“Are Pollution Permit Markets Harmful for Employment?“

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Abstract

This paper investigates if pollution permit markets are harmful for employment within a Wage Setting-Price Setting (WS-PS) model. The employment level is determined according to several financing unemployment benefits: a wage tax or the revenue of the pollution permit auction. We first show that a permit market weakens the union market power. Whatever the way that unemployment benefits are financed, the choice of the pollution cap is always neutral on the employment levels, and these latter always increase if the technology to reduce pollution become more efficient. Depending on the value of the wage tax, the employment level can be higher or lower when unemployment benefits are financed by pollution permits rather than a wage tax.

Keywords: Monopolistic competition; Equilibrium employment; Pollution permit market; Unemployment benefits

JEL Classification: E24, J50, L13, Q52, Q58

1 Introduction

Nowadays, pollution permit markets are considered as a useful tool to reduce pollution. As far as Greenhouse Gas Emissions are considered, the Kyoto

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protocol has implemented an international pollution permit market and the European Union Emission Trading Schema (EU ETS) is today the largest multi-national emissions trading scheme in the world. If the international carbon market is not well developed today to draw some conclusions, the first phase of the EU ETS (2005-2008) appears to be successful (Ellerman and al., 2010): emissions are effectively reduced at a lower cost than a command and control approach, as prescribed by the economic theory (Montgomery, 1972). However, these policies lead firms to bear supplementary costs and the consequences on the employment level are questioned. It is true that for many OECD countries - specially in Europe - the unemployment level remains higher and is a persistent problem. The question whether more stringent environmental policy and employment constitutes an inevitable trade-off is crucial.

The economic theory has explored this problem and has presented a very appealing effect: the double dividend. Assuming that the environmental policy enables to raise a revenue, and that the pre-existing taxation in the economy is distortionary, the collected revenue can be used to reduce these distortions. The idea that environmental policy can be pursued while reducing the unemployment level is a very nice promise. This strong form of the so-called double dividend hypothesis has yet been studies in several aspects. Using a theoretical general equilibrium framework in which all markets clear -including the labour market- Bovenberg and de Mooij [1994a, 1994b], Goulder [1995], Bovenberg and Goulder [1996] have shown that this double dividend form cannot be achieved. However, these retained assumptions are questionable specially as far the labour market is concerned. So, some authors have introduced involuntary unemployment, introducing several kinds of imperfections on the labour market: matching frictions (Bovenberg and van der Ploeg [1998], Wagner [2005]); wage bargaining using a Nash criteria (Marsili and Renström [2000]) or a "right-to-manage" model (Koskela and al. [1998]), efficiency wage (Schneider [1997]), monopoly unions (Strand [1998]). In each model, there is some cases where employment level is boosted.

These analysis are very heterogenous and some retained assumptions appear more or less important. They do not all consider a general equilibrium (see Koskela and al. [1998]), whereas it seems to be the most appropriate framework to analyze unemployment. Some models assume perfect competition on product market (see Strand [1998]), which is questionable. In addition to that, the wage bargaining using "right-to-manage" is, according to Stand
[1998], more realistic that monopoly unions - which "gives labor unions to much power wage setting, and perhaps too little power over employment". Finally, the Pigovian tax is always retained whereas pollution permit markets are the more tool used today\(^1\). It is true that these two instruments appear to be similar if pollution quotas are sold, but some differences have to noticed. Pollution quotas enables, in the one hand, to control ex-ante the environmental quality and, in the another hand, to analyze an intermediary situation than the Pigovian tax: the case where pollution permits are free given. None of these presented models retain all these particular assumptions\(^2\).

The main purpose of this article is to consider these elements together to evaluate whether pollution permit markets are harmful for employment. We develop an extended version of the Wage Setting-Price Setting (WS-PS) model proposed by Layard and Nickell (1985)\(^3\), taking into account "the right to manage" version. Two alternative kinds of initial pollution permit distribution are considered, a free one (as grandfathering) and a charge one (as an auction). The employment level is determined according to several financing unemployment benefits: a wage tax or the revenue of the pollution permit sale. In conformity with the existing literature, we do not take into account the innovation process.

We first show that a pollution permit market leads to weaken the union market power to fix a high level of wage. As they anticipate that some substitution between inputs detrimental for employment can arise, they reduce their mark-up on the reference wage. Two other interesting results are found: the choice of the pollution cap is always neutral on the employment levels and these latter always increase if the technology to reduce pollution become more efficient. These results hold whatever the way that unemployment benefits are financed. However, the employment levels are, in each case, different. Depending on the value of the wage tax, it appears that the employment level can be higher or lower if unemployment benefits are financed by pollution permits rather than by a wage tax.

The structure of the article is as follows. The model is exposed in Section

\(^1\) The Pigovian tax is not implemented at the European Union stage and the Pigovian tax project in France is going to be throw out.

\(^2\) For example, Koskela and al. (1998) assume imperfect competition on the product market with the "right-to-manage" model, but consider a Pigovian tax and only one firm. Marsiliani and Renström (2000) retain a general equilibrium with monopolistic firm but with a wage bargaining using a Nash criteria and a Pigovian tax.

\(^3\) The WS-PS model is presented in details in Layard and al. (1991).
2. Section 3 establishes employment levels according to different financing ways and compares them. Section 4 presents a summary of the main results of the paper and some concluding remarks.

2 The model

We first present the assumptions retained for this economy. We then expose the partial equilibrium to finally develop the general one.

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\(^4\):

\[
Y_i = (Y/N) p_i^{-\varphi}
\]

where \( Y \) represents the level of global demand, \( p_i \), firm \( i \)’ real price, and \( \varphi \), the elasticity of substitution between differentiated goods \( (\varphi > 1) \). Following Jouvet et al. (2005) and Strand (1998), we suppose that all firms produce according to the same Cobb-Douglas production technology:

\[
Y_i = z_i L_i^\alpha
\]

where \( z_i \) represents the index of the technology used, with \( 0 \leq z_i \leq 1 \). The variable \( L_i \) denotes efficient labor with \( \alpha \leq 1 \). We assume that the produced good and the level of pollution are joint products. We also suppose that the

\(^4\)See Blanchard and Kiyotaki (1987) for the micro-foundations 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 away during utility maximization and is therefore not present in the individual demand functions and hence in (1).
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:

\[
E_i = dz_i^\delta Y_i
\]  

(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 amounts of labor. The parameter \( \sigma \) indicates the efficiency of the pollution-reducing technology \( (z_i) \) in reducing emissions \( (\sigma > 1) \). The parameter \( d \) illustrates some potential improvement in the existing technology to abate emissions. A decrease in \( d \) implies that the technology used by firm \( i \) becomes less polluting, for given levels of the technology index and production. For instance, this new technology can be an end-of-pipe technology of abatement\(^5\).

### 2.1.2 Unions

Union \( i \)'s utility function is given by:

\[
\Omega_i = (w_i - w_r) L_i^\delta
\]

(4)

where \( w_i \) reads union \( i \)'s real wage and \( w_r \), the (real) 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 government

We assume that the government is concerned with two problems in this economy, the pollution one and the unemployment one.

**The environment concern** 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

\(^5\)We can quote, like an example, scrubbers which allow firms to produce electricity with coal without releasing SO2.
a pollution permit market. We assume that the pollutant is an uniformly mixed assimilated one\textsuperscript{6}. The environmental agency specifies the pollution cap\textsuperscript{7} $E$. We first assume that the initial allocation is free (for example 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 (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:

$$E = \sum_{i=1}^{N} E_i$$

(5)

We denote the real 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.

**The employment concern** We note the level of unemployment ($\overline{L} - L$), where $\overline{L}$ is the total labor force available in the economy. The government distributes unemployment benefits to unemployed workers. To do so, we firstly assume that it sets a tax denoted by $t$, on wage that firms pay to workers. We will relax this assumption hereafter, by considering that pollution permits can be sold and that the corresponding revenue is used by the government to finance unemployment benefits. We now turn to the resolution of the model.

\textsuperscript{6}If not, the pollution permit market has to take the spatial effect of pollution into account (see Montgomery, 1972).

\textsuperscript{7}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.
2.2 Partial equilibrium

2.2.1 Technology index and employment determination

We use the "right-to-manage" model in which unions set the wage and 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 firms take all aggregate variables as given when maximizing profit. Firm i’s real profit, which includes the purchase and the sale of pollution permits, is given by:

\[ \pi_i = p_i Y_i - (1 + t) w_i L_i - q E_i + \bar{E}_i \]  

(6)

Maximizing Eq. (6) with respect to \( z_i \) and \( L_i \), subject to the demand, the production and the emissions constraints respectively given by (1), (2) and (3), leads, after simplifying, to the optimal technology index and demand for labor:

\[ z_i = [(1 + \sigma) m] \frac{\varphi - \alpha (\varphi - 1)}{\Theta} \frac{1}{\Theta} \frac{\delta}{\delta q} \frac{(Y/N)}{(1 + t) w_i / (\alpha \sigma)} \]  

(7)

and

\[ L_i = [(1 + \sigma) m] \frac{(1 + \sigma)}{\Theta} \frac{\varphi - 1}{\Theta} \frac{\delta}{\delta q} \frac{1}{(1 + t) w_i / (\alpha \sigma)} \]  

(8)

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 \( L_i \).

2.2.2 Wage determination

Maximizing union i’s utility function (4) with respect to the real wage \( w_i \) yields:

\[ \frac{w_i}{w_i - w_r} + \delta \varepsilon_{W_i}^{L_i} = 0 \]  

(9)

where \( \varepsilon_{W_i/P}^{L_i} \) corresponds to the elasticity of labor demand with respect to the real wage. Isolating \( W_i/P \) in (9) yields the real wage fixed by union i:

\[ w_i = \Psi w_r \]  

(10)

where, using the value of \( \varepsilon_{W_i/P}^{L_i} \) given by (8) and simplifying:

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

(11)
Eq. (10) 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 of the pollution-reducing technology \((\sigma)\). In addition to that, we obtain that \( \partial \Psi / \partial \sigma < 0 \), which enables us to write this first proposition:

**Proposition 1** The pollution permit market reduces the union’s power to fix a high level of wage.

As already mentioned, a higher \( \sigma \) 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 (see Eq. (3)). This in turn induces firms to use a lower amount of labor input, while keeping their level of production constant (Eq. (2)). The elasticity of the firms’ labor demand with respect to wages increases (see Eq. (8)) and, finally, the unions’ wage markup - *i.e.* the unions’ power to fix high level of wage - is reduced.

### 2.3 General Equilibrium
#### 2.3.1 The price curve

At the symmetric equilibrium, \( z_i = z \), \( L_i = L/N \) and \( Y_i = Y/N \). Hence, using (2) at the symmetric equilibrium and substituting into (7), simplifying and isolating \( z \), we obtain the optimal technology index chosen by firms at the symmetric equilibrium:

\[
z^* = [(1 + \sigma) \; m dq]^{-\frac{1}{\sigma}}
\]

Now, taking (8) at the symmetric equilibrium \( (w_i = w) \), using (2) and replacing \( z \) by (12), we find the aggregate labor demand for a given permit price:

\[
L = [(1 + \sigma) \; m]^{-\frac{(1 + \alpha)}{(1 - \alpha)\sigma}} \; (dq)^{\frac{-1}{(1 - \alpha)\sigma}} \; [(1 + t) \; w/ (\alpha \sigma)]^{\frac{1}{1 - \alpha}} \; N
\]

Substituting (2) into (3) and the resulting equation into the permit market’s equilibrium condition (5) at the symmetric equilibrium \( (E_i = E) \), inserting
the equilibrium values of $z$ and $L$ respectively given by (12) and (13) and finally isolating $q$, we obtain the equilibrium pollution permit price:

$$q^* = [(1 + \sigma) m]^{-(1+\sigma)} d^1 \frac{1}{d(1+\sigma)} \frac{E^{-(1-\alpha) \sigma}}{[1 + t \cdot (\alpha \sigma)]^{(1+\sigma) \frac{1}{N \cdot (1-\alpha) \sigma}}} N^{(1-\alpha) \sigma}$$

(14)

Reinserting (14) into (13) and isolating $w$, we obtain the real wage firms are willing to pay to workers for a given level of global employment, i.e., the equation of the price setting curve ($PS$):

$$w_{ps} = \alpha \sigma \left[(1 + \sigma) (1 + t) m\right]^{-1} \left(E/d\right)^{\frac{1}{(1+\sigma)}} \frac{N^{(1-\alpha) \sigma}}{L^{\frac{1}{(1+\alpha) \sigma}}}$$

(15)

As shown by Eq. (15), 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 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 equation of the wage setting ($WS$) curve, we have to model the workers’ reference wage, $w_r$:

$$w_r = ub + (1 - u) \bar{w}$$

(16)

where $\bar{w}$ denotes the wage paid by firms to workers elsewhere in the economy. The unemployment rate, $u$, is defined by:

$$u = 1 - L/\bar{L}$$

(17)

Inserting the reservation wage (16) into the real wage set by union $i$ (10) at the symmetric equilibrium ($w_i = \bar{w} = w$), using the standard definition of the unemployment rate (17), and isolating $w$, one obtains the expression of the real wage set by unions in the economy, i.e. the ($WS$) curve equation:

$$w_{ws} = \Psi b \left(\bar{L} - L\right) / \left(\bar{L} - \Psi L\right)$$

(18)

According to Eq. (18), the ($WS$) curve is increasing and convex in the aggregate employment-real wage space. The union-determined real wage is increasing in the wage mark-up and the unemployment benefits.
3 The employment equilibrium

We determine the employment equilibrium considering several cases. Depending on the interpretation of $b$, we have to consider -or not- financing-sources.

3.1 Unemployment benefits non financed

As $b$ is the alternative income of workers who do not get a job, as Strand [1998], we can consider that $b$ could be the value of leisure or non market production. In this case, there is no needs for wage taxes\footnote{This analysis is true whatever the initial distribution of the pollution permits. If they are sold, we just consider that the revenue is not used.} and $t = 0$. From (15) and (18), we find the equilibrium level of employment. We can observe the consequences of a reduction in the pollution cap ($\Delta \bar{E} < 0$) and of an improvement in the technology enabling to pollute less ($\Delta d < 0$). The (WS) curve is never modified. This situation is depicted on Figure 1.

A decrease in the pollution cap leads to a rise in the pollution permit price (Eq. (14)), and thus, in the costs borne by firms. Consequently, firms raise their price and reduce their levels of production and employment. This trans-
lates into a downward move of the (PS) curve in the aggregate employment-real wage space. Thus, the equilibrium level of employment decreases if the environmental policy is more stringent.

As far as $d$ is concerned, if the technology becomes less polluting for exogenous reasons, the level of emissions will be lower for a given index of the technology used and a given level of production (see Eq. (3)). Hence, firms, having a cleaner and thus a less costly technology at their disposal, increase their level of production at equilibrium. In order to achieve this, they increase their demand for labour (Eq.8 ) and their index of technology (Eq. 7). In other words, firms accept to pay a higher real wage for a given level of employment. As indicated by Fig. 1, this translates into an upward move of the (PS) curve in the aggregate employment-real wage space.

These results are in conformity with intuition. However, in real economies, there are unemployment benefits which need to be financed. So, we turn now to analyze this more realistic situation.

3.2 Unemployment benefits financed

In this section, we consider $b$ as unemployment compensation which have to be financed. We retain three financing-sources: a wage tax, a mix-financing composed of the wage tax and of the revenue of the pollution permit sale and finally, the recycling of the pollution permit revenue.

The wage tax financing  We assume that the initial pollution permit distribution is free ($E_i > 0$) and that unemployment benefits are financed with the wage tax. The government budget constraint is given by:

$$b (L - L) = twL$$

Isolating $b$ in (19), and substituting into (18), we find immediately the labour supply of workers$^9$:

$$L^*_i = \frac{1}{(1+t)\Psi}$$

The equilibrium real wage is found by substituting (20) into (15):

$$w^*_i = \alpha \sigma (1 + \sigma) m^{-1} (1 + t)^{\frac{\sigma}{1+\sigma}} \frac{(E/d)^{\frac{1}{1+\sigma}}}{N^{\frac{(1-\alpha)^s}{1+\sigma}} (\Psi/L)^{\frac{1+(1-\alpha)^s}{1+\sigma}}}$$

$^9$We note that without pollution permit market, the equilibrium level of employment with $b$ financed by the wage tax is: $L^* = \frac{\alpha}{(1+t)m} L$. 

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The mix financing  We relax here the hypothesis according to which pollution permits are free. All pollution permits are sold, by means, one say, an auction, thus: $E_i = 0, \forall i$. We suppose that the revenue of the sale is used, with the wage tax, to finance unemployment benefits. According to this latter assumption, the government’s budget constraint now reads:

$$b(L - L) = t w L + q E$$

(22)

Isolating $b$ in (22), replacing $q$ by its equilibrium value (14), substituting into (18), we find the (WS) curve equation:

$$w_{ws} = [(1 + \sigma) m]^{-1} [(1 + t) / \alpha \sigma]^{\alpha \sigma \over \alpha + \sigma} \Psi^{[1 + (1 - \alpha) \sigma] \over 1 + \sigma} (E/d)^{1 \over 1 + \sigma}$$

$$\times N^{(1 - \alpha) \sigma \over 1 + \sigma} [L - (1 + t) \Psi L]^{-[1 + (1 - \alpha) \sigma] \over 1 + \sigma}$$

(23)

The equilibrium employment level is obtained by equalizing Eq. (15) and (23), which gives:

$$L^* = \frac{\alpha \sigma}{(1 + \alpha \sigma)} \frac{L}{1 + t}$$

(24)

Substituting (24) into either (15) or (23), we obtain the corresponding real wage:

$$w^*_2 = [(1 + \sigma) m]^{-1} (1 + t)^{\alpha \sigma \over \alpha + \sigma} (E/d)^{1 \over 1 + \sigma} N^{(1 - \alpha) \sigma \over 1 + \sigma} [(1 + \alpha \sigma) \Psi / L]^{1 + (1 - \alpha) \sigma \over 1 + \sigma}$$

(25)

The pollution permit revenue financing  If the unemployment benefits are only financed by the sale of the pollution permits, the wage tax can be suppressed: $t = 0$. Then, from (24) and (25), we obtain the following level of employment and the equilibrium real wage:

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

(26)

$$w^*_3 = (\alpha \sigma)^{\alpha \sigma \over 1 + \sigma} [(1 + \sigma) m]^{-1} (E/d)^{1 \over 1 + \sigma} N^{(1 - \alpha) \sigma \over 1 + \sigma} [(1 + \alpha \sigma) \Psi / L]^{1 + (1 - \alpha) \sigma \over 1 + \sigma}$$

(27)

3.3 Discussion

In this section, we discuss and compare our results in the more realistic case, i.e. if the unemployment benefits are financed. We first observe that whatever the kind of unemployment benefit financing, the employment levels given
by (20), (24) and (26) do never depend on any environmental parameter, i.e. neither on $d$, nor on $E$.

**Proposition 2** Whatever the way that unemployment benefits are financed, a more stringent environmental policy or some potential improvement in pollution-reducing technology are always neutral effects on equilibrium employment levels. In each case, the environmental shocks are absorbed by the real wage.

Eq. (20) (24) and (26) immediately implies that $\partial L_i^*/\partial E = \partial L_i^*/\partial d = 0, \forall i = 1, 2, 3$. From Equations (21), (25) and (27), we see that the equilibrium real wage is therefore the only variable that absorbs the environmental shocks. They decrease if the pollution cap is reduced whereas they increase if the technology becomes less pollutant. If the results are similar, the rationale underlying Proposition 2 are different according to the financing-sources for $b$. In each case, the (WS) curve is differently changed whereas the (PS) curve always remains the same (whether the unemployment benefits are either financed or not).

Figure 2 depicts the case where $b$ is financed only by the wage tax. As indicated by Eq. (20), the wage curve is vertical and fixes alone the level of employment. This latter is so entirely determined by the wage tax and the unions’ wage markup. Thus, we see that a reduction in the pollution cap decreases the real wage. The result is reversed for a reduction in $d$. Finally, for a same level of employment, wages are higher with an innovation enables to pollute less than a more stringent environmental policy.

The case where $b$ is mix-financed or totally financed by the revenue of the pollution permits is given by Figure 3. On the one hand, as we already see in Section 3.1, a decrease in the pollution cap translates into a downward move of the (PS) curve in the aggregate employment-real wage space. On the other hand, a lower pollution cap implies less receipts to finance unemployment benefits for the government, which weakens the outside opportunities of workers on the labour market\(^{10}\). This incites unions to set lower wages, which also leads to a downward move of the (WS) curve. The overall impact on real wages is thus unambiguously negative. Moreover, the aggregate employment level is not modified.

\(^{10}\)As for any market, the reduction in the permit supply leads to a fall in the government’s revenue if the price-elasticity of the permit demand is more than one. This condition is fulfilled here.
Figure 2: Effects of environmental shocks with unemployment benefits financed by the wage tax

Figure 3: Effects of environmental shocks with unemployment benefits financed by the receipt of permits
We indeed observe that the elasticities of the price-determined (15) and
the unions-determined real wages (23) with respect to $\bar{E}$ are of the same
magnitude. In the one hand, we know that the introduction of a pollution
permit market leads firms to support the equilibrium permit price. At the
general equilibrium, the global cost of environmental policy is given by $q^*\bar{E}$
and is integrated in the ($PS$) curve. In the other hand, as unemployment
benefits are financed (partly or totally) by the revenue of pollution permits,
unions are led to consider that in the ($WS$) curve, i.e. the cost of the pol-
lution permit market (given by $q^*\bar{E}$). This is exactly the value integrated in
the ($PS$) curve\(^{11}\).

As far as $d$ is concerned, we have already seen effects on the ($PS$) curve
in Section 3.1: a positive environmental shock leads firms to increase their
production and/or the real wage they are willing to pay to workers. The dif-
ference here is that unemployment benefits are now financed with the receipt
of permits. This therefore implies that the demand for permits, the price of
the latter (for a given pollution cap), and the wage tax receipt will increase,
leading to a rise in the government resources available for the financing of un-
employment benefits. Hence, outside opportunities of workers become better
which incite unions to increase wage claims. This effect translates into an addi-
tional upward move of the ($WS$) curve and a fall in employment. The latter
is exactly of the same magnitude than the increase due to the former move of
the ($PS$) curve so that the equilibrium employment level remains unchanged.

If these employment levels do not depend neither on $\bar{E}$ nor on $d$, it appears
that they all depend on the efficiency of the pollution-reducing technology,
$\sigma$. More precisely, we find the following result:

**Proposition 3** Whatever the way that unemployment benefits are financed,
the employment level always increases if the technology to reduce pollution
become more efficient:

$$\frac{\partial L_1^*}{\partial \sigma} > 0; \frac{\partial L_2^*}{\partial \sigma} > 0; \frac{\partial L_3^*}{\partial \sigma} > 0$$

\(^{11}\)More precisely, the rationale is the following. Using (3), (2) and (5) at the general
equilibrium and $z$ given by (12), we find: $q^*\bar{E} = [1 + \sigma m] \left(\frac{d\bar{E}}{\bar{E}}\right)^{\frac{1}{\sigma}} l^\sigma$. This value
is integrated in the ($WS$) curve. Expressed in function of $q^*$, the ($PS$) curve reads: $w_{ps} = \left[\alpha \sigma / (1 + t)\right] \left[1 + \sigma m\right] \left\{\frac{d\bar{E}}{\bar{E}}\right\}^{\frac{1}{\sigma}} l^\sigma$, i.e. $w_{ps} = \left[\alpha \sigma / (1 + t)\right] l^{-1} q^*\bar{E}$. 

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The variation of \((L_1^*)\) with respect to \(\sigma\) (Eq. 20) is not surprising\(^{12}\): it comes from immediately Proposition 1, because \(\Psi = f(\sigma)\) and \(\partial \Psi / \partial \sigma < 0\). We have already said that unions moderate their wage claims if they anticipate some substitution detrimental for employment. Consequently, firms increase their employment level. If unemployment benefits are financed by the pollution permits sale alone or coupled with the revenue of the wage tax, we find the same result\(^ {13}\). However, another effect appears in this case than one just exposed. A more efficient technology to reduce pollution enables firms to release less emission for a same level of production. Thus, if \(\sigma\) increases, depending on the permit price and on the wage level, firms choose to reduce more or less employment than pollution. In this case, the pollution permit demand diminishes, and so, the pollution permit price. In any cases, as there are less financing possibility for unemployment benefits, the outside opportunities of worker in the labour market are lower. Unions sets, again, lower wages\(^ {14}\). These two effects work in the same way and lead to increase the employment level.

Proposition 2 and 3 suggests that innovation which leads to a more efficient emission reduction technology is better for employment than just an improvement enabling to emit less emission. In the first case, that leads to a substitution between production factors, whereas we do not observe this effect in the second case.

It remains to determine which of the three financing methods considered yields the highest employment level. It is first obvious that:

\[
L_1^* > L_2^*
\]

\[
L_3^* > L_2^*
\]

With the mix financing, there are more possibilities to finance the unemployment benefits. The unions are incited to increase the wages which leads firms to reduce the level of employment. This latter is always higher if the

\(^{12}\)We immediately find \(\frac{\partial L_1^*}{\partial \sigma} = -\frac{L_2^\phi}{(1+\phi)\Psi}\). As \(\partial \Psi / \partial \sigma < 0\), we have: \(\frac{\partial L_1^*}{\partial \sigma} > 0\).

\(^{13}\)We have \(\frac{\partial L_2^*}{\partial \sigma} > 0\) if \(\frac{\Psi}{\sigma(1+\alpha \sigma)} > \partial \Psi / \partial \sigma\). As \(\partial \Psi / \partial \sigma < 0\), we obtain Proposition 3. In the same way, we obtain the proof for \(\frac{\partial L_3^*}{\partial \sigma}\).

\(^{14}\)This effect is more important if only the receipt of permits finances unemployment benefits: \(\frac{\partial L_2^*}{\partial \sigma} = (1 + \theta)\frac{\partial L_2^*}{\partial \sigma} > \frac{\partial L_2^*}{\partial \sigma}\). In this case, outside opportunities of worker are the lower.
exterior opportunities are the lower, i.e. in the case where there is just one financing source for $b$.

Comparison between $L_3^*$ and $L_1^*$ enables to state the following proposition:

**Proposition 4** The equilibrium level of employment is higher (lower) when unemployment benefits are financed by pollution permits ($L_3^*$) rather than by a wage tax ($L_1^*$) if $t > (<) \tilde{t}$, where $\tilde{t} = 1/(\alpha \sigma)$.

In one hand, if the level of wage tax is positive, the wage perceived by the firms is higher than this competitive level because of the presence both of unions and of the wage tax. In other hand, the pollution permit market increases the firms' costs. So, if the wage tax is relatively high ($t > \tilde{t}$), firms reduce employment especially because of this tax. In this case, full recycling of pollution permit revenue with the tax suppressing enables to increase the employment level. In the contrary, if the wage tax is relatively low ($t < \tilde{t}$), firms reduce the level of employment especially because of the pollution permit market. In this case, the wage tax-suppressing is not enough to lead firms to increase the level of employment.

The threshold $\tilde{t}$ depends on the efficiency of the pollution-reducing technology, $\sigma$. If $\sigma$ is very high, the value of $\tilde{t}$ is almost zero. In this case, whatever the level of the tax, $L_3^* > L_1^*$. If the pollution-reducing technology is very efficient, for a same level of production, the level of emission is low and $q$ diminishes. So, the environmental policy is less costly for firms and the unemployment comes from especially the wage tax. Thus, suppressing this tax obviously increases the level of employment.

4 Conclusion

In this article, we constructed a framework composed of different assumptions not yet studied together in the economic literature. Assuming monopolistic competition with "right to manage" way to fix wages, we seek to know whether pollution permit market is harmful for employment. We first show that the union’s power to fix high wages is reduced. As they anticipate possible factor substitution detrimental for employment, they are led to reduce their claims. We then define the employment level according to several way to finance unemployment benefits. If pollution permit are free given, unemployment benefits are financed with the wage tax. In the case where permits
are sold, their revenue can be recycled to finance unemployment benefits instead of the wage tax. It appears that whatever the kind of financing, the environmental policy has always neutral effects on the employment level, and this level always increases if the technology to reduce pollution become more efficient. However, the employment level is, in each case, different. According to the level of the wage tax, this latter can be higher (or lower) if the unemployment benefits are financed with the permit revenue recycling or the wage tax.

Our study suggests different economic policy recommendations. First, the pollution cap can be chosen without make difficult trade-off with the labour policy. This result also gives support to a reduction of costly lobbying activities which try to raise the pollution cap on behalf of the defense of employment\textsuperscript{15}. Then, we find conclusion about the pollution permit initial distribution. Since Montgomery [1972], we know that permits can be given or sold without affecting the post equilibrium exchange. However, the regulator sometimes prefers a free distribution in order to limit the possible negative consequences on employment or to favor program acceptance. To the contrary, the double dividend literature tends to retain a charge one. In this article, we highlight the better way to distribute pollution permits according to the wage tax level. Finally, our analysis advocates an active innovation policy, to improve the emission reduction technology efficiency.

This paper however remains particular on several respects. The reader surely noticed that the way that the wage is fixed in our model is mainly used in European countries and does not apply in, for example, the USA. For instance, we have considered a static model, in which the cost and the source of innovation have been taken as exogenous. One avenue for further research would be to consider this dynamic process. We have assume that the permit market is competitive. The study of the EU ETS first phase (2005-2007) tends to think that this assumption is realistic. However, we can note that 90\% of the permits are given to only 10 firms, that suggests possible market power\textsuperscript{16}. An improvement of this article would be to introduce some imper-

\textsuperscript{15}Hanoteau (2003) studies the lobbying activities which have been undertaken during the establishment of the American Acid Rain program. He shows that the states which were the most concerned with employment questions have organized to defend their own level of employment, and finally obtained more permits than initially decided by the Environmental Protection Agency.

\textsuperscript{16}See Hahn [1984] for a study about market power on the pollution permit market in a partial equilibrium.
ections into the permit market, in order to analyze whether our conclusions about initial distribution are challenge in this new context.
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