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

Jean De Beir*

Department of Economics,
University of Evry-Val-d'Essonne,
EPEE, TEPP (FR 3435),
F-77454, Evry, France
Email: jean.debeir@univ-evry.fr
*Corresponding author

Céline Emond and Yannick L'Horty

Department of Economics,
University of Paris-Est,
ERUDITE (EA 437),
UPEC, UPEM, TEPP (FR 3435),
F-77454, Marne-La-Vallée, France
Email: celine.emond@univ-mlv.fr
Email: yannick.lhorty@univ-mlv.fr

Laetitia Tuffery

Laboratoire d'Economie Forestière,
AgroParisTech – National Institute of
Agronomic Research (INRA),
14 rue Girardet, 54000 Nancy, France
Email: laetitia.tuffery@inra.fr

Abstract: We refer to jobs that promote biodiversity as bio-jobs. These jobs are located in a small number of sectors generally linked to natural resources: naturalist research, forestry, public works, water and waste management, etc. In this article, we examine two economic policies favouring the development of these bio-jobs. The government can support demand in sectors with bio-jobs through public procurement or can develop them through targeted exemptions. The most effective and relevant combination of these instruments is investigated via an original framework. We show that the government's action is driven by the nature of the sectors and especially by the level of any existing private demand. Then, the level of the wages plays a major role in the government's budget decision. Finally, we apply these recommendations to French data.

Keywords: biodiversity conservation; bio-jobs; public policy; multi-branch analysis; French data.

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Biographical notes: Jean De Beir is an Assistant Professor in Economics at the University of Evry-Val-d'Essonne. He is a member of the EPEE (Center for Economic Policy Studies) and TEPP (Labour, Employment and Public Policies) units; he focuses his researches on economics of recycling and market structure of raw and secondary material uses. For instance, one of his work in progress deals with the influence of a mining oligopoly on the scrap sector and its impacts on the environment. Since 2011, he also works on the biodiversity green jobs, also called 'bio-jobs'. In order to lead this work he is involved in the CELESTE unit.

Céline Emond is a Postdoctoral Researcher in Economics at the Emmaüs Défi since April 2017. Her PhD thesis focuses on social policies, household mobility and local redistribution. She now works on the evaluation of an experimental program implemented by Emmaüs Défi. The aim is to make a cost benefit analysis of a back-to-work organisation. She mainly uses econometric and applied methods on data.

Yannick L'Horty is a Professor of Economics at the University of Paris-East Marne-la-Vallée, since 2010, Director of the TEPP federation at the CNRS since 2008 and he is a member of ERUDITE research team. After he graduated from the University of Paris I and for the Ecole Normale Supérieure, he worked ten years for the French Minister of Finances and for the Prime Minister services. Then, he became an Associate Professor at the University of Evry and Full Professor since 1999. His research interest includes labour economics, urban economics and applied econometrics. His main fields of specialisation are employment and social policies evaluation as well as randomised control trials.

Laetitia Tuffery holds a PhD in Economics. Her research field includes environmental economics, urban economics and spatial analysis using geo-referenced information system. Her PhD thesis work focuses on the valuation of periurban forest recreational ecosystem services using spatial analyse and hedonic price method. Since 2016, she is employed as a postdoctoral researcher in the National Institute of Agronomic Research (INRA) on the INFORMED project. She works on the topics of public policies, climate change and forest ecosystem services.

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1 Introduction

Various principles of sustainable development are currently being integrated into national policies and programs. These principles mainly relate to human activity. One of the fields contributing to the transition to a sustainable society is green economy. One response to

the global challenges of sustainable development in human activities and labour markets is fostering a greener economy through the creation of green jobs. Sustainable development largely addresses climate change, pollution, energy, and natural resources. In this work, we focus on a thematic portion rather than the whole idea of sustainable development or green economy. We are interested in jobs related to biodiversity, both those that fight against its erosion and those that promote it. This definition is more restrictive than that of jobs targeting environmental preservation. More precisely, based on a previous work that identified jobs that promote biodiversity, we aim to define the public policies that are most likely to contribute to the development of such jobs.

The economic benefits of biodiversity have been widely demonstrated (Heal, 2004), and socio-economic evaluations insist that preservation is essential for the economy and the well-being of human beings (Costanza and Amanda, 2006; Tzoulas et al., 2007). For example, an important body of literature shows that water or air purification (Bockstael et al., 1987; Smith and Huang, 1996; MacKerron and Mourato, 2009) is as useful as the harvest of wood or recreational and sporting activities offered by the forest (Tyrvaïnen and Miettinen, 2000; Nalle et al., 2004; Bestard and Font, 2010). However, all studies on the development of ecosystems indicate that biodiversity is diminishing, essentially linked to recent human and economic development (Erlich, 1994; Chu and Yu, 2002; Tilman, 2012). Policies are confronted with a major difficulty stemming from the fact that biodiversity is a common good (Hardin, 1968). This generates market failure leading to not only the non-optimal use of resources but also the degradation of biodiversity.

We are interested in public policies concerned with the economic conservation of biodiversity that employ incentives and coercive measures to prohibit or regulate certain activities or access to certain resources. In a previous work (De Beir et al., 2015) we identified jobs that are essentially aimed at protecting and managing biodiversity. These jobs are called 'bio-jobs'. Here, biodiversity largely refers to all of nature (both species and natural ecosystem scales). Bio-jobs, 'in whole or part, contribute to the understanding, management, protection, promotion, and restoration of biodiversity, intentionally or not. They also contribute to building a judgement about the importance of biodiversity in other, less concerned economic sectors. Hence, they include activities such as communication and the financial support of projects promoting biodiversity'.¹ The current work aims to take into account all jobs corresponding to the preceding definition rather than only those corresponding to 'green core' jobs. For example, an activity such as quarrying² is not categorised as a green job but is considered a bio-job because it plays a part in restoring the environment. The analysis was conducted at the thinner available level, which is the sector level. All these sectors have a relationship with natural resources or ecosystems. Some of them, such as the naturalist research unit or the forestry sector, are explicitly and fully devoted to biodiversity conservation and management, whereas others, such as the water treatment sector, are less directly related to biodiversity protection.

After identifying the sectors that promote biodiversity and ecosystems and, specifically, the relevant jobs, we search for public policies that specifically promote these bio-jobs. We focus only on the sectors with bio-jobs because they are a proxy of the sectors with the potential to develop such jobs. Given that such employment is concentrated in a small number of sectors, it seems pertinent to reason within a multi-branch framework, in which public policy could differ across sectors. Two policies

can orient economic activity toward the development of bio-jobs. On the one hand, we can make production processes less harmful. With a given level of production, this could be accomplished through subsidies. Alternatively, with a given productive combination, we can develop activities that promote biodiversity by using public procurement to increase business in some sectors. From this basic analysis, we build a model in which the government has two types of economic tools: targeted public procurement and a price instrument aimed at modifying the impact of productive activities on biodiversity (subsidies). The government faces the problem of determining the correct mix of these two instruments given the particularities of each sector. The model that we implement is a partial equilibrium system. The essential objective of this article is to understand 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 do not take into account elements of macroeconomic closure such as public and household finance. The second part of this article empirically illustrates this model using French databases. Starting from our theoretical model and its conclusions, we predict where (in which sectors) and how (which specific policy) public policies promoting the development of bio-jobs must be applied to French economic sectors. Our main conclusion is that the government uses public procurement in the branches with higher wages and targeted exemptions in the branches with lower wages.

In the next section, we introduce the main economic instruments favouring the protection of biodiversity. We then analyse the behaviour of the representative producer and public policies promoting bio-jobs in the third section. We apply the model to French data in the last section.

2 Economic instruments favouring the protection of biodiversity

According to the final report of Bräuer et al. (2006), traditional tools have been developed to protect the global environment and have been only recently extended to biodiversity and nature. The first instruments used empirically stem from different kinds of regulatory approaches and are generally named command and control. They gather measures such as quotas that limit the amount of resources exploited and a whole set of environmental laws and norms. These instruments face a number of limits, including their cost and difficulties related to the identification of the targeted good and the monitoring of the instruments. Coercion has limited effectiveness here, and the regulator attempts to encourage voluntary co-operation through 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 (Chobotová, 2013). Hence, they have been slowly developed using 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 liability and compensation schemes. MBI are better adapted to biodiversity than other instruments because they are more specific and implemented at a more local scale. Furthermore, they are generally developed in sectors in which command and control

instruments already exist (Wätzold and Schwerdtner, 2005). Recent and traditional instruments are complementary. For example, regulation and MBI represent two sides of the same objective. One side is more constraining, and the other is more incentive; thus, they play the roles of the carrot and the stick (Engel et al., 2008; Wunder, 2007).

Driven by our objective to develop jobs that promote biodiversity, we pay specific attention to two particular MBI. Environmental subsidies and financial mechanisms seem to be the most relevant MBI in terms of promoting jobs and biodiversity. Environmental subsidies are used to initiate and promote changes in individuals' practices and behaviour. They can be targeted at individuals, businesses, institutions and/or charities. Financial mechanisms include financial support for activities that foster biodiversity or that prevent the deterioration of biodiversity (Bräuer et al., 2006).

Public procurement and targeted exemptions fall within this framework. In our approach, the economic tools are not applied to activities directly; rather, they act through jobs. One recurring limitation of the majority of the existing tools is that they are not placed in a long-term setting. The creation of new jobs or the development of existing jobs can deeply promote activities that foster biodiversity in the long run. We now provide greater detail about how our two instruments work.

The first instrument consists of public spending and takes the form of demand flow. Similarly, Parikka-Alhola (2008) proposes a policy of incentives for eco-conception through the public tendering process. Public buying can create clear incentives for eco-conception by reducing market risk (windfall effect of subsidies) and by facilitating economies of scale (through the promotion of production responding to public procurement). Michelsen and De Boer (2009) explain that rules regarding public purchasing that favour 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 Directives³, under revision since 2011, allows the inclusion of environmental criteria in key stages of public procurement.

The price instrument consists of a subsidy on 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 some countries, targeted aid takes the form of exonerating employers from paying social contributions. Lehmann and L'Horty (2014) explain that in France, 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, the subsidy is aimed at decreasing total pollution rather than decreasing individual pollution, as traditionally presented in the economics of the environment. This subsidy favours the development of employment whose disappearance would harm biodiversity.

The simultaneous use of these two instruments has not been considered in the literature on public policy promoting biodiversity. However, 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 limitations in terms of biological equivalences in compensation mechanisms. A conceptual framework for this kind of policy mix is needed and should be adaptable to many diverse and local issues (Barton et al., 2009).

3 The model

We propose a simplified model based on theoretical relationships between variables. Indeed, the model does not present empirical calibrations, and its heuristic is useful in illustrating the facts and theories. It leads to a normative approach: the state of biodiversity depends on bio-jobs, the production of each sector depends on two types of jobs and the government aims to reduce the degradation of biodiversity. The government has a budget and uses two policy instruments to promote bio-jobs and hence biodiversity.

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. Sectors favourable to biodiversity include forestry, extractive industries, agriculture, waste and water management, and certain administrative and voluntary sectors (De Beir et al., 2015).

The issue that the government faces is determining the best mix of these two types of actions, public procurement and targeted exemption, given the diversity of sectors involved in biodiversity. The question is how the government can best focus its aid between targeted exemption rate x_i and public procurement y_i . We analyse how government aid is shared across different branches of the economy.

3.1 Initial biodiversity and government objectives

We estimate that before the industrial revolutions, biodiversity was in an initial state B^* , which we call the initial level of biodiversity. The present level of biodiversity in the economy is written as B . The degradation of biodiversity imperils the quality of the environment, well-being, and the health of human populations and reduces the availability of resources. The government's objective is to avoid this degradation and to improve biodiversity such that it reaches its initial level B^* . In other words, the government aims to minimise the difference between B and B^* .

All employment in the economy N is composed of bio-jobs N^+ and non-bio-jobs⁴ N^- . We assert that the state of biodiversity B positively depends on employment that promotes it N^+ . The relation is presented in Figure 1, and we assume that

$$B = f(N_1^+, \dots, N_2^+, \dots, N_i^+)$$

with $f'(\cdot) > 0$ and $f''(\cdot) < 0 \forall i$.

The number of bio-jobs N^+ in the economy is equal to the number of bio-jobs N_i^+ in each sector i , and their share of total employment varies across sectors.

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

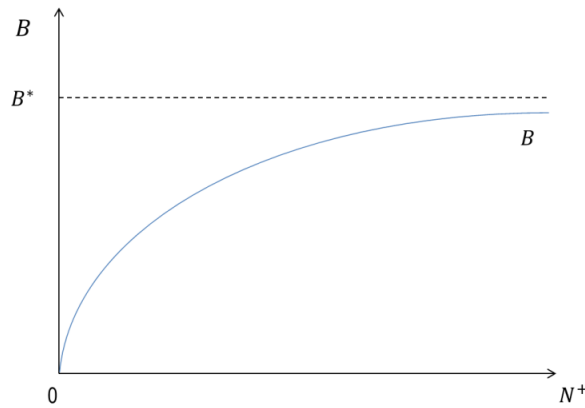
For the sake of realism, let us assume that the semi-elasticity of biodiversity β_i to the number of bio-jobs is not necessarily identical in all sectors. B_0 measures the degradation of biodiversity as a consequence of past economic activities. To simplify, we assume that B_0 is a fixed parameter⁵. The function of production of biodiversity is specified as follows:

$$B = B^* - B_0 + \sum_i \beta_i \text{Ln}(N_i^+) \tag{1}$$

with $\beta_i > 0$.

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

Figure 1 Biodiversity and bio-jobs (see online version for colours)



We note y_i as the public procurement addressed to the sectors i with bio-jobs. We note x_i as 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 practices to transform jobs unfavourable N_i^- to biodiversity into bio-jobs N_i^+ . For the 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 a role in the following modelisation. At the sector level, public spending is written as follows:

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

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

3.2 *The behaviour of the firm representing sector*

Our framework states that production depends on only two factors: conventional jobs and bio- jobs. We assume that these 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 following expression:

$$C_i = w_i^- N_i^- + w_i^+ (1 - x_i) N_i^+ \quad (4)$$

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

$$\begin{cases} \text{Min } C_i = w_i^- N_i^- + w_i^+ (1 - x_i) N_i^+ \\ \{N_i^+, N_i^-\} \end{cases} \quad (5)$$

$$\text{w.r.t } Q_i(N_i^+, N_i^-) = T_i (N_i^+)^{\alpha_i} (N_i^-)^{1-\alpha_i} = \bar{Q}_i$$

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

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

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 as follows (Annex 1):

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

The number of bio-jobs positively depends on the rate of exoneration x_i and the efficiency of bio-jobs, summed by the parameter α_i and the global demand placed on sector $y_i + y_{i0}$.

3.3 The government program for a given sector

The public target is to maximise the number 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 instruments x_i and y_i . The government's program can be written as follows:

$$\begin{cases} \text{Max } N_i^{+*} = (1 - x_i)^{\alpha_i - 1} (y_i + y_{i0}) A_i \\ \{x_i, y_i\} \end{cases} \quad (7)$$

$$\text{w.r.t } G_i = x_i w_i^+ N_i^+ + y_i$$

We note that global and constraint functions in this first state program are not concave or convex at any point; thus, we obtain two corner solutions. After 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 .

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

To obtain the highest number of these jobs, we minimise the function (Annex 2):

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

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

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

In the branches in which the government uses only targeted exemptions $(x_i^*; 0)$, x_i^* respects the following condition:

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

$$A_i = \frac{1}{p_i T_i} \left[\frac{w_i^- \alpha_i}{w_i^+ (1 - \alpha_i)} \right]^{1-\alpha_i}$$

We deduce the optimal rate of exoneration (see Annex 3), as determined by the following variables:

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

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As the budget is given, the exoneration rate is necessarily lower when the wages in 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. If we did not assume 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. Given the small labour force, the government is encouraged to use exemptions. We observe that these explicative factors of the level of exemption rate characterise the economic profile of each sector (technological efficiency, labour cost, size of the sector).

In the branches in which the government uses only public procurement to increase the share of bio-jobs $(0; y_i^*)$, the whole budget is absorbed by 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 consider how the government will allocate budget funds across different sectors i and j . Government budget criteria must assure the equalisation of marginal effectiveness of each Euro of public spending in light of the effect on biodiversity (equation 10). This value, which we note as k , must be constant and positive for all sectors.

The decision rule for the use of public resources is written as follows:

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

Using our definition of biodiversity, given by the expression (1), $B = B^* - B_0 + \sum_i \beta_i \ln(N_i^+)$, results in the following:

$$\frac{\partial B}{\partial G_i} = \frac{\partial N_i^+}{\partial G_i} \frac{\partial B}{\partial N_i^+} = \frac{\partial N_i^+}{\partial G_i} \frac{\beta_i}{N_i^+} \quad (11)$$

Note that when $\frac{\partial N_i^+}{\partial G_i} = 0$, the decision rule cannot be applied. This rule concerns only branches in which the government can increase the share of bio-jobs. When $\frac{\partial N_i^+}{\partial G_i} > 0$, one has to distinguish three theoretical cases (see Annex 4).

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

3.4.1 The two sectors and 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,

$$\frac{G_i + y_{i0}}{\beta_i} = \frac{G_j + y_{j0}}{\beta_j} \quad (12)$$

In sectors in which 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 we assume is not necessary identical in all sectors.

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

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

Combining expression (12) (Annex 4) and the expression of $N_i^{+*}(x_i)$ (8), we find the following:

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

As previously mentioned, the level of public budget decreases with private demand.

3.4.3 The two sectors and are type $(x_i^*; 0)$ and $(0; y_j^*)$

Applying the decision rule results in the following:

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

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

In sum, 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 serves as a substitute for private demand in supporting bio-jobs. When bio-jobs are numerous in a given branch due to private demand, the government does not need to provide strong support to this sector. The optimal allocation implies high public spending only when private demand is scarce.

4 An illustration using French data

We now propose an empirical illustration using the case of France. Using the theoretical model and our previous conclusion, we can draw some predictions from data on French sectors (*cf.* Figure 2).

In summary, we have found the following results:

- In all cases, the government supports economic sectors with bio-jobs. In other words, no public procurement or subsidy/tax exemption should be applied in sectors that do not include bio-jobs.
- The level of public budget decreases with private demand and increases with the semi-elasticity of biodiversity to bio-jobs (see part 3.4).
- The government chooses tax exemption, among other factors, when wages are low and, otherwise, chooses public procurement (see part 3.3).

In a multi-sectoral framework, two questions remain. Where should the government focus its action (i.e., which sectors can benefit from financial support)? The second question concerns the nature of the government's intervention. How does the government choose which specific policy to apply?

4.1 Which sectors should be given support?

In response to the first question, our model shows that the government should only support the sectors containing some bio-jobs. To define the list of such sectors, we use a previous work conducted in the Paris region (De Beir et al., 2015).

A total of 122 experts and scientists working in different fields were interviewed to estimate the number of bio-jobs in their sector (Annex 5). These experts were generally in charge of sustainable development or biodiversity policies or were training and job

specialists and were well aware of the composition of the jobs in their structure. We also asked experts in biodiversity to provide their opinion to confirm our estimations. We identified 16 sectors containing 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 are all linked to natural resources or habitats. Some of them, such as the naturalist research unit and the forestry sector, are explicitly and fully devoted to biodiversity conservation and management, whereas other sectors are not. One limitation is that we could hardly take into account emerging and innovating sectors that engage in activities that impact biodiversity. We then elaborated an original method based on the computation of a 'bio-coefficient' for each sector based on the interviews. The bio-coefficient measures the share of working time dedicated to the protection and conservation of biodiversity. For example, let us consider the architecture and engineering sector. We first identified the occupations that address biodiversity within the whole sector (landscape architect, ecological engineer). With the help of specialists in the field, we estimated the share of working time spent on actions especially favourable to biodiversity, resulting in the bio-coefficient. When several experts disagreed, we computed two estimations of the bio-coefficient surrounding the true number. With these two pieces of information, we then converted it into the number of bio-jobs in each sector. When we had information for only a single firm, we projected 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 that play a role in biodiversity; these are the activities whose production is used by the bio-jobs. One example is the activity of supplying seeds to landscape architects. To quantify them, we used the input-output table of the French National Accounts. Our results showed that bio-jobs represent only 1/1,000 jobs in the Paris region; the total number of such jobs is 6,400. Furthermore, 2,900 more jobs are induced by these bio-jobs.

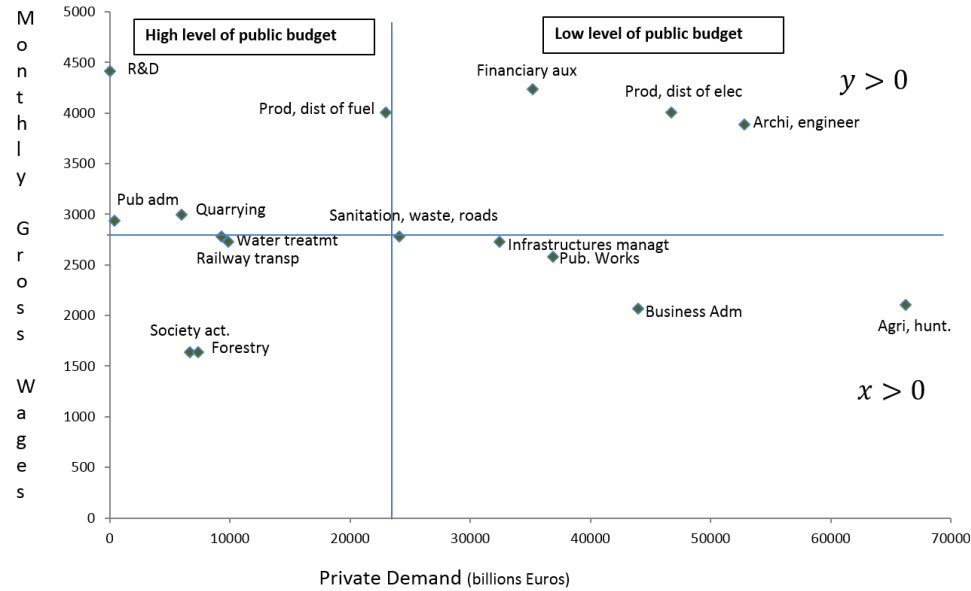
To run the empirical illustration at the scale of France, we use the list of the sectors presented below. This list of the sectors in the Paris region is identical to that in the French territory because all sectors present in France exist in the Paris region. Furthermore, one-quarter of all French jobs are located in the Paris region.

4.2 How can bio-jobs be supported?

To answer our second question, which aims to determine the actions that the government must undertake in each sector, we need to know the values of a few parameters; especially the level of private demand and the level of wages (see Annex 5).

We use the gross monthly salary from the 2008 Annual survey on firms in 114 sectors (DADS). We select the gross wage corresponding to the 16 sectors. To measure the private demand y_{10} we use the 2007 Input-Output table in 114 branches created by the French National Account, and we take the figures of the production and subtract the public demand corresponding to this production. Figure 2 plots gross wages and private demand in the 16 branches. Blue lines represent the median of these two parameters.

Figure 2 Tax exemption or public procurement: an illustration (see online version for colours)



Source: Déclaration Annuelle des Données Sociales (2008) and French National Accounts (2007) and authors' computation

The decision rule established from the former relation states that the level of the government 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 located on the right side of the graph. Then, the choice of the public policy tool depends on the wage level. When wages are high, the government will choose public procurement ($y > 0$), whereas when they are low ($x > 0$), she will use targeted exemptions. The first case is shown at the top left-hand side of the graph and represents when the public budget is high and public procurement is the most suitable tool. The following sectors are represented in this part of the graph: extractive industries; state and non-profit research and development; public administration; water treatment, treatment and distribution; fuel production and distribution. Given that individuals in these sectors are highly qualified and thus well remunerated, the government has no apparent interest in exempting such jobs. The level of public procurement should be relatively high to mitigate a lower private demand. On the left and bottom side of the graph, the public budget remains high because private demand is low, and the government prefers to act through exemptions. We find the following sectors in this portion of the graph: 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 on the right-hand side of the graph. At the top of this side, one finds sectors, such as insurance and auxiliary financial services and architecture and engineering (naturalist consultant, for example), who's development depends on private demand. However, because wages are high, exemptions would be less efficient. Finally, in the last case, when a sector is hardly based on private

demand and wages are low, public exemptions are expected to be high. The concerned sectors are as follows: agriculture; stock infrastructure management; business management; sanitation, road maintenance and waste management; public works.

5 Conclusions

What actions can be taken to support biodiversity? In our framework, we emphasise the importance of employment, focusing on bio-jobs within a multi-branch model in which the government can decide both the level of tax exemption and public procurement. This approach seems to be especially relevant considering the limitations of standard environmental economics tools concerning biodiversity.

First, the government does not need to take any action in the sectors without bio-jobs. It should focus its action on sectors that can potentially develop bio-jobs. In a previous empirical survey (De Beir et al., 2015), we identified 16 branches with bio-jobs among the 114 sectors in the NES nomenclature. In these sectors, the public budget must be positively proportionate to the elasticity of biodiversity to the bio-jobs, which is not identical across branches. Moreover, as the private demand in the branch decreases, public spending must increase, as it serves as a substitute for private demand.

Once the level of public budget is defined for each branch, the government determines the most suitable action according to the level of wages and productivity. In the branches with higher wages, it uses public procurement. In branches with lower wages, it uses targeted exemptions. Public policy must be frankly differentiated between all branches in regard to both the amount of public budget and the choice of the intervention.

According to the illustration using French data, in most cases, the government should focus its action on a small number of branches (16 out of 114). Specifically, the government should provide either a high or a low amount in the form of direct public order or a reduction of labour cost.

This policy is, of course, complementary to other instruments promoting the protection of biodiversity and favouring jobs related to biodiversity.

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Notes

- 1 This definition has been borrowed from the « Rapport du comité de filière biodiversité et services écosystémiques », Bénard and Frascaria-Lacoste (2011).
- 2 A part of quarrying activity is favourable to biodiversity and limits the negative impact of extraction activities because the restoration of extraction sites allows the development of biodiversity.
- 3 Directives 2004/17/CE and 2004/18/CE.
- 4 The jobs that are not considered to be 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.

Annex 1

The optimal bio-jobs of the firm representing sector i

The demand for goods placed on the sector \overline{Q}_i is composed of public procurement y_i and private demand y_{i0} . We do not pay attention 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 representing the price level for each sector i .

The optimal bio-jobs are as follows:

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

Annex 2

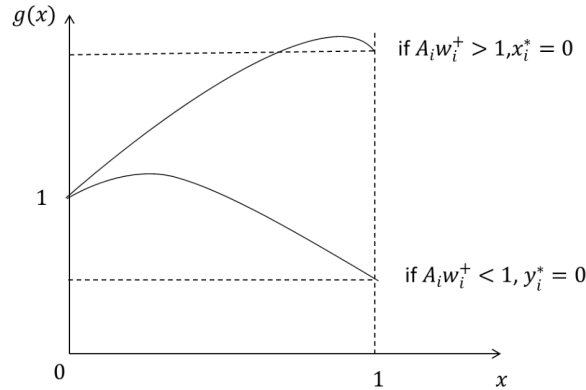
The most efficient public policy

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 3).

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 public procurement or targeted exemptions but does not realise 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 how 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 branch with low wages and low productivity, the optimal way for the government to support bio-jobs is through exemptions rather than public procurement.

Figure 3 Two corner solutions



We analyse 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 on public procurement and exemptions.

Annex 3

Deduction of the optimal rate of exoneration

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 $A_i, w_i^+, w_i^-, y_{i0}$. The parameter is composed by several elements. We rewrite it as follows:

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

and we obtain

$$A_i w_i^+ = \frac{1}{p_i T_i} (w_i^-)^{1 - \alpha_i} (w_i^+)^{\alpha_i} \left(\frac{\alpha_i}{1 - \alpha_i} \right)^{1 - \alpha_i}.$$

Annex 4

The decision rule depending on the type of the branch

The decision rule takes singular values depending on the type of branch. The sector is either type $(x_i^*; 0)$ or type $(0; y_i^*)$. The equality needs to be verified with k for all sectors, regardless of their type. We study the only three cases possible: the two sectors that are

type $(0; y_{i,j}^*)$; the two sectors that are type $(x_{i,j}^*; 0)$, the two sectors that 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

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

These expressions are useful for applying the decision rule in each sector.

Annex 5

Table A1 Data for the illustration based on France

<i>Classification</i>	<i>Sectors</i>	<i>Bio-coefficient</i>	<i>Private demand (billions euros)</i>	<i>Monthly gross wages</i>
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	Railwaytransp	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