Carbon Tax and Economic Stability: A Broader Approach to the Double Dividend of Ecological Taxation

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This article develops a Keynesian model of economic growth with involuntary unemployment in a situation of perfect competition in which we introduce an environmental tax. We show that it is possible to demonstrate a triple dividend from ecological taxation. This triple dividend is characterized by an ecological effect of reducing greenhouse gas emissions, and two possible economic effects: a possible positive effect on employment, and an effect of reducing the instability of the economy. We therefore broaden the double dividend issue by highlighting an implication of ecological taxation that has been little studied in the literature. We show that highlighting a double or triple dividend from ecological taxation does not require introducing elements of imperfect competition.

Keywords: double-dividend, carbon tax, growth, instability, perfect competition

INTRODUCTION

The double-dividend issue refers to the idea that introducing an environmental tax is likely to produce both ecological and economic benefits, with unchanged budget revenues (budget neutrality hypothesis). Ekins (1997) draws up a typology of the economic benefits that ecological taxation can bring: an employment dividend when it reduces unemployment, an efficiency dividend when it reduces tax distortions[1] (Goulder, 1994), or a social dividend when the redistribution process improves equity within the community of economic agents. Generally speaking, and to our knowledge, the theoretical and empirical literature on the double dividend is limited to analyzing these three types of benefit (Chiroleu-Assouline, 2001). Goulder (1994) adds another typology linked to the degree of benefit provided by the environmental tax: a weak version of the double dividend (the ecological tax makes it possible to reduce the gross costs of taxation), an intermediate version (the ecological tax makes the costs of taxation disappear) and a strong version (the ecological tax makes the gross costs of taxation negative).

The first models to study the occurrence of a double dividend from fiscal policy for environmental purposes were based on general equilibrium theory, with assumptions approaching perfect competition. Examples include Chiroleu-Assouline (2001), Bovenberg and Mooij (1994, 1997), Bovenberg and van der Ploeg (1996), Parry (1995) and Goulder (1995). Their results show that an environmental tax can solve an environmental externality while increasing tax distortions, to the extent that the introduction of such a tax can only be justified if the environmental benefit is large-scale.

Moreover, from an initial level of environmental taxation, any public decision to increase it leads to a drop in employment and production. By reducing workers' purchasing power, the environmental tax reduces labor supply. As Chiroleu-Assouline (2001) points out, "the essential role played in our results by the elasticity of labor supply concerning the purchasing power of wages emphasizes the essential assumptions of the general equilibrium analysis conducted by Bovenberg and de Mooij, namely pure and perfect competition and equilibrium in the labor market" (p. 13). The work of Gilles Kaltenrieder (2005), who built a general equilibrium model applied to Switzerland, confirms this analysis: based on assumptions of perfect competition, his work shows that the occurrence of a double dividend from ecological taxation in terms of employment is zero. Similarly, the article by Al Amin Siwar and Hamid (2009), which presents a computable general equilibrium model, fails to demonstrate this double benefit.

As we move towards a framework of imperfect competition, the possibility of a double dividend arises. This is the case, for example, when we assume that the real wage remains fixed at an excessive level, generating unemployment. As shown by Bovenberg and van der Ploeg (1996), the introduction of an ecological tax on the production factor "energy" then generates a substitution of labor for energy, if labor is a better substitute for energy than capital.

In a competition without price fixing model, such a tax leads to a drop in production instead of an increase in demand for labor. In a model with endogenous efficiency real wages (Schneider, 1997), ecological taxation has a favorable effect on employment if, in return, it reduces social charges on labor; in this case, it enables companies to reduce the wage offered without loss of effort and productivity on the part of workers, increasing the level of employment. In models where the real wage results from wage bargaining (Brunello, 1996), ecological taxation worsens the purchasing power of both employees and the unemployed. Still, employees benefit from a reduction in social charges on their wages, which improves employment. The double dividend here results from a transfer of the tax burden from workers to the unemployed

Marsiliani and Renstron (1997) and Holmlund and Kolm (1997) demonstrate that the second dividend (the economic dividend) is all the greater the less competitive the market. Similarly, Boitier et al. (2015, p.4) assert that "the flexibility of the labor market thus appears crucial for the sharing, within the population, of the effects of a rise in energy prices and the efficiency of the recycling of the amounts of a possible energy tax". The first empirical estimates from neo-Keynesian models confirmed the idea of a double employment dividend from eco-taxes when they are used to reduce labor costs (Godard and Beaumais, 1994; DGII-CEC, 1992; Barker et al., 1993)

More recently, Collonnec, Reynes, and Tamsamani (2012) have assessed the impact of the carbon tax in a neo-Keynesian model characterized by price and quantity adjustment viscosity and concluded that an improvement in the macroeconomic situation (growth, employment, public deficit) is linked to ecological taxation. The same applies to Chiroleu-Assouline and Fodha (2011). Hourcade and Ghersi (2000) reason in a computable general equilibrium model in which there is underemployment and reveal the occurrence of a double dividend of modest importance on employment and consumption. Finally, Crassous et al. (2009) use a static general equilibrium model with imperfect competition, notably in the labor market, to test the macroeconomic effect of implementing a carbon tax according to various recycling modalities. The macroeconomic gain (in terms of economic growth) appears to be greatest in the case of substitution for social security contributions on wages.

If we extend the analysis of environmental taxes to study their overall macroeconomic impact, we often find the same perfect competition/imperfect competition dichotomy. In the theoretical Global Supply/Demand model of Fagnard and Germain (2014), for example, the cyclical impact of the carbon tax is all the more negative the more flexible the prices and the closer the goods and labor markets are to a situation of perfect competition. Conversely, the coherent post-Keynesian stock-flow model of Girau et al. (2017), which is far removed from the perfect competition model, shows that the dynamics of firm indebtedness can only be halted if a carbon tax is introduced that cancels out net CO2 emissions by 2040.

Our article is part of the double-dividend approach, to demonstrate that the double dividend of ecological taxation extends to fields other than those traditionally considered (employment, tax distortions or redistribution), by analyzing its role in stabilizing the economy. At the same time, we will show that the framework of perfect competition is not an obstacle to demonstrating a possible double dividend from eco-taxes.

The exercise we undertake follows the guideline of Piluso and Le Heron (2017) article: to show in a Keynesian framework with Keynesian unemployment and perfect competition that ecological taxation can bring economic benefits in addition to improving environmental quality. How can we reconcile the perfect competition hypothesis with the Keynesian analytical framework? We will draw on the findings of the Glutoff (1968) and Cartelier (1996, 1995) models, which demonstrate the possibility of involuntary unemployment equilibria under perfect competition. Unlike the models of Glustoff (1968), Cartelier (1996) and Piluso (2017), however, our model is dynamic, as we seek to analyze a little-studied property of the carbon tax, namely its role as a cyclical stabilizer.

In the second section, we present the fundamental result of Glustoff and Cartelier that we will be using. In the third section, we present a novel Keynesian growth model in which a carbon tax is introduced. We answer the question of whether or not a double dividend can be ruled out under perfect competition. In the fourth section, we examine the dynamics of the economy and the role that a carbon tax can play in this.

The Keynesian Hypothesis of the Glustoff-Cartelier Model: Asymmetric Wage Relationships

Glustoff and Cartelier take up Keynes' rejection of the second classical postulate, according to which wage earners equalize their marginal disutility to the real wage. In their view, such a refutation means that wage earners cannot influence the level of employment (the labor supply curve is "deactivated") and that only entrepreneurs can decide on its level. Thus, if the real wage is higher than the equilibrium wage on the labor market, the demand for labor by companies substitutes for the supply of labor in the employee's budget constraint. As a result, Walras' law is restricted: the labor market is excluded (Cartelier, 1996, Piluso, 2011). All prices are assumed to be flexible except the nominal wage. Consequently, in most cases, all markets are in equilibrium except the labor market.

These equilibria are sustainable because, with the goods and financial markets in equilibrium, there is no reason for the price of the good or the interest rate to vary. As the labor market is excluded from Walras' law, it does not disturb the equilibrium of the other markets, even if they are unbalanced. This model removes the traditional problem of real rigidities from the analysis of unemployment since all prices are flexible except the nominal wage. It could then be argued that nominal wage rigidity is the cause of involuntary unemployment. However, in a standard general equilibrium model, nominal price rigidity in no way prevents the market from clearing. If, for example, the labor market has an excessive real wage with a fixed nominal wage, the adjustment occurs via the price of the good. Moreover, in Glustoff and Cartelier's model, lowering the nominal wage does not necessarily eliminate involuntary unemployment: as its impact on the marginal efficiency of capital is uncertain, a nominal wage cut may well lead firms to reduce investment and employment (Cartelier, 1995, Piluso, 2007). In the next section, we introduce elements of dynamics into the Cartelier/Glustoff model[2].

A Keynesian Model of Economic Growth With Climate Change and Carbon Tax: The Steady State of Involuntary Unemployment

Our starting point is a Cobb-Douglas per capita production function identical in every respect to that of the Solow model:

$$q = k^{1-c} \tag{1}$$

where q is the per capita product of the productive combination, k is the per capita capital and c is the production elasticity. We call n the growth rate of labor supply. Product growth can then be written as:

$$g = (1-c)g_K + cn \tag{2}$$

with g the product growth rate and g_K the growth rate of productive capital.

Companies' demand for labor follows the following function:

$$N^d = \frac{cQ}{w/p} \tag{2'}$$

with w/p the real wage rate. The dynamics of labor demand are therefore:

$$g_N = g - g_{w/p} \tag{2''}$$

Employees' propensity to consume is noted$(1-s)$. Their savings are fully invested in the form of securities $B_w(t)$[3] . In neoclassical theory, employees' budget constraint is (see Cartelier, 1995):

$$\frac{w}{p}(t)N(t) = C(t) + \frac{B_w(t)}{r(t)} \tag{3}$$

With $\frac{w}{p}(t)$ the real wage rate at time t,$N(t)$ the labor supply of employees at time t and $C(t)$ the consumption of employees at time t.$r(t)$ is the interest rate. The propensity of wage earners to consume, and therefore the division of income between consumption and savings, is determined by the interest rate *r(t)*.

The entrepreneurs' budget constraint is written as:

$$\left[Q^s(t) - f_{(t)}\alpha_{(t)}\big(T(t)\big)Q^s(t)\right] - \left[\frac{w}{p}(t)N_d(t)\right] - \left[\alpha_{(t)}\big(T(t)\big)Q^s(t)T(t)\right] + \left[\frac{B_e(t)}{r(t)}\right] = I(t) \equiv \dot{K}(t) + \theta K(t) \tag{4}$$

$Q^s(t)$ is the real aggregate supply of the good at period t. The function$f_{(t)}\alpha_{(t)}(T(t))Q^s(t)$ represents the real costs incurred by the firm and directly linked to climate change. It is a damage function that reduces the output produced by the firm (see appendix) before it can be offered on the market.$\alpha_{(t)}(T)Q^s(t)$ is an indicator of the carbon footprint of the production process. The$\alpha_{(t)}(T(t))$ function is used to measure the carbon footprint per unit of good produced. It is a decreasing function of the ecological taxation *T*: the higher the level of taxation, the more the firm reduces the carbon footprint of the production process by accumulating "greener" capital[4]. The expression $\alpha_{(t)}(T)Q^s(t)$ is the carbon footprint associated with the firm's total production (the unit footprint multiplied by the quantity of good produced).$N_d(t)$ is the representative firm's demand for labor. The expression$\alpha_{(t)}(T(t))Q^s(t)T(t)$ represents the ecological tax levy. This tax levy is the product of the total carbon footprint$\alpha_{(t)}(T(t))Q^s(t)$ and the tax .$T(t)$ $\frac{B_e(t)}{r(t)}$ is the firm's demand for securities to finance investment (alongside self-financing). This demand for securities represents the firm's borrowing and is therefore an additional resource for the company

There are several specifications of the production costs associated with climate change (and therefore greenhouse gas emissions): in the literature, we find damage functions affecting output only (Dietz and Stern, 2015)), damage functions affecting capital and output (Dafermos, 2016), or those affecting labor and capital productivity (Burke et *al.*, 2015). In our model, the cost of climate change is represented by the damage function$f_{(t)}$. This function depends on the size of the carbon footprint measured by$\alpha_{(t)}(T(t))Q^s(t)$.[5] This climate damage directly reduces product supply, as in the modeling of Dietz and Stern (2015). This means that a certain quantity of good is produced but directly destroyed by climate change. The expression indicates this $[Q^s(t) - f_{(t)}\alpha_{(t)}(T(t))Q^s(t)]$. The product to be distributed between wages and profit decreases accordingly.

The expression $[Q^s(t) - f_{(t)}\alpha_{(t)}(T(t))Q^s(t)] - [\frac{w}{p}(t)N_d(t)] - [\alpha_{(t)}(T(t))Q^s(t)T(t)]$ represents the firm's output (revenue) minus the cost of climate change, the cost of wages and the carbon tax. This is profit. The borrowing represented by the demand for securities is added to the profit to finance productive investment. The left-hand side of equation (4) therefore represents the firm's total resources (net profit + borrowing).

In short, the firm's gross investment$I(t)$ is financed on the one hand by borrowing and on the other by profit, the latter being reduced by ecological taxation and the costs associated with climate change. The investment in question includes the depreciation expense linked to the rate of capital depreciation θ

It is assumed that the good produced by the firm can be used for capital accumulation, household consumption or government operations. It is assumed that the eco-tax levied on the firm's profit is used to finance a public expenditure noted . $V(t)$

The government budget is assumed to be balanced. Thus, the State's budget constraint is written:

$$\alpha_{(t)}(T(t))Q^s(t)T(t) = V(t) \tag{5}$$

Let's check that the sum of the budget constraints leads to Walras' law:

$$[C(t) + V(t) + \dot{K}(t) + \theta K(t) + f_{(t)}\alpha_{(t)}(T(t))Q^s(t) - Q^s(t)] + \frac{w}{p}(t)[N^d(t) - N(t)] + \frac{1}{r(t)}[B_w(t) - B_e(t)] = 0 \tag{6}$$

According to Walras' law, the labor market cannot be in disequilibrium in isolation. Equilibrium involuntary unemployment is excluded.

The rejection of the Keynesian "second classical postulate" translates formally into the idea that firms' demand for labor substitutes for labor supply in the employee's budget constraint when the real wage is above its competitive equilibrium level:

$$\frac{w}{p}(t)N^d(t) = C(t) + \frac{B_w(t)}{r(t)} \tag{3''}$$

Walras' law is thus modified. For a real wage higher than the value that equilibrates the labor market, we have:

$$\left[C(t) + V(t) + \dot{K}(t) + \theta K(t) + f_{(t)}\alpha_{(t)}\left(T(t)\right)Q^s(t) - Q^s(t)\right] + \frac{1}{r(t)}[B_w(t) - B_e(t)] = 0 \tag{6'}$$

This restricted Walras' law allows the imbalance in the labor market to be matched by an equilibrium in all other markets. By virtue of the corollary of Walras' law, we can neglect the securities market and focus solely on the equilibrium of the goods market. This can be written as:

$$\left(\frac{Q^s(t) - f_{(t)}\alpha_{(t)}(T(t))Q^s(t)}{K}\right)c(1-s) + \frac{\dot{K}}{K} + \frac{V}{K} + \theta = \left(\frac{Q^s(t) - f_{(t)}\alpha_{(t)}(T(t))Q^s(t))}{K}\right) \tag{7}$$

Let's call$X = Q^s(t) - f_{(t)}\alpha_{(t)}(T(t))Q^s(t)$. This is output minus the cost of climate change. When the expression X is multiplied by the factor *c*, which is a parameter of the production function set out in equation (1), we obtain the portion of output (net of the cost of climate change) that accrues to employees, in other words the wage bill. Consumption expenditure is therefore obtained by multiplying the wage billcX by the marginal propensity to consume (*1-s*), *where s* is the marginal propensity to save.

The property application therefore includes:

- Employees' consumption expenditure (which depends on the portion of net product and the propensity to consume), i.e. $\left(\frac{Q^s(t)-f_{(t)}\alpha_{(t)}(T(t))Q^s(t)}{K}\right)c(1-s)$;
- net capital expenditure, i.e. $\frac{\dot{K}}{K}$;
- spending $\frac{V}{K}$;
- depreciation expense . θ

The supply of goods is given by the production function $Q^s(t)$. Part of this supply is destroyed by climate change, for an amount given by the expression$f_{(t)}\alpha_{(t)}(T(t))Q^s(t))$.

Let's call $Q^n(t)$ the real supply of goods net of the cost of climate change. We can therefore rewrite the equilibrium condition for the goods market as follows:

$$\frac{Q^n(t)}{K}c(1-s)+\frac{\dot{K}}{K}+\frac{V}{K}+\theta=\frac{Q^n(t)}{K} \quad (7')$$

This is equivalent to writing:

$$\frac{c(1-s)}{v(T)}+\frac{\dot{K}}{K}+\frac{\alpha(T)T}{v}+\theta=\frac{1}{v(T)} \quad (7'')$$

Therefore, the capital coefficient v(T) net of climate change costs depends on the ecological tax level T. The capital coefficient v is simply equal to$K/Q^s(t)$. Capital accumulation compatible with the equilibrium of the goods market is therefore:

$$g_K=\frac{1-c(1-s)}{v(T)}-\frac{\alpha(T)T}{v}-\theta \quad (8)$$

The steady-state condition (with constant capital per capita *k* and capital coefficient *v*) implies that the rate of change in accumulated capital is equal to the rate of change in labor demand:

$$g_K=g_N=g-g_{w/p} \quad (9)$$

If the market for the good is balanced, the price of good *p* no longer varies. According to the corollary of Walras' law, the savings market is balanced when supply equals demand in the market for the good. Consequently, the interest rate *r(t)* does not vary either. Since the nominal wage is exogenous, in accordance with Cartelier's model, the rate of change in the real wage is zero. We therefore have:

$$g_K=g_N=g=\frac{1-(1-s)c}{v(T)}-\frac{\alpha(T)T}{v}-\theta\leq n \quad (10)$$

It is thus quite possible that a steady state with involuntary unemployment noted $u=n-g_K$ exists. Cartelier (2018) points out that this is even the general case, the neoclassical full-employment configuration being a special case.

In Solow's model, balanced growth is maintained over time even when the population growth rate changes. Equilibrium capital per capita, corresponding to a certain capital coefficient *v*, changes thanks to price flexibility to ensure market equilibrium. In our "Keynesian" model, the economy does not adapt to the rate of growth of labor supply, because labor has a subordinate status. The economy adapts to changes in the rate of capital accumulation g_K (to which a certain capital coefficient *v* corresponds), which is exogenous due to the "animal spirits" reigning in a context of uncertainty. As Cartelier (2005) writes in his Macroeconomics mimeographed course, "what opposes Keynes to neoclassical economics is not the addition of rigidities of any kind, neither in prices, nor in wages, nor in the productive mix, but rather in the treatment of employees as reflected in the various budgetary constraints to which they are subject. Whereas standard theory sees dynamic evolution as an (optimal) response to changes in exogenous fundamentals, Keynes's economics sees it as proceeding from the accumulation of capital, reflecting the action of entrepreneurs as the dominant social group" (*ibid*, p. 101).

In our model, both the price of the good and the interest rate are perfectly flexible. We make no assumptions about the complementarity of factors of production (here, they are substitutable, as in Solow's model), nor about the fixity of the propensity to save (which is endogenous and depends on the interest rate). "By placing capital accumulation at the very heart of the growth process, rather than the optimal adaptation of a system in equilibrium to exogenous shocks, Keynes's economics returns to the classical tradition of Smith and Ricardo, for whom wage earners also occupied a subordinate position" (Cartelier, 2005, p. 101).

The question now is whether the introduction of a carbon tax in place of a "conventional" tax will deliver not only an ecological benefit, but also a benefit in terms of employment when the economy is in a steady state

In our model, a concise answer (positive or negative) is difficult to give, since our capital growth rate is exogenous for the time being. On *the other hand, it is impossible to exclude the occurrence of a double dividend, despite our analytical framework of perfect competition*. What are the effects of replacing a "conventional" tax with a carbon tax? The introduction of a carbon tax limits the impact of climate change on output, enabling the firm to free up cash flow for investment. The impact of an increase in profit on investment is uncertain, since Keynesian "animal spirits" (and thus, implicitly, the marginal efficiency of capital) govern the decision to invest. However, the possibility of a positive effect on employment cannot be ruled out, as is usually the case in neoclassical models with perfect competition. However, the present model does not provide a definitive answer to this question.

Intrinsic Instability of Keynesian Economics and the Carbon Tax

To study the dynamics of the economy, let's now assume that the rate of capital accumulationg_K depends positively on the difference between the realized and expected profit rates.

With the Cobb-Douglas function mentioned above, the expected or anticipated rate of profit is:

$$r^a = \frac{(1-c)(Q-f_{(t)}\alpha_{(t)}(T)Q)}{K} - \frac{\alpha_{(t)}(T)Q^S T(t)}{K} \tag{11}$$

which can be rewritten as follows:

$$r^a = \frac{1-c}{v(T)} - \frac{\alpha_{(t)}(T)T}{v} \tag{12}$$

Consequently, the expected profit is equal to the share of the product (net of climate change costs) that is not distributed in the form of wages, minus the tax levy for environmental purposes.

The realized profit rate can be written as:

$$r = \frac{\dot{K}}{K} + \theta + \frac{V}{K} + (1-s)c(\frac{Q - f\alpha(T)Q}{K}) - c(\frac{Q - f\alpha(T)Q}{K}) - \frac{\alpha_{(t)}(T)QT}{K}$$

hence:

$$r = g_K + \theta + \frac{c((1-s)-1)}{v(T)} \tag{13}$$

because $\frac{\alpha_{(t)}(T)QT}{K} = \frac{V}{K}$.

In other words, realized profit is equal to the sum of revenues generated by entrepreneurs (gross investment, plus consumption and public spending) minus the sum of costs (the net proceeds of the costs of climate change distributed in the form of wages and the ecological tax levy).

The difference between the realized profit rate and the expected profit rate is equal to:

$$r - r^a = g_K + \theta + \frac{c((1-s)-1)}{v(T)} - \frac{1-c}{v(T)} + \frac{\alpha_{(t)}(T)T}{v} \tag{14}$$

The expression can be arranged as follows:

$$r - r^a = g_K + \theta + \frac{c(1-s)-1}{v(T)} + \frac{\alpha_{(t)}(T)T}{v} \tag{15}$$

The evolution of the rate of capital accumulation is given by the following differential equation:

$$\dot{g}_K(t) = \lambda(r(t) - r^a(t)) = \lambda(g_K + \theta + \frac{c(1-s)-1}{v(T)} + \frac{\alpha_{(t)}(T)T}{v})$$

The solution is given by the expression:

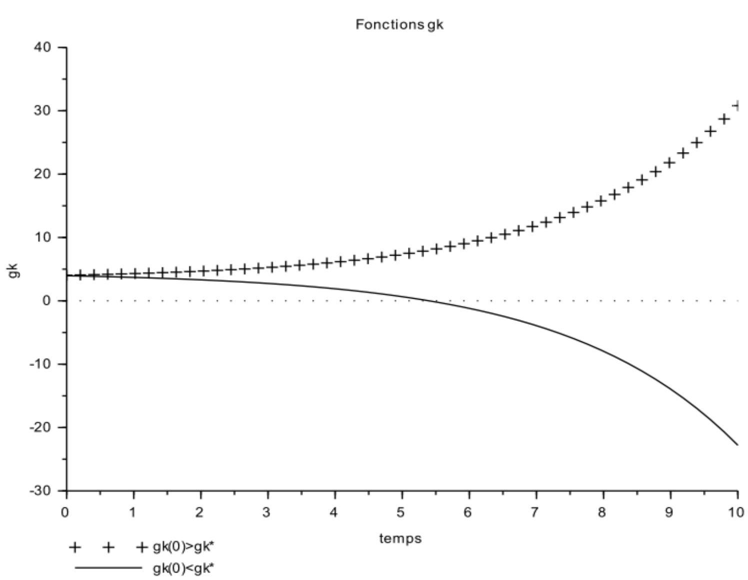
$$g_K(t) = g_K(0)e^{\lambda t} + (\theta + \frac{c(1-s)-1}{v(T)}) + \frac{\alpha_{(t)}(T)T}{v})(e^{\lambda t} - 1) \tag{16}$$

Let's call$g_K^* = \frac{1-(1-s)c}{v(T)} - \frac{\alpha(T)T}{v} - \theta$ the stable state of the economy. It is then possible to rephrase (15):

$$g_K(t) = e^{\lambda t}(g_K(0)) - g_K^*) + g_K^* \tag{16'}$$

An initial deviation from the equilibrium path is amplified over time, corresponding to Harrod's razor-edge result. Keynesian economics is inherently unstable.

FIGURE 1
UNSTABLE ECONOMIC GROWTH



However, the carbon tax, the only discretionary variable in the model, offers the State a tool for stabilizing the economy through a triple channel:

- the traditional T tax channel, which reduces profits but generates public demand for goods (assuming a balanced budget);
- the carbon footprint channel $\alpha_{(t)}(T)$, which varies according to the level of the tax;
- the damage function channel f linked to climate change (impact on $v(T)$), which affects the output, and which is also more or less significant depending on the level of the tax.

In an economy characterized by instability, the carbon tax thus offers a double dividend: an ecological benefit (the carbon footprint is always lower with the existence of a carbon tax instead of a traditional tax) and an economic benefit (reduced economic instability). To our knowledge, economic literature (theoretical or empirical) has not really considered a double dividend of this nature in a relatively "standard" theoretical framework. *The eco-tax offers a tool for stabilizing the economy by enriching the transmission channels of traditional taxation over the long term*. If we assume that an increase in the carbon tax leads to increased tax revenues and therefore in public demand for goods, then eco-taxation is theoretically more effective than the traditional tax tool. Indeed, by reducing the carbon footprint, ecological taxation minimizes the negative impact of climate change on output and modulates aggregate demand from firms.

CONCLUSION

While it is usually necessary to reason in a model of imperfect competition with various types of price rigidities, or to adopt post-Keynesian stock-flow models, to theoretically account for the existence of a double dividend, we have attempted to show with a model of perfect competition that it is possible to demonstrate the possibility of a triple dividend from the eco-tax: an ecological benefit (reduction of the carbon footprint), and two economic benefits: a possible beneficial effect on unemployment and a channeling of the economic instability typical of the Keynesian vision of the economy. The literature has focused mainly on the short-term economic benefits of ecological taxation in terms of employment, GDP growth, taxation or social equity. The model results show that we should not ignore that, in the long term, ecological taxation enriches the levers of traditional taxation to control and stabilize growth dynamics.

ENDNOTES

1. Tax distortion refers to the gap between the yield of a tax and the loss of utility for the economic agent resulting from its introduction.
2. Cartelier (2018) presented the characteristic features of Keynes's economic dynamics
3. A security is defined by a right to a unit of good at all subsequent periods. Its nominal price is given by *p/r(t)*.
4. In microeconomic theory, the firm's optimal choice of pollution abatement is given by the equality between the marginal cost of abatement and the marginal gain in abatement measured by the carbon tax *T*. This leads to the following result: the higher the carbon tax, the more the firm agrees, up to a certain point, to limit greenhouse gas emissions by acquiring less polluting capital (see Fagnard and Germain, 2014).
5. See appendix.

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APPENDIX

In this appendix, we specify the carbon footprint$\alpha_{(t)}(T(t))$ and climate change cost functions. $f_{(t)}\alpha_{(t)}(T(t))Q^s(t)$.

We adopt the carbon footprint model from the article by Fagnard and Germain (2014). They write the carbon footprint of a unit of good produced as follows:

$$Z = \delta - A$$

with δ the pollution intensity of the production of one unit of goods and *A* the quantity of CO2 emissions avoided (by producing one unit of goods) thanks to the company’s pollution reduction effort. Z is therefore an evaluation of the unit carbon footprint on which ecological taxation *T* is based. The pollution reduction effort *A* is an increasing function of ecological taxation.

To simplify modeling, let’s assume that $A = \alpha T$ with α a parameter whose value is greater than unity. The carbon footprint function is then written as :

$$\alpha(T(t)) = Z = \delta - (\alpha T)$$

The carbon footprint function is therefore a decreasing function of the level of ecological taxation decided by the public authorities. The higher the carbon tax, the greater the company’s effort to reduce pollution and the smaller its footprint.

In addition, we draw on the climatic damage function $f_{(t)}\alpha_{(t)}(T(t))Q^s(t)$ of Dietz and Stern (2015), which in this article takes the following form:

$$f_{(t)}\alpha_{(t)}(T(t))Q^s(t) = \varphi[\alpha_{(t)}(T(t))Q^s(t)]$$

with φ a parameter whose value is greater than zero.

In other words, when the carbon tax increases, the footprint decreases. This reduction in pollution translates into a reduction in the cost of climate change.