Are Pollution Permit Markets Harmful for Employment?

Nicolas Sanz * Sonia Schwartz †

Abstract

This paper investigates the consequences of a pollution permit market on equilibrium employment in a monopolistic competition framework. We consider two alternative kinds of initial permit distribution, the grandfathering and the auction. In the first case, we assume that the level of unemployment benefits is set exogenously and show that a reduction in the pollution cap is harmful for employment. In the second case, where unemployment benefits are assumed to be financed by the revenue of the pollution permits, we find a particular form of the double dividend: the environmental policy has no impact on equilibrium employment. We finally demonstrate that the effects of the environmental policy on employment remain the same in the long run.

Keywords: Monopolistic competition; Equilibrium employment; Pollution permit market

JEL Classification: E24, L13, Q28

1 Introduction

Among environmental tools designed to reduce pollution, emission permit markets offer attractive properties for the regulator. On the one hand, pollution permit markets lead each firm to choose the efficient level of emission
reduction. On the other hand, this efficient level is chosen whatever the initial distribution of pollution permits (Montgomery, 1972). Consequently, the regulator can distribute pollution permits whatever their equity concept and objectives, as raising a revenue or not. For the above reasons, pollution permit markets are more and more established. One can quote the CO₂ European market and the future international CO₂ market established by the Kyoto Protocol, which came into force on February 13, 2005.

However, the properties of pollution permit markets remain attractive only if markets are competitive. Indeed, consequences of market imperfections are well-known. If the permit market is not competitive, the efficient outcome is not reached and initial distributions matter. Stavins (1995) studies transaction costs in pollution permit markets, Hahn (1984) and Westskog (1996) introduce market power in an emission permit market and Schwartz (2005, 2007) investigates market power in an ambient permit market. Moreover, introducing the output market, Sartzetakis (2004) shows that the welfare can be lower with a pollution permit market than with a command and control approach if the pollution permit market is competitive whereas the output market is not.

These analysis usually use partial equilibrium frameworks. Studies conducted within general equilibrium models with competitive markets only focus on the comparison of tools designed to reduce pollution or on the initial distribution if a pollution permit market is chosen. Considering the first problem, Crettez (2004) uses a dynamic general equilibrium model with overlapping generations to compare emission taxes with pollution permits. To deal with the second issue, Jouvet and al. (2005) analyze the optimal growth path and its decentralization in an overlapping generation model too. The authors show that there is a unique management of permits such that the equilibrium coincides with the optimal path. They obtain some conclusions about initial permit allocations, as Jouvet and al. (2004). In this latter article, the economic consequences of different allocation rules are studied in a general equilibrium framework with two countries. Nevertheless, none of these contributions take market imperfections into account.

However, assuming competitive output markets but unemployment and distortionary labour taxation, lots of paper analyze the double dividend hypothesis : raising taxes on pollution or selling pollution permits yield an improvement in environmental quality but can also boost employment\(^1\). For

\(^1\)For a survey on the double dividend hypothesis, see Goulder (1995).
instance, Bovenberg and van der Ploeg (1998), assuming fixed real wages, analyze green tax swaps in identifying conditions under which the revenue-neutral combination of labor taxes and taxes on energy improves employment. With endogenously determined wages, Schneider (1997) explores the implications of an environmental tax reform in the presence of involuntary unemployment. He finds that green tax swaps can have positive employment effects, depending on the existing tax system and on the characteristics of the labour market. Consequently, environmental policy can generate a second dividend.

Taking into account, now, imperfectly competitive output market, Marsiliiani and Renström (2000) consider the consequences of environmental taxes under monopolistic competition, focusing their analysis on the double dividend hypothesis from environmental taxation. They show that employment and welfare always increase when the revenue from the introduction of a Pigouvian tax is fully recycled to cut the rate of the pre-existing labour tax. Vetter (2005) examines the use of environmental taxes in monopolistically competitive markets. He finds that the optimal firm specific tax is always less than the Pigouvian tax.

It appears therefore that there is no available analysis of a pollution permit market within general equilibrium model with unemployment in the economic literature. One aim of this article is to fill this gap. Contrary to above analysis, we do not assume distortionary taxes in the economy. This paper focus on the consequences of the introduction of a pollution permit market on equilibrium employment in a monopolistically competition framework. We develop an extended version of the Wage Setting-Price Setting model proposed by Layard and Nickell (1985), in which the global level of emissions is determined by the pollution index and the production level chosen by firms\(^2\). We then introduce explicitly a pollution permit market next to the goods and the labor markets in order to study the implications of the interactions between these markets for the determination of global employment. We study these interactions under two alternative kinds of initial pollution permit distribution, a free one like grandfathering and a distribution in which all pollution permits are sold by mean of, say, an auction.

In the first case, we assume that the level of unemployment benefits is

\(^2\) The WS-PS model is an extended version of the monopolistic competition model developed by Dixit and Stiglitz (1977), which puts the mechanisms of wage setting forward. This model is therefore useful to study the labor market and the determination of aggregate employment in modern economies (see Layard and al., 1991, for a detailed presentation).
set exogenously. We then show that a pollution-reducing technological innovation leads to an increase in employment. Conversely, a reduction in the pollution cap appears to be harmful for employment, since the buying of permits increases the costs borne by firms. In a monopolistic environment, this makes firms increase their price and reduce their output level. In the second case, the revenue of the pollution permits’ sale enables to finance the unemployment benefits. So we find a particular form of the double dividend: we show that the environmental policy has no impact on equilibrium employment. Indeed, a reduction of the pollution cap both increases the permits’ price and reduces the amount of unemployment benefits available for unemployed workers, which induces unions to moderate their wage claims. All in all, the firms’ costs and their price, output and employment decisions remain unchanged.

The structure of the article is as follows. The model is presented in Section 2. Section 3 discusses the effects of the environmental policy on equilibrium employment when unemployment benefits are set exogenously. The case where pollution permits are used to finance unemployment benefits is analyzed in section 4. In Section 5, we present the long run properties of the model. Section 6 offers a summary of the main results of the paper and some concluding remarks.

2 The model

2.1 The economy

The economy is assumed to be made up of \( N \) identical imperfectly competitive firms, indexed by \( i = 1, \ldots, N \). In each firm, wages are set by a monopoly union. The firm then chooses the index of pollution and the level of employment.
2.1.1 Firms

Each firm faces the following demand function:

\[ Y_i = \frac{Y}{N} \left( \frac{P_i}{P} \right)^{-\varphi} \]  

(1)

where \( Y \) represents the level of global demand, \( P_i \), firm \( i \)'s price, \( P \), the aggregate price level, and \( \varphi \), the elasticity of substitution between differentiated goods (\( \varphi > 1 \)). Following Jouvet and al. (2005), we suppose that all firms produce according to the same Cobb-Douglas production technology:

\[ Y_i = z_i L_i^\alpha K_i^\beta \]  

(2)

where \( z_i \) represents the index of the technology used, with \( 0 \leq z_i \leq 1 \). The variables \( L_i \) and \( K_i \) respectively denote efficient labor and capital. We assume that the produced good and the level of pollution are joint products. We also suppose that the level of emissions is proportional to the production level and that it increases with the index of the technology used by firm \( i \) according to:

\[ E_i = dz_i^\sigma Y_i \]  

(3)

The case \( z_i = 1 \) corresponds to the dirtiest technology (see Stokey, 1998). Thus, a technology index such that \( z_i < 1 \) means that firms choose to reduce their level of emissions. This implies that without any restraint on the pollution level, firms are not willing to reduce their pollution level (i.e. \( z_i = 1 \)), so that the output is maximum for given labor and capital inputs. The parameter \( \sigma \) indicates the efficiency of the pollution-reducing technology (\( z_i \)) in reducing emissions (\( \sigma > 1 \)). The parameter \( d \) illustrates some potential innovations abating the emissions of the existing technology. A decrease in \( d \) implies that the technology used by firm \( i \) becomes less polluting, for given levels of the technology index and production. We consider in this paper that innovation is exogenous. Firms can benefit from foreign innovations corresponding to a positive externality. This new technology can be an end-

\footnote{See Dixit and Stiglitz (1977) and Blanchard and Kiyotaki (1987) for the microfoundations of the demand function (1). The disutility of the total amount of emissions can be explicitly introduced into the preferences of households. However, since the pollution cap, like all aggregate variables, is taken as given by consumers, it vanishes from the individual demand functions and hence from eq. (1).}
of-pipe technology of abatement\textsuperscript{4}. Finally, note that elimination of $z_i$ between (2) and (3) enables to show that the production function (2) is equivalent to:

$$Y_i = d_i^{\frac{1}{\sigma+1}} L_i^{\frac{\alpha}{\sigma+1}} K_i^{\frac{\beta}{\sigma+1}} E_i^{\frac{1}{\sigma+1}}$$

which has constant returns to scale with respect to labour, capital and emissions if $\alpha + \beta = 1$ (see Ono, 2002; Jouvet and \textit{al.}, 2005).

2.1.2 Unions

Union $i$'s utility function is given by:

$$\Omega_i = \left( \frac{W_i}{P} - W_r \right) L_i^\delta$$

where $W_i$ is the nominal wage and $W_r$, the reference wage with which workers compare the wage they receive from firm $i$. The parameter $\delta$ reflects the weight attributed by union $i$ to the defense of employment with respect to wages ($0 < \delta < 1$).

2.1.3 The environmental agency

We assume that without any environmental policy, the uncontrolled emission level of each firm is too high ($z_i = 1$). These emissions then generate damages in terms of health and environment. In order to reduce emissions, the environmental agency chooses to introduce a pollution permit market. We assume that the pollutant is an uniformly mixed assimilated one. If not, the pollution permit market has to take the spatial effect of pollution into account (see Montgomery, 1972). The environmental agency specifies the pollution cap $E$. Note that the first best pollution cap results from a trade-off between the marginal benefit and the marginal damage from polluting. In practice, because of asymmetric information on marginal benefit, the pollution cap is determined by a trade-off between estimated benefits and damages. We first assume that the initial allocation is free (for example

\textsuperscript{4}We can quote, like an example, scrubbers which allow firms to produce electricity with coal without releasing SO2. At the beginning of the U.S. Acid Rain program, the low price of pollution permits has been explained by scrubber investments (see Joskow and \textit{al.}, 1998).
based on grandfathering), with \( E = \sum_{i=1}^{N} E_i \), and that \( E_i \) is the initial endowment of pollution permits distributed to firm \( i \). This assumption will be relaxed later to consider the sale of pollution permits by means of an auction (in this case, \( E_i = 0, \forall i \)). We further suppose that pollution permits can be freely traded on a secondary market and that intertemporal trade of pollution permits \( \text{i.e.} \) banking and borrowing) is not allowed. Let us denote \( E_i \), the number of pollution permits hold by firm \( i \) after trade. Consequently, \( E_i - \overline{E}_i > ( < ) 0 \) means that firm \( i \) has bought (sold) some permits. The pollution permit market clears if:

\[
\overline{E} = \sum_{i=1}^{N} E_i
\]  

We denote the nominal price of permits by \( Q \). We suppose that \( Q \) is determined competitively on the pollution permit market and that each firm chooses conformity: it buys the quantity of permits that exactly covers its emissions. Hence, to simplify, no distinction will be made between the emissions and the number of pollution permits hold by firms. We turn now to the resolution of the model.

2.2 Partial equilibrium

We start our study by firstly analyzing the behavior of the economy in the short run, where the capital stock used by firms is supposed to be fixed \( (K_i = \overline{K}_i) \). The long run properties of the model are studied in Section 5.

2.2.1 Technology index and employment determination

We use the right to manage model in which unions set the wage and the firms then decide their level of employment. This implies that when maximizing profits, each firm takes the nominal wage as given. We also assume that the number of firms is high enough so that firm \( i \) takes all aggregate variables as given. If \( W_i \) and \( R \) denote respectively the nominal wage and the nominal cost of capital, the real profit of firm \( i \), which includes the purchase and the
sale of pollution permits, is given by:

\[ \frac{\Pi_i}{P} = \frac{P_i}{P} Y_i - \frac{W_i}{P} L_i - \frac{R}{P} K_i - \frac{Q}{P} (E_i - E_i) \] (7)

Taking the definition of the amount of emissions given by (3) into account, maximization of equation (7) with respect to \( z_i \) and \( L_i \) subject to the demand and the production constraints respectively given by (1) and (2) leads to the optimal technology index and demand for labor:

\[ z_i = m \frac{\Theta}{\Theta} \left( \frac{Y}{N} \right)^{\frac{1-\sigma}{\Theta}} \left( \frac{dQ}{P} \right)^{\frac{\theta}{\sigma}} \frac{K_i}{\Theta} \frac{\bar{W}}{\Theta} \left( \frac{W_i}{P} \right)^{\frac{\delta}{\sigma}} \] (8)

\[ L_i = m \frac{\Theta}{\Theta} \left( \frac{Y}{N} \right)^{\frac{1+\sigma}{\Theta}} \left( \frac{dQ}{P} \right)^{\frac{\theta}{\sigma}} \frac{K_i}{\Theta} \frac{\bar{W}}{\Theta} \left( \frac{W_i}{P} \right)^{\frac{\delta}{\sigma}} \] (9)

where \( m = \varphi / (\varphi - 1) \) is the mark-up of price over marginal cost in the standard monopolistic competition model, and \( \Theta = 1 + [\varphi - \alpha (\varphi - 1)] \sigma > 0 \), the necessary condition for firm \( i \)'s profit function to be concave in \( z_i \) and \( L_i \). Equation (8) shows that the optimal technology index increases with the global demand for goods and the real wage and that it decreases with firm \( i \)'s mark-up, the capital stock, the innovation parameter and the permit's price. According to (9), the optimal demand for labor rises with the capital stock, the global demand and decreases with the mark-up, the innovation parameter, the permit's price and the real wage.

2.2.2 Wage determination

Maximizing union \( i \)'s utility function (5) with respect to the real wage \( W_i/P \) yields:

\[ \frac{W_i}{P} - W_r \frac{W_i}{P} = 0 \] (10)

where \( \varepsilon_{W_i/P} \) corresponds to the elasticity of labor demand with respect to the real wage. Isolating \( W_i/P \) in (10) yields the real wage fixed by union \( i \):

\[ \frac{W_i}{P} = \Psi W_r \] (11)

\(^5\)We assume that competition on the international capital market is perfect, so that \( R \) is set exogenously and is taken as given by firms when maximizing profits.

\(^6\)For the sake of clarity, we ignore all multiplicative terms in \( \alpha \) and \( \sigma \), which have no qualitative implication for our analysis.
where, using the value of $\varepsilon^L_{W_i/P}$ in (9) and simplifying:

$$\Psi = \frac{(1 + \varphi \sigma) \delta}{(1 + \varphi \sigma) \delta - [(1 - \alpha) \varphi \sigma + 1 + \alpha \sigma]}$$

(12)

Equation (11) corresponds to a common result in the literature on the labor market. It shows that the real wage set by unions is equal to the reference wage times a mark-up, $\Psi$. As usually, the wage mark-up is a function of the standard parameters of the monopolistic competition model ($\alpha$, $\varphi$, $\delta$). However, in our model, the wage mark-up also depends on the efficiency level of the pollution-reducing technology to reduce emissions ($\sigma$):

**Proposition 1** The unions’ wage mark-up decreases with the efficiency of the pollution-reducing technology.

Derivation of equation (12) with respect to $\sigma$ shows that: $\partial \Psi / \partial \sigma < 0$. As already mentioned, a rise in $\sigma$ corresponds to a better efficiency of the pollution-reducing technology. Such a rise enables firms to use a more polluting technology (a higher $z_i$), while keeping the amount of their emissions unchanged (Eq. (3)). This in turn yields a positive technological change onto the production function (Eq. (2)) which induces firms to use a lower amount of labor input, while keeping their level of production constant. The higher is $\sigma$, the stronger are the latter effects, the higher is the elasticity of firms’ labor demand with respect wages (see Eq. (9)). This induces unions to moderate their wage claims.

In order to model the reference wage $W_r$, we suppose, as Danthine and Kurmann (2006), that workers compare the wage paid by their firm with a mean between the production per worker inside the firm and the reservation wage, i.e. the unemployment benefits that workers receive if they become unemployed$^7$:

$$W_r = \left( \frac{Y_i}{L_i} \right)^{\nu} \left( \frac{B}{P} \right)^{1-\nu}$$

(13)

with $0 < \nu < 1$.

$^7$Danthine and Kurmann (2006) use eq. (13) in an efficiency wage model based on Akerlof’s notion of gift. We have not introduced the effort function used by the above authors into the production function (2), since with their specification, the optimal level of effort is constant in equilibrium and has therefore no qualitative effect on our results.
2.3 General Equilibrium

2.3.1 The price curve

At the symmetric equilibrium, \( z_i = z \), \( L_i = L/N \), \( \bar{K}_i = \bar{K}/N \) and \( Y_i = Y/N \). Hence, using (2) at the symmetric equilibrium and substituting into (8), simplifying and isolating \( z \), we obtain the technology index chosen by firms at the symmetric equilibrium:

\[
z = \left( \frac{mdQ}{P} \right)^{\frac{1}{\beta - \alpha}} \tag{14}
\]

Now, taking (9) at the symmetric equilibrium \( (W_i = W) \), using (2) and replacing \( z \) by (14), we find the aggregate labor demand for a given permit price:

\[
L = N^{\frac{1}{1+\alpha}} m^{\frac{\beta}{1+\alpha}} K^{\frac{\beta}{1+\alpha}} d^{\frac{1}{1+\alpha}} \left( \frac{Q}{P} \right)^{\frac{1}{1+\alpha}} \left( \frac{W}{P} \right)^{\frac{-\alpha}{1+\alpha}} \tag{15}
\]

Substituting (2) into (3) and the resulting equation into (6) at the symmetric equilibrium \( (E_i = E) \), inserting the equilibrium values of \( z \) and \( L \) respectively given by (14) and (15) and isolating \( Q \), we obtain the equilibrium pollution permit price:

\[
\frac{Q}{P} = m^{\frac{-1}{1+\alpha}} N^{\frac{1}{1+\alpha}} K^{\frac{\beta}{1+\alpha}} d^{\frac{1}{1+\alpha}} E^{\frac{-1}{1+\alpha}} \left( \frac{W}{P} \right)^{\frac{-\alpha}{1+\alpha}} \tag{16}
\]

Reinserting (16) into (15) and isolating \( W/P \), we obtain the real wage firms are willing to pay to workers in the economy, i.e., the short-run equation of the price setting curve (PS):

\[
\left( \frac{W}{P} \right)^{SR}_{PS} = m^{-\frac{1}{1+\alpha}} N^{\frac{1-(\alpha+\beta)}{1+\alpha}} K^{\frac{\beta}{1+\alpha}} d^{\frac{-1}{1+\alpha}} E^{\frac{1}{1+\alpha}} L^{\frac{-1}{1+\alpha}} \tag{17}
\]

As shown by equation (17), the (PS) curve is decreasing and convex in the aggregate employment-real wage space. The price determined real wage is increasing in the number of firms, the capital stock and the pollution cap, and decreasing in the mark-up over marginal cost, the innovation parameter and the aggregate employment level.
2.3.2 The wage curve

To determine the wage curve (WS) equation, we insert the reference wage \((13)\) into the real wage \((11)\), use the production function \((2)\) and replace \(z\) by its equilibrium value \((14)\) at the symmetric equilibrium \((z_i = z, L_i = L/N, K_i = K/N)\). Rearranging and finally isolating \(W/P\), we find the expression of the real wage set by unions in the economy, \(i.e.\) the (WS) curve equation:

\[
\left( \frac{W}{P} \right)_{WS} = m^{\alpha\nu} N^{(1-\alpha)[1-(\alpha+\beta)]\sigma\nu} K^{(1-\alpha)\beta\sigma\mu} d^{-(1-\alpha)\nu} E^{(1-\alpha)\sigma} \times \Psi^{1+(1-\alpha)\sigma} \left( B \right)^{\frac{1+(1-\alpha)\sigma[1-\nu]}{1+\nu}} \left( \frac{L}{P} \right)^{-(1-\alpha)[1+(1-\alpha)\sigma]\nu}
\]

where \(\Gamma = 1 - \alpha\nu + (1 - \alpha) \sigma > 0\). According to equation \((18)\), the (WS) curve is decreasing and convex in the aggregate employment-real wage space, as in Altenburg and Straub (1998) and Danthine and Kurmann (2006)\(^8\). The union determined real wage is increasing in the mark-up over marginal cost, the number of firms, the capital stock, the pollution cap, the wage mark-up and unemployment benefits, and decreasing in the innovation parameter and the level of aggregate employment\(^9\).

\(^8\)In the major part of the litterature on the labor market, the (WS) curve is increasing in the aggregate employment-real wage space. Since the reservation wage is assumed to be equal to a weighted average between the wage workers may earn in another firm and the unemployment benefits they receive if they do not find another job elsewhere in the economy, an increase in aggregate employment raises the probability of finding another job, \(i.e.\), the reservation wage and hence, the real wage claimed by unions. Conversely, the specification used here for the “reference wage” (eq. \((13)\)) implies that if aggregate employment increases, the production per worker falls, for a given production level, which reduces the reference wage and induces unions to set lower real wages.

\(^9\)Note that the short run (WS) equation depends on the capital stock, which is unusually. The reason is that the reservation wage depends on the per capital production level within each firm, which itself is a function of the capital stock. This will have important consequences in the long run.
3 Environmental policy with exogenous unemployment benefits

In this section, we solve the model by assuming that the initial pollution permit distribution is free and that unemployment benefits are exogenously determined, i.e. \( B = B_0 \). The equilibrium level of aggregate employment is obtained by equating equations (17) and (18) and isolating \( L \):

\[
L^* = m \frac{-(1+\sigma)}{1+\sigma} N \frac{\psi}{K} \frac{\partial \psi}{\partial \Phi} \left( \frac{E}{d} \right)^{\frac{1}{\psi}} \frac{-(1+\sigma)}{1+\sigma} \psi \left( \frac{B}{P} \right)^{\frac{-(1+\sigma)}{\psi}}
\]

where \( \Phi = 1+(1-\alpha)\sigma > 0 \). Since the elasticity of the real wage with respect to employment in (17) is higher than the one in (18), the shape of the (PS) curve is more than the (WS)'s one. The overall situation is depicted in the figure below, where the intersection between the (PS) and the (WS) curves gives the macroeconomic equilibrium of the model. Equation (19) enables us to evaluate the impacts of a change in the environmental parameters of the model, \( d \) and \( E \), on equilibrium employment\(^{10}\).

Proposition 2 A pollution-reducing technological innovation increases the equilibrium level of aggregate employment.

Equation (19) indeed clearly indicates that \( \partial L^* / \partial d < 0 \). A decrease in \( d \) moves both the (PS) and the (WS) curves upwards in the aggregate employment-real wage space. If an innovation allowing to pollute less occurs \((\Delta d < 0)\), the level of emissions is lower for given levels of the technology index and production (see Eq. (3)). The firms’ demand for pollution permits thus decreases. For a given pollution cap, the permit price and hence, the costs borne by firms, fall. In this case, firms set lower prices, and increase their production and employment levels at the symmetric equilibrium. But since a fall in \( d \) leads to rise in production, it also increases, for a given employment level, the production per worker inside firms, which rises the reference wage, induces unions to set higher wages and pushes the (WS) upwards. However, comparison of equations (17) and (18) shows that the elasticity with respect to the parameter \( d \) of the price determined real wage

\(^{10}\)At this stage, it is too complicated to evaluate the impact of \( \sigma \) on the equilibrium level of employment, since it is present within all the terms of the right-hand side of equation (19).
is higher than the one of the union determined real wage. This implies that all in all, an innovation allowing to pollute less leads to an increase in global employment and real wages. This result suggests that innovation towards emission reduction is good for employment whereas it is not usually the case when it is developed to improve the production efficiency. Concerning the impact of a change in the pollution cap, we have the following proposition:

**Proposition 3** A reduction in the pollution cap decreases equilibrium employment.

Equation (19) also indicates that $\frac{\partial L^*}{\partial E} > 0$; see the figure). A decrease in the pollution cap leads to a rise in the permit price (see Eq. (16)), and thus, in the costs borne by firms. This induces firms to raise their price and to reduce their levels of production and employment, which translates into a downward move of the (PS) curve in the aggregate employment-real wage space. Conversely, the fall in production and in the production per worker reduces the reference wage and incites unions to set lower wages, which also leads to a downward move of the (WS) curve. Once again, comparison between the corresponding elasticities shows that the impact on the (PS) curve is higher than the one on the (WS) curve, so that all in all, a reduction in the pollution cap leads to a fall in equilibrium employment.
4 Unemployment benefits financed by pollution permits

In this section, we relax the hypothesis according to which pollution permits are free ($E_i = 0$, $\forall i$), and suppose that their sale enables to finance unemployment benefits. According to this assumption, the government’s budget constraint reads:

$$ B(L - L) = QE $$

(20)

where $L$ denotes the total labor force available in the economy. Isolating $B$ in (20), substituting into (18), replacing $Q/P$ by its equilibrium value (16) and finally isolating $W/P$, one obtains the (WS) curve equation when unemployment benefits are endogenous:

$$ \left( \frac{W}{P} \right)_{WS}^{B=B(\cdot)} = m \frac{\alpha e^{(1+\sigma)(1+\rho)}}{(1-\alpha)(1+\sigma)} N \frac{[1-(\alpha+\beta)]^{e}}{1+\sigma} K \frac{\beta e}{1+\sigma} \left( \frac{E}{d} \right) \frac{1}{1+\sigma} $$

(21)

Combining the (WS) curve equation (21) with the (PS) one (17) and solving for $L$ yields the equilibrium employment level when unemployment benefits are financed by pollution permits:

$$ L^* = \frac{1}{1 + (m^e \Psi) \frac{1}{1+\sigma}} $$

(22)

Equation (22) immediately indicates that the equilibrium level of employment does not depend on the environmental parameters of the model, $d$ and $E$, which leads to the following proposition:

**Proposition 4** If unemployment benefits are financed by the sale of pollution permits, equilibrium employment does not depend on the pollution-reducing technological innovation parameter neither on the pollution cap.

A reduction of, for instance, the pollution cap, leads to a fall in the firms’ demand for labor. Nevertheless, the reduction in the number of permits sold
leads to a reduction in the unemployment benefits. This decreases the workers’ reservation wage and hence, induces unions to set lower wages. The fall in real wages incites firms to increase their labor demand. In our setting, both effects on the (PS) and (WS) curves are of the same magnitude and therefore neutralize each other, so that there is no impact on equilibrium employment at all. Proposition 4 thus highlights the fact that global employment does not depend on the environmental variables but only on the characteristics of the goods and the labor market through the marginal cost and union’s wage mark-ups.

To conclude our study, let us turn to the consequences of the environmental policy in the long run.

5 Long run analysis

In the long run, firms choose the optimal level of capital they use to produce too. Maximizing firm $i$’s profit function (7) with respect to $K_i$, again subject to the demand and the production constraints respectively given by (1) and (2) and using (3), yields:

$$K_i = m^{-\frac{\varphi + \sigma}{\alpha}} \left( \frac{Y}{N} \right)^{\frac{1 + \varphi}{\alpha}} \left( \frac{bQ}{P} \right)^{-\frac{(\varphi - 1)}{\alpha}} \left( \frac{R}{P} \right)^{-\frac{[\varphi - \sigma (\varphi - 1)]}{\alpha}} \left( \frac{W_i}{P} \right)^{-\frac{\sigma (\varphi - 1)}{\alpha}}$$

\[ (23) \]

\[ ^{11} \text{As for any market, the reduction in the supply of permits leads to a fall in the government’s revenue if and only if the price-elasticity of the demand for permits is more than one. One can verify that this condition is fulfilled here by inserting (14) and (15) into (2), and the latter, again using (14), into (3). One can then show that } \left( \frac{E_{Q/P}}{P} \right) = \frac{1 + (1 - \alpha) \varphi}{(1 - \alpha) \sigma} > 1. \]

\[ ^{12} \text{In order to analyze the long-run general equilibrium, it would be necessary to define a law of motion for capital, in which case eq. (1) would no longer correspond to the global demand, as it neglects investment expenditures. Following Manning (1992), we do not take the firms’ investment decisions into account, since the model presented in our paper is essentially static. Neither do we consider the “very long run”, where the equilibrium would be defined by a zero-profit condition and the number of firms be endogenous. This situation is beyond the scope of this paper. Nevertheless, one can think that if the number of firms were endogenous, the entry of new firms due to an increase in global production and profits would probably lead to a rise in the demand of permits. This in turn would yield an increase in the permits’ price and hence in the costs borne by firms and finally reinforce the short-run effects.} \]
where \( \Lambda = 1 + [\varphi - (\alpha + \beta)(\varphi - 1)]\sigma > 0^{13} \). The optimal capital stock chosen by firm \( i \) thus depends positively on \( Y \) and negatively on \( m, N, b, Q/P, R/P \) and \( W_i/P \).

We obtain the following proposition, which remains valid whatever the initial permits’ distribution and thus, the assumption retained about the financing of unemployment benefits:

**Proposition 5** *In the long run, the effects of a pollution-reducing technological innovation and of a reduction in the pollution cap on equilibrium employment are of the same signs as in the short run.*

Equation (2) indicates that the qualitative properties of the equilibrium employment level are of the same kind as in the short run. Only the magnitudes of the effects of the environmental policy are different between the short and the long runs, except for the case where unemployment benefits are financed by the sale of pollution permits, in which effects are always null. This result is not surprising since all the effects in our model translate through the permits’ price. Thus, the endogenization of the capital stock does not change the main mechanisms of the model.

### 6 Conclusion

The aim of this article is to investigate the consequences of a pollution permit market on equilibrium employment in an economic environment where firms behave in an imperfectly competitive manner. To do this, we introduce explicitly a competitive pollution permit market in a WS-PS model. We then study its interactions with the goods and the labor markets according to two distinct rules of initial permit distribution, grandfathering and auction.

Firstly, we show that environmental factors can have some important effects on the labor market, since the wage mark-up set by the unions depends on the efficiency parameter of the pollution reduction technology used by firms. This first result thus suggests that there may be some important interactions between the labor and the permit markets. It shows that

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\(^{13}\)In this paper, we assume that returns to scale can be decreasing, constant, or even slightly increasing.
improvements concerning the environmental properties of production technologies may have some important consequences on employment. It indicates that a rise in the efficiency of the pollution-reducing technology can induce firms to adopt a more emission intensive technology instead of using standard labor inputs, which in turn incites wage setters to moderate their claims in order to limit the latter negative effect. The reaction of wage setters towards such an environmental shock appears to finally support employment. Besides, we highlight two important results concerning the environmental policy in the case where the level of unemployment benefits is set exogenously. Whereas a pollution-reducing technological innovation increases the level of equilibrium employment, a more stringent environmental policy has a negative effect on the latter. This suggests that an active policy in favour of innovation should be conducted by policy makers. We pursue our analysis by studying the consequences of the environmental policy on employment when unemployment benefits are financed by the sale of pollution permits. We show that in this case, both the pollution-reducing innovation shock and the pollution permit market have no impact on global employment. This result is of interest because it suggests that a more stringent environmental policy can be achieved without having negative effects on employment, i.e., that employment and the environmental quality may not always correspond to two opposite objectives for the policy designer. Thus, we highlight a particular form of the double dividend without assuming distortionary taxation. Besides, this may suppress costly lobbying activities which try to raise the pollution cap on behalf of the defense of employment. Moreover, Proposition 5 underlines the fact that improvements concerning the efficiency of the pollution-reducing technology may even stimulate production and employment, by inducing wage setters to moderate their claims in order to support employment. Finally, we show that our results remain stable in the long run, which reinforces the main conclusions of the paper.

The literature usually stresses the fact that the way pollution permits are distributed does not matter if the pollution permit market is competitive. Conversely, we show that when the permit market is competitive whereas the goods and the labor markets are not, the initial distribution of pollution permits...
permits does matter for the efficiency of the whole economy when revenue-recycling is taken into account. Our paper offers some recommendations concerning the environmental policy to the regulator, while acknowledging him about the consequences such a policy can have on employment. However, there remain of course some limits in our analysis. For instance, we have not considered the cost of innovation itself and the source of innovation has been considered as exogenous. Moreover, the pollution permit market has been assumed to be perfectly competitive. It would be interesting to introduce some imperfections into the pollution permit market too, in order to analyze how the initial distribution of pollution permits eventually matters in our theoretical context. One avenue for further research would be therefore to extend our analysis by taking the above considerations explicitly into account.
Appendix: the long run equilibrium

Taking (23) at the symmetric equilibrium \((K_i = K/N, Y_i = Y/N)\) while using (2), (14) and (15) and isolating \(K\), we find the aggregate capital stock for a given permit price\(^{15}\):

\[
K = m \frac{-(1 + \sigma)}{(1 - (\alpha + \beta)\sigma)} N d \frac{1}{1 - (\alpha + \beta)\sigma} \left( \frac{Q}{P} \right)^{\frac{-1}{1 - (\alpha + \beta)\sigma}} \left( \frac{R}{P} \right)^{\frac{1 - \alpha}{1 - (\alpha + \beta)\sigma}} \left( \frac{W}{P} \right)^{\frac{-\alpha}{1 - (\alpha + \beta)\sigma}} \tag{24}
\]

Reinserting (24) into (15), we obtain the aggregate labor demand in the long run for a given permit price:

\[
L = m \frac{-(1 + \sigma)}{(1 - (\alpha + \beta)\sigma)} N d \frac{1}{1 - (\alpha + \beta)\sigma} \left( \frac{Q}{P} \right)^{\frac{-1}{1 - (\alpha + \beta)\sigma}} \left( \frac{R}{P} \right)^{\frac{-\beta}{1 - (\alpha + \beta)\sigma}} \left( \frac{W}{P} \right)^{\frac{-\alpha}{1 - (\alpha + \beta)\sigma}} \tag{25}
\]

As in the short-run case, we must finally determine the equilibrium permit price in the long run. Inserting (14), (24) and (25) into (2) at the symmetric equilibrium, then (2) into (3), (3) into (6), and finally isolating \(Q/P\), we find:

\[
\frac{Q}{P} = m \frac{-(1 + \sigma)}{1 + (1 - (\alpha + \beta)\sigma)\sigma} d \frac{1}{1 - (\alpha + \beta)\sigma} E \frac{1}{1 - (\alpha + \beta)\sigma} \left( \frac{R}{P} \right)^{\frac{1 - \beta}{1 - (\alpha + \beta)\sigma}} \left( \frac{W}{P} \right)^{\frac{-\alpha}{1 - (\alpha + \beta)\sigma}} \tag{26}
\]

Finally, substituting (26) into (25) and isolating \(W/P\), we obtain the long-run pricing equation, which exhibits the same qualitative properties as the short-run one:

\[
\left( \frac{W}{P} \right)^{LR} = m \frac{-(1 + \sigma)}{(1 + (1 - \beta)\sigma)e} d \frac{1}{1 - (\alpha + \beta)\sigma} E \frac{1}{1 - (\alpha + \beta)\sigma} \left( \frac{R}{P} \right)^{\frac{-\beta}{1 + (1 - \beta)\sigma}} L^{\frac{1}{1 + (1 - \beta)\sigma}} \tag{27}
\]

As far as the (WS) curve is concerned, inserting (26) into (24) and the new equation into (18), one obtains the long run (WS) equation.

\[
\left( \frac{W}{P} \right)^{LR} = m \frac{\nu(\alpha - \beta)\sigma}{\Delta} N \frac{1}{\Delta} \frac{\nu(1 - (\alpha + \beta))}{\Delta} d \left( \frac{1 - \alpha}{\Delta} E \right)^{(1 - \alpha)\nu} \frac{-(1 - \beta)\sigma}{\Delta} \left( \frac{R}{P} \right)^{\frac{-\beta}{\Delta}} \left( \frac{B}{P} \right)^{\frac{1 + (1 - \alpha)\sigma}{\Delta} (1 - \nu)} L^{\frac{-(1 - \alpha)(1 + (1 - (\alpha + \beta))\sigma)}{\Delta}} \tag{28}
\]

\[^{15}\text{Still ignoring multiplicative constant in } \alpha \text{ and } \sigma.\]
where $\Delta = [1 - (\alpha + \beta) + \alpha \beta \nu] \sigma + 1 - \alpha \nu > 0$. Combining (27) and (28), and isolating $L$ yields the equilibrium level of aggregate employment when unemployment benefits are set exogenously in the long run:

$$L^* = m \frac{1 + (1 - \beta) \sigma}{N} \frac{1}{1 - (\alpha + \beta)} \frac{1}{\nu} \frac{1}{\psi} \frac{1}{d} \frac{1}{E} \left( \frac{R}{P} \right)^{-\phi} \left( \frac{B}{P} \right)^{-\frac{1}{\phi}}$$

(30)

where $\psi = 1 + [1 - (\alpha + \beta)] \sigma > 0$. One can verify that equilibrium employment decreases with $d$ and increases with $E$ in the long run, as in the short run.

The method that has been used to find (21) can be applied to determine the (WS) equation if unemployment benefits are financed by pollution permits in the long run case:

$$\left( \frac{W}{P} \right)^{LR}_{WS} = m \frac{\nu (\alpha - \beta \sigma)}{r} \frac{1}{N} \frac{\nu (1 - \alpha)(1 - \beta)}{r} \frac{d^{-1} (1 - \alpha) \nu}{r} \frac{E^{(1 - \alpha) \nu}}{r} \left( \frac{R}{P} \right)^{-(1 - \alpha) \beta \sigma \nu} \left( \frac{B}{P} \right)^{-\frac{1}{\phi}}$$

(31)

$$\times \psi \frac{1}{L^{(1 - (\alpha + \beta)) \sigma}} \frac{1}{L^{-1}} \frac{1}{(1 - \alpha)(1 + \beta)(1 - \alpha) \sigma \nu}$$

(32)

where $F = 1 + (1 - \beta) \sigma > 0$. The equilibrium level of aggregate employment when unemployment benefits are financed by the sale of pollution permits in the long run is finally obtained by combining (27) and (31), which yields (22), which is equal to the short run one.

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References


