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Abstract

The activities of intermediary organisations in the context of payments for agri-environmental services have broadly increased in all European countries over the last two decades. However, the impact of this new governance mechanism on environmental protection and changes in individuals' behavior has not yet studied in the economic literature. To explore this issue, we develop a new theoretical economic framework that allows us to compare the main environmental effects of an incentive mechanism with intermediaries, such as environmental knowledge brokers and information providers, as compared to those of a standard central governance mechanism. This paper bridges the knowledge-brokering theory developed in the literature in environmental science with the process of individual preferences formation and transmission developed in the economic literature. The analysis shows that the emergence of knowledge intermediaries is particularly valuable in the context of payments for agri-environmental services in a situation where individuals, such as farmers, initially have a low level of environmentally awareness. The same conclusion holds when the public institution organizing the scheme is not sufficiently apprised of individuals' characteristics. This allows us to give a theoretical justification for previous empiric results on payment schemes for agri-environmental measures.

Key words: Knowledge Brokers, Intermediaries, Pro-environmental Culture, Cultural Transmission, Moral Hazard, Principal-agent

JEL Classification: Q51, Q58, Z13.

1   Introduction

The role of agricultural policy in preserving and enhancing sustainability and biodiversity is widely recognized. The Agri-environment Council Regulation (EEC) of 30 June 1992 on agricultural production methods has strongly improved the Common

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agricultural Policy (CAP) in the European Union (EU), introducing various targets to offset the loss of biodiversity and to improve environmental awareness among the population of farmers. The reform also underscored the shift from product support to producer support by launching direct payments to farmers. In line with the objective of the 1992 regulation, the EU Council of agricultural ministers reached an important agreement in 2003 on a reform of the CAP introducing so called *decoupling*: a single payment scheme not linked to production of any particular products.[1] The main objective of the new scheme of payments, called *agri-environment measures* (AEMs), is to encourage farmers to protect and enhance the environment on their farmland by paying them for the provision of environmental services. These payments are provided by national or regional governments to farmers who subscribe, on voluntary basis, to environmental commitments related to the preservation of the environment. In the implementation of the scheme, Governments may delegate to non-profit organizations or individuals the role of creating links with the farmers, and may transfer to these organizations the payment for environmental services. In practice, therefore, this mechanism has been accompanied by the proliferation of networks of supporting organisations, often under the legal form of service-oriented businesses owned by non-profit organizations, able to provide screening activities for the public administrations as well as valuable social learning and knowledge to farmers. This new governance mechanism, based on network bridging organizations, contrasts with the traditional central governance mechanism, also called 'command and control' policy, in which the national or regional authority that allocates monetary resources to farmers to provide agri-environment services does not delegate the policy implementation.

An empirical analysis of the new situation has been initiated in a recent paper by Dedeurwaerdere et al. (2015), who have shown that farmers who have periodic contacts with network bridging organizations are more inclined to achieve changes in management practices for environmental protection. More precisely, using a series of structured in-depth field interviews with farmers adhering to certain agri-environmental schemes of the Wallon Region in Belgium, they show that, if farmers are involved in knowledge co-production and social learning processes organized by network-bridging organizations, there is a strong improvement in both change to environmental practices and adhesion to deep green AEMs. In the current work we carry out a dynamic theoretical analysis of this phenomenon. We are able to give further justification to the results of Dedeurwaerdere et al. (2015), and to provide policy implications for promoting environmental behavior in the farming population in the long run. We also characterize the economic conditions which determine the effectiveness of the new policy strategy.

In our theoretical framework we consider two payment schemes for environmen-

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[1]Prior to the 2003 reform, the scheme was based on direct payments associated with a specific line of production of crop and livestock. The 2003 reform decoupled these direct payments into a single payment. The 2013 reform has continued this orientation.

tal services that can be clearly distinguished:[2] *light green* agri-environment measures (for instance, preserving hedge rows or isolated trees in the existing landscape) and *deep green* AEMs (such as preservation of local breeds or restoring natural grasslands). The former are characterized by low ecological effects with low payments, the latter are clearly important for the long-term environmental effectiveness of the policy but entails high payments.

Deep green AEMs can greatly contribute to social-environmental returns, but they can be successfully carried out only if farmers actively participate by making a specific environmental effort. As Vanslembrouck et al. (2002) observed in a similar context, "programs based on voluntary participation will only be environmentally effective if the required changes in management practices result in environmental improvement and if farmers enroll in such schemes". In a context where the possibility of an ex-ante commitment is low, a key role is played by farmers' pro-environmental preferences, i.e. their level of *environmental consciousness*.[3] Our economic argument for the emergence of a network of social intermediaries to implement AEMs is that their presence may allow us to envision a situation that might promote a process of cultural convergence between the growth of the non-profit sector and the key stakeholders that benefit from the knowledge services provided by this sector.

For the purpose of the analysis we distinguish between two observable elementary behaviors of the part of the farmers: behavior with environmental effort (designated hereunder as *pro-environmental behavior*) and behavior with no environmental effort (designated hereunder as *non-pro-environmental behavior*). We model environmental preferences as inherent characteristics transmitted through generations of farmers. More precisely we suppose that farmers' preferences for the environment are acquired through a cultural transmission process across generations: the consciousness of young farmers (children) is influenced by the effort that old farmers (parents) make in transmitting this value concerning the protection of the environment.[4] This approach finds its roots in the literature on evolutionary process of cultural selection, developed by Cavalli-Sforza and Feldman (1981) and introduced in the economics literature by Bisin and Verdier (1998).

In this theoretical framework we study two possible governance mechanisms for the public legislator to promote environmental consciousness within the farmers' population and generate environmental effectiveness of the policy. In the first (Section 2) we consider the case where it is possible to change the cost structure to

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[2]In reality, more complex combinations are financed, even though these two categories already capture certain important features of the existing payment schemes made possible under the CAP.

[3]The psychological literature has already analysed the role of pro-environmental individual behaviors (Stern, 2000). Following Zelezny and Schultz (2000) we refer to environmental consciousness as a specific psychological factor related to the propensity to engage in pro-environmental behaviors.

[4]The assumption of preferences' formation within families of farmers strongly reflects the characteristics of the farming system in European Union. Data from Eurostat (2016) show that the vast majority of farms (96.2 % of 10.8 million farms in the EU-28 in 2013) are classified as family farms.

promote the emergence of a network of environmental intermediaries such as knowledge brokers. In the second (Section 3), instead of financing the intermediaries, the resources are transferred to local/regional governments which use their budgets to identify how many farmers are likely to adopt deep green measures and provides the knowledge advice through its own services. The advantage of this latter policy is that the farmers have complete information about the level of knowledge support that they will receive. Instead of depending upon an evolving population of knowledge brokers, this support is fixed in governmental policy. The disadvantage is that the local institution is not able to adjust the policy rapidly, which might lead to a low probability of having accurate knowledge about AEMs.

Our objective is to understand the difference between the equilibrium when a network of knowledge brokers is formed and when the local public authority itself takes on the task of targeting of AEMs. We then explore (Section 4) under which conditions the former is more effective than the latter in terms of diffusion of deep green agri-environment measures and of support for pro-environmental sensibility in the population. First we show that, not too surprisingly, relying on intermediaries is more effective in the case of poor knowledge of the farmers' characteristics, so that the presence of a network of environmental intermediaries is more desirable the lower is the probability that the public institution will be able to correctly match the environmental projects and farmers' profiles. Then we prove that the emergence of intermediaries is particularly valuable in the situation where initial farmers' preferences are not very eco-friendly. More precisely, we argue that the lower the initial environmental awareness the more likely it is that the emergence of a network of knowledge brokers will generate more environmental effectiveness in the long run compared to a command and control policy. In certain circumstances, developing the brokers' network can also be a way to escape "low environmental awareness traps" in which an inefficient low number of deep green projects are run; this situation can show up in the context of the more traditional compensations scheme. At the same time the brokers' network effectiveness is stronger the higher the (endogenous) number of intermediaries in the long run and the more frequent their interactions with farmers. As discussed in Section 4, these results comprise a theoretical counterpart to the empirical findings of Dedeurwaerdere et al. (2015) both in terms of the behaviors of the farmers and the effectiveness of the policies.

As already mentioned, this work is the first to model the dynamic relation between the emergence of knowledge-environmental intermediaries and the evolution of the willingness of farmers to make changes in their management practices. More generally, this paper is the first to bridge the knowledge-brokering theory developed in the literature on environmental science with the process of individual preferences' formation developed in the economics literature. The former (see for instance Shapin, 1998, Sverrisson, 2001, Meyer, 2010 and, in a slightly different context, Klerkx et al., 2012, Dedeurwaerdere et al., 2016) has mainly concentrated on the rise of knowledge brokers as a means to connect researchers and their various audiences, such as decision- and policy-makers. The objective of this literature has

been to study the role of knowledge brokers in facilitating the translation of research findings into policies (Pennell et al., 2013 and Klerkx et al., 2012). The latter was initiated adapting models of evolutionary biology to the transmission of cultural traits, Cavalli-Sforza and Feldman (1981), and extended to a dynamic economics context by Bisin and Verdier (2001). It has been applied to several contexts in the economic literature, such as for instance the evolution of ethnic traits (Bisin and Verdier, 2000, and Bisin et al., 2004), corruption (Hauk and Saez-Marti, 2002), social capital (Francois and Zabojnik, 2005), political ideology (Melindi-Ghidi, 2012), perceptions of pollution (Bezin, 2015), to name few. Connecting these two research areas opens the possibility of providing a dynamic theory of the emergence of knowledge-brokering activities within the agri-environment sector (in particular as regards the implementation of AEMs), and understanding the consequences of this process on the preferences of farmers as regards the environment - and, therefore, on the effectiveness of the policies put into practice.

The paper proceeds as follows: Section 2 develops the theoretical model concerning the scenario when a network of knowledge brokers promoting deep green AEMs emerges. Section 3 delves into the standard governance model, in which local public institutions autonomously decide which AEMs offer to farmers, without delegating some tasks to knowledge intermediaries, whether these be for better matching of payments or direct knowledge support to the farmers. Section 4 compares the two scenarios to shed light on the policy implications. Section 5 concludes. Proofs of the results are contained in Appendix A.

2 The Economy with Environmental Intermediaries

In this section we present a model which describes the situation where the policy maker decides to promote the emergence of a network of environmental intermediaries such as knowledge brokers, to which it partly delegates the implementation of policy.

We consider an infinitely lived economy in which there exists a public institution that has to allocate public funds through investment in agri-environment practices. At each period of time t, a unit measure of farmers is born. Each farmer voluntarily subscribes to agri-environmental measures (AEMs) and receives a monetary transfer for the provision of environmental services, such as protect and enhance the environment in their farmland. Farmers differ in therm of preferences for the environment. They can have pro-environmental preferences (e-type) or non-pro-environmental preferences (n-type). At time t a unit of environmental intermediaries is born as well. They live only for one period. The intermediaries liaise between the public institution and the farmer population. Their main role is to target agri-environment measures and therefore public transfers to farmers for

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investment in agri-environment practices, as well as to promote change in practice in the agricultural sector through advice and knowledge transfers. Environmental intermediaries can be thought of as businesses owned by non-profit organizations or social enterprises able to collect revenues for their members. They apply strategies to maximize the improvements in social and environmental well-being, rather than maximizing profits for external shareholders (see Subsection 2.5).

2.1   Light and Deep Green Agro-Environmental Measures

We assume that the public legislator (e.g. European Union) allocates an amount $x^b > 0$ of monetary resources to non-profit intermediaries with the objective to provide the knowledge support to implement certain agri-environment measures. These intermediaries are able to decide autonomously whether to offer support to farmers in the context of one of the two following direct payments: a deep green AEM (Project 1) or a light green AEM (Project 2). Project 1 generates a larger payment to the farmer than Project 2: $y_1 > y_2 > 0$.

The intermediaries specialize. We call *environmental knowledge brokers* all those social enterprises or intermediaries which secure the availability of knowledge for putting deep green environmental actions into practice and offering Projects of type 1 to farmers. Conversely, we call *environmental information providers* those that specialize in information provision for light green measures and which are able to offer only light green AEMs.[5]

The potential environmental impact of a light green AEM is marginal with respect to a deep green AEM, so we can suppose, rather approximately, that its environmental impact is independent of the effort of the farmer, and concentrate our attention on the conditions for the correct implementation of deep green AEMs. A deep green AEM is successfully implemented only if farmers actively participate in making sufficient investment for the realization of an agri-environment measure (thus in this way reducing their monetary outcome).

In the model the characteristics of the farmers are private, so the intermediary cannot know ex-ante if they will induce a specific farmer to provide the necessary effort to implement a deep green AEM; moreover, once a knowledge broker proposes a Project of type 1 to a farmer, she cannot control the farmer's actions any longer, and in particular she cannot oblige him to make the effort. In fact, in the model the only stimulus to make the effort will come from the possibly pro-environmental preferences of the farmers. This will explained in detail in Subsection 2.4, but for the sake of clarity it is worth knowing now that, in the model, a farmer targeted with a Project of type 1 will make the necessary effort in terms of investment if and only if she is pro-environmental (*e*-type). This behavior is consistent with the

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[5]In the remainder of the paper we designate the environmental knowledge brokers as "knowledge brokers" and the environmental information providers as "information providers".

empirical evidence in the environmental science literature, which suggests that pro-environmental farmers make bigger efforts when implementing agricultural practices (see for instance Thompson et al., 2015).

2.2 The Implementation Cost of the Measures

The total implementation cost of a Project of type i, with $i \in \{1,2\}$ is the sum of the implementation costs faced by intermediaries, such as provision of knowledge or information, and the implementation costs faced by farmers, such as learning, to efficiently realize the measure. The farmers (but not the intermediaries) who do provide the necessary effort will need to face a supplementary cost (independent of the formation and learning process) as explained in detail in Subsection 2.4.

Implementation costs are shared between intermediaries and farmers, with β (respectively $1 - \beta$) being the exogenous share of total implementation costs supported by the intermediary (respectively farmer) necessary to implement a specific type of AEM.[6]

For the sake of analytical tractability, we normalize implementation costs for light green AEMs to zero because the costs for implementing deep green AEMs are larger by definition. Total implementation costs for the realization of a deep green AEM are endogenously determined and positively depend on the share b_t of knowledge brokers in the economy, $s[b_t]$. The reason for the endogenous and increasing costs comes from the observation that the targeting of a green deep AEM becomes more difficult the larger is the number of knowledge brokers in the economy, when the obvious candidates have already been identified by other intermediaries. Put differently, the price of a single interaction increases with the decreasing opportunities of correctly targeting the measure.[7] More precisely, we assume that $s[b_t] \geq 0$, $s[0] = 0$, $s'[b_t] > 0$, $s''[b_t] \geq 0$. The implementation costs of a deep green AEM as faced by knowledge brokers at time t is then $d[b_t] = \beta s[b_t]$. Note that $d[1] > d[0]$ are respectively the higher and the lower bound of the deep green AEM brokers' cost function $d[b_t]$.

2.3 The Pay-off of the Environmental Intermediaries

As already noted, each intermediary receives the same monetary transfer x^b to realize the implementation of a particular AEM. We assume monetary transfers cannot be lower than the implementation expenses of the knowledge brokers. More

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[6]In reality, parameter β is decided through a bargaining process between the intermediary and the farmer. We assume exogeneity because this bargaining process is not the focus of interest of this paper.

[7]Alternatively, increasing costs could be thought of as the consequence of the increased competition in the market that reduces the probability, given the size of pro-environmental farmers in the population, of realizing a green interaction.

precisely, we suppose that the monetary transfer equals the total maximum expenses necessary for the implementation of a deep green AEM, that is when the knowledge costs are at the upper bound (i.e. when all intermediaries offer Project 1): $x^b = y_1 + \beta s^u$ with $s^u = s[1]$. Therefore, the material payoff for a knowledge broker is equal to zero if all intermediaries offer a deep green AEM, while it is strictly positive otherwise. This is a reasonable assumption since the pay-off of each intermediary can be interpreted as payments for knowledge or information activities.

When a knowledge broker is able to target a deep green AEM to a farmer who will provide the necessary investment effort to realize the measure, the implementation will be successful and a positive social-environmental return for having reached his objectives is generated. This return, $\psi > 0$, is the 'environmental effectiveness' achieved by intermediaries and institutions when a deep green AEM is correctly implemented. In our model, light green AEMs would generate a much less significant social-environmental return since, by definition, these measures are not able to provide substantial social environmental benefit. For simplicity of the model, we fix the return to zero in the case of implementation of light environmental measures.

We denote by π_1 and π_2 the intermediary's return of a single interaction with a farmer respectively when a Project 1 and a Project 2 is proposed. From what we said above, we have $\pi_1 = x^b - y_1 - \beta s[b_t] + \chi\psi$ and $\pi_2 = x^b - y_2$ where the parameter χ takes the value of 1 (respectively, 0) if the farmer decides (respectively, not) to make the investment effort. Observe that the described form of the return formalizes our assumption that intermediaries are non-profit social enterprises. Indeed, intermediaries will try to maximize a payoff where a social utility term $\chi\psi$ appears, so that they are not profit-maximizers but their purpose is also to achieve environmental goals.

Assumption 1. *The social return generated by the environmental effectiveness of a successful implementation of a deep green AEM is sufficiently high: $\psi > \Delta y + \beta s^u$, with $s^u = s[1]$ and $\Delta y = y_1 - y_2$.*

If Assumption 1 holds, deep green AEMs implemented by a farmer who makes the necessary investment effort yield higher expected returns to intermediaries than light green AEMs.

2.4 Farmers' Preferences

The pecuniary payoff for each farmer is produced through a match with an intermediary offering one of the two AEMs. This match is random and works as follows: at each time t, with probability b_t a farmer receives from a knowledge broker support for a deep green AEM. With probability $(1 - b_t)$ a farmer is matched with an information provider offering a light green AEM. More precisely, the monetary payoff of a farmer equals the difference between the direct payments received for implementing an agri-environment practice and the costs of putting the measure into practice,

that is $\lambda_r = y_r - \chi k_r$, with k_r defining the operational cost of the project $r = (1, 2)$ to be supported by the farmers and χ taking the value of 1 (respectively, 0) if the farmer decides (respectively, not) to make the investment effort.[8]

The operational costs of a Project of type 1 is the sum of some fixed costs and the share of the implementation costs (learning) supported by farmers correctly realizing a deep green AEM: $k_1 \equiv k_1[b_t] = \bar{k}_1 + (1 - \beta)s[b_t]$, with $\bar{k}_1 > 0$ the fixed cost. Since by the hypotheses of our stylized model, the implementation of a light green AEM does not require any investments in knowledge, learning or change in practice by farmers, the cost for the farmers correctly implementing a light green AEM is simply $\bar{k}_2 > 0$. Considering that the realization of a deep green AEM necessarily requires higher fixed initial investments for the farmer, we suppose $\bar{k}_1 > \bar{k}_2$.

As for knowledge intermediaries, farmers' well-being does not only depend on pecuniary payments or monetary costs. More precisely, we assume that farmers with pro-environmental preferences (i.e. e-type) suffer from behaving as non-pro-environmental: e-type farmers enjoy behaving as pro-environmental since they are endowed with an "environmental consciousness" which generates a non-pecuniary psychological loss, $\gamma > 0$, when behaving non-pro-environmentally.[9] Tables 1 and 2 show the utility matrix for e-type and n-type agents.

Table 1: Utility of an e-type farmer

Type/Project	Project 1 (deep green AEM)	Project 2 (light green AEM)
pro-environmental	$y_1 - k_1[b_t]$	$y_2 - \bar{k}_2$
non-pro-environmental	$y_1 - \gamma$	$y_2 - \gamma$

Table 2: Utility of an n-type farmer

Type/Project	Project 1 (deep green AEM)	Project 2 (light green AEM)
pro-environmental	$y_1 - k_1[b_t]$	$y_2 - \bar{k}_2$
non-pro-environmental	y_1	y_2

As we can observe from Table 2, an n-type farmer will never behave pro-environmentally. However, neither the institution nor the intermediary are able

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[8]Note that the budget constraint of farmer i is given by the direct payment received by the intermediary; $y_r = y_1$ if $r = 1$ and $y_r = y_2$ if $r = 2$.

[9]This intrinsic parameter is a fundamental component of many individuals' utility and it has already been recognized in the socio-psychological and socio-economic literature. See, for instance, Schlegelmilch et al. (1996), Mainieri et al. (1997) Lubell (2002), Ferrara and Serret (2008), Fourcade (2011), García-Valiñas et al. (2012).

to observe the cultural traits of the farmer *ex-ante*. This lack of information creates a moral hazard problem, because farmers have more information about their own rational behavior. Thus, in the eyes of the intermediary, the uncertainty over the cultural trait remains because environmental consciousness generates a psychological utility loss to pro-environmental farmers behaving non pro-environmentally.

We now introduce an assumption which guarantees that, as claimed above, a farmer in the model will make the necessary investment for the AEM if and only if she is pro-environmental (*e*-type).

Assumption 2. *The environmental consciousness of the pro-environmental farmer is such that: $\gamma > max\{k_1^u; \bar{k}_2\}$, with $k_1^u = \bar{k}_1 + (1 - \beta)s[1]$.*

Assumption 2 guarantees that the dominant strategy for *e*-type agents is to always act pro-environmentally. It requires that the potential loss γ, measured in the utility metric, for *e*-type agents is larger than the maximum cost of behaving pro-environmentally when implementing the project. Note that k_1^u defines the upper bound of the total operational costs for the pro-environmental farmer implementing Project 1.

2.5 The Behavior of Non-profit Environmental Intermediaries

It is reasonable to assume that environmental intermediaries know the approximate preference distribution in the population, that is the share of pro-environmental farmers q_t in the population. However, as already remarked above, since cultural traits and preferences are not observable, they do not know the preference of any specific farmer so they cannot know in advance the type of farmer they will face.

As already recalled the single return of Project 1 is $\pi_1 = x^b - y_1 - \beta s[b_t] + \chi \psi$. The parameter $\chi \in \{0, 1\}$, and thus the return, depends on the farmer matched: the latter is equal to $\pi_1^e = x^b - y_1 - \beta s[b_t] + \psi$ if the knowledge broker matches a pro-environmental farmer, and to $\pi_1^n = x^b - y_1 - \beta s[b_t]$ if a non-pro-environmental farmer is targeted. The expected return of Project 1 to a knowledge broker is then given by $\Pi_1[b_t] = q_t \pi_1^e + (1 - q_t)\pi_1^n$. Conversely, the return to an information provider is independent from the type of agent matched, $\pi_2 = x^b - y_2$, so that the expected return equals the monetary pay-off $\Pi_2 = \pi_2$.

We borrow from the theoretical contribution on trust and social capital of François and Zabojnik (2005) the assumption for which producers adjust instantaneously to changes in the economy. Reasonably, we suppose that socio-economic opportunities allow intermediaries to change their behavior relatively quickly compared to the speed at which inherent cultural traits change, so that the evolution of preferences in the farmer population adjusts relatively slowly relative to the adjustment of the behavior of intermediaries in the agri-environment scheme (i.e. their decision to spe-

cialize and become 'knowledge brokers' or 'information providers'). More formally, we suppose that b_t adjusts to the level of q_t: when pro-environmental farmers are numerous, the production of environmental effectiveness, ψ, is more probable, so that more intermediaries have incentives to change their specialization and to offer a deep green AEM. More formally, when $\Pi^b[b_t] \equiv \Pi_1[b_t] - \Pi_2 = q_t\psi - (\beta s[b_t] + \Delta y) > 0$, some intermediaries have an incentive to become 'knowledge brokers' and offer Project 1 rather than remaining 'information providers' and offering Project 2. Conversely, when $\Pi^b[b_t] < 0$ the costs of targeting pro-environmental farmers and offering Project 1 are relatively large, and therefore some knowledge brokers find it profitable to switch to being information providers and offer Project 2 rather Project 1. Only when $\Pi^b[b_t] = 0$ does each intermediary have no incentive to change strategy so the share adjusts as follows:[10]

$$b_t = g[q_t] \equiv \begin{cases} 0 & \text{if } (q_t\psi - \Delta y)/\beta < s[0] \\ s^{-1}[(q_t\psi - \Delta y)/\beta] & \text{if } (q_t\psi - \Delta y)/\beta \in [s[0], s[1]] \\ 1 & \text{if } (q_t\psi - \Delta y)/\beta > s[1]. \end{cases} \quad (1)$$

Remark that, interestingly enough, if any intermediary finds it profitable to offer Project 2, then the social network of knowledge brokers will be not formed. The highest value of q_t that entails the non-formation of the social network of knowledge brokers (that is, the highest value of q_t that corresponds to $b_t = 0$ in (1)) is given by $q^0 = \frac{\Delta y + \beta s[0]}{\psi}$. Conversely, the lower value of q_t in which all intermediaries decide to offer Project 1 is given by $q^1 = \frac{\Delta y + \beta s[1]}{\psi}$. Notice that, by Assumption 1, both q^0 and q^1 belong to $]0, 1[$.

In order to understand the dynamic proprieties of our economy, as well as to characterize the possible steady states, we have to analyze the socialization mechanism that governs the evolutionary forces in the population of farmers and, therefore, to consider family behavior as regards whether or not to protect their own cultural trait.

2.6 Education Choice and the Cultural Evolution of Preferences

In this section we explain how the process of the determination of individual traits works, drawing from the mechanism of cultural transmission introduced by Cavalli-Sforza and Feldman (1981) and first formalized in the economics literature by Bisin and Verdier (1998). We assume that reproduction is asexual and there is a one-for-one reproduction in a constant population of farmers. As explained in the introduction, the assumption of preferences' transmission within families of farmers reflects the characteristics of the farming system in European Union in which the vast majority of farms (96.2 % in 2013) are classified as family farms. For

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[10]Observe that s^{-1}, the inverse of the function s, in the second line of (1) is well defined since s is strictly increasing in the interval $[s[0], s[1]]$.

the sake of analytical tractability, we assume that each farmer has only one child that becomes active in the next period and participates in the implementation of some AEMs. Hence, the total farmer population is stationary. Individuals differ in terms of preferences for the environment that are transmitted between generations through a stochastic socialization process. In particular, an individual exhibits one of two types of preferences: either 'pro-environmental' or 'non-pro-environmental', as discussed previously.

Children are born naïve and are subject to a process of socialization that determines their type of preferences. The education process works as follows: parents educate their children to have the same preferences as themselves by making certain education efforts (also equal to the probability of successfully transmitting their cultural traits) τ_t^i with $i \in \{e, n\}$: e pro-environmental and n non-pro-environmental. If parents fail to educate their children to their trait, an indirect socialization mechanism occurs so that, with probability $1 - \tau_t^i$, children's traits will be determined by imitating a random adult outside the family. If we denote by p_t^{ij} the probability that a child of parent i will adopt the trait j we can thus write the transition probabilities as follows:

$$p_t^{ee} = \tau_t^e + (1 - \tau^e)q_t; \quad p_t^{en} = (1 - \tau^e)(1 - q_t); \tag{2}$$

$$p_t^{nn} = \tau_t^n + (1 - \tau^n)(1 - q_t); \quad p_t^{ne} = (1 - \tau^n)q_t. \tag{3}$$

The expected utility at time t of an i-type parent having a j-type child, V^{ij}, depends on both the type and the matching outcome of the child, but also on the probability b_t of matching a knowledge broker willing to implement a deep green AEM. Its formal expression is given by $V^{ij}[b_t] = b_t V_1^{ij} + (1 - b_t)V_2^{ij}$ with $(i, j) \in \{e, n\}$ and $(1, 2)$ the project offered by the intermediary. The values of V_1^{ij} and V_2^{ij} are given in Tables 1 and 2. We work under the assumption of *imperfect empathy* and, therefore, parents evaluate the expected lifetime utilities that their children would obtain by using their own preferences, that is by using their own utility matrix.

Assume that education effort τ_t^i is costly and denote by $C(\tau^i)$ the (supposed) increasing and concave cost functions, and suppose that each individual chooses $\tau_t^i \in]0, 1]$ to solve the following maximization problem:

$$max_{\tau^i} \quad \left(p_t^{ii} V^{ii}[b_t] + p_t^{ij} V^{ij}[b_t] - C(\tau_t^i) \right). \tag{4}$$

Maximizing (4) with respect to τ^i leads to the well-known first-order condition of cultural transmission:

$$C'(\tau_t^i) = \frac{\partial p_t^{ii}}{\partial \tau_t^i} V^{ii}[b_t] + \frac{\partial p_t^{ij}}{\partial \tau_t^i} V^{ij}[b_t]. \tag{5}$$

We will concentrate on the case $C(\tau) = \frac{1}{2}\tau^2$, which is the simplest cost structure that satisfies the three conditions mentioned above and is often used as a benchmark

in the literature. In this case the previous equation gives

$$\begin{cases} \tau_t^e[q_t, V^{ee}[b_t] - V^{en}[b_t]] = (1 - q_t)(V^{ee}[b_t] - V^{en}[b_t]) \\ \tau_t^n[q_t, V^{nn}[b_t] - V^{ne}[b_t]] = q_t(V^{nn}[b_t] - V^{ne}[b_t]), \end{cases} \tag{6}$$

so that, as expected, the dynamics of cultural trait critically depends on the probability of matching a knowledge broker offering Project 1 rather than an information provider offering Project 2.

Observe that in our model direct vertical socialization and oblique socialization are cultural substitutes when utility is evaluated using parents' preferences. If Assumption 2 holds, using the utility functions for e-type and n-type agents, we can show that, independently from the project offered by the intermediary, all parents always have an incentive to socialize their children to their own preferences, i.e. $V^{ii} > V^{ij}$.

Using the utility matrix in Tables 1 and 2, we can derive the optimal education effort for both e-type and n-type parents. Observe that $V^{ee}[b_t] - V^{en}[b_t] = \gamma - b_t(\bar{k}_1 + (1 - \beta)s[b_t]) - (1 - b_t)\bar{k}_2 > 0$ and $V^{nn}[b_t] - V^{ne}[b_t] = b_t(\bar{k}_1 + (1 - \beta)s[b_t]) + (1 - b_t)\bar{k}_2 > 0$. Using equations (6), we obtain $\frac{\partial \tau^e}{\partial q_t} = -(V^{ee}[b_t] - V^{en}[b_t]) < 0$ and $\frac{\partial \tau^n}{\partial q_t} = V^{nn}[b_t] - V^{ne}[b_t] > 0$. These facts imply that both types of parent have less incentive to socialize their children to their own trait, the larger is the size of their type in the population. The reason is quite intuitive: the larger q_t is, the better children are socialized to the pro-environmental trait in the social environment. Conversely, the socialization effort chosen by non-pro-environmental parents, τ^n, increases with q_t.

Notice that the direction of evolutionary change depends on the sign of the difference $\tau^e - \tau^n$. If the socialization effort of a type-e (type-n) parent exceeds that of a parent of different type, cultural transmission promotes an increase in type-e (type-n).

In discrete time, the difference equation describing how traits evolve in time is a simple version of replicator dynamics in evolutionary biology for a two-trait population, and it crucially depends on the socialization efforts of different parents. Indeed, from (2) and (3) we get:[11]

$$q_{t+1} - q_t = q_t(1 - q_t)(\tau^e[q_t, V^{ee}[b_t] - V^{en}[b_t]] - \tau^n[q_t, V^{nn}[b_t] - V^{ne}[b_t]]). \tag{7}$$

As in standard evolutionary models we will concentrate on the continuous time limit version of this dynamic, namely

$$\frac{dq_t}{dt} = q_t(1 - q_t)(\tau^e[q_t, V^{ee}[b_t] - V^{en}[b_t]] - \tau^n[q_t, V^{nn}[b_t] - V^{ne}[b_t]]). \tag{8}$$

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[11]Observe that $q_{t+1} = q_t p_t^{ee} + (1 - q_t)p_t^{ne} = q_t(\tau_t^e(1 - q_t) + q_t) + (1 - q_t)(\tau_t^n + q_t)$.

Substituting (6) and then the expected utility functions of e-type and n-type individuals into (8) we derive:

$$\frac{dq_t}{dt} = q_t(1 - q_t)[\gamma(1 - q_t) - b_t(\bar{k}_1 + (1 - \beta)s[b_t]) - (1 - b_t)\bar{k}_2]. \qquad (9)$$

The above differential equation describes the motion of q_t in the population. It depends on the educational behavior of parents of the different traits. It is reasonable to concentrate only on the scenario in which one of the two traits is not always selected irrespective of the environment. In other words, in line with the theory developed in Bisin and Verdier (2001), we need to exclude choices of the parameters in which one trait culturally dominates, that is $\tau_t^e > \tau_t^n$ or $\tau_t^e < \tau_t^n$ for all $t \geq 0$. For this reason we introduce the following assumption.

Assumption 3. *Evolutionary forces are such that no cultural trait is dominant:*

$$1 - \frac{\Delta y}{\phi} > \frac{\bar{k}_2}{\gamma} \qquad and \qquad 1 - \frac{\Delta y + \beta s[1]}{\phi} < \frac{\bar{k}_1 + (1 - \beta)s[1]}{\gamma}.$$

The first of the two conditions in Assumption 3 guarantees that, if the knowledge and learning costs of Project 1 are at the lower bound, i.e. $b_t = 0$, then evolutionary forces will promote the pro-environmental trait (see the proof of Proposition 1 for details). Conversely, if the implementation costs of Project 1 reach the maximum, that is $b_t = 1$, then the second condition implies that the socialization effort of non-pro-environmental parents will be stronger than the effort of pro-environmental parents. Therefore, depending on the dynamics of the network of knowledge brokers, b_t, and on the total implementation cost function, $s[b_t]$, evolutionary forces might or might not promote the pro-environmental trait in the population.

The relation (9) together with (1) gives

$$\frac{dq_t}{dt} = q_t(1 - q_t)[\gamma(1 - q_t) - g[q_t](\bar{k}_1 + (1 - \beta)s[g[q_t]]) - (1 - g[q_t])\bar{k}_2]. \qquad (10)$$

2.7 Dynamics

The dynamic proprieties of our economy can be analyzed by studying the solutions to (10). The direction of the evolutionary dynamics will depend on both the role of knowledge brokers in the implementation processes of deep green AEMs and the socialization effort of parents within families.

Proposition 1. *Suppose that Assumptions 1, 2 and 3 are satisfied. Then (10) admits a unique interior steady state $\bar{q}^b$, and it is asymptotically stable. In other terms, for any initial condition $q_0 \in]0, 1[$, q_t converges to $\bar{q}^b$ when t goes to infinity. In the steady state $\bar{q}^b$ a network of knowledge brokers of size $\bar{b}^b \in]0, 1[$ is formed.*

14

Proof. See Appendix A for the formal proof, and Figure 1 for the graphical representation of the dynamics. $\qquad\square$

Figure 1: Phase diagram: internal solution
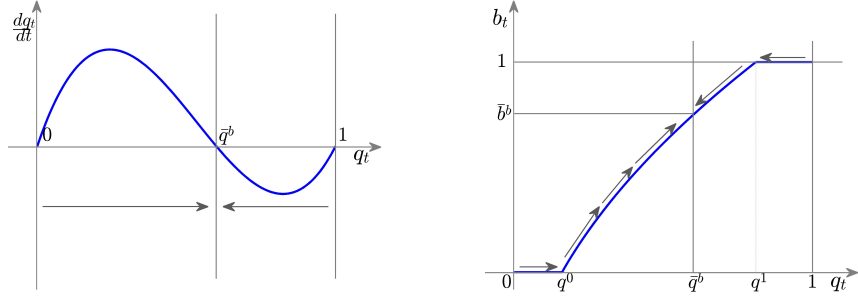
As remarked in the proposition, at the stable steady state $\bar{q}^b$, a network of knowledge brokers of size $\bar{b}^b \in]0, 1[$ is formed. This network provides evolutionary incentives for having a share of pro-environmental agents equal to

$$\bar{q}^b = \frac{\gamma - \bar{b}^b((1-\beta)s[\bar{b}^b] + \bar{k}_1) - \bar{k}_2(1-\bar{b}^b)}{\gamma} \in]0, 1[.$$

If, for instance, at time $t = 0$ the economy is characterized by a low share of knowledge brokers and b_0 is below its steady state level $\bar{b}^b$, then knowledge and learning costs are relatively low. Since the targeting of a pro-environmental farmer is more likely, we will observe an increase in the share of knowledge brokers, which stimulates the promotion of the environmental culture in the next generation. Even though knowledge and learning costs tend to increase when a larger share of intermediaries offer Project 1, evolutionary forces will tend to promote the environmental trait and the willingness to implement green deep AEMs in the population.

However, even in the presence of a large share of pro-environmental agents at time $t = 0$, if $b_0 > \bar{b}^b$, some intermediaries will find it profitable to avoid investment in the implementation of deep green AEMs. The reason is that in the presence of a large share of knowledge brokers, the targeting of this measure is more difficult and the costs of implementation of a deep green AEM are high. Therefore, some intermediaries will offer Project 2 in the next period rather than Project 1. The decreasing presence of knowledge brokers in the economy will reduce the share of effort-making pro-environmental parents as regards the protection of the pro-environmental trait. Because of these two opposing tendencies we observe an equilibrium position where the increase in learning costs for getting the remaining farmers on board exceeds the societal benefits that can be attained and claimed by the knowledge brokers.

15

Two more (non-interior) steady states appear in the dynamics: the two boundary points $q = 0$ and $q = 1$ which correspond to the two trivial situations where, respectively, all of the farmer population is of type n or of type e. Of course, when all the farmers are of the same type neither the direct nor the indirect socialization mechanism can cause deviation from the norm and we have a steady state. Still, neither of these two steady states is stable, and as soon as the initial condition of the system is perturbed, the dynamics will converge to the unique stable steady state $\bar{q}^b$.

3 The Command and Control Policy

The emergence of knowledge brokers in the process of implementation of deep green AEMs might have important effects on the policy choices of the public authorities, as well as on the long-run evolution of pro-environmental preferences in the population. If a public institution aims to promote a pro-environmental culture, it has to take into account the effects that the presence of a network of knowledge brokers can have on the family socialization process and, therefore, on the evolution of cultural traits. The standard scenario alternative to the scheme in which intermediaries have an active role in targeting the payment scheme, is to transfer resources to local public authorities which directly pay farmers for the implementation of AEMs, without knowledge support. To model this schema, known as a 'command and control policy' we develop a standard principal–agent model where farmers' payoffs are still produced through a random matching process, in which at each time t every farmer is matched with a new public institution. We assume that in each period of time the local public institution has to assign a particular agricultural environmental project to the farmer she is randomly matched with.

The first difference from an economy with non-profit intermediaries, is that the public legislator does not have to invest resources in knowledge activities. The second difference is that the process of targeting the deep *versus* light AEMs on the part of the knowledge intermediaries, and, therefore, the instantaneous adjustment in the intermediary market, does not apply in this scenario.[12] It remains to be seen whether these differences lead to a substantial difference in environmental effectiveness, which is the object of our analysis.[13]

We assume that in a command and control policy scenario, the local public institution receives from the public legislator (e.g. European Union) a fixed amount of resources equal to x^c for the implementation of any project. Reasonably, we

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[12] This argument follows from the fact that there is no information leakage across principals. In a command and control policy scheme, local authorities do not invest resources in targeting pro-environmental farmers within the population, so that they are not able to adjust instantaneously to changes in cultural traits.

[13] As in the previous section, the cost of Project 2 is supposed to be zero and it cannot generate any social return in the form of environmental effectiveness.

also assume that the local public institution knows the distribution of traits in the population, q_t, and that Assumption 2 still holds in the presence of exogenous operational costs for pro-environmental farmers, that is $k_1[0] = \bar{k}_1$.[14] It follows that a pro-environmental agent will be never revealed as non-pro-environmental. However, the uncertainty over the non-pro-environmental agent remains, because the material pay-off of behaving pro-environmentally is exactly the same for both type of farmers (see Tables 1 and 2 considering exogenous costs $\bar{k}_1$). Therefore, an agency problem persists due to the asymmetric information between farmers and the public institution. Following Hauk and Saez-Marti (2002), we suppose that the local institution can know if the type of the farmer that she will match is non-pro-environmental only with exogenous positive probability, $\phi > 0$. As in the previous section, Project 1 yields a higher return than Project 2 if the former project is offered to a pro-environmental agent through the production of environmental effectiveness, $\psi > \Delta y$. However, in this scenario it is the local public institution that directly manages the targeting of the agri-environment payments. Thus the social returns which we defined in the previous section are attained by the public institution if such a match is realized.

Potentially, public authorities can adopt one of the following strategies: a pooling strategy or a separating strategy. A pooling strategy implies that either Project 1 or Project 2 are offered to all the farmers within the population. A separating strategy consists in offering a deep green AEM to seemingly pro-environmental farmers, and a light green AEM to farmers who are discovered with probability ϕ to be non-pro-environmental, assuming that the dominant strategy of potentially non-pro-environmental farmers is to behave non-pro-environmentally, that is $0 < \phi < \frac{\bar{k}_1}{\Delta y}$.[15] For Project 1, the public institution's return from a single match is $\pi_1 = x^c - y_1 + \chi\psi$, with $\chi = 1$ (respectively $\chi = 0$) if the agent matched has pro-environmental (respectively non-pro-environmental) preferences for Project 1, while, for Project 2, $\pi_2 = x^c - y_2$. We denote by $\pi_1^e = x^c - y_1 + \psi$ and $\pi_1^n = x^c - y_1$ the return under Project 1 if the agent matched is respectively pro-environmental or non-pro-environmental. The expected aggregate returns of the pooling strategy of offering Project 1 and Project 2 are, respectively, $\Pi_1^p = q_t\pi_1^e + (1 - q_t)\pi_1^n$ and $\Pi_2^p = \pi_2$ while the expected aggregate return of the separating strategy is $\Pi^s = q_t\pi_1^e + \phi(1 - q_t)\pi_2 + (1 - \phi)(1 - q_t)\pi_1^n$.

We can easily observe that the pooling strategy of offering Project 1 will be never chosen by rational institutions who maximize the aggregate expected return and can recognize with probability $\phi > 0$ whether the agent matched has a non-pro-environmental trait. Indeed, $\Pi^s > \Pi_1^p$ for all $q \in]0, 1[$.

Comparing Π^s with Π_2^p we can derive the threshold that determines the optimal strategy of the principal in each period of time t. Indeed, the institution will

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[14]Since implementation costs are zero when the public institution directly offers Project 1, $s[0] = 0$.

[15]Throughout the paper we will consider this parameter restriction. The same argument can be found in Hauk and Saez-Marti (2002).

implement a separating strategy if the share of pro-environmental agents at time t is sufficiently high: $\frac{(1-\phi)(y_1-y_2)}{\psi-\phi(y_1-y_2)} < q_t < 1$. Define $\tilde{q}[\phi] \equiv \frac{(1-\phi)(y_1-y_2)}{\psi-\phi(y_1-y_2)}$. The institution can change strategy over time, depending on the evolution of cultural traits in the population as well as parents' socialization efforts within the family. More precisely, if at time t the share of pro-environmental agents is sufficiently high, $q_t > \tilde{q}[\phi]$, it will offer a separating strategy. If it is not the case, that is $\tilde{q}[\phi] > q_t$, the public institution will find it optimal to offer a light green AEM to all the agents in the population.

In order to characterize the steady state of this economy, we have to take into account that the parents' behavior in the socialization process depends on the decision taken by the public institution. We denote the principal's strategy at time t by $\sigma_t^l \in \{\sigma^s, \sigma^p\}$, where σ^s is the choice of the separating strategy while σ^p denotes the pooling strategy, i.e. offering Project 2 to all agents. We denote by $V^{ij}[E[\sigma_t^l]]$ the expected utility of a parent of type i having a child of type j.[16] The optimal education effort of both types of parents is a function of the strategy decided by the principals: $\tau_t^i = \tau[q_t, V^{ii}[E[\sigma_t^l]] - V^{ij}[[\sigma_t^l]]]$. As in the previous section, we assume that imperfect empathy holds, education effort τ_t^i is costly, and socialization costs are given by $C(\tau^i) = \frac{1}{2}\tau^{i^2}$. Re-adapting equations (5)-(6) and (8)-(9) to this standard principal-agent scenario, after some algebraical manipulation, we derive the usual trivial steady states $\bar{q} = 0$, $\bar{q} = 1$ and two new non-trivial steady states: the first, $\bar{q}^s = 1 - \frac{\bar{k}_1 - \phi(\Delta y)}{\gamma}$, arises if a separating strategy is implemented in the long run while the second, $\bar{q}^p = 1 - \frac{\bar{k}_2}{\gamma}$, is the result of the strategy of long-run pooling of Project 2. If $\phi > \frac{\bar{k}_1 - \bar{k}_2}{\Delta y}$, the steady state under the separating strategy is larger than the steady state under the pooling strategy: $\bar{q}^s > \bar{q}^p$.

Assumption 4. *The probability of recognizing a non-pro-environmental farmer is such that $\frac{\bar{k}_1 - \bar{k}_2}{\Delta y} < \phi < \frac{\bar{k}_1}{\Delta y}$.*

Proposition 2. *Under Assumption 4, a command and control policy exhibits the following dynamic properties:*

(i) *if $\tilde{q}[\phi] < \bar{q}^p$ then q_t converges to $\bar{q}^s$;*

(ii) *if $\tilde{q}[\phi] > \bar{q}^s$ then q_t converges to $\bar{q}^p$;*

(iii) *if $\bar{q}^p < \tilde{q}[\phi] < \bar{q}^s$, expectations are stationary and the long-run equilibrium depends on initial conditions:*

(iii.a) *q_t converges to $\bar{q}^s$ when $q_0 > \tilde{q}[\phi]$,*

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[16]For instance, the expected utilities at time t under the separating strategy are given by $V^{ee}[E[\sigma_t^s]] = V_1^{ee}$, $V^{en}[E[\sigma_t^s]] = \phi V_2^{en} + (1-\phi)V_1^{en}$, $V^{nn}[E[\sigma_t^s]] = \phi V_2^{nn} + (1-\phi)V_1^{nn}$, and $V^{ne}[E[\sigma_t^s]] = V_1^{ne}$. Using the utility matrix in Tables 1 and 2 we can derive the expected utilities V_r^{ij} with $r \in \{0; 1\}$ representing the project offered by the principal. The expected utilities when the public institutions offer a pooling strategy of Project 2 can be directly derived assuming constant operational costs.

(iii.b) q_t *converges to* $\bar{q}^p$ *when* $q_0 < \tilde{q}[\phi]$.

Proof. See Appendix A for the formal proof, and Figure 2 for a graphical representation of the dynamics. □

A similar dynamic can be found in the cultural transmission model of corruption set out by Hauk and Saez-Marti (2002) (cf. Proposition 1, p. 321). Notice that the threshold that determines the principal's behavior negatively depends on the probability of identifying a non-pro-environmental agent in the population, ϕ. When ϕ is low, the threshold $\tilde{q}[\phi]$ for the separating strategy is high. This scenario can be characterized by a situation in which, even in presence of a high initial share of pro-environmental farmers, the dynamics converges to the low pro-environmental steady state with pooling $\bar{q}^p$. The reason is quite intuitive: pro-environmental parents do not make strong efforts to educate their children to their own trait, because the reward of being non-pro-environmental rather than pro-environmental is larger, the lower is the probability of identifying the pro-environmental agents.

Figure 2: Dynamics: The Command and Control Policy
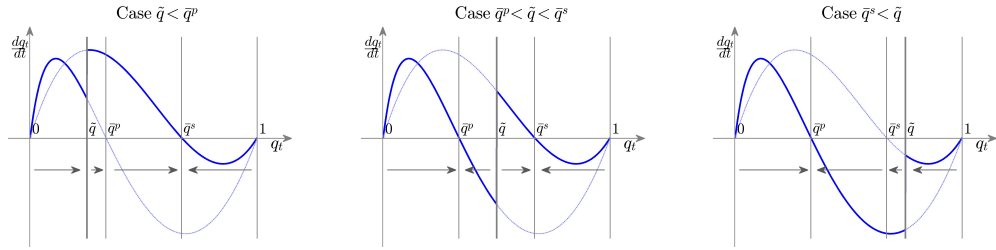
Notice that the command and control policy implies a different long-run equilibrium distribution of environmental preferences compared to the case in which knowledge brokers operate as intermediaries to implement the AEMs. We will compare the effects of the two in the next section.

4 The Emergence of Brokers' Networks *versus* Institutional Governance

The decision by the public legislator to stimulate the emergence of intermediaries rather than to use a more traditional direct subsidy scheme, is a matter of open debate and argument. One of the main controversies is related to the analysis of benefits and costs of these different policies. The presence of intermediaries might

require larger investments for the legislator, such as payments for the organisation of learning. However, the public institution might find it profitable to promote this governance mechanism if one of its main objectives is to seek the social benefits of environmental effectiveness and the promotion of a pro-environmental culture.

To compare the two policies we see what happens when the two per-project transfers x^b and x^c, and then the costs of the two policies, are the same. In this case the decision by the public legislator to adopt a command and control policy rather than investing extra resources to finance intermediaries, depends on the level of benefits generated by the environmental effectiveness of the implementation of deep green AEMs. We concentrate on the long-run share of pro-environmental agents and the long-run number of (per-period) successfully implanted deep green AEMs as measures of the total environmental effectiveness generated by different policies. We have the following result.

Proposition 3. *Suppose that Assumptions 1, 2, 3 and 4 are verified. Then*

(i) *The emergence of a network of knowledge brokers generates more environmental effectiveness in the long run compared to a command and control policy if and only if ϕ is smaller than a certain threshold Ψ. Moreover a change in the parameters that increases the level of $\bar{b}^b$ without affecting other fundamental values increases Ψ.*

(ii) *The lower the initial share q_0 of pro-environmental agents the more likely it is that the emergence of a network of knowledge brokers generates more environmental effectiveness in the long run compared to a command and control policy.*

Proof. See Appendix A. □

The first point of the proposition compares the efficiency of the two systems in terms of the capacity of promoting a pro-environmental culture and to support an higher number successfully implanted deep green AEMs. On the one hand, the parameter ϕ measures the probability, in the command and control context, of correctly matching a non-pro-environmental farmer with a light green project, so it measures the ability of the policy maker to know the preferences of the farmers. The higher the capability of the local public institution of itself correctly analyzing the context, the lower the requirement for external competences and experts like brokers. On the other hand, the system of intermediaries is more valuable if it is more extensive and diffused. In that situation, the number (or, equivalently, the share $\bar{b}^b$) of knowledge brokers working in the economy at the equilibrium will be higher as well. In other words, the higher the (long run) size $\bar{b}^b$ of the network of knowledge brokers, the higher the value of the threshold Ψ, so the easier it is for the network of knowledge brokers to generate more environmental effectiveness in the long run compared to a command and control policy. These results are

consistent with (and can justify) the empirical finding of Dedeurwaerdere et al. (2015) (Table 4) which shows that (i) governmental monitoring and (ii) network bridging organisations have a positive impact on the decisions of farmers to comply with deep/light green measures.

The second part of the proposition shows that the importance of promoting the development of a brokers' network is higher when the initial environmental awareness of the farmers is low, so the presence of the intermediaries can also be effective in "unblocking" the system. In this sense, we can indeed observe something more: in certain situations using the network of knowledge brokers can be a way to escape a certain low-equilibrium trap. This is the case for instance when $\bar{q}^p < \tilde{q} < \bar{q}^b < \bar{q}^s$ and $q_0 < \tilde{q}$. In this case the long-run value of q_t under the command and control policy is $\bar{q}^p$. By using the network of knowledge brokers the policy-maker can increase the level of q_t (at some time) and overtake the level $\tilde{q}$. Once this level is reached, restoring a command and control policy can bring the system in the long-run to the even higher level $\bar{q}^s$. In this respect, our findings are a possible theoretical justification of the empirical results of Dedeurwaerdere et al. (2015), which emphasize that the work of intermediaries is effective in convincing farmers to change their agri-environmental choices.

5   Conclusion

The development of a network of knowledge intermediaries plays an important role in many implementation mechanisms of the agro-environmental measures conceived under the EU Common agricultural Policy. The objective of these mechanisms is to better reallocate and target monetary resources to farmers for the implementation of deep green agri-environment measures.

In this paper we study the process of the emergence of the intermediaries' network, its interaction with the dynamics of the farmers' environmental preferences, and its impact on policy effectiveness. It is the first theoretical analysis to bridge the knowledge-brokering theory developed in environmental science with the process of transmission of individual preferences developed in the economics literature.

We compare the effect of a policy of sustaining knowledge brokers with a more traditional subsidy scheme where the local public institutions autonomously decide which kind of project to allocate to each farmer. We show that the emergence of intermediaries is particularly valuable in the situation of scarce knowledge of the farmers' characteristics and preferences, and of low initial environmental awareness. Developing the broker network can also be a way to escape certain "low equilibria" traps characterized by a low number of deep green projects being realized in the economy. Our theoretical results can provide theoretical support to existing empirical findings.

References

Bezin, E. (2015). A cultural model of private provision and the environment. *Journal of Environmental Economics and Management*, 71:109–124.

Bisin, A., Topa, G., and Verdier, T. (2004). Religious intermarriage and socialization in the united states. *Journal of political Economy*, 112(3):615–664.

Bisin, A. and Verdier, T. (1998). On the cultural transmission of preferences for social status. *Journal of Public Economics*, 70(1):75–97.

Bisin, A. and Verdier, T. (2000). Beyond the melting pot: cultural transmission, marriage, and the evolution of ethnic and religious traits. *The Quarterly Journal of Economics*, 115(3):955–988.

Bisin, A. and Verdier, T. (2001). The economics of cultural transmission and the dynamics of preferences. *Journal of Economic theory*, 97(2):298–319.

Cavalli-Sforza, L. L. and Feldman, M. W. (1981). *Cultural transmission and evolution: a quantitative approach*. Number 16. Princeton University Press.

Dedeurwaerdere, T., Admiraal, J., Beringer, A., Bonaiuto, F., Cicero, L., Fernandez-Wulff, P., Hagens, J., Hiedanpää, J., Knights, P., Molinario, E., et al. (2016). Combining internal and external motivations in multi-actor governance arrangements for biodiversity and ecosystem services. *Environmental Science & Policy*, 58:1–10.

Dedeurwaerdere, T., Polard, A., and Melindi-Ghidi, P. (2015). The role of network bridging organisations in compensation payments for agri-environmental services under the eu common agricultural policy. *Ecological Economics*, 119:24–38.

Eurostat (2016). Agriculture statistics - family farming in the eu - 2016. Technical report, Eurostat.

Ferrara, I. and Serret, Y. (2008). Household behaviour and the environment, reviewing the evidence. *Organization for Economic Cooperation and Development: Paris, France*, pages 153–180.

Fourcade, M. (2011). Price and prejudice: on economics, and the enchantment/disenchantment of nature. *The Worth of Goods*, pages 41–62.

Francois, P. and Zabojnik, J. (2005). Trust, social capital, and economic development. *Journal of the European Economic Association*, 3(1):51–94.

García-Valiñas, M. A., Macintyre, A., and Torgler, B. (2012). Volunteering, pro-environmental attitudes and norms. *The Journal of Socio-Economics*, 41(4):455–467.

Hauk, E. and Saez-Marti, M. (2002). On the cultural transmission of corruption. *Journal of Economic Theory*, 107(2):311–335.

Klerkx, L., Schut, M., Leeuwis, C., and Kilelu, C. (2012). Advances in knowledge brokering in the agricultural sector: towards innovation system facilitation. *IDS Bulletin*, 43(5):53–60.

Lubell, M. (2002). Environmental activism as collective action. *Environment and Behavior*, 34(4):431–454.

Mainieri, T., Barnett, E. G., Valdero, T. R., Unipan, J. B., and Oskamp, S. (1997). Green buying: The influence of environmental concern on consumer behavior. *The Journal of social psychology*, 137(2):189–204.

Melindi-Ghidi, P. (2012). A model of ideological transmission with endogenous parental preferences. *International Journal of Economic Theory*, 8(4):381–403.

Meyer, M. (2010). The rise of the knowledge broker. *Science communication*, 32(1):118–127.

Pennell, K. G., Thompson, M., Rice, J. W., Senier, L., Brown, P., and Suuberg, E. (2013). Bridging research and environmental regulatory processes: the role of knowledge brokers. *Environmental science & technology*, 47(21).

Schlegelmilch, B. B., Bohlen, G. M., and Diamantopoulos, A. (1996). The link between green purchasing decisions and measures of environmental consciousness. *European journal of marketing*, 30(5):35–55.

Shapin, S. (1998). Placing the view from nowhere: historical and sociological problems in the location of science. *Transactions of the Institute of British Geographers*, 23(1):5–12.

Stern, P. C. (2000). Towards a coherent theory of environmentally significant behavior, journal of social issues, 56.

Sverrisson, Á. (2001). Translation networks, knowledge brokers and novelty construction: Pragmatic environmentalism in sweden. *Acta Sociologica*, 44(4):313–327.

Thompson, A. W., Reimer, A., and Prokopy, L. S. (2015). Farmers views of the environment: the influence of competing attitude frames on landscape conservation efforts. *Agriculture and human values*, 32(3):385–399.

Vanslembrouck, I., Huylenbroeck, G., and Verbeke, W. (2002). Determinants of the willingness of belgian farmers to participate in agri-environmental measures. *Journal of agricultural economics*, 53(3):489–511.

Zelezny, L. C. and Schultz, P. (2000). Psychology of promoting environmentalism: promoting environmentalism. *Journal of Social Issues*, 56(3):365–371.

A Proofs

Proof of Proposition 1. Denote

$$q(1-q)\left(\gamma(1-q) - g[q](\bar{k}_1 + (1-\beta)s[g[q]]) - (1-g[q])\bar{k}_2\right).$$

by $F(q)$. The steady states of (10) are the values of q that satisfy the condition $F(q) = 0$. Two of these steady states are given by $q = 0$ and $q = 1$. Moreover, if we look at the expression $G(q) \equiv \left(\gamma(1-q) - g[q](\bar{k}_1 + (1-\beta)s[g[q]]) - (1-g[q])\bar{k}_2\right)$, we can easily see that:

(i) Its value is strictly positive in 0 (thanks to Assumption 2 and the fact that $g[0] = 0$)

(ii) Its value is strictly negative in 1 (recall that $g[1] = 1$)

(iii) It is strictly decreasing in the interval $[0,1]$. To see this fact we can rewrite the expression as $\left(\gamma(1-q) - g[q](\bar{k}_1 - \bar{k}_2) - (1-\beta)g[q]s[g[q]] - \bar{k}_2\right)$. Since g and s are increasing functions and $\bar{k}_1 > \bar{k}_2$ by hypothesis, each term of the previous expression is decreasing (and the first one strictly decreasing).

Since the expression is continuous we have a third steady state that is interior (and unique thanks to (iii)). We call this $\bar{q}^b$. Since $q(1-q)$ is always positive in $]0,1[$ the sign of the $F(q)$ only depends on the sign of $G(q)$ that, thanks to (i), (ii) and (iii) above, is strictly positive on $]0, \bar{q}^b[$ and strictly negative on $]\bar{q}^b, 1[$ so for any initial condition $q_0 \in]0,1[$ q_t converges to $\bar{q}^b$ when $t \to \infty$.

It only remains to prove that in the steady state $\bar{q}^b$ a network of knowledge brokers is formed, i.e. that $g[\bar{q}^b] > 0$. We will actually show that $g[\bar{q}^b] \in]0,1[$. To see this fact it is enough to check that $G(q^0) > 0$ and $G(q^1) < 0$, i.e. that $\gamma\left(1 - \frac{\Delta y}{\psi}\right) - \bar{k}_2 > 0$ and $\gamma\left(1 - \frac{\Delta y + \beta s[1]}{\psi}\right) - (\bar{k}_1 + (1-\beta)s[1]) < 0$. These conditions are verified thanks to Assumption 3. $\qquad\square$

Proof of Proposition 2. As in the case of the economy with knowledge brokers (Section 2), the dynamics of the system is given by

$$\frac{dq_t}{dt} = q_t(1-q_t)(\tau_t^e - \tau_t^n)$$

and it can be obtained in exactly the same way as (8). Since the cost function is given once more by $C(\tau) = \frac{1}{2}\tau^2$, we can get, as in (6),

$$\tau_t^e = (1-q_t)(V_t^{ee} - V_t^{en}) \qquad \text{and} \qquad \tau_t^n = q_t(V_t^{nn} - V_t^{ne}).$$

Using the utilities described in Tables 1 and 2 we can understanding the previous expressions respectively as the pooling strategy of offering Project 2 to all the agents and the separating case.

The pooling case. In this case we have $\tau_t^e = (1 - q_t)((y_2 - \bar{k}_2) - (y_2 - \gamma))$ and $\tau_t^n = q_t(y_2 - (y_2 - \bar{k}_2))$ and then

$$\frac{dq_t}{dt} = q_t(1 - q_t)((\gamma - \bar{k}_2) - \gamma q_t).$$

If we set the right hand side equal to zero we find the steady states of the system: the two trivial steady states 0 and 1 and $\bar{q}^p = 1 - \frac{\bar{k}_2}{\gamma}$ that is in $]0, 1[$ thanks to Assumption 2. The sign of the right hand side is positive for $q_t \in]0, \bar{q}^p[$ and negative for $q_t \in]\bar{q}^p, 1[$ so, if we consider the pure pooling case, q^p is an attractor for any initial datum $q_0 \in]0, 1[$.

The separating case. In this case we have $\tau_t^e = (1 - q_t)((y_1 - \bar{k}_1) - (\phi(y_2 - \gamma) + (1 - \phi)(y_1 - \gamma)))$ and $\tau_t^n = q_t((\phi y_2 + (1 - \phi)y_1) - (y_1 - \bar{k}_1))$ and then, after some computations,

$$\frac{dq_t}{dt} = q_t(1 - q_t)((\gamma - \bar{k}_1 + \phi(y_1 - y_2)) - \gamma q_t).$$

So we again find the two trivial steady states 0 and 1, and the third steady state $\bar{q}^s = 1 - \frac{\bar{k}_1 - \phi(y_1 - y_2)}{\gamma}$ that is smaller than 1 thanks to the second part of Assumption 4, and bigger than $\bar{q}^p$ thanks to the first part of the same assumption. Similar to what we had before, the sign of the right hand side of the previous equation is positive for $q_t \in]0, \bar{q}^s[$ and negative for $q_t \in]\bar{q}^s, 1[$, so, if we consider the pure separating case, $\bar{q}^s$ is an attractor for any initial datum $q_0 \in]0, 1[$.

The whole system. The entirety of the command and control policy dynamic is described by the following equation

$$\frac{dq_t}{dt} = h(q_t) := \begin{cases} q_t(1 - q_t)((\gamma - \bar{k}_2) - \gamma q_t) & \text{if } q_t < \tilde{q} \\ q_t(1 - q_t)((\gamma - \bar{k}_1 + \phi(y_1 - y_2)) - \gamma q_t) & \text{if } q_t \geq \tilde{q}. \end{cases}$$

There are three possible configurations of the system depending on the relative positions of $\bar{q}^p$, $\bar{q}^s$ and $\tilde{q}$ (see also Figure 2):

(i) $\tilde{q} < \bar{q}^p < \bar{q}^s$: in this case $h(q_t) > 0$ for any $q_t \in]0, \bar{q}^s[$ and $h(q_t) < 0$ for any $q_t \in]\bar{q}^s, 1[$ so that $\bar{q}^s$ is an attractor for initial datum $q_0 \in]0, 1[$.

(ii) $\bar{q}^p < \tilde{q} < \bar{q}^s$: in this case $h(q_t) > 0$ for $q_t \in]0, \bar{q}^b[$ and $q_t \in]\tilde{q}, \bar{q}^s[$ while $h(q_t) < 0$ for $q_t \in]\bar{q}^p, \tilde{q}[$ and $q_t \in]\bar{q}^s, 1[$ so that $\bar{q}^b$ is an attractor for the trajectories originating from an initial datum $q_0 \in]0, \tilde{q}[$ while $\bar{q}^s$ is an attractor for the trajectories originating from $q_0 \in]\tilde{q}, 1[$.

(iii) $\bar{q}^p < \bar{q}^s < \tilde{q}$: in this case $h(q_t) > 0$ for any $q_t \in]0, \bar{q}^p[$ and $h(q_t) < 0$ for any $q_t \in]\bar{q}^p, 1[$ so that $\bar{q}^p$ is an attractor for initial datum $q_0 \in]0, 1[$.

This concludes the proof. □

Proof of Proposition 3. We start by looking at the effects on the long-run value of q_t. We need to compare the long-run values of q_t in the two situations: creation of the brokers' network (BN) and the command and control policy (C&C). In the BN case the long-run value of q_t is always $\bar{q}^b$ as shown in Proposition 1. In the case of C&C it is $\bar{q}^p$ or $\bar{q}^s$

depending on the values of q_0 and $\tilde{q}$ (see Proposition 2 for details). We write $BN \succ C\&C$ (respectively $BN \prec C\&C$) if the long-run value of q_t under the BN policy is bigger (respectively smaller) than the long-run value of q_t under the C&C policy. We have the following eight cases:

Condition(s)	Comparison
$\bar{q}^b < \bar{q}^p$	$BN \prec C\&C$
$\bar{q}^p < \bar{q}^b < \tilde{q} < \bar{q}^s$ and $q_0 < \tilde{q}$	$BN \succ C\&C$
$\bar{q}^p < \bar{q}^b < \tilde{q} < \bar{q}^s$ and $q_0 > \tilde{q}$	$BN \prec C\&C$
$\bar{q}^p < \bar{q}^b < \bar{q}^s < \tilde{q}$	$BN \succ C\&C$
$\bar{q}^p < \tilde{q} < \bar{q}^b < \bar{q}^s$ and $q_0 < \tilde{q}$	$BN \succ C\&C$
$\bar{q}^p < \tilde{q} < \bar{q}^b < \bar{q}^s$ and $q_0 > \tilde{q}$	$BN \prec C\&C$
$\tilde{q} < \bar{q}^p < \bar{q}^b < \bar{q}^s$	$BN \prec C\&C$
$\bar{q}^s < \bar{q}^b$	$BN \succ C\&C$

We use this fact to prove part (i) of the proposition. First observe that $\bar{q}^b$ and $\bar{q}^p$ do not depend on ϕ, that $\bar{q}^s = 1 - \frac{\bar{k}_1 - \phi(y_1 - y_2)}{\gamma}$ is increasing as a function of ϕ (since $y_1 > y_2$ by hypothesis) and that $\tilde{q} = \frac{(1-\phi)(y_1 - y_2)}{\psi - \phi(y_1 - y_2)}$ is decreasing as a function of ϕ (recall that $\psi > y_1 - y_2$ thanks to Assumption 1). Using these facts it is easy to verify that, if for a certain choice of the parameters and of the initial condition the system is in one of the cases where $BN \succ C\&C$, it remains in one of these cases even when (keeping the same value for all other parameters and for the initial datum) we decrease the value of ϕ. Conversely one can easily see that, if a certain configuration implies that $BN \prec C\&C$, *ceteris paribus* increasing the value of ϕ again gives a configuration where $BN \prec C\&C$. So there exists a threshold $\Psi \in [0,1]$, depending on the choice of q_0 and of all the parameters except ϕ, such that $BN \succ C\&C$ for any $\phi < \Psi$ and $BN \prec C\&C$ for any $\phi > \Psi$ (observe that, if $\Phi = 0$ or $\Phi = 1$ one of these two sets is void).

Similarly, to prove the second claim of part (i) observe that, we can observe that, if changing the set of the parameters the value of $\bar{q}^b$ (or equivalently $\bar{b}^b$, since they are linked by the strictly increasing relation described in (1)) maintaining the levels of $\bar{q}^p$, $\tilde{q}$ and $\bar{q}^s$ we can only switch from configurations where $BN \prec C\&C$ toward configurations where $BN \succ C\&C$, while the opposite never happens.

We can verify part (ii) of the proposition with a similar argument: we can observe indeed, looking at the table of the cases above, that in the cases (i.e. in the choices of the parameters) where the choice of q_0 is relevant, decreasing, *ceteris paribus* the value of q_0 can only allow the system to switch from configurations where $BN \prec C\&C$ toward configurations where $BN \succ C\&C$, while the opposite never happens.

When, instead of looking at the long-run level of q_t, we look at the long-run number of (per-period) successfully implanted deep green AEMs, the situation is the same. Indeed in the the C&C case a deep green AEM is proposed to all the *e*-type farmers and then the number of successfully implanted deep green AEMs is equal to the long-run level of q_t while in the BN case the number of successfully implanted deep green AEMs is given by $\bar{q}\bar{b} = \bar{q}g[\bar{q}]$. Since $g[\cdot]$ is an increasing function all the previous considerations can be repeated. $\square$