.

Since the developed country partly controls the utility function in the developing country, the latter cannot maximize its own utility function, which can be written as:

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$$U\left(\rho Y_R, X_P\right) = \rho Y_R^{\gamma} \cdot X_P^{\,1-\gamma}, \tag{4}$$

where ρ and $\gamma < 1$. γ are parameters characterizing the preferences of the developing country. ρY_R represents the quantity of green goods ordered by the developed country and X_p is the quantity of consumer goods distributed among the population.

The quantity of green goods to be produced in the developing country (ρY_R) is paid for by the developed country through payments for environmental services; the entire tax revenue of the developing country is used to finance the consumer good (X) that is distributed to satisfy the immediate needs of the population, i.e.:

$$\left(1-\omega\right)T = P_x X_P. \tag{5}$$

The multinational firm producing green goods is located in developing and developed countries. It has a single-factor production function, which is denoted as follows:

$$Y = aY^{\varnothing} L^{\propto}, \tag{6}$$

where $aY^{\varnothing}$ represents the average labor productivity, which depends on the global warming process. a and $\varnothing$ are parameters < 1 that respectively capture the productive efficiency of the labor factor and the effect of global warming on production of goods. The idea is as follows: the higher the production Y of the green good, the higher the labor productivity since global warming is limited at the same time. Conversely, the lower the parameter $\varnothing$, the more global warming will handicap labor productivity and the level of production of green goods. Thus, the effects of global warming on labor productivity are both exogenous (parameters a and $\varnothing$) and endogenous (the level of production of green goods). $\propto$ is a parameter that measures the elasticity of production with respect to the labor factor. The production function can be rewritten as follows:

$$Y = a^{\frac{1}{1-\varnothing}} \cdot L^{\frac{\alpha}{1-\varnothing}}. \tag{7}$$

The firm producing green goods determines its global demand for labor (L) in such a way as to maximize its profit:

$$\begin{aligned} Max\,\pi\left(L\right) &= P \cdot Y - wL \\ &= P \cdot a^{\frac{1}{1-\varnothing}} \cdot L^{\frac{\alpha}{1-\varnothing}} - wL, \end{aligned} \tag{8}$$

where w is the prevailing wage rate. This gives the following labor demand function:

$$L = \left(\frac{1}{a^{\frac{1}{1-\varnothing}}}\right)^{\frac{1-\varnothing}{\propto-1+\varnothing}} \left(\frac{w}{P}\right)^{\frac{1-\varnothing}{\propto-1+\varnothing}} \left(\frac{1-\varnothing}{\alpha}\right)^{\frac{1-\varnothing}{\propto-1+\varnothing}}. \tag{9}$$

To maintain the standard hypothesis of diminishing marginal returns, it can be assumed that

$$\frac{1-\varnothing}{\propto -1+\varnothing} < 0\,car \propto -1+\varnothing < 0. \tag{10}$$

Consequently, the supply of green goods can be determined by replacing L with its expression given in equation (9) to obtain the production function:

$$Y = a^{\frac{1}{1-\varnothing}} \left(\frac{\frac{1-\varnothing}{\alpha}}{a^{\frac{1}{1-\varnothing}}}\right)^{\frac{\alpha}{(\propto-1+\varnothing)}} \cdot \left(\frac{w}{P}\right)^{\frac{\alpha}{(\propto-1+\varnothing)}}. \tag{11}$$

The multinational firm producing the polluting final consumer good (X) follows a "Ricardian" technical system: it produces goods with its own good, whose quantity is denoted as G and whose price is denoted as r. The firm's profit-maximizing program is then written as:

$$Max\,\pi\left(G\right) = r\left(f\left(G\right)\right) - rG - T, \tag{12}$$

under the constraint of a production function

$$f\left(G\right) = Y^{\varnothing} bG^{\mu}, \tag{13}$$

where $b > 1$ and $0 < \mu < 1$. $Y^{\varnothing}b$ represents the productivity of the factor of production and b is a parameter representing the exogenous component of productivity, while Y represents its endogenous dimension. It is assumed that productivity within the firm producing the polluting goods also depends on global warming. The greater the production of the green goods (Y), the less global warming and the higher the productivity of the production factor within the polluting firm. T is the flat-rate tax levied on the polluting firm's profits.

The above profit maximization program gives the following demand function for the production factor G:

$$G_p = \left(\frac{1}{Y^{\varnothing} b\mu}\right)^{\frac{1}{\mu-1}}, \tag{14}$$

and the supply function of the polluting good, Y_n:

$$Y_n = \left(\frac{1}{Y^{\varnothing} b \mu} \right)^{\frac{\mu}{\mu - 1}}. \tag{15}$$

In the global labor market, households usually arbitrate between consumption of the polluting goods (whose quantity is denoted as X_m) and leisure (whose quantity is denoted as S) according to their respective price P_x and wage rate w. However, in a situation of unemployment (the prevailing real wage is assumed to be higher than the equilibrium wage), the representative firm that hires labor will control the household budget constraint (Cartelier, 1995). Thus, the firm's demand for labor figures in the household budget constraint instead of supply. The household utility function is denoted as:

$$U_M \left(S, X_m \right) = S \cdot X_m, \tag{16}$$

and the household's budget constraint is:

$$P_x \left(X_m - X_R - X_P \right) + wS = wJ + N, \text{ or } \quad P_x \left(X_m - X_R - X_P \right) = w \left(J - S \right) + N, \tag{17}$$

where X_R and X_P are the quantities of goods allocated respectively by developed and developing countries to households (as public aid), J corresponds to the time available in a day (24 hours), and N is the sum of the profits of the two firms that is not deducted as taxes.

Since the firm producing green goods unilaterally determines the level of employment, the household budget constraint is finally written as:

$$P_x \left(X_m - X_R - X_P \right) = wL + N, \tag{18}$$

where L is the quantity of labor the green firm has decided to use. In the final analysis, since the wage w, the quantity of employment, the price of polluting goods, and the firms' profits are imposed on households that cannot maximize the utility of the good in question, and consequently the total demand for this good is given by:

$$X_m = X_R + X_P + \frac{w}{P_x} L + \frac{N}{P_x}. \tag{19}$$

In this model, the labor market is excluded from Walras's law, since the household budget constraint is controlled by the firm producing green goods. Walras's law, therefore, only applies to two markets: the market for green goods and the market for polluting goods. The sum of the budget constraints gives:

$$P \left(Y - Y_R \right) + P_x \left(Y_n - X_m \right) = 0. \tag{20}$$

According to the corollary of Walras's law, if the market for the green good is balanced, the market for the polluting good will also be balanced. It is, therefore, possible to solve the model by focusing solely on the equation representing the equilibrium of the market for the green good, i.e. $Y = Y_R$.

The equilibrium market price of green goods (i.e., the solution to the equation) is written as:

$$P = \left(\frac{1}{2} \frac{\omega T}{w^{\frac{\alpha}{(\propto - 1 + \varnothing)}} \left(\frac{1 - \varnothing}{\frac{\alpha}{a^{\frac{1}{1 - \varnothing}}}} \right)^{\frac{\alpha}{(\propto - 1 + \varnothing)}} \cdot a^{\frac{1}{1 - \varnothing}}} \right)^{\frac{(\alpha - 1 + \varnothing)}{(\varnothing - 1)}}. \tag{21}$$

The money wage w is also parametric (nominal wage rigidity). By substituting the equilibrium price (given in equation 21) into the supply equation (11), it is possible to obtain the production of the equilibrium green goods:

$$\begin{aligned} Y = {} & a^{\frac{1}{1 - \varnothing}} \left(\frac{1 - \varnothing}{\frac{\alpha}{a^{\frac{1}{1 - \varnothing}}}} \right)^{\frac{\alpha}{(\propto - 1 + \varnothing)}} \\ & \times (w)^{\frac{\alpha}{(\propto - 1 + \varnothing)}} 2w^{\frac{(\alpha - 1 + \varnothing)}{(\varnothing - 1)} \frac{\alpha}{(\propto - 1 + \varnothing)} \frac{\alpha}{(\propto - 1 + \varnothing)}} \\ & \times \left(\left(\frac{1 - \varnothing}{\frac{\alpha}{a^{\frac{1}{1 - \varnothing}}}} \right)^{\frac{\alpha}{(\propto - 1 + \varnothing)}} a^{\frac{1}{1 - \varnothing}} \right)^{\frac{(\alpha - 1 + \varnothing)}{(\varnothing - 1)} \frac{\alpha}{(\propto - 1 + \varnothing)}} \\ & \times (\omega T)^{\frac{-\alpha}{(\varnothing - 1)}}. \end{aligned} \tag{22}$$

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2. RESULTS

The first outcome of the model is as follows: increasing the tax T on a fraction of the profits of the polluting multinational firm leads to an increased production of green goods.

The proof of this result is given below:

$$\frac{\partial Y}{\partial T}=\frac{-\alpha}{(\varnothing-1)}a^{\frac{1}{1-\varnothing}}\left[\left(\frac{1-\varnothing}{\frac{\alpha}{a^{\frac{1}{1-\varnothing}}}}\right)^{\frac{\alpha}{(\propto-1+\varnothing)}}\right.$$

$$\times(w)^{\frac{\alpha}{(\propto-1+\varnothing)}}2w^{\frac{\alpha}{(\propto-1+\varnothing)}\frac{(\alpha-1+\varnothing)}{(\varnothing-1)}\frac{\alpha}{(\propto-1+\varnothing)}} \tag{23}$$

$$\times\left.\left(\left(\frac{1-\varnothing}{\frac{\alpha}{a^{\frac{1}{1-\varnothing}}}}\right)^{\frac{\alpha}{(\propto-1+\varnothing)}}\cdot a^{\frac{1}{1-\varnothing}}\right)^{\frac{\alpha}{(\propto-1+\varnothing)}}\right]$$

$$\times(\varpi T)^{\frac{-\alpha-\varnothing+1}{\varnothing-1}}>0.$$

The level of production of green goods is an increasing function of the tax levied to finance environmental services. This tax has no recessionary effect on overall economic activity, since the level of production of the polluting good is independent of the flat-rate tax (equation 15).

The second outcome of the model is that, in a Keynesian world with involuntary unemployment (the labor supply function is deactivated), a levy on household wages to finance the ecological transition would have the same effects as a flat-rate levy on profits. There would be no negative effect on the prevailing level of employment, since solely entrepreneurs (equations 9 and 11) control the latter.

In other words, if there were a fall in household labor supply as a result of the fall in take-home pay, this would have no effect on the level of employment and the level of production, since labor supply does not come into play in the process of determining the level of employment in a situation of involuntary unemployment. The production of green goods always increases with the tax levy. There is no effect on the equilibrium price (equation 21) or the production of the green good (equation 22), both of which depend solely on the demand of the developed country and the technology of the green firm. Furthermore, in a general equilibrium model, a levy on wages or a lump-sum levy on profits on the demand for polluting goods would have identical effects, since households are both employees and shareholders of the firms (they receive the profits as well as wages from the same firms (equation 17)).

The third outcome of the model is that combating global warming by increasing payments for environmental services has a negative effect linked to the increased production of polluting goods (equation 15). Indeed, mitigating global warming has a positive effect on the productivity of all factors of production. There is therefore a kind of rebound effect. Payments for environmental services are insufficient from an environmental point of view if the technology of polluting firms is not modified toward greater respect for nature. The production of polluting goods is written as follows:

$$Y_p=Y^{\varnothing}b\mu^{\frac{\mu}{1-\mu}}, \tag{24}$$

Thus, the incremental growth in production is:

$$\frac{\delta Y_p}{\delta Y}=\varnothing Y^{\varnothing-1}b\mu^{\frac{\mu}{1-\mu}}>0. \tag{25}$$

3. DISCUSSION

The first theoretical outcome derived from the general equilibrium model suggests that an increase in the flat-rate tax levy would enable a rise in the production of environmental services without leading to any overall recessionary effect, and, therefore, without any drop in the population's standard of living. The system of payments for environmental services means that green investment is not incompatible with growth and development in poor countries: the increase in tax revenues earmarked to combat global warming will mechanically increase the production of green goods without reducing the production of the usual consumer goods. The benefits are both ecological (increased CO2 capture) and economic (increased employment).

However, it is necessary to note that, empirically, payments for environmental services sometimes produce contradictory results, and these generally depend on the specific context of their implementation, the objectives pursued, and the environmental characteristics of the territory concerned.

Indeed, several studies claim that payments for environmental services have a disincentive effect on economic activity. Wang et al. (2019) claim that PES reduce the proportion of cultivated land and salaried labor, while Arriagada et al. (2015) and Wang et al. (2019) revealed that such schemes exert a negative effect on economic growth in rural areas. PES schemes can also lead to lower agricultural productivity (Kanchanaroek & Aslam, 2018; Manjula et al., 2019; Treacy et al., 2018).

Nevertheless, Hayes et al. (2017), Wang et al. (2019), and Duong and De Groot (2020) consider that PES schemes improve total income and promote access to credit for the development of agricultural production. Kalunda (2016) showed that PES can provide additional income for low-income families and additional profits for crop planting. For Moros et al. (2019), PES increases investment in the agricultural sector and stimulates consumption. In comparison, Izquierdo-Tort et al. (2019) maintain that PES schemes generate more jobs while diversifying agricultural production and encouraging the development of the tourism industry.

Although the present paper is based on a theoretical model, it leads to conclusions that converge with the results of Nguyen et al. (2021), according to which payments for environmental services make it possible to protect the environment and generate multiple incomes for beneficiary households living in the regions concerned by such schemes. In other words, payments for environmental services can combat global warming without any disincentive or recessionary effects.

The discrepancy between the empirical results cited above and the theoretical model presented in this study can be explained by the fact that some of the different financing methods taken into account may represent a disincentive to production activities. In addition, there may be a difference in the time horizons considered. The presented model shows no disincentives or trade-offs for tax avoidance insofar as the levy is assumed to be flat-rate and uniformly affects all polluting multinational firms (at least, those represented by the firm in the model). If the tax in the model were proportional to profit, the tax levy would effectively lead to a fall in the supply of the polluting consumer good, partly offset by an increase in demand from the country (which is linked to the increase in the tax levy).

Some authors fear that environmental taxation could affect the competitiveness of companies subject to these taxes, particularly if other countries do not adopt similar policies. However, the impact on competitiveness can be moderate or even positive, depending on how the additional tax revenues are reinvested (Bovenberg & Goulder, 1996; Fullerton & Heutel, 2007). In the presented model, these tax levies indirectly increase profits since they also improve productivity in the medium to long term, thus offsetting the losses resulting from environmental taxation. In general, two conditions are necessary to ensure a positive link between the tax levy, the production of green goods, and economic activity:

i) implementation of a uniform flat-rate tax; and

ii) a medium- to long-term perspective that considers the beneficial effects of global warming on the productivity of production factors. In the case of a proportional tax, the loss in profits would be partly offset by the increased demand from governments and the rise in productivity made possible by the PES mechanism.

The second outcome evidences the equivalence of uniform taxation of polluting firms' profits and workers' wages. Taxation of polluting activities can have significant economic consequences both in terms of incentives to reduce pollutant emissions and the effects on economic growth. Some authors argue that ecological taxation can lead to disproportionate costs for low-income households, while others believe well-designed policies can mitigate these inequalities (Parry et al., 1999; Bovenberg & Goulder, 1997).

According to standard neoclassical theory, an increase in taxes has a disincentive effect on labor supply, explaining the fall in economic activity and

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the decline in tax revenues (Blundell & Macurdy, 1999). The idea that tax levies can have disincentive effects on labor supply is often associated with the Laffer curve (Piluso, 2023). According to this theory, there is an optimal level of tax levies that maximizes government revenues without excessively discouraging labor supply. When tax rates are very high, they produce disincentives for individuals to work, who may then look for ways to avoid taxes or turn to informal activities.

All these orthodox models presuppose full employment of the workforce and the joint participation of labor supply and demand in determining the equilibrium level of employment. On the other hand, since labor supply is deactivated (equation 9) in a world of involuntary unemployment (Keynes, 1936; Cartelier, 1995), the disincentive effect on labor supply does not affect economic activity. This is because labor supply is replaced by labor demand in the employees' budget constraint, and only the firms' demand for labor determines the level of production and employment. In addition, the reduction in income induced by tax levies on households is offset by the distribution of additional income made possible by the introduction of environmental services (increased production of green goods).

In view of the massive involuntary unemployment worldwide (particularly in developing countries), it is more appropriate to reason in terms of labor market imbalances rather than constructing models assuming full-employment equilibria, as is usually the case in the literature.

The third outcome establishes that an increase in the production of green goods leads to an increase in the production of polluting goods. The increase in levies for the implementation of PES enables the intensification of the fight against global warming, which in turn also increases the production of polluting goods. This is because the fight against greenhouse gas emissions makes it possible to limit the negative impact of climate change on productivity. When productivity increases steadily from one period to another, it is possible to show (at least theoretically) that combating global warming reinforces the dynamics of productivity gains.

However, according to Cayla (2023), it is not possible to increase the production of goods enabling the ecological transition without at the same time enhancing the production of (possibly polluting) final consumer goods:

"We know that the ecological transition will require an enormous collective investment effort[1]. In concrete terms, this means renovating our housing stock, building new railroads and decarbonizing our energy system. We'll have to change almost all our vehicles, replace our gas and coal-fired power plants, and produce steel without coal... All this will have a considerable real cost. Energy resources and raw materials will have to be redirected for this purpose. The problem is that all the resources that will be devoted to producing more capital goods cannot be used to produce consumer goods. In other words, to organize the ecological transition, we'll have to reorient our economy towards more investment and less consumption [...]; The ecological transition will be implemented all the more rapidly and effectively if household purchasing power is reduced overall" (Cayla, 2023).

The present model shows that this is not the case: for constant quantities of production factors and productive resources, the production of green goods improves the productivity of sectors involved in the mitigation of global warming, thus enabling an increase in the production of goods in other sectors.

Global warming can have disastrous effects on the productivity growth. Global warming leads to higher production costs and waste[2] . By mitigating global warming, the production of green goods reinforces the upward momentum of productivity gains. Cayla (2023) also overlooks the knock-on effect of tax levies. The introduction of an ecological tax to combat global warming

1 The International Energy Agency (IEA) estimates that achieving net zero emissions by 2050 would require an average annual investment of USD 4.4 trillion in clean energy technologies.

2 There are a number of policy briefs for the production costs associated with climate change (and therefore greenhouse gas emissions): the literature only deals with damage functions affecting the output (Dietz & Stern, 2015), affecting capital and output (Dafermos et al., 2017), or affecting labor and capital productivity (Burke et al., 2015).

affects an immediate drain on household income (corresponding to wages or profits in the model presented here), but also, in return, an increase in the quantity of income distributed via the rise in demand for and supply of green goods.

This is precisely why the production of green goods is not a sufficient solution, as a rebound effect is to be feared. To counteract this rebound effect, is not enough to simply increase the production of green goods (payments for environmental services are an essential vector for developing countries) or the environmental efficiency of green goods since this policy would reinforce the upward momentum of productivity in all sectors. The adoption of a tax proportional to the level of production or profits (and therefore correlated with CO2 emissions) would discourage supply but would in no way eliminate the rebound effect linked to the boosting of productivity. The polluting sector must itself adopt cleaner technologies or simply be radically eliminated and replaced by economic activities more respectful of the environment. This could be applicable, for example, in the case of sectors exploiting or producing fossil fuels.

This theoretical analysis opens up new perspectives considering certain aspects of imperfect competition. There is a need to determine whether some of the conclusions could be modified or relativized in view of the fact that economic agents are also price-makers. In particular, it would be interesting to see if ecological taxation in the presence of mark-up behavior could attenuate the rebound effect of payments for environmental services.

CONCLUSION

In this study, the economic and ecological efficiency of payments for environmental services is assessed using a general equilibrium model with involuntary unemployment. If payments for environmental services are financed by a tax on the profits of polluting firms or on workers' wages, there is a direct link between higher taxation and higher production (in the green or brown sectors), without the recessionary effect usually noted in the classic literature. In particular, the model shows that while payments for environmental services can help combat global warming, they also limit the damage caused to the increased performance of all factors of production in the economy. However, this can have a rebound effect on polluting activities linked to the increased production of polluting goods. This implies that while the PES mechanism may be effective, it is not sufficient to limit the rise in CO2 emissions. The environmental efficiency of the production of green goods must be strengthened in parallel with the implementation of PES, or, failing that, certain activities with a high carbon footprint should be definitively abandoned.

AUTHOR CONTRIBUTIONS

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