CONSOLE

CONtract Solutions for Effective and lasting delivery of agri-environmental-climate public goods by EU agriculture and forestry

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Report on performance and design of solutions for the provision of AECPGs in value chain perspective

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1 Summary

Deliverable D4.4. reports on the modelling exercises and results related to “ Task 4.5 Modelling AECPGs in value chain perspective”. Three models have been developed. Two of them assume a theoretical perspective based on the impure public-good framework focusing on the effect of different labels and on the optimal source of agri-environmental public good financing. The third model simulates the up-scale of a local initiative targeting fertiliser reduction. The main finding of the deliverable is that market-based instruments cannot substitute public policies, while they can be seen as complementary.

2 Introduction

Deliverable D4.4. reports on the modelling exercises and results related to “Task 4.5 Modelling AECPGs in value chain perspective”. The main goal of the task is to analyse how market instruments can lead to the provision of agri-environmental public goods (AECPGs). The main subobjectives of the task are: 1) investigating the degree of efficiency of market-based solutions with respect to the social optimum, 2) the comparison between the performance of market-based solutions and public policies, and 3) the role of policy instruments. Within these goals, the task focuses on agricultural product value chains, the rural tourism value chain and the potential for value added of consumers’ segmentation.

The models developed and used for simulation in the task cover the task’s objectives (table 1).

Table 3.1-1. Overview of the key characteristics of the modelling exercises.

Model code	AECPGS	Key aspects covered
VC_INRAE	Global public good (ex: Climate)	Effects of health vs eco label on private provision of agri-environmental public goods
VC_UNIBO	Biodiversity	Optimal source of financing (market, taxes or mix) agri-environmental public goods
VC_TI	Water quality and climate change mitigation	Upscaling of market segmentation for provision of agri-environmental public goods through a label

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The model VC_INRAE explores the effects of labels targeting different characteristics of food products. the authors expand the impure public goods model by Kotchen (2007). More specifically, the model theoretically compares the level of agri-environmental public good that is provided in case consumers can purchase, in addition to a conventional product, a green product with private health benefits. The authors analyse different labels linked to (and signalling the characteristics of) a green product: 1) ecolabel, 2) health label, 3) health and ecolabel. They compare the market equilibrium under the three label conditions with the social optimum provision and with an environmental agency provision. In this prospect, the model responds to the objective of investigating the degree of efficiency of market-based solutions with respect to the social optimum.

The model VC_UNIBO extends the impure public good model by Kotchen (2007) to analyse what is the most effective source of financing for the provision of agri-environmental public goods. The authors consider, similarly to VC_INRAE, that consumers through the agricultural value chain, can either purchase conventional or green food. At the same time, a regulator can tax consumers to directly finance the provision of agri-environmental public goods. The two sources of financing present trade-offs. On one hand, the regulator ignores, and cannot take into account, the heterogeneity of preferences for the public goods in deciding the tax rate. On the other hand, private provision, through the value chain, is inefficient given the (impure) pure public good feature of green food. In the modelling exercise, the authors compare two extreme situations, where the only possibility is either through taxation or through the value chain, and the mix of the two. The model VC_UNIBO covers the whole set of the task's objectives, comparing market instruments with policy instruments and assessing the mix.

Finally, the model VC_TI builds upon, and simulates the upscale of, a real case study, the "Water protection bread". In the case study (thoroughly described in Eichhorn et al. (2020), CONSOLE Project - Deliverable 2.1) an innovative value chain between bakeries, mills and farmers growing wheat is built through the creation of a label. The label is based on the idea that farmers are paid for wheat irrespectively on the protein content. In such a way, fertilizer use is reduced and ultimately water quality is increased as well as GHG emissions are reduced. The authors simulate the upscaling to whole Germany assuming agronomic practices in line with the label). Differently to the previous

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models, VC_TI has a deeper empirical setting and focuses on an actual agricultural value chain.

3 Models' descriptions

3.1 Modelling value chain and assessing the optimality conditions of different labelling strategies (VC_INRAE)

3.1.1 Introduction

There is growing evidence that consumers exhibit a positive willingness to pay for food produced with environment-friendly practices (Moon et al., 2002; Teisl et al., 2002). Providing consumers with the information on the environmental positive externalities through food labelling is therefore an opportunity for raising more contributions in financing agri-environment-climate public goods (AECPG). However, the theoretical economic literature stresses that one of the main weaknesses of eco-labelling is that it is based on voluntary contributions, hence not sufficient on its own to reach an optimal provision of AECPG (Cornes and Sandler, 1984). Empirical studies showed that health concerns are often the main motives for buying environment-friendly products, in particular organically certified ones (Aldanondo-Ochoa and Almansa-Sáez, 2009; Brécard et al., 2012; Verhoef, 2005). Hence, a hypothesis is that, when joint provision of health and public environmental benefits occur, higher contributions and AECPG provision could be reached by providing scientific evidence on their positive effects on health.

In this study, we theoretically assess the market efficiency and optimality conditions of a label targeting health and environmental aspects. Based on microeconomics theory, we first describe the utility maximisation problem a consumer seeks to solve when allocating his/her income to buy a food product, and the profit maximisation problem a producer seeks to solve when allocating his/her variable inputs to food production according to a conventional or environment-friendly agricultural production technology. Second, we characterise the market equilibrium and the conditions under which the provision of AECPG is optimal from a social planner's or an environmental agency's perspectives. Finally, we assumed a functional form to the utility function of consumers to conduct simulations of global AECPG provision under different market settings.

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With respect to the objective of "Task 4.5 Modelling AECPG in value chain perspective", the model evaluates to what extent value chain solutions based on market differentiation for consumers ("end part" of value chain contracts) of a food product produced with environment-friendly practices with the joint provision of health benefits would perform under different labelling strategies.

3.1.2 Model description

In our theoretical model (Letort et al., unpublished), we expand the impure public good model developed by Kötchen (2005, 2006) in which food products can be described according to several public and private characteristics valued by consumers. In our economy, we define good g as a labelled food product exhibiting public (environmental benefits) and private (food, health benefits) characteristics, and good c as its conventional substitute with only one private characteristic (food).

We consider 1 representative producer, who produces both c and g with 2 production technologies. The agricultural production technologies are such that 1 unit of c (respectively g) corresponds to 1 unit of food X. The agricultural production technology of g is environment-friendly, such that each unit of g requires less polluting variable inputs compared with its conventional substitute c, and jointly provides β units of an AECPG noted Y. In addition, the composition of g is healthier than c, such that one unit of g also provides α units of health benefits H. The technological constraint of the representative producer constraining the amount of goods that can be produced in our economy are represented by the transformation frontier $T(c,g) = 0$. In order for both c and g to be produced in our economy, we assume the marginal cost of producing good g is greater than the marginal cost of producing good c such that g is sold on the market at a higher price than c. The producer's optimal allocation of inputs meets the condition (1):

$$\frac{\partial T(c,g)/\partial g}{\partial T(c,g)/\partial c} = \frac{p_g}{p_c} \tag{1}$$

We consider I homogeneous consumers, each allocating his/her wealth r_i to purchase a quantity c_i of conventional good c at price p_c and a quantity g_i of labelled good g at price p_g, such that $p_c c_i + p_g g_i = r_i$ (budget constraint) (2).

$$\max_{c_i g_i} U \mid p_c c_i + p_g g_i = r_i \tag{2}$$

Consumers' preferences are represented by a strictly increasing and strictly quasi-concave utility function driving their food consumption choices between the conventional

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and the labelled goods. Their utility $U(X^i, H^i, Y)$ is affected by three characteristics of the goods: food X, health benefits H, and global AECPG provision Y. The AECPG is a global public good, meaning that all consumers derive utility (benefit) from each unit provided in the economy. For each individual i, the contribution of others to AECPG provision is exogenous such that $Y = \beta g^i + \beta g^{-i}$. It is assumed that $p_g > p_c$ to ensure the viability of the conventional good on the market, which implies that buying good c is the most inexpensive method of obtaining private characteristic X.

In our theoretical framework, consumers' behaviour changes according to the information provided on the label of the food products. We consider three market settings (Table 3.1-1). In the first market, consumers know good g is produced with environment-friendly practices and provide the global AECPG, but have no a priori information on its health benefits (ecolabel). Consumers allocate their income to c and g according to characteristics X and Y. In the second market, consumers are now informed about the health benefits of consuming g, but have no information on the environmental benefits of its agricultural production technology (health label). Consumers allocate their income to c and g according to characteristics X and H. In the third market, the information on the characteristics of g is complete (health and environment label). Consumers allocate their income to c and g according to characteristics X, Y and H. Although consumers are not aware of it, the joint production technology of g is such that the global AECPG is provided following $Y = \beta g^i + \beta g^{-i}$.

Table 3.1-1. Market settings investigated.

Market	Good	Characteristics	Utility function
Ecolabel	c	Private characteristic X	$U(X^i, Y) = U(c^i + g^i, \beta g^i + \beta g^{-i})$
	g	Private characteristic X and public characteristic Y	
Health label	c	Private characteristic X	$U(X^i, H^i) = U(c^i + g^i, \alpha g^i)$
	g	Private characteristics X and H	
Health and environment label	c	Private characteristic X	$U(X^i, Y, H^i) = U(c^i + g^i, \beta g^i + \beta g^{-i}, \alpha g^i)$
	g	Private characteristics X and H, and public characteristic Y	

Solving the consumer optimisation problem (2) for each market setting, and considering the producer's optimum (1), we derive the market equilibrium conditions.

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To identify the markets optimality conditions, we also solve the social's planner and environmental agency's problems. We assume the social planner seeks to regulate food, global AECPG and health benefits provision to maximise the sum of the utility $U^i(X^i, Y, H^i)$ of all consumers, while the environmental agency seeks to regulate food and global AECPG provision to maximise the sum of the utility $U^i(X^i, Y)$ of all consumers (3).

$$\max_{c,g} \sum_i U^i \mid c = \sum_i c_i, g = \sum_i g_i, T(c,g) = 0 \quad (3)$$

To calculate and compare AECPG provision levels and run simulations, we assume functional forms to the production functions of the producer and the utility functions of consumers. Agricultural technologies exhibit a translated quadratic form (Carpentier and Letort, 2012; Femenia and Letort, 2016) and the utility function a translog form. θ_X, θ_Y and $and\ \theta_H$ represent respectively consumers preferences for food, global AECPG provision and health benefits.

3.1.3 Main results

In coherence with public economic theory, the AECPG provision level with an ecolabel is suboptimal in all situations. The larger the number of consumers I, the more underprovided the AECPG compared with the regulators' objectives. Consumers contribute to the provision of AECPG by purchasing g only up to their individual marginal utility, without considering the utility it also provides to the other consumers, and therefore underestimate the willingness to pay of society for each unit of Y. Displaying information on health benefits greatly increases the provision of AECPG. The provision of AECPG at the market equilibria of the health label is optimal in the point of view of an environmental agency when preferences for health are higher than for the global AECPG. When consumers have positive preferences for both health and the environment, the AECPG provision is always the highest under the market outcome of the health and environment label. However, the level is still suboptimal from the point of view of a social planner, as consumers' willingness to pay for the global AECPG remains individualised. The market size little affects the relative environmental performance of the labels. However, the larger the number of consumers, the less effective the ecolabel and the smaller the difference of AECPG provisions between the health and environment label and the health label. The difference between a health label and a health and environment label also decreases when consumers' preferences for health relative to the AECPG increase. The results of a simulation are presented in Figure 3.1-1 for illustration.

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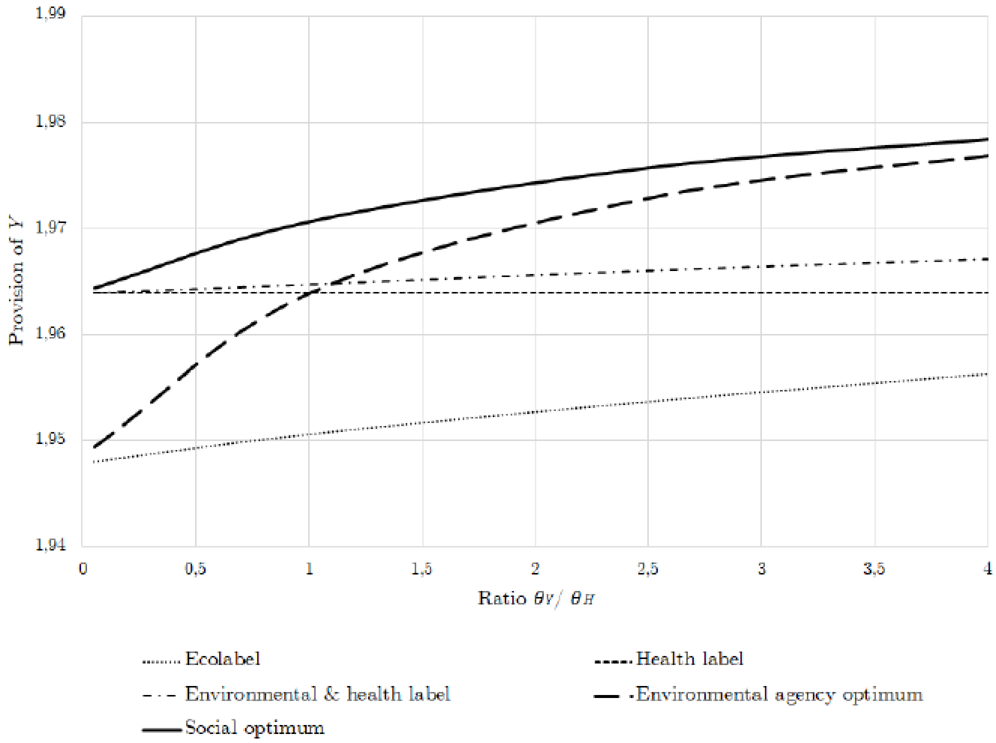
Figure 3.1-1. Global AECPG provision.



Utility function: $U\left(X^i, Y, H^i\right) = a \ln X^i + b \ln Y + c \ln H^i$

Number of consumers I=50

Income r= 5

Preferences for food $\theta_X = 0.8$

3.1.4 Conclusions

Our theoretical analysis, which only applies when environment-friendly agricultural practices jointly improve an intrinsic characteristic of a food product, shows that health labelling increases the provision of AECPG compared with ecolabels. When consumers only have access to partial information (ecolabel or health label), only a health label leads to an optimal amount of AECPG under certain conditions on consumers preferences. AECPG provision is further increased under full information on the public and private characteristics of the food product on the label. The extent of this increase depends mainly on the consumers' preferences (weight health/environment) and the number of consumers.

The necessary condition of these results is that there is indeed a complementary provision of private health and public environmental benefits for the food commodity produced using environment-friendly agricultural practices. It is for example the case of

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the BBC label for ruminant animal products in France, offering consumers differentiated food products that provide nutritional benefits to human health (Weill et al., 2002), while decreasing enteric methane emissions of ruminant (Martin et al., 2008) by enriching the diet of livestock with sources of unsaturated omega-3 fatty acids (see also D2.1 for Eco-Methane case study). Our theoretical findings suggest that a health and environment label such as the BBC label would contribute more to methane emissions abatement than a dairy ecolabel.

Some limits to the generalisation of our findings are related to the model assumptions. Transaction costs are likely to differ if a food product is labelled according to one or more characteristics, which would affect prices and the market outcomes. In the simulations, we also define homogeneous and homothetic preferences of consumers, while empirical evidence show that demands for health and environmental benefits differ according to socio-demographics, such as income and education levels, and age (Aldanondo-Ochoa and Almansa-Sáez, 2009; Brécard et al., 2009; Lusk et al., 2007; Moon et al., 2002; Schifferstein and Ophuist, 1998).

3.2 Public or private funds for the provision of agri-environmental public goods? (VC_UNIBO)

3.2.1 Introduction

Traditionally, agri-environmental PGs have been financed by public subsidies, such as the agri-environmental schemes, that are financed through taxation (Baylis et al., 2008). However, in the last years, consumers awareness for the environmental has partially changes consumption patterns and green markets, i.e. markets relying on eco-labels, such as organic certification, that signal the environmental quality of a marketable product, have emerged. Along the entire value chain, consumers reward the costly environmental efforts of farmers through a price premium (Crowder and Reganold, 2015), thus incentivizing their implementation (Bonnet and Bouamra-Mechemache, 2016). Given the increasing role of the value chain in providing funds for agri-environmental efforts, what is the role of public subsidies in this context? What would be the best source of agri-environmental public goods funds?

On the one hand, the economic theory suggests that private contribution to PG are inefficient, as each individual contributes to the PG only taking into account her own benefits and neglecting those of others (Samuelson, 1954). On the other hand, optimal provision of PG requires the implementation of individually-targeted prices (Lindahl,

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1958), that, given the heterogeneity of individuals, are in practice impossible to implement (Foley, 1970). Moreover, the contribution to PG through the food value chain is characterized by both private (food intake) and public (the contribution of environmentally friendly practices) characteristics. Organic food can be thus interpreted as an *impure* PG (Cornes and Sandler, 1984) i.e. a good that presents both characteristics of private and public goods. Despite the relevance of the concept of impure public goods, no studies have addressed the issue here at stake within this prospect. Moreover, despite a huge literature on contributions to public goods, to the best of our knowledge, no works have investigated the optimal source of financing of agri-environmental PGs (Kotchen, 2005).

The objective of this model is to assess the optimal regime to finance agri-environmental PGs. We analyze three regimes. In the private regime only consumers, by purchasing the impure PG in the green value chain, can contribute to the PG. The public regime is characterized by the lack of green markets, and only public subsidies, financed through taxations, can be used to contribute to the PG. Finally, the mixed regime combines the previous ones.

3.2.2 Model description

3.2.2.1 Theoretical analysis

Imagine a population of consumers of different types i with the utility function $U_i\left(y_i, x_i, Z\right)$, where y_i is the private goods (conventional food), x_i is the impure PG (organic food) Z is the total amount of PG. Assume that consumers can contribute to the public good only through the consumption of impure PGs. The social planner can however raise taxes and finance the provision of the pure public good. The total amount of PG is equal to the quantity of pure PG provided by the social planner G and the total amount of purchased impure PG by all of the consumers (noted X), i.e. $Z = G + b\, X$. To ease the numerical expressions, we assume that the utility function takes the following form:

$$U_i\left(y_i, x_i, Z\right) = \ln\left(y_i + x_i\right) + \alpha_i \cdot \left(\beta \cdot X + G\right) \qquad (1),$$

and that there are only two groups of consumers $i \in \{H; L\}$ of the same size but with different PG preferences $\{\alpha_H; \alpha_L\}$ with $1 > \alpha_H > \alpha_L > 0$. Similarly, we assume that the two groups are of identical size $N \geq 2$. Moreover, we assume that the social planner only

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knows the distribution of the preferences among the population but not the individual ones. Finally, we assume that the social planner can implement a single tax rate *t*, and hence her budget constraint is:

$$2 \cdot N \cdot m \cdot t = G \qquad (2).$$

Given these preliminaries, we analyze the problem of maximizing the welfare of society under different regimes: the private regime (where PG is provided only through the purchase of the impure public good), the public regime (where the PG is provided by the social planner) and the mixed regime (where the impure PG is available for consumption and the pure PG is financed by income taxation).

In the private regime, each consumer chooses the level of impure PG that maximizes its utility (1) under a budget constraint and taking for granted the consumption of the other consumers:

$$\max_{x_i} U_i\left(y_i, x_i, Z\right) = \ln\left(m - p \cdot x_i + x_i\right) + \alpha_i \cdot \beta \cdot \left(x_i + X_{-i} + X_j\right) \quad \text{s.t. } x_i \geq 0 \qquad (3),$$

where X_{-i} corresponds to the purchase of impure PG by the other consumers of type *i* and X_j corresponds to the purchased of impure PG by the consumers of the other type ($j \neq i$). The solution to (3) is the Nash equilibrium:

$$x_i^{ne} = \begin{cases} 0 & \text{if } m \leq (p-1)/(\alpha_i \cdot \beta) \\ \tilde{x}_i^{ne} = \dfrac{m}{p-1} - \dfrac{1}{\alpha_i \cdot \beta} & \text{if } (p-1)/(\alpha_i \cdot \beta) \leq m < p \cdot (p-1)/(\alpha_i \cdot \beta) \\ \bar{x}_i^{ne} = \dfrac{m}{p} & \text{if } m > p \cdot (p-1)/(\alpha_i \cdot \beta) \end{cases} \qquad (4),$$

where the upperscript *tilde* on the left-hand side of (4) denotes the solutions for the unrestricted problem (3), the upperscript *bar* denotes the upper-bound restricted solutions and the subscript *ne* denotes the solution for the consumers in the Nash equilibrium. (4) indicates that contributions increase with the income, preferences for the PG and environmental productivity of the impure PG, while they decrease with the price of the impure PG.

In the public regime, the social planner decides the tax rate, maximizing the welfare of society, when consumer can only purchase the private good:

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$$\max_t W(t) = 2\cdot N\cdot \ln\left(m\cdot(1-t)\right) + \left(N\cdot\alpha_H + N\cdot\alpha_L\right)\cdot 2\cdot N\cdot m\cdot t$$
$$\text{s.t. } 1\geq t\geq 0 \qquad (5).$$

The solution to (6) is:

$$t^s = 1 - \frac{1}{m\cdot N\cdot\left(\alpha_H + \alpha_L\right)} \qquad (6),$$

(7) shows that the optimal tax rate in the public regime increases with the income, with the population and with the preferences for PG. Substituting (7) we obtain the total provision of PG:

$$G^S = 2\cdot\frac{m\cdot N\cdot(\alpha_H+\alpha_L)-1}{(\alpha_H+\alpha_L)} \qquad (7).$$

In the mixed regime, the social planner decides on the tax rate taking into account the effect that such a tax rate has on the private consumption patterns:

$$\max_t W(t) = N\cdot\ln\left(m\cdot(1-t) - (p-1)\cdot\hat{x}_H^m(t)\right) + N\cdot\ln\left(m\cdot(1-t) - (p-1)\cdot\hat{x}_L^m(t)\right)$$
$$+\left(N\cdot\alpha_H + N\cdot\alpha_L\right)\cdot\left(\beta\cdot\left(N\cdot\hat{x}_H^m(t) + N\cdot\hat{x}_L^m(t)\right) + 2\cdot N\cdot m\cdot t\right) \qquad (8),$$
$$\text{s.t. } 1\geq t\geq 0,\ \hat{x}_H^m(t)\geq 0,\ \hat{x}_L^m(t)\geq 0$$

with $\hat{x}_H^m(t)$ being the reaction function of the consumer H facing an income tax t and $\hat{x}_L^m(t)$ the reaction function of consumer L. These reaction functions are the solution of:

$$\max_{\hat{x}_i^m} U_i\left(\hat{x}_i^m, Z; t\right) = \ln\left(m(1-t) - (p-1)\cdot\hat{x}_i^m(t)\right) + \alpha_i\cdot\left(\beta\cdot\hat{x}_i^m(t) + \beta\cdot\left(\hat{X}_{-i}^m(t) + \hat{X}_j^m(t)\right) + t\cdot m\cdot\left(N_H + N_L\right)\right)$$
$$\text{s.t. } \frac{m(1-t)}{p}\geq\hat{x}_i^m(t)\geq 0$$

which leads to:

$$\hat{x}_i^m(t) = \begin{cases} \bar{x}_i^m(t) = \dfrac{m\cdot(1-t)}{p} & \text{if } t < 1 - \dfrac{p(p-1)}{\alpha_i\cdot\beta\cdot m} \\ \tilde{x}_i^m(t) = \dfrac{m\cdot(1-t)}{p-1} - \dfrac{1}{\alpha_i\cdot\beta} & \text{if } 1 - \dfrac{p(p-1)}{\alpha_i\cdot\beta\cdot m} \leq t < 1 - \dfrac{p-1}{\alpha_i\cdot\beta\cdot m} \\ 0 & \text{if } t\geq 1 - \dfrac{p-1}{\alpha_i\cdot\beta\cdot m} \end{cases}$$

(9),

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where the upper bar $\bar{x}_i^m(t)$ indicates the maximum consumption, corresponding to the whole available income (after tax), and the *tilde* indicates a consumption level that does not saturate the income constraint. To evaluate the different regimes we rely on numerical examples based on a realistic parametrization for organic food and for the heterogeneity of the preferences in the population. The simulations are run on GAMS.

3.2.3 Results

Figure 3.2-1 displays the welfare, the aggregated level of PGs, the optimal tax and the share of public funds in the aggregated PG provision for different α_H over the range $\beta \in [0.01;0.99]$ with $N=2$, $m=10$, $p=11$ and $\alpha_L=0.1$. Panel (a) shows that the welfare is higher in the private regime than in the public regime when the environmental productivity of the impure PG (β) increases. However, the advantage of the private regime is reduced as the preferences of the *H*-type consumers increase. Not surprisingly, the welfare in the mixed regime is always the highest, but the private regime comes close (or equals it) for very high values of β and low values of α_H. Moreover, the aggregated level of PG is sometimes higher in the private regime than in the public regime when β is high, and the mixed regime always provides (slightly) lower PG than the public regime (Figure 3.2-1.b). This illustrates that if the mixed regime always represents an improvement for the economy, it does not necessarily increase PG provision; its benefits are due to a reallocation of funding.

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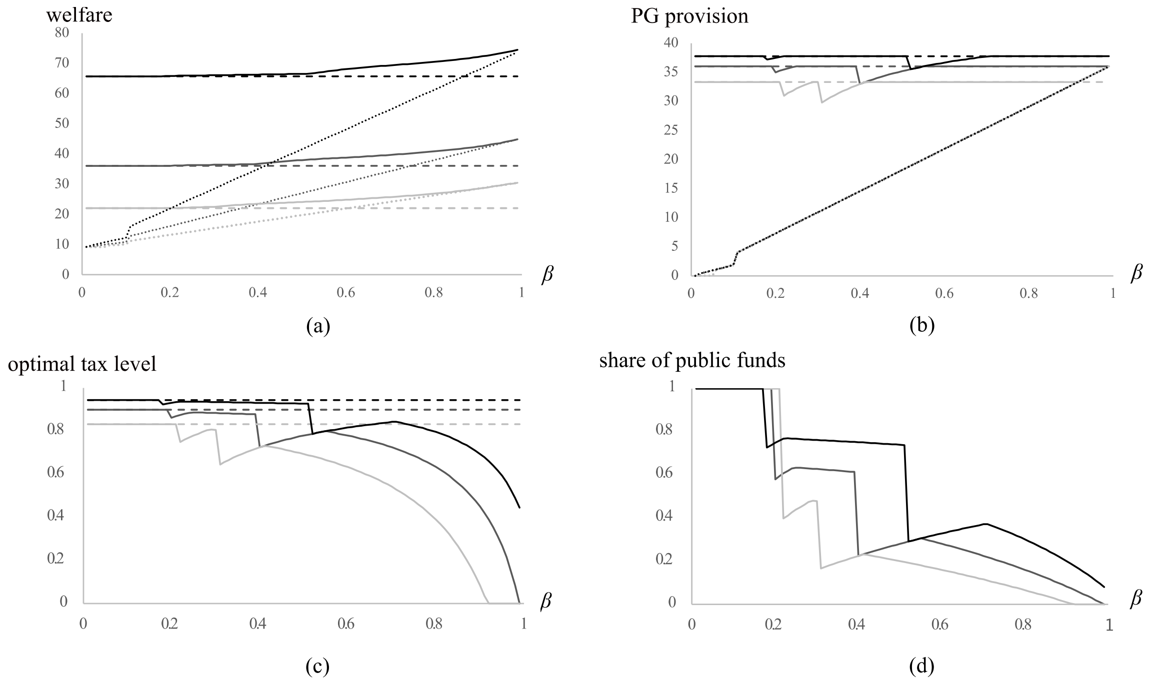

Figure 3.2-1: (a) welfare, (b) aggregated PG provision, (c) optimal tax levels and (d) share of public funds in the aggregated PG provision in function of the environmental productivity of the impure PG (β) under the private regime (dotted line), the public regime (dashed line) and the mixed regime (solid line) with $\alpha_H = 0.2$ (light grey), $\alpha_H = 0.4$ (grey) and $\alpha_H = 0.8$ (black). The results are displayed for $N = 2$, $m = 10$, $p = 1.1$ and $\alpha_L = 0.1$.

Panel c in Figure 3.2-1 highlights the complex relationship between the optimal tax rate in the mixed regime and the environmental productivity of the impure PG (β). As β increases, the tax rate is first bounded at a similar tax rate to the public regime $t^m = t^m_{0,0} = t^s$ for which consumers do not contribute to the impure PG. After a threshold ($\beta = 0.22$ in Figures 2.c), the tax rate is settled at $t^m = \bar{t}^m_{0,\bar{x}_H}$ for which consumers H spend their entire available incomes on the consumption of impure PG. The tax rate increases with β on this portion but remains lower than the tax rate in the public regime. Finally, the tax rate is equal to $t^m = t^m_{\bar{x}_L,\bar{x}_H}$ for higher levels of β where consumers H and L spend their entire available incomes on the consumption of the impure PG. In detail, the tax rate takes the value (i) $t^m = \bar{t}^m_{\bar{x}_L,\bar{x}_H}$ from $\beta = 0.31$ to $\beta = 0.41$, where the tax increases with β , (ii) $t^m = \tilde{t}^m_{\bar{x}_L,\bar{x}_H}$ from $\beta = 0.42$ to $\beta = 0.91$, where the tax decreases with β and (iii) $t^m = \underline{t}^m_{\bar{x}_L,\bar{x}_H}$ from $\beta = 0.92$ to $\beta = 0.99$, where the tax rate is null. The form of this

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piecewise function is similar for higher levels of α_H, even if the threshold and levels differ accordingly (Figure 1.c). Interestingly, the level of $t^m = \underline{t}^m_{\bar{x}_L,\bar{x}_H}$ is not reached for $\alpha_H = 0.8$, implying that, as the PG preferences increase for the H-type consumers, the optimal tax rate *increases*. This result calls for a comment on the policy implications. Counterintuively, these results suggest that when the preferences for environment increases (for a part of the population at least), private funds should not substitute public funds. Indeed, the results show that the opposite should occur: policymakers should tax *all consumers* more to increase the utility of consumers *H*. As a result, the share of the public funds on the aggregated PG increases as α_H increases (on all parts of the curve, except for some cases due to the different threshold on $t^m = t^m_{0,0} = t^s$; see Figure 3.2-1 panel d). Similarly, to the tax rate, the share of public funds in the aggregated PG provision depends in a complex way on β.

3.2.4 Conclusions

The main objective of the analysis is to assess what is the optimal source of financing when a green value chain enables consumers to contribute to an agri-environmental PG in addition to the standard subsidies financed through taxation.

We find in the public regime that those consumers with the highest preferences for the PG may be willing to contribute to the impure PGs if they have the possibility. This supports the idea that the organic market could provide additional funds to biodiversity conservation and, above all, that policymakers should integrate this reaction into the design of the optimal tax rate. Accordingly, we showed that the optimal tax rate in the mixed regime is lower or equal to the optimal tax rate in the public regime. Indeed, we proved that the mixed regime was the best regime to finance PGs. However, the simulations emphasize that the impure PGs need to be highly productive and cheap, otherwise the social planner behaves as in the public regime and consumers do not purchase the impure PG. In most cases, we highlighted that the highest share of funds for PGs should be public.

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3.3 Contractual solution for water and climate friendly wheat production - environmental engagement along the value chain (VC_TI)

3.3.1 Introduction

Besides the use of public funds for environmentally friendly farming practices, increasing attention is given to value chain approaches where the farmers are paid by the market for their environmental efforts. While most of the value chain initiatives are either driven by the food processing industry or retailers, there are also examples of bottom-up collaboration along the whole value chain from primary producers to consumers. A particular case is a Bavarian initiative in which public water suppliers, mills and regional bakeries collaborate with farmers to reduce nitrogen fertilisation of wheat for bakery purposes to protect drinking water (see 'Water protection bread' in CONSOLE Deliverable D2.6, pages 60-64). Instead of following the current standardized pricing system of quality wheat for human consumption that is based on the protein content in the grain, farmers in this initiative are encouraged to grow wheat breeds that deliver good baking properties regardless a lower protein content. This enables farmers to apply less nitrogen fertilisers. Bakery products from water-friendly produced wheat are specifically labelled and attention is given to regional craftmanship. By buying such bakery products consumers do not only contribute to water protection, the reduced fertilisation also mitigates greenhouse gas emissions. A more widespread implementation of a reduced wheat fertilisation and in particular a discontinued late nitrogen fertilisation that is common practice to achieve high protein contents would have major environmental and climate effects. In Germany, wheat was cultivated on 2.9 million hectares in 2021 with a total production of 21.1 million tonnes, of which 7.2 million tonnes were for human consumption, making it the most important food grain (Destatis 2022). Most of it is used as baking cereal resulting in a per capita consumption of 72 kg of wheat per year in Germany (BLE 2022). Building upon the positive experiences from the 'water protection bread' initiative, we assess how such value chain contracts may incentivise farmers to adapt their practices and how sustainability outcomes resulting from changes in wheat production go along with business profitability.

3.3.2 Model description

The current standardized pricing system for national as well as international trade is strongly based on crude protein content in wheat. This continues to apply even if the

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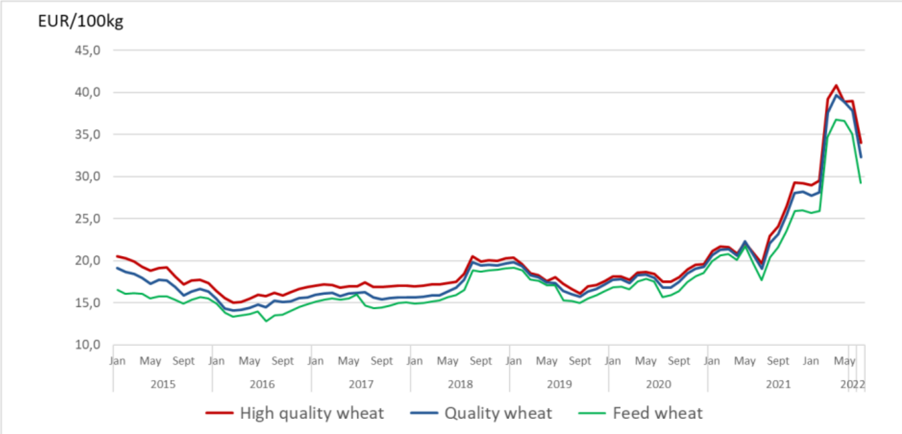
crude protein content has not been longer part of the official quality classification for winter wheat breeds in Germany since 2019. However, the settlement modalities in trade still continue to be largely based on the crude protein content of the wheat lot. This leads to a situation in Germany that wheat should have a protein content of at least 13% to be priced as food wheat, otherwise the wheat becomes feed wheat with considerable price discounts (see Figure 3.3-1).

Figure 3.3-1. Farm gate prices for wheat of different qualities in Germany 2015-2020



Source: AMI time series, wheat prices ex-farm, last query of the data in February 2022

As shown in the graph, the price differences are particular pronounced during harvest period when many farmers are delivering their harvest to the country store. While price differences between high quality wheat (>14% protein content, red line) and quality wheat (at least 13%, blue line) have decreased over time, they remain important between these two baking cereal qualities and feed wheat (green line).

In order to increase the crude protein content of wheat, farmers do a final application of nitrogen fertilisers at the time between ear emergence until blooming, the so-called quality fertilisation. As not all the nitrogen applied ends up in the plant this late fertilisation leads to an increased risk of nitrogen leaching into groundwater alongside with GHG emissions, in particular through increased N_2O losses to the atmosphere. Especially, in the advanced vegetation stage the wheat plants only take up part of the applied nitrogen and low soil humidity or drought periods in summer lead to a further reduction in their uptake. Taking the reduced fertilisation practice of the water protection bread initiative as starting point, we upscale the environmental benefits across Germany. We make some suggestions how value chain contracts could be designed aiming at a

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reduced fertilisation. The high volatility in fertiliser and wheat prices and the sharp price increase in the last months puts farmers as well as their business partners into a situation where product contracts need to be reconsidered and renegotiated where necessary. At the same time this may be an opportunity to include environmental specifications.

3.3.2.1 Theoretical approach

On an exemplary basis the potential environmental and climatic effects of a reduced nitrogen fertilisation of wheat for human consumption induced by value chain contracts are calculated. By comparing the common fertilisation practice in Germany to the one applied in the water protection bread initiative, we derive potential effects on water quality and climate emissions alongside with price effects. Data collected from farmers participating in the initiative have been used to investigate effects on water quality. In order to assess potential effects of reduced nitrogen leaching into groundwater, the value of the residual nitrate content has been measured in autumn after wheat harvest making a distinction between soil covered by winter cereals or catch crops. Fertiliser production releases GHG gases at the plant site as well as nitrous oxide emissions from fertilised soils. For the latter a generally accepted statement is that the higher the nitrogen application the greater the losses to the air (LfL 2021). For 2020, Germany reported a total of 56,8 million tons CO_2eq emissions from agriculture sector, out of which account approximately 18.7 million tons CO_2eq from nitrous oxide emissions from fertilisation production and application (UBA 2022).

3.3.2.2 General assumptions and empirical evidence

While contract farming would allow the introduction of bilaterally negotiated environmental clauses it received little attention in the cereal sector until now. With the introduction of the new fertiliser ordinance in Germany to comply with the EU nitrates directive requirements such contracts have the potential to become a game changer. Farmers have to adapt their fertilizer practices in order to comply with more severe fertilizer requirements, making it even more difficult to reach today’s quality criteria for wheat. This is particularly relevant for those farmers having land in the so called “red areas”, highly nitrate-polluted areas on which farmers must use 20% less fertiliser compared to the thresholds set for whole Germany. Together with the considerable price increase to be observed for mineral fertilisers over the past months, there is a growing interest from farmers’ side to produce wheat for bakery purposes with lower protein

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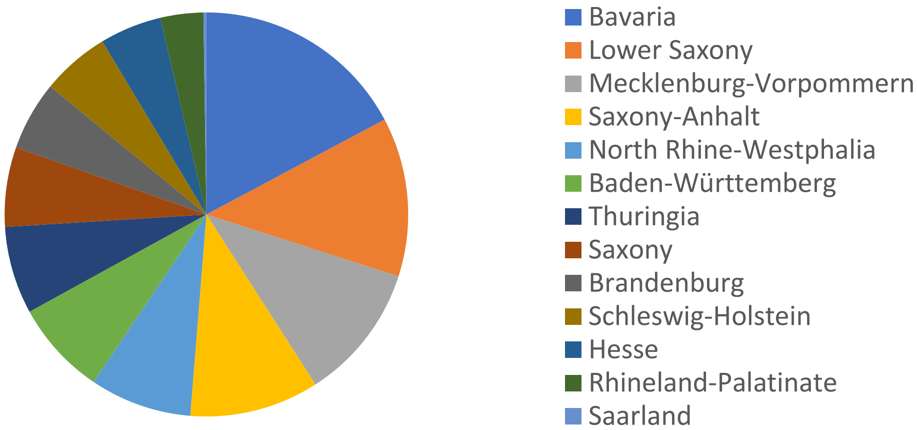
content while being rewarded for lowering the negative effects on environment and climate.

As the wheat production is distributed unevenly across Germany, with Bavaria having grown winter wheat on 0,493 million ha in 2021, followed by Lower Saxony, Mecklenburg-Vorpommern, and Saxony-Anhalt; all four together making 51% of the German wheat production (Destatis 2021). Some regions are known for their traditional quality wheat production, mainly because of particular good growing conditions like on loess and loam sites. In other regions farmers traditionally grow varieties used for human consumption because of low livestock densities, resulting in low demand for feed wheat.

Figure 3.3-2 shows, the wheat production is distributed unevenly across Germany, with Bavaria having grown winter wheat on 0,493 million ha in 2021, followed by Lower Saxony, Mecklenburg-Vorpommern, and Saxony-Anhalt; all four together making 51% of the German wheat production (Destatis 2021). Some regions are known for their traditional quality wheat production, mainly because of particular good growing conditions like on loess and loam sites. In other regions farmers traditionally grow varieties used for human consumption because of low livestock densities, resulting in low demand for feed wheat.

Figure 3.3-2. Surface grown with winter wheat in Germany in 2021



Today, most of the wheat produced in Germany is sold directly to local land trade or via the stock market, so that value chain contracts are still rare and those that exist usually target regionality and/or specific quality criteria. At the same time, positive developments can already be seen on the domestic market: Even if the quantities remain low, a growing number of farmers produce and deliver single-variety batches of wheat with specific quality parameters through contract farming to mills. This is offering an

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opportunity for a modified pricing approach. Yet, only little information is available on such business-to-business contracts, in particular as regards the fertiliser use by the participating wheat producers.

In the business year 2018/2019, 5.96 million tons of wheat were traded through the market for domestic human consumption (BLE 2021). As there are no official statistics regarding the share of wheat qualities harvested across Germany, we make a number of assumptions for our calculations. We use the average wheat yield for 2021 that is 7.3 tons/ha (Destatis 2021), and derive the environmental effects by ignoring the influence of varying soil characteristics and water content in the soils on nitrogen losses to air and water. In line with the fertiliser ordinance we fix for conventional quality wheat an average fertilisation of 230 kg N/ha. In the water protection wheat initiative, the maximum fertilisation is fixed at 160 kg N/ha, this leads to a 70 kg N/ha reduction. Since such a reduction over several years is likely to have considerable negative effects on the yield level, we assume a reduction of 40 kg N/ha through suspended late fertilisation. This results in a maximum of 190 kg N/ha for wheat grown on contractual basis in our simulation exercise. As it is unlikely that all wheat grown for human consumption is traded through contracts following the restrictive fertiliser requirements, we assume a gradual increase of the quantities. For the first year a share of 10% is assumed, increasing to 25% of the domestic wheat consumption for human food in the fourth year.

3.3.3 Quantitative results

In order to assess the effects on water quality as well as for GHG emission reduction we compare the conventional quality wheat production with wheat grown in value chain contracts that contain the obligation to abolish late fertilisation. Besides environmental benefits, also economic effects are looked at.

<u>Nitrate leaching reduction potential resulting from changed wheat fertilisation practice</u>

a) Water protection bread initiative

The residual nitrate content measured in soil samples in autumn serves as an indicator for nitrogen leaching into groundwater. Therefore, samples were taken from farmers participating in the water protection bread initiative. The lower the measured nitrate content the lower the risk of leaching over winter. In autumn 2020 after harvest 118 wheat fields from 31 farmers who participated in the initiative were sampled. Out of

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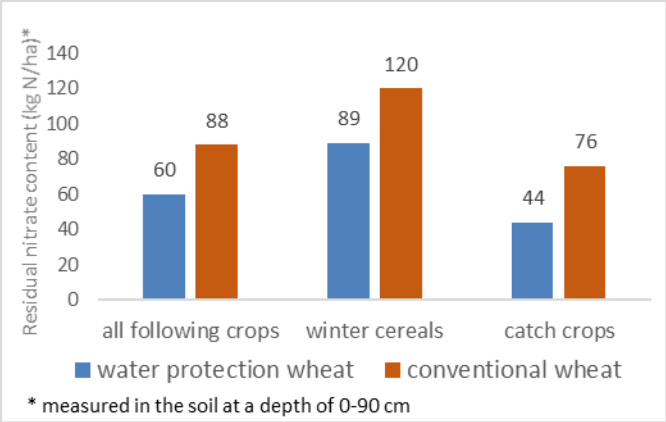
them 96 plots were grown under the regime of water protection wheat and 22 under conventional farming.

Figure 3.3-3. Residual content in autumn under different fertilisation regimes for wheat



Source: Report Monitoring-Programm Wasserschutzweizen 2020“, GeoTeam GmbH 2021

The results show that for those plots grown with water protection wheat the residual nitrate content is considerably lower than for plots with conventionally grown wheat. For the water protection wheat production, the residual nitrate in autumn was on average one third lower compared to conventional farming, resulting in around 25 kg nitrogen per hectare less with lowest values under catch crops. Parts of the residual nitrate content can still be taken up by the crop in the following vegetation period, with sandy and /or shallow soils being particularly vulnerable to leaching and a low groundwater recharge rate putting water quality at particular risk. In the typical wheat-growing areas of Franconia, the measured reduction of the nitrate content in soil in autumn is having significant positive effects on the ground water quality. It leads to a reduction of the nitrate content in the leachate by 30 to 35 milligrams per litre. This is particularly beneficial as most of the plots participating in the water protection wheat initiative are located within drinking water protection zones.

b) Hypothetical contracting

As these figures are a result of a 160 kg N/ha application without late fertilisation and not all soils across Germany being as vulnerable to leaching, it is unlikely that a projected overall reduction of fertilisation will result in such high reductions in the leachate. But the assumed reduction of 40 kg N/ha would contribute to improved groundwater quality. Germany is obliged to prevent nitrate concentrations above the threshold value of 50 mg nitrate per litre for groundwater, which is set uniformly throughout Europe in the EU Groundwater Directive 2006/118/EC. Around 2.9 million hectares of agricultural land exceeding this threshold (delimitation at Laender level is

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ongoing and expected for October 2022). If farmers engage in sustainable value chain contracts without risking considerable discounts for not achieving the 13% protein content, this would allow to continue growing wheat for bakery purposes also in those nitrate sensible regions. At the same time mills which have so far procured goods from such regions could continue to do so.

GHG emission reduction potential resulting from changed wheat fertilisation practice

a) Water protection bread initiative

In the water bread initiative 370 ha have been cultivated with 160 kg N/ha, meaning a reduction of 70 kg N/ha compared to the legally allowed maximum fixed in the new fertiliser ordinance. This leads to a reduction of GHG emission resulting reduced mineral fertiliser production as well as less application on the field.

Depending upon the type of fertiliser applied, the emissions vary. While for urea with a N content of 46% it is 0.89 kg CO_2eq/kg product, CAN with a content of 27% reaches 1 kg CO_2eq/kg fertilizer at production site. But for urea there are additional emissions released shortly upon application to soil, resulting in additional 0.73 kg CO_2/kg urea (Bentrup and Hoxha 2016). For simplification we assume that farmers of the water protection bread initiative apply CAN, thus when using 70 kg N/ha less and GHG emission savings at plant level of 3.7 kg CO_2eq for 1 kg N, this results in savings of 259 kg CO_2eq per ha when wheat is grown with reduced fertilisation. In addition to those savings resulting from less mineral nitrogen fertilisers bought by the farmers, on-field savings resulting from lower N_2O emissions have to be added. In IPCC reporting the emission factor for N_2O is calculated as the proportion of N input emitted as N_2O. Here we use the value for synthetic fertilisers in wet climate that is 1.6% (1.3–1.9%) derived from global N_2O measurements (IPCC, 2019). For the saved 70 kg N/ha this results in savings per hectare of 1,12 kg N_2O or 334 kg CO_2eq given that releasing 1 kg of N_2O into the atmosphere is about equivalent to releasing 298 kg of CO_2. Per hectare grown for the initiative this sums up to 593 kg CO_2eq, which considerably reduces the ecological footprint of wheat production and consumption. For the 370 ha grown under the initiative it sums up to mitigated emissions of 219 t CO_2eq.

b) Hypothetical contracting

In a second step, we calculated the achievable emission reduction when reducing fertiliser use by 40 kgN/ha on 10% (25% respectively) of wheat area used for human

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production. Assuming a harvest of 7.2 tons/ha and an annual wheat consumption of 5.96 million tons in Germany brings us to the following figures in Table 3.3-1:

Table 3.3-1. CO_2eq savings from reduced N fertilisation for different shares of wheat

	40kg N reduction for 10% of wheat for human consumption	40kg N reduction for 25% of wheat for human consumption
Surface	81.699 ha	204.247 ha
N fertiliser saved	3.268 t	8.170 t
CO_2eq savings at fertiliser plant	12.108 t	30.269 t
CO_2eq savings at field level	15.580 t	38.950 t
Total CO_2eq savings	27.688 t	69.219 t

Economic effects resulting from changed wheat fertilisation practice

For German mills processing wheat to flour it might become increasingly interesting to engage in contracts targeting a reduced fertilisation for several reasons. It gets more difficult to purchase wheat with high protein content produced in Germany due to the new fertiliser law, therefore it becomes even more important to secure wheat with good bakery qualities to supply the domestic market. This year the crude protein content decreased significantly in Germany to 11.8% compared to 12.7% in the previous year (BMEL 2022). Furthermore, the reduction of 338.9 kg CO_2eq/ha resulting from reduced fertilisation has a value by itself. Allowances traded under the EU ETS scheme are becoming more and more expensive and mills purchasing wheat through such value chain contracts might include the emission savings in their own GHG calculations.

Farmers will only participate in value chain contracts if the modifications in the fertilisation regime do not harm their profitability, at best it is financially even more interesting than conventional quality wheat production. In the water protection bread initiative, farmers have the guarantee that they get the same price for their wheat grown with reduced fertilisation as for quality wheat (on certain cut-off dates) as long as their wheat complies with sanitary requirements. Such a simplified reward approach is unlikely to be applied on a broader scale across Germany. Therefore, we look into the cost structure for wheat production comparing current practice with reduced fertilisation.

We compare the gross margins for conventional quality wheat (grown with 230 kg N/ha), low fertilisation wheat sold as quality wheat or as feed wheat (both with 190 kg N/ha) and the water protection wheat (with 160 kg N/ha) with prices in 2020 and current prices in 2022. The product price/nitrogen price ratio is the decisive factor for the economic optimum at farm level. We assume that the yield for quality wheat grown

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conventionally is 3,5% higher, reaching 7.5 t instead of 7.2t while for water protection wheat they are lower, reaching 7.1 t /ha. The prices for wheat nearly doubled within the last two years, with the price difference between feed and food wheat remaining important. In 2020 the fertiliser price was 0.76 EUR/ kg N and reached 2.91 EUR / kg N in 2022, other inputs increased as well in the prices, but to a much lower rate.

Table 3.3-2. Gross margins for wheat under different fertiliser regimes for the years 2020 and 2022

	Quality wheat conventional	Quality wheat low fertilisation	Feed wheat	Water protection wheat	Quality wheat conventional	Quality wheat low fertilisation	Feed wheat	Water protection wheat
Year	2020	2020	2020	2020	2022	2022	2022	2022
Price (EUR/ 100 kg)	16.8	16.8	15.6	16,8	33	33	29	33
Yield (100 kg)	75	73	73	71	75	73	73	71,5
Revenue	1260	1226	1139	1193	2475	2409	2117	2360
Seeds	112	112	112	112	139	139	139	139
Fertilisation	**175**	**144**	**144**	**121,6**	**669**	**553**	**553**	**466**
Plant protection	171	171	171	171	195	195	195	195
other cost (incl. machinery)	376	362	362	362	494	476	476	476
total variable costs	834	790	790	767	1497	1363	1363	1276
Gross margin	426	437	349	426	978	1046	754	1084

Own calculations, based on values from statistics (AMI, KTBL) and from Top-Agrar 08/22, page 44+46

When comparing the gross margins for the four variations of wheat production in 2020, the most profitable is the quality wheat with low fertilisation with 437 EUR/ha as long as the farmer does not get a price reduction. If he or she is only paid the price for feed wheat which is 1.2 EUR/100kg lower he loses 77 EUR /ha compared to conventional wheat. With a yield reduction of not more than 5% for the water protection wheat compared to the conventional wheat both gross margins are with 427 EUR/ha the same. In 2022 with significantly higher wheat prices but also fertilisers being much more expensive, the highest gross margin is achievable with the water protection wheat, reaching 1084 EUR/ha, which is 38 EUR/ha more than for the quality wheat with low fertilisation (1046 EUR/ha). But if the farmer is only paid for feed wheat quality his profit considerably drops. The fear of not reaching the required 13% protein content in order to get a good price is certainly an obstacle for changes in the fertiliser practices across Germany. At the same time, contractual solutions might become a win-win option for farmers and mills, in particular as new breeds with lower protein content and high nutrient efficiency have proven their suitability for bread production. For sure, it would require some adaptations in the bakery process, in particular as regards a longer resting time for the dough. For the consumer it might result in bread with a slightly lower volume, as the dough tends to rise less.

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3.3.4 Conclusions

While there is in principle a high degree of freedom for product contracts, in the case of wheat standard contracts between farmers and land trade or mills based on crude protein content still dominate the market. Regardless the recognition that baking properties are, especially in the higher protein range, not directly linked to the protein content in wheat but more dependent upon protein type and other quality aspects that can be influenced through breeding (Gabriel et al. 2017), for trade the crude protein content remains a key value for the price. Examples like the water protection bread initiative where the bakery products receive a dedicated label have proven that for environmental purposes it is possible to change this, as long as all actors along the value chain collaborate and consumers are willing to buy bread produced out of it. A growing domestic market needs to be organised on the basis of dedicated sustainability contracts for domestic consumption as changes in trade standards are likely to be even more difficult. In order to boost such contracts, it is important that not only local bakeries join in, but also industrial bread making companies, at the best by using a specific label allowing consumers an easy choice. A lower protein content would require to adapt their production processes as bread made with such flour needs a longer resting period before baking.

While in our calculations no differentiation has been made regarding site conditions, targeting wheat production areas that are particularly vulnerable in terms of water quality through value chain contracts would benefit from an environmental point of view as well as secure regional supply of wheat for human consumption in future. Furthermore, a regional differentiation of the N_2O emissions across Germany as undertaken by Mathivanan et al. (2021) could provide further indications where from an environmental point of view such contracts are most beneficial.

3.3.5 Acknowledgments

We would like to express our sincere thanks to Nicole Nefzger and Katharina Meyer from FiBL Deutschland e.V. for their valuable insights into the initiative "Wasserschutzbrot".

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4 Discussion and Conclusion

The models developed within task 4.5 provide several insights on the value chain as a mean of contributing to the provision of agri-environmental public goods (see table Table 3.3-1).

Table 3.3-1 Main results from the model exercises of task 4.5

Model	Issues analysed	Main results
VC_INRAE	Effects of health vs/and eco label on private provision of agri-environmental public goods	Any market instrument is socially suboptimal, but health labelling can reduce the inefficiency of eco-labelling and be optimal from the point of view of an environmental agency.
VC_UNIBO	Optimal source of financing (market, taxes or mix) agri-environmental public goods	Government provision of agri-environmental public goods should still be relevant even if green value chains exist.
VC_TI	Upscaling of market segmentation for provision of agri-environmental public goods through a label	Changes in (private) pricing standards could lead to a reduced fertilisation of wheat and thus substantial improvement in water quality and less GHG emissions

Two of the models are inspired by the recent literature on impure public goods (Kotchen, 2005). Indeed the impure public good model fits appropriately the problem at stake when considering the purchase of food product with some environmentally friendly practices. The purchase of green-food provides both private and public characteristics, and taking into account these features shed lights on the issues around the green value chains. The VC_INRAE model addresses the problem of investigating the degree of efficiency of market-based solutions with respect to the social optimum. The model finds that the private contributions to AECPGs through the market are not capable to reach the social optimum. Moreover, the authors find that health labels are more efficient than environmental labels in providing contributions to AECPGs. The difference is that the

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health label only signals private characteristics, while the ecolabel signals a public characteristic that in turn causes a free-riding behaviour and its well-known issues. The modelling exercise shows that, when there is scientific evidence of complementary provision of health benefits, health labelling of a green product is an efficient way to increase contributions to the provision of AECPG.

On a similar fashion, but with a different perspective, VC_UNIBO analyses what is the most efficient source to finance the provision of agri-environmental public goods. The authors start from the idea that both public and private contributions are characterised by inefficiencies (respectively, the impossibility of addressing heterogenous preferences, and free-riding behaviours). The main result of their model is that while private contributions can certainly provide additional funds, the role of public contribution remains fundamental. Over-relying on private contributions might generate inefficiencies.

The analysis VC_TI is an upscale of a local value chain initiative and gives a more empirical perspective than the previous two models. The simulation is inspired by the "water bread initiative" where through collaboration among farmers, mills and bakery wheat is priced based on its baking properties and not to the protein content. This in turn enables farmers to reduce the amount of fertilizers applied, that is the main driver to increase the wheat protein content. The simulations show that upscaling such an initiative would entail substantial benefits from the environmental point of view. However, the economic performance of the initiative from the farmers point of view depends heavily on wheat prices (and consumer preferences).

The models developed in task 4.5 are a first answer to the ambitious objectives of the task (see Table 3.3-2). The main message that is coming out from the exercises is that surely the value chain might help the provision of agri-environmental public goods but that it should be seen as a complementary tool to the more traditional public policies rather than their substitute. In this perspective, numerous areas of further research, from both the theoretical and the empirical point of view, are identified. First, for example, the current analyses only take into account the fact that the government only cares about one (agri-environmental) public good. A more comprehensive picture could be given if the analysis would take into account different (non agri-environmental) public goods. More in general, the analyses here carried out have a normative perspective that assumes an efficient welfare maximizing benchmark. A political economy perspective (where public

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policies objectives are endogenously taken) could shed further lights on the relative importance of public policies and value chains in incentivizing agri-environmental public goods.

Table 3.3-2 Task objectives and main messages

Task objectives	Main messages
1) investigating the degree of efficiency of market-based solutions with respect to the social optimum	Market instruments are likely not to lead to the social optimum. In this prospect, providing information on the complementary health benefits of green products is more effective for private public good provision than eco-labelling.
2) the comparison between the performance of market-based solutions and public policies	Trade-offs exist among the two instruments. Despite the emergence of green value chains, the results of the tasks suggests that the public provision of agri-environmental public goods has still a strong role.
3) role of policy instruments	Policy instruments such as label seems a priority.

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