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Protecting biodiversity by developing bio-jobs:
a multi-branch analysis with an application on French data

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Abstract

There are jobs favourable to biodiversity, which we call bio-jobs. These jobs are located in a small number of sectors generally linked to natural resources: naturalist research, forestry sector, public works, water and waste management, etc. In this article, we are interested in two economic policies favoring the development of these bio- jobs. The government can support demand in sectors concentrating bio-jobs through public procurement, or she can develop them through targeted exemptions. The most effective and relevant combination of these instruments is looked for via an original framework. We show that the action of the government is driven by the nature of the sectors and especially the level of an existing private demand. Then, the level of the wages plays a major role in the government budget decision. We finally apply these recommendations to French data.

Key words: Employment, biodiversity conservation, public policy
JEL Codes : J21, Q57

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1. Introduction

The economic benefits of biodiversity have been widely demonstrated (Heal, 2004) and socio-economic evaluations insist on the idea that preservation is essential for the economy and the well-being of human beings (Costanza and Amanda, 2006; Tzoulas *et al.*, 2007). For example, water or air purification (Bockstael *et al.*, 1987; Smith and Huang, 1996; MacKerron and Mourato, 2009) as much as a forest does with the harvest of wood or recreational and sporting activities (Tyrvainen, 2000; Nalle *et al.*, 2004; Bestard *et al.,* 2009). However, all studies on the development in ecosystems indicate a continuing retreat of biodiversity, essentially linked to recent human and economic development (Erlich, 1994; Chu and Yu, 2002; Tilman, 2012). Policies are confronted with a major difficulty linked to biodiversity's character as common goods (Hardin, 1968). This situation is at the root of the market failure leading not only to a non-optimal use of resources but also to the degradation of biodiversity.

We are interested in economic conservation of biodiversity policies that employ incentives and forgo coercive measures seeking to prohibit or regulate certain activities or the access to certain resources. In a previous work (De Beir *et al.*, 2015), we have identified employment that are concerned with protection and management of biodiversity. 122 experts and scientists working in this field were interviewed in order to estimate the number of such jobs, we called "bio-jobs", in the Paris region. Biodiversity is considered in a very large way; it refers to the whole nature (both species and natural ecosystem scales). These jobs*,* "in whole or part, contribute to the understanding, management, protection, promotion, and restoration of biodiversity, intentionally or otherwise. They also contribute to an appreciation of the importance of biodiversity in other economic sectors. Hence, they include activities such as communication and the founding of projects promoting biodiversity"[1]. In order to take into account all the jobs corresponding to the preceding definition and not only those corresponding to "green core" jobs, such as quarrying activities[2] for example, the analysis is lead at the sector level. We have found that 16 sectors contain such bio-jobs: forestry products; extractive industries; state and non-profit research and development; charities and societies; agriculture; public administration; public works; stock infrastructure management; architecture; engineering and management; water treatment, treatment and distribution; generation and distribution of electricity; railway transportation; sanitation, road maintenance and waste management; business management; fuel production and distribution; insurance and auxiliary financial services. These sectors all have a link to natural resources or habitats. Some of them are explicitly and totally devoted to biodiversity conservation and management such as naturalist research unit or forestry sector, other like water treatment sector, are less directly related to biodiversity protection. To be precise and to distinguish these two cases, we have elaborated an original method based on the computation of a "bio-coefficient" for each sector using the interviews. The bio-coefficient measures the share of working time dedicated to the protection and conservation of biodiversity. For example let us take the sector of architecture and engineering. We have first identified the occupations focusing on biodiversity inside the whole sector (landscape architect, ecological engineer). With the specialists of the field, we have estimated the share of working time spent on actions favourable to biodiversity, the bio-coefficient, and we have converted it in a number of jobs, the bio-jobs, in each sector. When we only had the information for a single firm, we extrapolated it to the whole sector thanks to the French activity nomenclature, in which one can find the workforce for each sector. Some of the sectors do not refer "directly" to activities playing a role on biodiversity; these are the activities whose production is used as intermediate consumption by bio-jobs. One can think of seeds suppliers for the landscape architects. To quantify them we used the Input-Output Table of the French National Accounts. Our results showed that bio-jobs only represent 1/1000 job in the Paris region: they are 6400 and 2900 more jobs are induced by the latters.

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[1] This definition has been borrowed from the « Rapport du comité de filière biodiversité et services écosystémiques », Bénard and Frascaria-Lacoste (2012).

[2] A part of quarrying activity is favourable to biodiversity, and limits the negative impact of extraction activities, since when restoring the extraction sites they let the development of biodiversity.

In this article, we are interested in the public policies favouring biodiversity, thus specifically promoting bio-jobs. We only focus on the sectors having bio-jobs because they are a proxy of the sectors having a potential of development of such jobs. Given that this employment is concentrated in a small number of sectors (16 sectors), it seems pertinent to reason within a multi-branch framework, where the public policy could be different from one sector to another. There are two ways to orient economic activity to develop bio-jobs. On one hand, we could imagine changing production practices to make them less harmful. With a given level of production, this could be done by using subsidies. The alternative is, at a given productive combination, to develop activities favourable to biodiversity using public procurement in order to increase business in some sectors. From this base, we build a model where government has these two types of economic tools: targeted public procurement, and a price instrument aiming at modifying the impact of productive activities on biodiversity (subsidies). The problem for government is to determine the correct mix of these two instruments, given the particularities of each sector. The model we implement is only a partial equilibrium system. The essential objective of this article is to know how the government will differentiate the intensity and the nature of her action. We thus focus on the public trade-off within each branch and we do not take into account elements of macroeconomic closure such as public and household finance.

After presenting the main economic instruments favouring the protection of biodiversity in the following part, we analyse the behaviour of the representative producer and the public policy promoting bio-jobs in the third section. We apply the model on French data in the last section.

2. Economic instruments favoring the protection of biodiversity

According to the final report of Bräuer et al (2006), traditional tools have been developed in order to protect global environment in the first place and have been only recently extended to biodiversity and nature. Empirically, the first instruments used are different kinds of regulatory approaches, generally named Command and Control. They gather measures such as quotas which limit the amount of resources exploited and a whole set of environmental laws and norms. These instruments face a number of limits such as their cost, and the difficulties related to the identification of the targeted good, or to their monitoring. Coercion has limited effectiveness here, and the regulator tries for voluntary co-operation by using incentives (Sinclair-Desgagné, 2005). In central and eastern Europe, biodiversity protection programs are being confronted by questions of private property rights, rights of passage, the transparency of regulations and monitoring and their application (Chobotovà, 2013). Hence, they have been slowly completed by market based instruments (MBI). MBI include environmental taxes, environmental subsidies and support, tradable permits, financial mechanisms, labelling and certification, contractual approaches (including payments for “ecosystem services”), and finally liability and compensation scheme. MBI are better adapted to biodiversity in that they are more specific and implemented at a more local scale. Furthermore they are generally developed where Command and Control instruments pre-exist (Wätzhold and Schwerdtner, 2005). Recent and traditional instruments are complementary. For example, regulation and MBI represent two sides of a same objective, one more constraining, and the other more incentive, playing the role of stick and carrot (Engel, Pagiola, Wunder 2008; Wunder 2007).

Driven by our objective of developing jobs that are favourable to biodiversity, our attention is hold by two particular MBI. Environmental subsidies and financial mechanisms seem the most relevant to promote jobs and biodiversity. Environmental subsidies are used to initiate and promote changes in individuals’ practices and behaviour. They can be targeted towards individuals, businesses, institutions and charities. Financial mechanisms include financial support towards activities that favour biodiversity or prevent them from deteriorating it (Bräuer et al, 2006).

Public procurement and targeted exemptions fall within this framework. The difference is that, in our approach, the economic tools are not applied to activities directly but they act through jobs. As one of the recurring limit of the majority of the preceding tools is that they do not place themselves in a long-term setting. Acting through the creation of new jobs or the development of existing jobs is a mean to deeply promote activities in favour to biodiversity on the long-run. We now develop more accurately our two instruments.

The first instrument consists of public spending taking the form of demand flow. Along the same lines, Parikka-Alhola (2008) proposes a policy of incentives for eco-conception through the public tendering process. Public buying could create clear incentives for eco-conception by reducing market risk (windfall effect of subsidies) and by facilitating economies of scale (by the promotion of production responding to public procurement). Michelsen and De Boer (2009) explain that public buying rules favouring goods and services with low ecological impact promote innovation in the protection of habitats. Public procurement is a very conventional instrument of state intervention, and amounts to between 15% and 20% of GDP in OECD member countries. In France, it stands at 10% of GDP and the proportion of public contracts with environmental clauses rose from 2.6% in 2009 to 5.1% in 2010. Elsewhere, European Directives[3], under revision since 2011, allow the inclusion of environmental criteria in key stages of public procurement (MEDDE, 2012).

The price instrument consists of a subsidy paid for the factor of production considered the most favourable to bio-jobs. The subsidy takes the form of a targeted exemption of social contributions that reduces the cost of labour of bio-jobs. In different countries, targeted aid takes the form of exonerations from social contributions paid by the employer. In France, Lehmann and L'Horty (2014) explain that the targeted exonerations are grouped into three categories and measures: exonerations for particular types of employment, regional and local tax exemptions, and assistance to certain sectors. In our case, it is not a subsidy for the decrease of individual pollution but for a decrease of total pollution, such as is traditionally presented in the economics of the environment. It is a subsidy permitting the development of employment whose disappearance would harm biodiversity.

This simultaneous use of two instruments has not been considered in the literature on public policy promoting biodiversity. It allows us to limit the disadvantages of other instruments such as the choice of tax base for biodiversity use, asymmetric information in contractual approaches and PES, as well as the limitations in terms of biological equivalences in compensation mechanisms. A conceptual framework for this kind of policy-mix is needed, adaptable to many diverse and local issues (Barton *et al.*, 2009).

3. The model

We consider a competitive economy composed of sectors i $(i = 1, 2, \dots, m)$ of the same size. Each sector i is composed of identical firms. The employment in the sectors is more or less favourable to biodiversity. In other words, the biodiversity content differs according to the sectors. Among the sectors favourable to biodiversity, we think of forestry, extractive industries, agriculture, waste and water management, and certain administrative and voluntary sector.

The issue facing government is the best mix of these two types of actions, public procurement and targeted exemption, given the diversity of sectors concerning biodiversity. The question is how government can best focus its aid between targeted exemption x_i and public procurement y_i. Secondly, we analyse how government aid is shared between different branches of the economy.

[3] Directives 2004/17/CE and 2004/18/CE.

3.1 Initial biodiversity and government objectives

Before the industrial revolutions, we estimate that biodiversity was in an initial state B^* that we could call initial biodiversity. The present level of biodiversity in the economy is written B. The degradation of biodiversity imperils the quality of the environment, well-being, the health of human populations and reduces the availability of resources. The government objective is to avoid this degradation, even to improve biodiversity to its initial level B^*. This means to minimize the difference between B and B^*.

All the employment in the economy N is composed of bio-jobs N^+ and non-bio-jobs[4] N^-. We posit that the state of biodiversity B depends positively on employment that is favourable to it N^+. The relation is presented in figure 1 and we suppose that:

$$B = f(N_1^+, \dots N_2^+, \dots N_i^+)$$
$$\text{with and } \ f'(.) > 0 \ \text{ and } \ f''(.) < 0 \quad \forall i$$

The number of bio-jobs N^+in the economy is itself equal to the number of bio jobs N_i^+ in each sector i, knowing that their share of total employment varies from one sector to another.

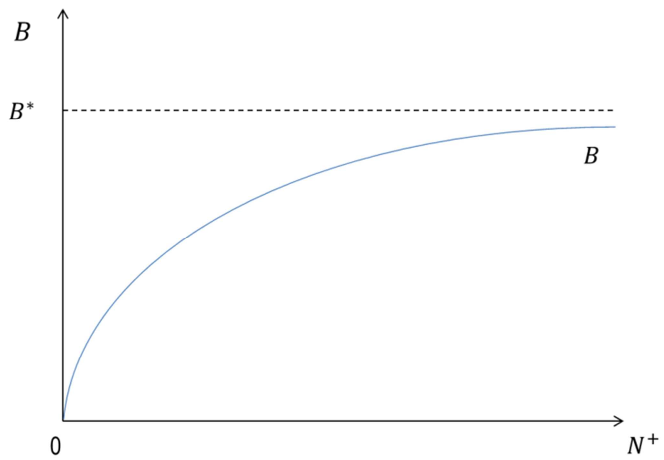
$$N^+ = \sum_i N_i^+$$

For realism, let us suppose that the semi-elasticity of biodiversity, β_i to the number of bio-jobs is not necessarily identical in all the sectors. B_0 measures the degradation of biodiversity as a consequence of past economic activities. To simplify, we assume that B_0 is a fixed parameter[5]. The function of production of biodiversity is specified as:

$$B = B^* - B_0 + \sum_i \beta_i Ln\,(N_i^+) \qquad (1)$$
$$\text{with } \ \beta_i > 0$$

The function $\sum_i \beta_i Ln\,(N_i^+)$ is concave and links positively the state of biodiversity to bio-jobs (*cf.* figure 1).

Figure 1. Biodiversity and bio-jobs



We note y_i the public procurement addressed to the sectors i having bio-jobs. We note x_i the rate of exoneration applied in the sectors i to the unit cost of labour w_i^+ of bio-jobs, with $x_i \in [0; 1[$. The latter aims at changing

[4] The jobs that are not considered as favourable to biodiversity could have a neutral or negative effect on it.
[5] A public policy promoting bio-jobs would have a negative second order effect on economic activities that would reduce the degradation of biodiversity. We do not take this effect into account.

practices to transform jobs unfavourable N_i^- to biodiversity into bio-jobs N_i^+ . For sake of realism we distinguish two levels of wages (w_i^+ and w_i^-) for bio-jobs and non-bio-jobs but this hypothesis does not play any role in the following modelisation. At sector level, public spending is written:

$$G_i = x_i w_i^+ N_i^+ + y_i \tag{2}$$

Besides, we do not consider the different ways of financing public expenses, which would not have any impact on the trade-off between the two instruments, corresponding to the case when public revenue is not affected to public spending.

3.2 The behaviour of the firm representing sector i

We place ourselves in a framework where production depends on only two factors: conventional jobs and bio-jobs. We suppose that the two types of employment are substitutes and we use Cobb-Douglas type technology. For parsimony, we do not consider capital formation or staff training. The quantity produced is determined by the function of the following production:

$$Q_i(N_i^+, N_i^-) = T_i(N_i^+)^{\alpha_i}(N_i^-)^{1-\alpha_i} \tag{3}$$

T_i is a technological parameter for each sector i.

The total cost supported by the firm is given by the expression:

$$C_i = w_i^- N_i^- + w_i^+(1 - x_i)N_i^+ \tag{4}$$

The firm's program consists of minimizing the cost for a given level of production:

$$\begin{cases} Min\ C_i = w_i^- N_i^- + w_i^+(1 - x_i)N_i^+ \\ \{N_i^+, N_i^-\} \\ w.r.t\ \ Q_i(N_i^+, N_i^-) = T_i(N_i^+)^{\alpha_i}(N_i^-)^{1-\alpha_i} = \overline{Q_i} \end{cases} \tag{5}$$

We obtain the optimal demand for factors of production for the representative firm (or the sector i):

$$N_i^{+*} = \frac{\overline{Q_i}}{T_i}\left[\frac{\alpha_i}{1-\alpha_i}\frac{w_i^-}{(1-x_i)w_i^+}\right]^{1-\alpha_i}$$

The demand for goods addressed to the sector $\overline{Q_i}$ is composed of public procurement y_i and private demand y_{i0}. We do not pay intention to the determinants of variation of private demand, we thus consider it as exogenous. We write $\overline{Q_i} = \frac{y_i + y_{i0}}{p_i}$, with p_i the price level for each sector i.

The optimal bio-jobs becomes:

$$N_i^{+*} = \frac{y_i + y_{i0}}{p_i T_i}\left[\frac{\alpha_i}{1-\alpha_i}\frac{w_i^-}{(1-x_i)w_i^+}\right]^{1-\alpha_i}$$

In positing $A_i = \frac{1}{p_i T_i}\left[\frac{w_i^- \alpha_i}{w_i^+(1-\alpha_i)}\right]^{1-\alpha_i}$, the optimal demand (6) for bio-jobs is written :

$$N_i^{+*} = \frac{(y_i + y_{i0})A_i}{(1-x_i)^{1-\alpha_i}} \tag{6}$$

The number of bio-jobs depends positively on the rate of exoneration x_{i}, of the efficiency of bio-jobs, summed up by the parameter α_{i} and of global demand addressed to the sector $y_i + y_{i0}$.

3.3 The government program for a given sector i

The public target is to maximize the level of bio-jobs N_i^+ in a given sector with respect to a given budget constraint. This level of employment can be declined for each sector i and we are interested in the arbitrage between the two instruments x_i and y_i. The program of the government can be written as follows:

$$\begin{cases} Max \;\; N_i^{+*} = (1-x_i)^{\alpha_i - 1}(y_i + y_{i0})A_i \\ \{x_i, y_i\} \\ w.r.t \; G_i = x_i w_i^+ N_i^+ + y_i \end{cases} \quad (7)$$

We note that global and constraint functions in this first State program are not concave or convex in any point (Annex 1), so obtain two corner-solutions. Replacing y_i by its expression in the budget constraint, we obtain the expression of the optimal demand of bio-jobs for a given level of G_i.

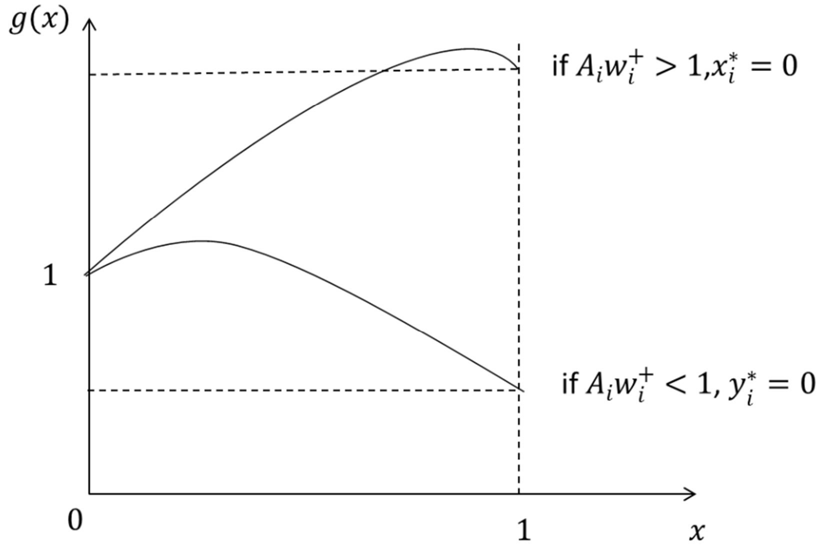
$$N_i^{+*}(x_i) = \frac{(G_i + y_{i0})A_i}{A_i w_i^+ x_i + (1-x_i)^{1-\alpha_i}} \quad (8)$$

In order to get the highest number of these jobs, we minimize the function :

$$g(x) = A_i w_i^+ x_i + \; (1-x_i)^{1-\alpha_i} \, .$$

This function $g(x)$ is concave and we obtain corner-solutions for x_i and y_i, $(x_i^*; 0)$ and $(0; y_i^*)$. According to the level of $A_i w_i^+$, if $A_i w_i^+ > 1$, N_i^+ is maximum for $x_i^* = 0$ and if $A_i w_i^+ < 1$, N_i^+ is maximum for $y_i^* = 0$ (*cf.* figure 2).

Figure 2 : Two corner solutions



We reach a main result. For a given budget, the most efficient public policy is to use only one tool at a time. The government uses or public procurement or targeted exemptions, but would not realize both actions simultaneously in a given sector. We exclude any politics combining both levers at the same time within a branch.

We notice that the level of wages and productivity within a branch plays a crucial part in the way the government will intervene. When the wages of the bio-jobs are high or when productivity is high (A_i high), the optimal level for the exemption rate is null and the best way for the government to intervene is via public procurement. Inversely, for a low-wage and low productivity branch, the optimal way for the government to support bio-jobs is through exemptions and without any public procurement.

We analyze the two corner solutions for x_i and y_i $(x_i^*; 0)$ and $(0; y_i^*)$ for which all the budget would be spent in public procurement and exemptions.

We consider there exists only two types of branches: those where the government intervenes through exemptions and the other where it intervenes through public procurement. From the equation (6) and from the budgetary constraint expressed in the public program (7), we obtain:

$$G_i = \frac{A_i w_i^+ x_i (y_i + y_{i0})}{(1-x_i)^{1-\alpha_i}} + y_i \quad (9)$$

In the branches where government only uses targeted exemptions $(x_i^*; 0)$, x_i^* respects the condition:
$\frac{G_i}{A_i w_i^+ y_{i0}} = \frac{x_i^*}{(1-x_i)^{1-\alpha_i}}$. .

The right-hand side of the expression is increasing in x. As a consequence, x rises with G_i, but for a given level of G_i , it decreases with A_i, w_i^+, w_i^- , y_{i0}. Regarding the parameter A_i, it is composed by several elements. We rewrite it as follows:

$\mathrm{A_i} = \frac{1}{\mathrm{p_i T_i}} \left[\frac{\mathrm{w_i^- \alpha_i}}{\mathrm{w_i^+ (1-\alpha_i)}} \right]^{1-\alpha_i}$, and we obtain $\mathrm{A_i w_i^+} = \frac{1}{\mathrm{p_i T_i}} (\mathrm{w_i^-})^{1-\alpha_i} (\mathrm{w_i^+})^{\alpha_i} (\frac{\alpha_i}{1-\alpha_i})^{1-\alpha_i}$.

We deduce the optimal rate of exoneration, determined by the following variables:

$$x_i^* = g(\underset{+}{G_i}, \underset{-}{y_{i0}}, \underset{+}{p_i}, \underset{+}{T_i}, \underset{-}{w_i^-}, \underset{-}{w_i^+})$$

As the budget is given, the exoneration rate is necessarily lower when the wages of the branch are high. The signs of the wages are the same for bio-jobs and non-bio-jobs. The difference between the two wages does not play a role in the model. We could have not assumed this distinction, we would have found the same results. y_{i0} represents the size of the branch. When the workers are numerous, exemptions are lower. The level of the prices of the goods and the technology indicates a high capitalistic intensity. As there is little labor force, government is encouraged to use exemptions. We observe that these explicative factors of the level of exemption rate characterize the economic profile of each sector (technological efficiency, labor cost, size of the sector).

In the branches where the government only uses public procurement in order to increase the share of bio-jobs $(0; y_i^*)$, the whole budget is absorbed by the public procurement $y_i = G_i$. The level of public procurement depends on the level of expenses defined for each branch. We determine this amount in the next section.

3.4 Government programs for all sectors

We have analysed government choices for a given amount of public expenditure. We now wonder how government will allocate budget funds between different sectors i and j. Government budget criteria must assure the equalization of marginal effectiveness of each Euro of public spending in light of the effect on biodiversity (equation 10). This value, that we note k, must be constant and positive for all sectors.

The decision rule for the affectation of public resources is written:

$$\frac{\partial B}{\partial G_i} = \frac{\partial B}{\partial G_j} = k, \text{ with } \forall\ i,j \text{ and } k > 0 \tag{10}$$

With our definition of biodiversity, given by the expression (1), $B = B^* - B_0 + \sum_i \beta_i Ln\,(N_i^+)$, this gives:

$$\frac{\partial B}{\partial G_i} = \frac{\partial N_i^+}{\partial G_i}\frac{\partial B}{\partial N_i^+} = \frac{\partial N_i^+}{\partial G_i}\frac{\beta_i}{N_i^+} \tag{11}$$

Notice first that when $\frac{\partial N_i^+}{\partial G_i} = 0$ the decision rule cannot be applied. This rule concerns only branches where it is possible for the government to increase the share of bio-jobs. When $\frac{\partial N_i^+}{\partial G_i} > 0$, one has to distinguish three theoretical cases. The decision rule takes singular values depending on the type of the branch. Either the sector is type $(x_i^*; 0)$ or type$(0; y_i^*)$. The equality needs to be verified with k for all sectors, whatever their type. We study the only three cases possible: the two sectors are type $(0; y_{i,j}^*)$; the two sectors are type $(x_{i,j}^*; 0)$, the two sectors are type $(x_i^*; 0)$ and $(0; y_j^*)$.

For the sector type $(0; y_{i,j}^*)$, from (8), we know that $N = A(G + y_{i0})$ because $x = 0$, and then $\frac{\partial N_i^+}{\partial G_i} = A_i$.

For the sector type $(x_{i,j}^*; 0)$, from (8) we can directly compute $\frac{\partial N_i^+}{\partial G_i} = \frac{A_i}{A_i w_i^+ x_i + (1-x_i)^{1-\alpha_i}}$.

Combining with (11), we obtain

$$\frac{\partial B}{\partial G_i} = \frac{A_i \beta_i}{[A_i w_i^+ x_i + (1-x_i)^{1-\alpha_i}] N_i^+} \tag{12}$$

These expressions are useful to apply the decision rule in each sector.

3.4.1 The two sectors i and j are type $(0; y_{i,j}^*)$

With the relation (11) we write $\frac{A_i\beta_i}{N_i^+} = \frac{A_j\beta_j}{N_j^+}\ \ \forall i, j$

With $N_i = (G_i + y_{i0})A_i$ we obtain $\frac{G_i + y_{i0}}{\beta_i} = \frac{G_j + y_{j0}}{\beta_j}$ (13)

In sectors where private demand is high, public budget is low. G_i is inversely proportional to private demand. Public budget is also positively related to the semi-elasticity of biodiversity with respect to the number of bio-jobs β_i, which is not necessary identical in all sectors, by assumption.

3.4.2 The two sectors i and j are type $(x_i^*; 0)$

The decision rule is still $\frac{\partial B}{\partial G_i} = \frac{\partial B}{\partial G_j}$.

Combining expression (12) and the expression of $N_i^{+*}(x_i)$ (8), we find:

$$\frac{\partial B}{\partial G_i} = \frac{\beta_i}{G_i + y_{i0}} = \frac{\beta_j}{G_j + y_{j0}} = \frac{\partial B}{\partial G_j}$$

The level of public budget decreases in private demand, as previously pointed out.

3.4.3 The two sectors i and j are type$(x_i^*; 0)$ and $\left(0; y_j^*\right)$

Applying the decision rule, it gives:

$$\frac{\partial B}{\partial G_i} = \frac{A_i \beta_i}{N_i^+} = \frac{A_j \beta_j}{N_j^+\left(A_j w_j^+ x_j + (1 - x_j)^{1-\alpha_j}\right)} = \frac{\partial B}{\partial G_j}$$

This leads to the same results as in the latter cases.

To sum up, two mechanisms operate to fix the level of public expenditure for every branch. First the budget is null for branches without any bio-jobs, because we posed that in this case $\frac{\partial N_i^+}{\partial G_i} = 0$. Second, as far as $\frac{\partial N_i^+}{\partial G_i} > 0$, the public budget is high when the semi-elasticity of biodiversity is important and when the private demand is low. Public procurement plays as a substitute of private demand for supporting bio-jobs. When bio-jobs are numerous in a given branch due to private demand, it is not relevant for government to give strong support to this sector. The optimal allocation implies high public spending only when private demand is scarce.

4. An application on French data

From the theoretical model and his conclusion we can draw some predictions to French sectors data (*cf*. figure 3). To summarize our results we have seen that:

- The level of public budget decreases in private demand and increases with the semi-elasticity of biodiversity to bio-jobs (see part 3.4).
- Among others factors, government would choose tax exemption when the wages are low and she would choose public procurement otherwise (see part 3.3).

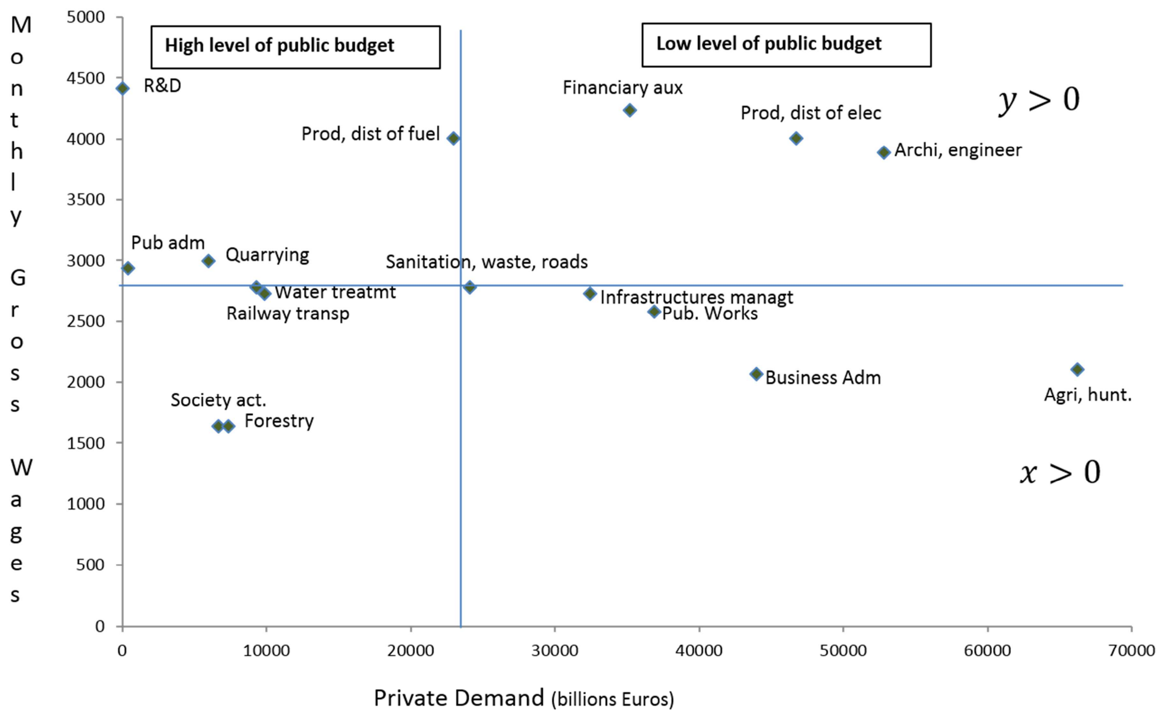
In order to determine the government action in each sector, we need to know the values of a few number of parameters: the number of bio-jobs, the private demand and the level of the wages.

As presented in the introduction, we use the bio-coefficient as an indicator of the number of bio-jobs (N_i^+) in each sector (Annex 1). As a reminder the bio-coefficient computes the share of working time spent in activities favourable to biodiversity. We have found that 16 sectors comprise 6400 bio-jobs.

We use gross monthly salary from the 2008 Annual Survey on Firms in 114 sectors (DADS). We select the gross wage corresponding to the 16 sectors. In order to measure the private demand y_{i0}, we use the 2007 Input-Output table in 114 branches made by the French National Account and we take the figures of the production from which we subtract the public demand corresponding to this production. The figure 3 plots gross wages and private demand in the 16 branches. Blue lines represent the median of these two parameters.

The decision rule established from the former relation affirms that the level of state intervention G_i is inversely proportional to the level of private demand. We can already comment on this level of intervention. The sectors placed on the left of the figure benefit from higher public spending than those on the right side of the graph. Then the choice of the public policy tool depends on the importance of the wages. When the wages are high, government will rather choose public procurement ($y > 0$) whereas when they are lower ($x > 0$), it will use targeted exemptions. The first case is the top left hand side of the graph. It corresponds to the case when the public budget is higher and public procurement is the most suitable tool. The sectors represented in this part of the graph are: extractive industries; state and non-profit research and development; public administration; water treatment, treatment and distribution; fuel production and distribution. As individuals are highly qualified and thus well remunerated, government has apparently no interest in exempting such jobs. The level of public procurement should be relatively high to mitigate a lower private demand. In the left and bottom side of the graph, the public budget is still high because private demand is low and the government would prefer act through exemptions. We find the following sectors: forestry products; charities and societies; railway transportation. It is for example relevant for the societies acting on social inclusion linked to environmental management which are indeed currently exonerated. The level of public budget is then lower for the sectors in the right hand side of the graph. At the top of it, one finds sectors like insurance and auxiliary financial services and architecture and engineering (naturalist consultant for example) whose development depends mainly on private demand. But as wages are high, exemptions would be less efficient. Finally, in the last case, when a sector is hardly based on private demand and the wages are low, public exemptions are expected to be high. The concerned sectors are: agriculture; stock infrastructure management; business management; sanitation, road maintenance and waste management; public works.

Figure 3. Relation between wages and number of bio jobs



Sources : DADS (2008), French National Accounts (2007), authors computation

5. Conclusion

What could be done to support biodiversity? In our framework, we emphasize the importance of employment, focusing on the bio-jobs within a multi-branch model where the government can decide both the level of tax exemption and public procurement. This approach seems to be more relevant considering the limits of standard tools of environmental economics concerning biodiversity.

First, government has nothing to do into the sector where there are no bio-jobs. It has to focus his action on sectors that have a potential of development of bio-jobs. In a previous empirical survey (De Beir *et al.,* 2015) we have identified 16 branches with bio-jobs among the 114 in the NES nomenclature. In these sectors the public budget has to be positively proportionated to the elasticity of biodiversity to the bio-jobs, which is not identical in every branch. Moreover, the lower the private demand into the branch is, the greater the public spending has to be. The latter plays as a substitute of private demand.

Once the level of public budget defined for each branch, the government determines his most suitable action according to the level of the wages and the productivity. In the branches where wages are higher, he uses public procurement. In branches where the wages are lower, he would rather use targeted exemptions. Public policy must so be frankly differentiated between all branches in what regards both the amount of public budget and the choice of the intervention.

From the application on French data, in most of the cases, the government must not do anything. He should focus his action in a small number of branches (16 out of 114) consecrating either a high or a low amount, either in the form or direct public order, either in the form of a reduction of labor cost.
This policy is, of course, complementary to other instruments promoting the protection of biodiversity and favouring jobs which are related to it. Actions of all kinds should thus be considered and studied together in future analysis.

Bibliography

Barton D.N, Rusch G., May P., , Ring I., Unnerstall H., Santos R., Antunes P., Brouwer R., Grieg-Gran M., Similä J., Primmer E., Romeiro A., DeClerck F., Ibrahim M., 2009. Assessing the role of economic instruments in a policy mix for biodiversity conservation and ecosystem services provision: a review of some methodological challenges, *Munich Personal RePEc Archive*, pp.36.

Bénard, S. and, Frascaria-Lacoste, N., 2011. Rapport du comité de filière biodiversité et services écosystémiques, Comité national du plan de mobilisation des territoires et des filières sur le développement des métiers de la croissance verte, *Conseil général de l'environnement et du développement durable*, pp.32.

Bestard A.B., Font A.F., 2010. Estimating the aggregate value of forest recreation in a regional context, *Journal of Forest Economics,* vol. 16, pp.205-216.

Bockstael N.E., Hanemann W.M. and Kling C.L., 1987. Estimating the Value of Water Quality Improvements in a recreational Demand Framework, *Water Resources Research*, vol. 23(5), pp.951-960.

Bräuer I., Müssner R., Marsden K., Oosterhuis F., Rayment M., Miller C., Dokova A., 2006. The Use of Market Incentives to Preserve Biodiversity. *Final Report. Ecologic.* A project under framework contract for economic analysis, pp.51.

Chobotovà V., 2013. The role of market-based instruments for biodiversity conservation in Central and Eastern Europe, *Ecological Economics*, vol.95, pp.41-50.

Chu C. Y. C. and Yu R. R., 2002. Population Dynamics and the Decline in Biodiversity: A Survey of the Literature, *Population and Development Review*, Supplement: Population and Environment: Methods of Analysis, Vol. 28, pp.126-143.

Costanza R. and Amanda W., 2006. The role of human, social, built, and natural capital in explaining life satisfaction at the country level: Toward a National Well-Being Index (NWI), *Ecological Economics*, vol.58, pp.116-133.

De Beir J., Emond C., L'Horty Y. and Tuffery L., 2015.Les emplois favorables à la biodiversité en Ile-de-France, *Economie et Prévision,* (forthcomming).

Engel S., Pagiola S., and Wunder S., 2008. Designing payments for environmental services in theory and practice: an overview of the issues, *Ecological Economics*, vol. 65 (2008), pp.668-674.

Erlich P.R., 1994. Energy use and the loss of biodiversity, *Philosophical Transactions of The Royal Society*, vol. 344, no. 1307, pp.99-104.

Hardin G., 1968. Tragedy of the Commons, *Science*, vol. 162 (3859), pp.1243-1248.

Heal G., 2004. Economics of Biodiversity: an introduction, *Resources and Energy Economics*, vol.26, pp.105-114.

Lehmann E. and L'Horty Y., 2014. Renforcer la progressivité des prélèvements sociaux, *Revue Française d'Economie*, vol XXIX, no. 1, pp.25-61.

MacKerron G., Mourato S., 2009. Life satisfaction and air quality in London, *Ecological Economics*, vol.68 (5), pp. 1441-1453.

MEDDE (Ministère l'Ecologie, du Développement durable et de l'Energie), 2012, http://www.developpement-durable.gouv.fr/Une-commande-publique-durable.html

Michelsen, O., De Boer L., 2009. Green procurement in Norway; a survey of practices at the municipal and county level, *Journal of Environmental Management,* Vol. 91 (1), pp160-167.

Nalle Darek J., Montgomery Claire A., Arthur Jeffrey L.,Polasky Stephen, Schumaker and Nathan H.; 2004. Modeling joint production of wildlife and timber, *Journal of Environmental Economics and Management*, Vol. 48, Issue 3, pp.997–1017.

Parikka-Alhola K., 2008. Promoting environmentally sound furniture by green public procurement, *Ecological Economics*, vol. 68, pp.472-485.

Sinclair-Desgagné B., 2005. Analyse économique et préservation de la biodiversité, *Economie publique*, vol.16, pp.3-16.

Smith V.K. and Huang J.C., 1996. Hedonic Models and Air Pollution:Twenty-five Years and Counting. *New-Horizons in Environmental Economics series, Duke University and Resources for the Future*, pp.365-378.

Tilman D., 2012. Biodiversity & Environmental Sustainability amid Human Domination of Global Ecosystems, Daedalus Vol. 141, no 9, pp.108-120.

Tyrvainen L., Miettinen A., 2000. Property prices and Urban Forest Amenities, *Journal of environmental economics and management*, vol 39, pp.205-223.

Tzoulas K., Korpela K ., Venn S., Yli-Pelkonen V., Kazmierzak A., Niemela J., James P., 2007. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review, *Landscape & Urban Planning*, Vol. 81, pp.167-178.

Wätzold F., Schwerdtner K., 2005. Why be wasteful when preserving a valuable resource? A review article on the cost-effectiveness of European biodiversity conservation policy, *Biological Conservation*, vol.123(3), 327–338pp.

Wunder S., 2007. Efficiency of payments for environmental services, *Conservation Biology*, Vol.21, No.1.

Annex 1 : Data for French application

Classification	Sectors	Bio-coefficient	Private demand (billions euros)	Monthly gross wages
GN23	Business Adm	6,52E-05	43962	2067
GG2B	Prod, dist of fuel	8,74E-05	22984	4009
GN34	Sanitation, waste, roads	2,07E-04	24069	2780
GK01	Railway transp	2,16E-04	9853	2727
GN25	Archi, engineer	1,22E-03	52792	3889
GH02	Pub. Works	1,34E-03	36889	2577
GR10	Pub adm	1,73E-03	396	2934
GG2A	Prod, dist of elec	1,76E-03	46731	4009
GK07	Infrastructures managt	3,25E-03	32432	2727
GG22	Water treatmt	3,77E-03	9273	2780
GA01	Agri, hunt.	1,99E-02	66247	2108
GR20	Society act.	2,62E-02	6696	1636
GL03	Financiary aux	5,00E-02	35178	4239
GN4B	R&D	5,77E-02	23	4412
GA02	Forestry	2,41E-01	7356	1641
GF12	Quarrying	2,89E-01	5971	2994