Building Bridges for the Adoption of Green Agro-environmental Measures: The Impact of Environmental Knowledge Brokers

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Abstract

In this paper we study the process of the emergence of intermediaries, such as knowledge brokers, for the implementation of deep green agri-environmental measures (AEMs). Green AEMs generate direct payments but impose specific requirements which may require substantial changes and new knowledge to farmers. The emergence of knowledge intermediaries has been promoted by the EU Common Agricultural Policy with the main objective of better reallocate and target monetary resources to farmers for the implementation of deep green AEMs. This process might have an impact on the preferences for the environment in the farmers' population through the transfers of knowledge and resources for the preservation of the environment. We show that if the environmental effectiveness of the implementation of deep green AEMs is sufficiently high, a system with knowledge intermediaries might promote pro-environmental values compared to a standard *command and control* policy in which the local institution directly targets the type of AEM to farmers.

Key Words: Knowledge Brokers, Agri-environmental Measures, Pro-environmental Culture, Moral Hazard

JEL Codes: Q51, Q38, Z13

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1 Introduction

Scholars in public good economics have elaborated a set of basic models to explain the existence and the efficiency benefits of cooperation between government and non-profit organisations in complex market economies (Weisbrod, 1988). The basic economic approach to non-profit organisations explains their existence as a consequence of a situation of demand heterogeneity for public goods. In a situation of demand heterogeneity, different population groups (such as pro-environmental groups versus rural development organisations) have divergent demands for public goods in both quantity and quality. They can for instance agree upon a basic level of maintenance of green infrastructure in agro-environmental landscapes (such as maintenance of hedges and isolated trees), but might disagree on the priority of other more demanding aspects such as local breeds or natural grasslands. Under the hypothesis where the government first attempts to satisfy the demands of the statistically average person, this might lead to a set of unmet demands of these social groups. These unmet demands might be satisfied by non-profit organisations, such as such as social enterprises and entrepreneurs.[1]

Based on these premises of public good economics, one would expect that national/ regional governments will focus their implementation efforts of the agro-environmental measures (AEMs) on the rather consensual light measures, instead of the more demanding deep and medium measures for which there is much higher demand heterogeneity. For instance, the national/regional governments implementation of the EU agro-environmental payment scheme has indeed led to a higher investment in the light measures, in spite of the obligation under EU rules to address at least some of the deep and medium measures as well. However, in parallel to this first trend, the unmet social demands of a more full-fledged implementation of the agro-environmental policy has led to the emergence of a thriving non-profit sector that provides technical services, knowledge sharing and advice for improving the provision of the various agro-environmental

[1]Non-profit organisations are established and financed by a mixed funding mechanisms, which combines membership contributions (in fees and time), donations (in money and in kind), payments for market services offered by the non-profit organisations, and governmental subsidies/support. In particular, citizens and stakeholders who want to increase the output or the quality of the more demanding public goods might provide voluntary contributions.

public goods. The existence of these non-profit service providing organisations in turn opens up interesting possibilities for cooperation between governmental and non-profit organisations (Salamon 2002; Anheier 2005). Indeed, taken on their own, the non-profit organisations might be subject to a set of governance failures, such as lack of broader social accountability or lack of financial stability. On the other hand, these organisations have developed a set of capacities that can provide resources to the government for improving its efficiency in implementing its own public good policies, in particular their capacity to operate at the agro-environmental landscape level and their in depth knowledge of the local contexts in which the farmers operate. In addition, the non-profit organisations are in a better position to inspire trust and to play a facilitating role for social learning with the farmers, compared to private sector operators that would be paid by the state to provide an equivalent level of services (Anheier 2005).

In theory, the economic argument for the emergence of non-profit social entrepreneurs, such as knowledge brokers, allows to envision a situation that promotes 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. Indeed, the availability of more knowledge for putting 'deep green' environmental actions into practice might lower the barriers for new actors to behave in a pro-environmental way and thereby promotes the cultural transmission of pro-environmental behaviour to new actors. On the other hand, the process of cultural convergence might be hampered as well. Indeed, support to 'deep green' environmental actions (such as preservation of local breeds or restoring natural grasslands) has a higher costs in terms of knowledge advice and social learning, compared to the light green actions (such as preserving hedge rows or isolated trees in the existing landscape). In addition, the knowledge broker needs to identify the farmers that are willing to step into the 'deep green' environmental measures. This targeting process for willing farmers becomes, for instance, more difficult over time, when the obvious candidates have already been identified and new farmers need to be found willing to adopt deep green measures.

A knowledge broker that receives subsidies from the government for promoting the implementation of agro-environmental measures will therefore face a trade-off: if he uses the available budget for specializing in knowledge advise for deep green measures he might generate a social return from the green interactions, as these are targeted to the more demanding deep green measures that are under-provided, but he will also face a higher costs, both search costs and difference in cost between knowledge advice for the deep green and the light green. On the contrary, if he specializes in information provision for the light measures, it will be more difficult to generate environmental effectiveness, but he can use the available government subsidy to promote the light measures at a lower cost. As a result, depending on these various costs and benefits the process of cultural evolution of preferences can also lead to economies where a low share of deep green knowledge brokers will emerge and no new farmers change their behaviour and investment in the transmission of pro-environmental preferences.

In this paper we consider two typical measures that can be clearly distinguished. In reality, more complex combinations are financed under the agro-environmental measures scheme. Deep green AEMs, entail high ecological effects with high payments. For example natural grass lands, local landraces. Light green AEMs, characterized by low ecological effects with low payments. For example, hedge rows (50 euro/200 m), isolated trees (25 euro /10 trees).

For the purpose of analysing the impact of specialized knowledge brokers on the operational costs to the farmer, we distinguish between two observable elementary behaviours of the farmers: behaviour with environmental effort and behaviour with no environmental effort. It is reasonable to assume that the farmers making no environmental effort have no costs for the realization of the scheme, while the farmers making environmental effort will have an operational cost to implement the measures[2].

Non pro-environmental behavior has no operational costs since it does not imply to make any changes to the farm practices. It only implies to preserve existing landscape elements, instead of destroying them. For instance, the preservation of an existing natural grass land on a farm that has always be doing extensive farming or the preservation of existing hedges around the fields. By contrast, environmental behavior implies to make

[2] The normalization of the operational cost for non pro-environmental farmers to zero is reasonable, as it is sufficient to 'inform' them about the existence of the subsidy scheme, which is not a major cost.

substantial changes to the farm practices and the farm landscape. The operational cost will be substantial if farmers have to make an environmental effort to implement a deep green measures, while they will be less important if they have to make an effort to implement a light green measures[3].

In this paper, we only consider the elementary situation where farmers with strong pro-environmental preferences are always making an environmental effort, while the farmers without strong pro-environmental preferences are only willing to accept subsidies if they do not have to pay operational costs or make such effort. For the latter, this is rather straightforward, as such effort would imply a operational cost, without leading to any additional pecuniary or intrinsic reward. For the case of the pro-environmental farmer, theoretically one could envision the case of pro-environmental farmers that have made so much effort in the past in building hedges, restoring grass lands, etc. on a voluntary basis that they can now comply to the subsidy scheme without making any effort. This is not entirely unlikely, but however is rather an exceptional situation in practice and, moreover, depends on the perception by the farmer on the level of effort to be made to comply with the 'good practice' standards fixed by the EU for the conservation of hedges, grass lands etc. Therefore, we suppose that pro-environmental farmers still have to make these changes on their farm or consider that changes are necessary even though some landscape elements might already be present on their farm. However, when pro-environmental farmers are not able to reach such optimal implementation, they suffer from being non pro-environmental because they are endowed with an *environmental conscience* which favors pro-environmental effort.

In line with these views, we model environmental preferences as inherent characteristics transmitted through generations. In particular, the social norm that will play an important role in our theoretical setting is the *environmental conscience*, a cultural value that parents may choose to teach to their children even though it leads to lower economic rewards. This approach to preferences seems reasonable in a context in which farmers have to to implement AEMs to protect the environment.

[3]For example, for deep green measures, the restauration of natural grass lands by introducing extensive grazing and cutting the grassland only late in the season on a farm that has not be used to these practices. For light green measures, the planting of new hedges on his land.

This paper introduces in the literature on agri-environmental economics the approach of preferences evolution developed by Cavalli-Sforza and Feldman (1981) and applied to the economic literature by Bisin and Verdier (2001). The main difference of the latter approach with the standard evolutionary theory is that in cultural selection models the parent's values play a fundamental role in determining the selection of the cultural trait. Following this literature, we assume that preferences for the environment are acquired through a cultural transmission process between parents and children. More precisely, preferences of children are influenced by parents, who maximizes their children's expected welfare based on their own preferences, that is, always promoting their cultural trait. The pioneering framework developed by Bisin and Verdier (1998, 2001) has been applied to several contexts in the economic literature, but only recently, this framework has also been applied to explain the evolution of environmental cultural trait defined as perception of pollution (Bezin, 2015, Litina et al., 2014). However, it has never be used to explain the process of formation of non-profit social enterprises in the agro-environmental payment scheme.

This paper studies two possible strategies for the public legislator to promote the environmental culture into the farmers' population and generate environmental effectiveness of the policy. Or it is possible to change the cost structure, for example by raising the EU subsidy with a reasonable amount, to promote the emergence of a network of knowledge brokers. Or, when this is not possible, the state, instead of financing the knowledge brokers, can use its budget to identify how many farmers are likely to adopt deep green measures and provide the knowledge advice through its own services. The advantage is that the farmers have a complete knowledge 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 the governmental policy, for example 3 visits in 5 years as in the current Walloon agro-environmental scheme. The disadvantage is that the state is not able to adjust the policy instantaneously, which might lead to a low probability to have the correct knowledge of these preferences.

Observing the difference between the equilibrium when a network of knowledge brokers is formed or when the state decide autonomously the targeting of AEMs, is the main objective of this paper. To this purpose, we develop a theoretical model that is able to explain which are the reasons behind the process of formation of a network of knowledge brokers we observe in reality.

The paper proceed as follows: Section 2 develops the theoretical model when a network of knowledge brokers emerges. Section 3 delves into the standard command and control policy in which the public institution decide autonomously which AEMs offer to farmers. Section 4 compares the two possible models to shed light the policy implications. Section 5 concludes.

2 The Theoretical Framework

In this section we develop a theoretical model that embeds the process of pro-environmental preferences evolution in farmers' population who subscribe to environmental commitments related to the preservation of the environment. We consider an economy infinitely lived in which there exists a public institution that has to allocate public funds through investment in agro-environmental practices.[4]

At each period of time t, is born a unit measure of farmers who participate in agricultural environmental targeted measures. Farmers can be of two types: pro-environmental (e-type) or non pro-environmental (n-type). At the same time, is born a unit measure of *ex-ante* identical non-profit organizations that live only for one period.[5] These non-profit organizations are social enterprises that act as intermediaries between the public institution and the farmers' population. Their main role is to target the public subsidy to farmers for investments in agro-environmental practices as well as to improve the change

[4]Agri-environment measures may be designed at the national, regional, or local level so that they can be adapted to particular farming systems and specific environmental conditions. In the European Union, agri-environment measures are co-financed by Member States. The EU commission observe that expenditure on agri-environment measures amounts for the period 2007 - 2013 to nearly 20 billion EUR or 22% of the expenditure for rural development. See $http://ec.europa.eu/agriculture/envir/measures/index_en.htm$

[5]As observed by Francois and Zabojnik (2005), the assumption of equal numbers of agents on both sides of the market may seem artificial. However, since brokers can freely decide to offer project 1 or project 2, we could, without loss of generality, assume a potentially larger population of intermediaries. Otherwise, we could assume that intermediaries offering project 1 (2) only emerge when a local institution decides to implement project 1 (2), so that their number would coincide with the number of project 1 (2) offered by the local institution to farmers.

in practice in the agricultural sector through advices and knowledge transfers. These social enterprises can be thought as business owned by non-profit organizations. For this reason, they are able to collect revenues for their members. However, these social enterprises might also apply strategies to maximize improvements in social and environmental well-being, rather than maximizing profits for external shareholders. Indeed, one of their main purpose is to achieve social and/or environmental aims.

In our simplified model, the public institution has to decide between the implementation of two direct payment schemes, such as AEMs: first, it can allocate directly public resources to farmers. In this scenario, namely "command and control" policy, the public institution autonomously decides which agro-environmental measure allocates to each farmer. This type of policy will be modelized as a standard principal-agent model in section 4. Second, it can delegate to non-profit intermediaries the targeting of the agri-environmental measures. This particular scenario is characterized by a more expensive policy in monetary terms. The reason is simple: social entrepreneurs act as intermediaries and they have to be paid for their knowledge or information activities. Even though this policy is more expensive for the public actor, it might lead to a better targeting compared to the command and control policy and, therefore, generate a larger environmental effectiveness for the society. As said above, it is one of the objectives of this paper to explore under what conditions the legislator would opt for a more expensive policy that might lead to a better targeting of the agro-environment measures and promote environmental practices.

2.1 The Economy with Knowledge Brokers

In this section, we assume that the public legislator allocates an amount $x^b > 0$ of monetary resources to non-profit organizations, such as social enterprises, with the objective to implement some agro-environmental measures. These social enterprises are intermediaries able to decide autonomously whether to offer to farmers one of the two following direct payments: a deep green AEM (project 1) or a light green AEM (project 2). The former project generates a larger payment to the farmer, y_1, than the latter, y_2, where $y_1 > y_2 > 0$. The implementation of deep green environmental measures, necessarily requires larger implementation costs than those of a project involving a light green environmental measures. Indeed, support to deep green environmental actions, such as preservation of local breeds or restoring natural grasslands, has a fix cost in terms of administration and control but it has also a cost in terms of knowledge advice and learning, compared to the light green actions, such as preserving hedge rows or isolated trees in the existing landscape. We define *environmental knowledge brokers* all the social enterprises or intermediaries providing the availability of more knowledge for putting deep green environmental actions into practice and offering project 1 to farmers. By contrast, we define *environmental information providers* those that specialize in information provision for the light measures and are able to offer only light green AEMs. For the sake of simplicity, we assume that total implementation costs of providing information on the light green AEM are normalized to zero, while implementation costs are strictly positive for project 1.[6]

A deep green AEM is successfully implemented if and only if farmers actively participate to its implementation. If for instance a knowledge broker offers a deep green AEM to a farmer with non pro-environmental preferences, the implementation of this measures will never be successful. The reason is that a non pro-environmental farmer will never make any effort or investment for the realization of an agri-environmental measure. While pro-environmental farmers always invest resources or make effort to implement an AEM, non pro-environmental farmers do not.[7] The cost that farmers have to support when participating in the realization of a deep green AEM can be thought as the compensation payment for both, the effort for protecting the environment and the technical or knowledge advice provided by a knowledge intermediary or the learning cost necessary for change their farm practice and landscape. Indeed, the knowledge advice for a deep green AEM offered by a knowledge broker is very demanding and will vary according to the type of production system, the geographical region and the kind of farm.

[6]In the remaining of the paper we designate the 'environmental knowledge brokers' by 'knowledge brokers' and the 'environmental information providers' by 'information providers'.

[7]In reality also non pro-environmental farmers incur in some operational costs. However, for the sake of simplicity, we normalize to zero the cost of behaving non pro-environmental. Evidence suggests that pro-environmental farmers exert a large effort when implementing agricultural practices.

We define total knowledge and learning costs for deep green AEMs as the sum of these costs faced by both actors, i.e. the knowledge broker and the farmer, involved in the implementation of the measure. For instance, knowledge brokers have a cost to identify the farmers willing to learn: offering deep green AEMs need to identify and advice farmers who are willing to step into these deep green environmental measures. At the same time, farmers with pro-environmental behavior need to invest time and resources in learning when participating in the implementation process of a deep green AEM, even if he might benefit from the learning process as it gives him access to the implementation of project 1. Therefore, the correct implementation of a deep green AEM necessarily require investments from both side of the market. We assume that total knowledge and learning costs are shared between knowledge brokers and farmers, with β (resp. $1-\beta$) the constant share of total knowledge (resp. learning) costs supported by the knowledge broker (resp. pro-environmental farmer) necessary to implement this type of agri-environmental measure.

Our view is that total knowledge and learning 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 of endogenous and increasing costs comes from the observation that the targeting of a green deep AEM become 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 interactions increases with the decreasing opportunities of correctly targeting the measure[8]. In particular, we assume that $s[b_t] \geq 0$, $s[0] = 0$, $s^{'}[b] > 0$, $s^{''}[b] \geq 0$.

Moreover, to ensure the implementation of a deep green AEM, knowledge brokers also incur in some fixed administrative or control costs, $\bar{d} > 0$. It follows that the implementation costs of project 1 faced by knowledge brokers at time t are defined as the sum of some fixed administrative costs with knowledge variable costs: $d[b_t] = \bar{d} + \beta s[b_t]$. Note that $d[0] > 0$ and $d[1] > d[0]$ are respectively the lower and the upper bound of the deep green AEM cost function $d[b_t]$.

[8] Alternatively, increasing costs could be thought as the consequence of the increased competition in the market that reduces the probability, given q_t, to realize a green interaction.

Each intermediary receives from the public institution the same monetary transfer x^b to realize the implementation of a particular AEM. We assume that this monetary transfer equals the total maximum expenses necessary to the implementation of a deep green AEM, that is when the knowledge and learning costs are at the upper bound because all intermediaries offer project 1: $x^b = y_1 + \bar{d} + \beta s^u$ 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 is strictly positive otherwise[9]. When a knowledge broker is able to target project 1 to a pro-environmental farmer, the implementation of a deep green AEM will be successful and a positive social return for having reached his objectives is generated. This social return, $\psi > 0$, is defined as the "environmental effectiveness" achieved by a knowledge broker when a deep green AEM is correctly implemented by a pro-environmental farmer.

By contrast, in our model a light AEM would generate much less important social return since, by definition, this measure is not able to provide any substantial social environmental effectiveness. For simplicity of the model, we normalize the social return to zero in the case of light environmental measures. To summarize this financing mechanism thorough intermediaries, we define respectively with π_1 and π_2 the broker's expected return of a single interaction with a farmer, where $\pi_1 = x^b - y_1 - (\bar{d} + \beta s[b_t]) + \rho\psi$ and $\pi_2 = x^b - y_2$ with $\rho \in \{0, 1\}$. The parameter ρ takes the value of 1 if project 1 is implemented by a pro-environmental agent, or the value of 0 if the deep AEM is implemented by a non pro-environmental agent.

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

If assumption 1 holds, deep green AEMs implemented by pro-environmental farmers, yield higher expected returns to intermediaries rather than light green AEMs. Light AEMs are less costly than deep AEM, because they have no implementation costs, $d = 0$,

[9]This is a reasonable assumption since the revenues of each intermediary can be interpreted as payments for knowledge or information activities. However, social enterprises are not profit maximizer since their purpose is also to achieve environmental goals.

and because they generate lower direct payments for farmers, $y_2 < y_1$. However, these environmental measures do not allow for any social return in terms of environmental effectiveness generated by the successful green interaction between knowledge brokers and pro-environmental farmers. Indeed, light AEMs generate a positive and constant revenue for information providers that is completely independent from the type of agent matched.

2.1.1 Farmers' Preferences

The pecuniary payoff of each farmer is produced through a match with an intermediary offering one of the two AEMs. This match is random and it works as follows: at each time t, with probability b_t a farmer receives from a knowledge broker 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 some agro-environmental practices and the costs of putting in practice the measure, that is $\lambda_r^i = y_r^i - \delta^i k_r$, with k_r defining the total operational cost of the project $r = (1, 2)$ supported by the farmers $i = (e, n)$. Therefore, the budget constraint of farmer i is defined by the direct payment received by the intermediary, with $y_r = y_1$ if $r = 1$ and $y_r = y_2$ if $r = 2$.

It is reasonable to assume that operational costs depend on agent type i. It follows that $\delta^i \in \{0, 1\}$ is a step function depending on farmer's preferences. If $i = e$ then $\delta^e = 1$; if $i = n$ then $\delta^n = 0$. Indeed, as discussed before, in the latter case non pro-environmental farmers do not incur in operational costs because these costs are related to the pro-environmental behavior as well as to the effort that these type of farmers exert to put in practice the AEM . We define the operational costs of project 1 as the sum of the fixed cost of behaving pro-environmental under project 1 and the share of knowledge and learning costs supported by pro-environmental farmers when matching a knowledge broker and implementing a deep green AEM: $k_1 \equiv k_1[b_t] = \bar{k}_1 + (1 - \beta)s[b_t]$, with $\bar{k}_1 > 0$. Since the implementation of a light green AEM does not require any knowledge, learning or change in practice investments by farmers, the cost of behaving pro-environmental is constant under project 2, $\bar{k}_2 > 0$. Notice that we do not make any assumptions on the size of the fixed behavioural cost under project 1 and project 2. Indeed, it is possible that fixed operational costs of a pro-environmental farmer under light green AEMs are larger than those under deep green AEMs to compensate for the missing knowledge advice.

Farmers' well-being does not only depend on pecuniary payments or operational costs. In our specific context, potentially pro-environmental agents suffer from behaving non pro-environmental. Thus, these pro-environmental farmers are agents with unobservable environmental characteristics. Pro-environmental agents enjoy behaving as pro-environmental since they are endowed with an "environmental conscience" which generates a non-pecuniary psychological loss, $\gamma > 0$, when behaving non pro-environmentally[10].

To sum-up, table 1 and 2 define the utility matrix to a potentially pro-environmental, $u_r^i = \lambda_r^i - (1 - \delta^i)\gamma$, and potentially non pro-environmental agent, $u_r^i = \lambda_r^i$, respectively. For the sake of simplicity, agents' utilities are assumed to be linear in disposal income.

Table 1: Utility of a potentially pro-environmental agent

Type/Project	Project 1	Project 2
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 a potentially non pro-environmental agent

Type/Project	Project 1	Project 2
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, a potentially non pro-environmental agent will never behave as pro-environmental. However, the intermediary is not able to observe

[10]This intrinsic parameter is a fundamental component of many individuals' utility and it has already been recognized in the socio-psychological and economic literature. See Lubell (2002), Serret and Ferrara (2008), Garcia-Valinas et al. (2012).

the cultural trait of the farmer because a non pro-environmental agent behaving pro-environmental is not distinguishable from a pro-environmental agent behaving pro-environmentally. Is this his lack of information that creates a moral hazard problem because farmers have more information about their rational behavior than the broker. Thus, to the eyes of the intermediary, the uncertainty over the cultural trait remains because pro-environmental preferences generate a kind of warm glow to pro-environmental farmers behaving environmentally. In our setting, we model this warm glow for environment as an intrinsic psychological utility loss.[11]

Assumption 2 *The environmental values of the pro-environmental farmer are 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 that the incentive compatibility constraint is satisfied, since the dominant strategy for potentially pro-environmental agents is to act always pro-environment. It requires that the potential loss γ, measured in the utility metric, for pro-environmental agents is larger than the maximum cost of behaving pro-environmentally when implementing an AEM[12]

2.1.2 The Strategic Behaviour of Non-profit Environmental Intermediaries

It is reasonable to assume that environmental intermediaries know approximately the preferences distribution in the population, that is the share of pro-environmental farmers q_t in the population, which is generally known from existing statistics. However, since cultural traits and preferences are not observable, they do not know what farmer has what preference, so they cannot recognize in advance the type of the farmer they will face. In other words, each intermediary maximizes his expected returns considering that agents' type is unobservable but knowing with probability q_t to match a pro-environmental agent.[13] Intermediaries have no informations about the type of agents

[11] This interpretation does not alter the main results of this paper.

[12] k_1^u defines the upper bound of the total operational costs for pro-environmental farmer implementing project 1.

[13] This assumption is standard in cultural transmission models when actors have preferences for not observable intrinsic rewards. See for instance Hauk and Saez-Marti (2002).

in the population, because they are not able to observe the specific features that characterize each pro-environmental agents, such as their behaviour for the environment or some non-pecuniary intrinsic rewards. Depending on expected returns, each intermediary has to decide which project to delegate to the farmer. The assumption that a deep AEM might generate environmental effectiveness at the expenses of higher pecuniary transfers, y_1 and positive implementation costs, $d[b_t] > 0$, exposes intermediaries to a trade-off based on the uncertainty over the type of farmers matched. More precisely, a moral hazard problem arises because some farmers can obtain a private benefit if not acting in the best interest of the intermediary.

We assume that the the decision of each environmental intermediary to offer project 1 or project 2 is instantaneous.[14] Indeed, socio-economic opportunities allow intermediaries to change their behaviour relatively quickly to the speed at which inherent cultural traits change. Depending on the share of pro-environmental farmer in the population, each intermediary has to decide either to offer project 1 or project 2 to the farmer she will match. The single return of project 1, $\pi_1 = x^b - y_1 - (\bar{d} + \beta s[b_t]) + \rho\psi$, with $\rho \in \{0, 1\}$, will depend on the farmer matched. We define $\pi_1^e = x^b - y_1 - (\bar{d} + \beta s[b_t]) + \psi$ the return of a knowledge broker matching a pro-environmental farmer, and with $\pi_1^n = x^b - y_1 - (\bar{d} + \beta s[b_t])$ the return of a knowledge broker matching a non pro-environmental farmer. It follows that the expected return of project 1 to a knowledge broker is uncertain and is given by $\Pi_1[b_t] = q_t\pi_1^e + (1 - q_t)\pi_1^n$. Conversely, the expected return to an informational 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 $\Pi_2 = \pi_2$.

It is straightforward to demonstrate that there exist an indifference condition in which non-profit intermediaries' expected returns are zero: $\Pi^b[b_t] = 0$ with $\Pi^b[b_t] \equiv \Pi_1[b_t] - \Pi_2 = q_t\psi - (\bar{d} + \beta s[b_t] + \Delta y)$. In this case at least one intermediary, i.e. the marginal intermediary, is indifferent between the two projects. If assumption 1 holds, there exists

[14] A similar assumption can be found in a paper on trust and social capital by Francois and Zabojnik (2005) in which profit maximizing firms, rather than non-profit intermediaries, adjust instantaneously to changes in the economy. In our setting, this assumption reflects the evidence that evolution of preferences in the farmers' population adjusts relatively slowly relative to the adjustment of the behaviour of intermediaries in the agri-environmental scheme. We should note that the analytical framework developed in this section and the proof of Proposition 1, borrows from the theoretical contribution of Francois and Zabojnik (2005).

a unique network of knowledge brokers, $\bar{b} \in [0,1]$, implicitly defined by $\Pi^b[b_t] = 0$. The latter determines the locus at which $db = 0$, representing the combinations of endogenous variables and parameters at which intermediaries are indifferent to offer project 1 or 2. It follows from the definition of total implementation costs, $d[b_t] > 0$, that the locus db is upward sloping in (q, b) space. The reason is quite intuitive: a higher share of pro-environmental farmers can support a larger network of knowledge brokers, and therefore a greater offer of project 1 to farmers, even though the marginal cost is increasing with b_t. Indeed, when pro-environmental farmers are too numerous, the production of environmental effectiveness, ψ, is more likely, so that more intermediaries have incentives to offer a deep green AEM. In particular, we observe that when $\Pi^b[b_t] > 0$, then some intermediaries have an incentive to offer project 1 rather than project 2 because $b_t < \bar{b}$. Conversely, when $\Pi^b[b_t] < 0$, we derive $b_t > \bar{b}$. In the latter case, the costs of targeting pro-environmental farmers and offer project 1 are relatively large. Therefore, some intermediaries would find profitable to offer project 2 rather project 1. Only when $\Pi^b[b_t] = 0$ each intermediary has no incentive to change strategy and $b_t = \bar{b}$.

Interestingly enough, observe that if any intermediary finds profitable to offer project 1, then the social networks of knowledge brokers will be not formed. Solving $\Pi^b[b_t] = 0$ in terms of q_t, we derive the threshold $\tilde{q}[b_t] = \frac{\Delta y + \bar{d} + \beta s[b_t]}{\psi}$. Therefore, when the social network of knowledge brokers is not formed, the resulting share of pro-environmental farmers will be given by $\tilde{q}[0] = \frac{\Delta y + \bar{d} + \beta s[0]}{\psi}$; by contrast, if all intermediaries decide to offer project 1, the share of pro-environmental farmers will be given by $\tilde{q}[1] = \frac{\Delta y + \bar{d} + \beta s[1]}{\psi}$. Notice that, by assumption 1, both solutions belong to the domain, $\{\tilde{q}[0]; \tilde{q}[1]\} \in]0,1[$.

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

2.1.3 The 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 well recognized mechanism of cultural transmission introduced by Cavalli Sforza and Feldman (1981) and formalized in the economic literature by Bisin and Verdier (1998, 2001). We assume that reproduction is asexual and there is a one-for-one reproduction. Each farmer has a child that becomes active in the next period and participates to the implementation of some AEMs. Hence, fertility is exogenous and total farmers' 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 type of preferences: either 'pro-environmental' or 'non pro-environmental', as discussed previously.

Children are 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 with some education effort τ_t^i with $i \in \{e, n\}$, with e pro-environmental and n non pro-environmental type. If parents fail to educate their children to their trait, an indirect socialization mechanism occurs. More precisely, with probability equal to education effort τ_t^i, children will adopt the same trait of their own parents. Otherwise, with probability $1 - \tau_t^i$, children's traits will be determined by imitating a random adult outside the family. Let p_t^{ij} be the probability that a child of parent i will adopt the trait j. By the law of large numbers, p_t^{ij} also denotes the fraction of children born in a type i family who are socialized to trait j. We can thus write the transition probabilities as follow:

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

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

The expected utility at time t of a 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 to match a knowledge broker willing to implement a deep green AEM. Define the expected utility $V^{ij}[b_t] = b_t V_1^{ij} + (1 - b_t) V_2^{ij}$ with $(i, j) \in \{e, n\}$ and $(1, 2)$ the project offered by the intermediary. Assume that education effort τ_t^i is costly and socialization costs, $C(\tau^i)$, are convex. It is standard in the economic literature on cultural transmission to consider a cost function with the following properties[15]: $C'(\tau^i) > 0$ for all $\tau^i \in]0,1]$, $C(0) = C'(0) = 0$ and $C''(\tau^i) > 0$. Each individual chooses $\tau_t^i \in]0,1]$ to solve the following maximization problem:

$$max_{\tau^i} \quad p_t^{ii} V^{ii}[b_t] + p_t^{ij} V^{ij}[b_t] - C(\tau_t^i) \tag{1}$$

Maximizing (1) with respect to τ^i leads to the well-know first order condition of cultural transmission literature:

$$C'(\tau_t^i) = \frac{\partial p_t^{ii}}{\partial \tau_t^i} V^{ii}[b_t] + \frac{\partial p_t^{ij}}{\partial \tau_t^i} V^{ij}[b_t] \tag{2}$$

The solution of (2) allows us to derive the optimal education effort of both type of parents, that is $\tau_t^i = \tau[q_t, V^{ii}[b_t] - V^{ij}[b_t]]$. It is clear that the dynamics of cultural trait critically depends on the probability to match 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. Indeed, assumption 2 guarantees *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. 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. $V^{ii} > V^{ij}$ for all t.

Using the utility matrix in table 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 (1), (2) and considering convex socialization costs, we obtain $\frac{\partial \tau^e[q_t, V^{ee}[b_t] - V^{en}[b_t]]}{\partial q_t} = -\frac{V^{ee}[b_t] - V^{en}[b_t]}{c''[\tau^e[q_t, V^{ee}[b_t] - V^{en}[b_t]]]} < 0$ and $\frac{\partial \tau^n[q_t, V^{nn}[b_t] - V^{ne}[b_t]]}{\partial q_t} = \frac{V^{nn}[b_t] - V^{ne}[b_t]}{c''[\tau^n[q_t, V^{nn}[b_t] - V^{ne}[b_t]]]} > 0$. These results imply that both parents have less incentive to socialize their children to their

[15] As already underlined in Bisin and Verdier (1998), the cost function must be convex enough so that the solution of the socialization problem will be strictly smaller than 1.

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. On the other hand, 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 $\tau^e[q_t, V^{ee}[b_t] - V^{en}[b_t]] - \tau^n[q_t, V^{nn}[b_t] - V^{ne}[b_t]]$. 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). The differential equation describing how traits evolve in time, is a simple version of the replicator dynamics in evolutionary biology for a two-trait population that crucially depends on socialization efforts of different parents:

$$dq_t = q_t(1 - q_t)(\tau^e[q_t, V^{ee}[b_t] - V^{en}[b_t]] - \tau^n[q_t, V^{nn}[b_t] - V^{ne}[b_t]]) \tag{3}$$

Substituting the expected utility functions of e-type and n-type individual into (3) we derive:

$$dq_t = q_t(1 - q_t)[\gamma(1 - q_t) - b_t(\bar{k}_1 + (1 - \beta)s[b_t]) - (1 - b_t)\bar{k}_2] \tag{4}$$

The above differential equation describes the motion of q_t in a population. It depends on the educational behaviour of parents of the different traits. It is reasonable to concentrate our attention only on the scenario in which one of the two traits is not always selected irrespective to the environment. Following Bisin et al. (2002) and Francois and Zabojnik (2005), we need to exclude parametrizations in which one trait culturally dominates, that is $\tau_t^e > \tau_t^n$ or $\tau_t^e < \tau_t^n$ $\forall\ t \geq 0$. Since, imperfect empathy is always guaranteed by assumption 2. Protection of the family trait, that is $V^{ii} > V^{ij}$ $\forall\ t \geq 0$ and $(i, j) \in \{e, n\}$, requires simultaneously that τ^e is increasing in $V_b^{ee}[b_t] - V_b^{en}[b_t]$ as well as that τ^n is increasing in $V_b^{nn}[b_t] - V_b^{ne}[b_t]$. It follows that $\tau^e - \tau^n$ should be increasing in $V_b^{ee}[b_t] - V_b^{en}[b_t] - (V_b^{nn}[b_t] - V_b^{ne}[b_t])$. If this latter expression is positive (negative), evolutionary forces favor pro-environmental (non pro-environmental) trait.

Assumption 3 *Evolutionary forces are such that no cultural trait is dominant:* $2\bar{k}_2 < \gamma < 2(\bar{k}_1 + (1 - \beta)s[1])$.

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 pro-environmental trait. Indeed, the condition $\gamma - 2k_2 > 0$ guarantees that utility is strictly positive also when variable operational costs for implementing project 1 are at minimum. Conversely, if the operational costs of project 1 reach the maximum, that is $b_t = 1$, then $\gamma - 2(\bar{k}_1 + (1-\beta)s[1]) < 0$. This latter condition implies that in presence of sufficiently high knowledge and learning costs, 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 total knowledge and learning cost function, $s[b_t]$, evolutionary forces might promote or not pro-environmental trait in the population.

2.1.4 Dynamics

The dynamic proprieties of our economy can be analyzed considering the following system of equations:

$$\begin{cases} dq_t = q_t(1-q_t)[\gamma(1-q_t) - b_t(\bar{k}_1 + (1-\beta)s[b_t]) - (1-b_t)\bar{k}_2] \\ q_t\psi = \Delta y + \bar{d} + \beta s[b_t] \end{cases} \tag{5}$$

The first equation of the above system represents the evolutionary replicator dynamics, while the second the intermediaries' indifferent condition to offer a deep or a light green environmental project. Solving for a steady state requires that both equations are simultaneously satisfied. Therefore, the steady states of this economy are defined by the pairs (q, b) that simultaneously solve both equations in system (5).

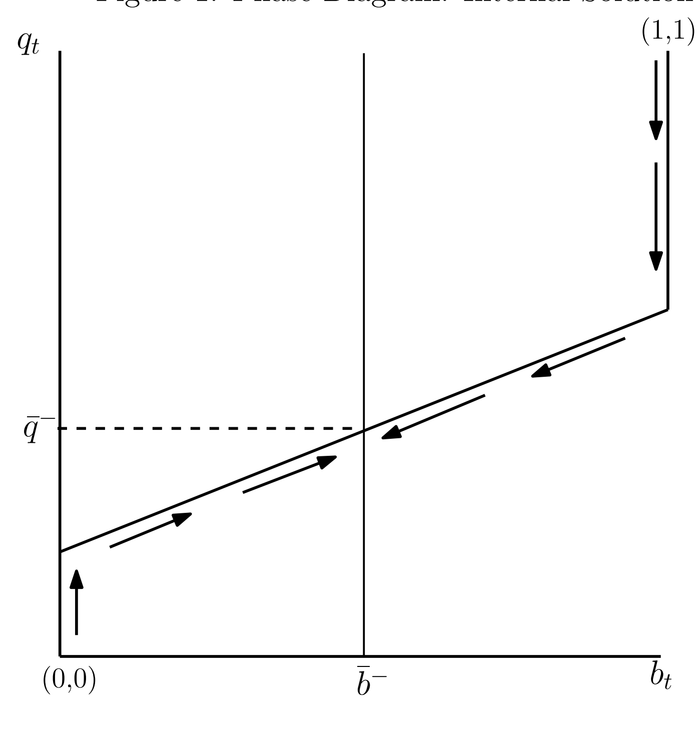
Under assumption 1, project 1 yields a higher return to the knowledge broker when the deep green AEM is offered to a pro-environmental agent. As already observed in the previous pages, there exists a unique network of knowledge brokers, $b^* \in]0, 1[$, for which intermediaries are indifferent between the 2 projects, that is $\Pi^b[b_t] = 0$. If all intermediaries find profitable to offer project 1, i.e. $b_t = 1$, the level of q_t that guarantees $db = 0$ will be given by $q[1] = \frac{\Delta y + d + \beta s[1]}{\psi}$. Remember that, the locus $db = 0$

is upward sloping in the space (q, b) and that assumption 1 guarantees that the locus db is sufficiently flat and belongs to the domain. Moreover, assumption 3 implies that the evolutionary forces do not always promote one particular cultural trait at the expenses of the other one. Even though imperfect empathy and promotion of family trait is guaranteed by assumption 2, the direction of the evolutionary dynamics will depend on both the role of knowledge brokers in the implementation process of a deep AEMs and the socialization effort of parents within families.

Proposition 1 *Under assumptions 1-3, the dynamic system defined by (5) admits a unique stable interior steady state* $(\bar{q}^b, \bar{b}^b)$ *in which a network of knowledge brokers is formed.*

Proof See Appendix A

Figure 1: Phase Diagram: Internal Solution



In the stable steady state $(\bar{q}^b, \bar{b}^b)$, 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 the pro-environmental farmer is more likely, we will observe an increase in the share of knowledge brokers that 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 presence of a large share of pro-environmental agents at time $t = 0$, if $b_0 > \bar{b}^b$, some intermediaries will find profitable to avoid investments in implementation of deep green AEMs. The reason is that in presence of a large share of knowledge brokers, the targeting of this measure is more difficult and the cost of implementation of a deep green AEM to high. Therefore, they will offer project 2 in the next period rather than project 1. The decreasing presence of knowledge brokers in the economy, will reduce the effort of pro-environmental parents in the protection of the pro-environmental trait.

3 The Command and Control Policy

The emergence of knowledge brokers in the process of implementation of deep AEM, might have important effects on the policy choice of the public institution as well as the long run evolution of pro-environmental preferences in the population. If a public institution aims to promote 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. An alternative and less costly scenario to the scheme in which intermediaries have an active role in targeting the payment scheme, is the direct payments of the public institution to farmers for the implementation of AEMs. This type of scenario, know as "command and control policy", implies that the public institution directly delegates to farmers the AEM. To model this 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 public institution has to assign a particular agricultural environmental project to the farmer she is randomly matched.

The first difference with an economy with non-profit intermediaries, is that the public legislator has not to invest resources in knowledge activities. In this scenario, total knowledge and learning costs are thus normalized to zero. Indeed, the monetary cost of the policy is lower compared to the model in which a network of knowledge brokers is formed. We assume that in a command a control policy scenario, the public institution invests a fixed amount of resources equals to $x^c = y_1 + \bar{d}$. This amount of monetary resources x^c is lower than in the scenario with intermediaries, $x^c < x^b$, because there is no costs related to the organisation of the learning.[16] The second difference is that the process of targeting the AEM and, therefore, the instantaneous adjustment in the intermediary market does not apply in this scenario.[17]. It remains to be seen if these differences lead, or not, to a substantial decrease in environmental effectiveness, which is the object of our analysis[18]

We assume that the public institution knows the traits' distribution in the population, q_t and that assumption 2 still holds in presence of exogenous operational costs for pro-environmental farmers, that is $k_1[0] = \bar{k}_1$.[19] 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 a potentially non pro-environmental agent behaving pro-environmentally is not distinguishable from a potentially pro-environmental agent who always behave in the spirit of the protection of the environment. Therefore, an agency problem persists due to asymmetric information between farmers and the

[16]Alternatively, we can assume that the monetary resources invested by the public institution are the same in both scenarios. It is rational to believe that the resources that are not used by a public institution to actively implement a deep green AEM under the command and control policy, are given back to the EU legislator or used for other public investments. Under this assumption, the main results of the paper are the same.

[17]This argument follows from the fact that there is no information leakage across principals. In a command and control policy scheme, local institutions 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.

[18]As in the previous section, the cost of project 2 is normalized to zero and it cannot generate any social return environmental effectiveness.

[19]Since implementation costs are zero when the public institution directly offer project 1, $s[0] = 0$

public institution. Following Hauk and Saez-Marti (2002), the 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, $\psi > \bar{d} + \Delta y$. However, in this scenario is the public institution that directly manages the targeting of the agro-environmental payments. Thus, it is logic that the social returns which we defined in the previous section is perceived by the public institution if such a match is realized.

Potentially, every public institutions can take one of the following strategies: pooling strategy or separating strategy. A pooling strategy implies that either project 1 or project 2 are offered to every farmers within the population. A separating strategy consists in offering a deep AEM to seemingly pro-environmental farmers and a light AEM to farmers who are discovered with probability $\phi > 0$ to be non pro-environmental. We define the public institution returns from a single match, $\pi_1 = x^c - y_1 - \bar{d} + \rho\psi$, with $\rho = 1(\rho = 0)$ if the agent matched has pro-environmental (non pro-environmental) preferences for project 1, and $\pi_2 = x^c - y_2$, for project 2. Therefore, $\pi_1^e = x^c - y_1 - \bar{d} + \psi$ and $\pi_1^n = x^c - y_1 - \bar{d}$, is the return under project 1 if the agent matched is respectively a pro-environmental and non pro-environmental agent. The aggregate expected return will be given by: $\Pi_1^p = q_t\pi_1^e + (1-q_t)\pi_1^n$, $\Pi_2^p = \pi_2$ and $\Pi^s = q_t\pi_1^e + \phi(1-q_t)\pi_2 + (1-\phi)(1-q_t)\pi_1^n$ where Π_1^p and Π_2^p are respectively the aggregate expected returns of the pooling strategy of offering the project 1 and the project 2, while Π^s is the aggregate expected return of the separating strategy.

We can easily observe that the pooling strategy of offering project 1 will be never choosen by rational institutions who maximize the aggregate expected return and can recognize with probability $\phi > 0$ if the agent matched has a non pro-environmental trait. Indeed, $\Pi^s > \Pi_1^p \; \forall q \in (0, 1)$. To respect the incentive compatibility constraint, we have to assume that potentially non pro-environmental farmers will always behave non pro-environmentally. Therefore, given constant operational costs ($\bar{k}_1$ and $\bar{k}_2$) for pro-environmental farmers, potentially non pro-environmental farmers will always behave non pro-environmentally under separating strategy if: $\phi V_2^{nn} + (1 - \phi)V_1^{nn} > V_1^{ne}$ or

$\phi < \frac{\bar{k}_1}{\Delta y}$. However, the institution cannot observe this farmers' behaviour due to the asymmetric information.

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

In order to characterize the steady state of this economy, we have to consider that the parents' behavior in the socialization process depends on the expectations about the decision taken by the public institution in the future. Indeed, the expected utility of a parent of type i having a child born in t with preferences j when adult, depends on the expected policy of the parent at time $t+1$. Let $E[\sigma_t^l] = \{\sigma_z^l\}_{z=t+1}^{\infty}$ be the principal optimal strategy at time t with $\sigma^l \in \{\sigma^s, \sigma^p\}$ describing the separating strategy, σ^s, and the pooling strategy of offering project 2 to all the agents, σ^p. Consequently the optimal education effort of both type of parents will be 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, $\gamma > \bar{k}_r$ with $r \in \{1, 2\}$, education effort τ_t^i is costly, and socialization costs, $C(\tau^i)$, are convex. Considering constant operational costs for both farmers, $\bar{k}_1$ and $\bar{k}_2$, we are able to derive the steady states and the long-run equilibrium of this economy keeping in mind that the expected utility of a parents of type i having a child of type j also depends on policy expectations. Define with $Vij[E[\sigma_t^l]]$ the expected utility of a parent of type i having a child of type j[20]. Re-adapting equations (2) and (4) to this standard principal-agent

[20]For instance, the expected utilities at time t under 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 table 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.

scenario, after some algebraical manipulations, we derive the following steady states for this economy: $\bar{q} = 0$, $\bar{q} = 1$ and $\bar{q} = \bar{q}^l \in]0, 1[$ with $\bar{q}^l \equiv \bar{q}[E[\sigma^l]]$. If a separating or a pooling of project 2 strategy is implemented in the long-run, then the resulting non-trivial steady state will be respectively given by $\bar{q}^s = 1 - \frac{\bar{k}_1 - \phi(\Delta y)}{\gamma}$ or $\bar{q}^p = 1 - \frac{\bar{k}_2}{\gamma}$. The steady state under separating strategy is larger than the steady state under pooling strategy: $\bar{q}^s > \bar{q}^p$ if $\phi > \frac{\bar{k}_1 - \bar{k}_2}{\Delta y}$.

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

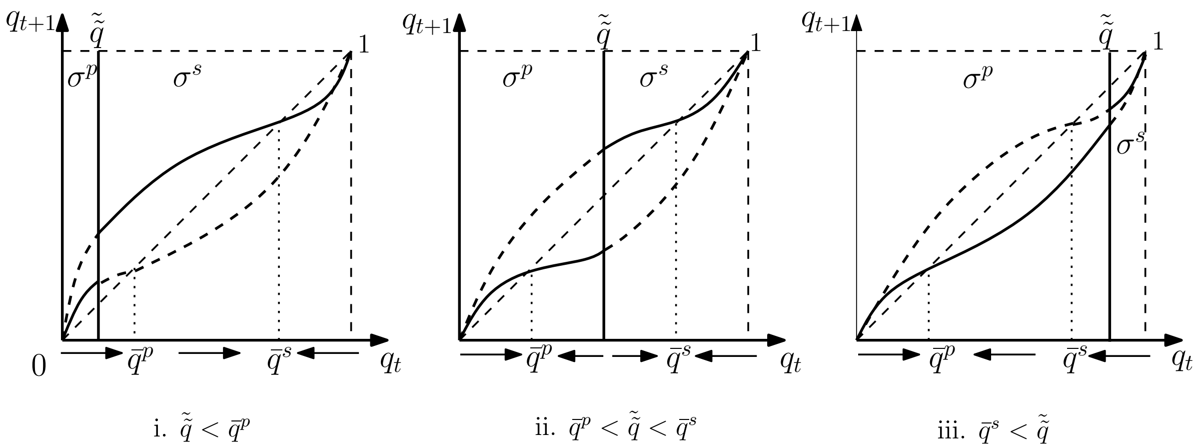
Proposition 2 *Under Assumption 4, a command a control policy exhibits the following dynamic properties:*

- *if* $\tilde{\tilde{q}} < \bar{q}^p$ *then* q_t *converges to* $\bar{q}^s$*;*
- *if* $\tilde{\tilde{q}} > \bar{q}^s$ *then* q_t *converges to* $\bar{q}^p$*;*
- *if* $\bar{q}^p < \tilde{\tilde{q}} < \bar{q}^s$*, expectations are stationary and the long run equilibrium depends on initial conditions:*
  - q_t *converges to* $\bar{q}^s$ *when* $q_0 > \tilde{\tilde{q}}$*,*
  - q_t *converges to* $\bar{q}^p$ *when* $q_0 < \tilde{\tilde{q}}$*.*

Proof See Appendix B

The same dynamics can be found in Hauk and Saez-Marti (2002) in a cultural transmission model of corruption (cf. Proposition 1, page 321). Notice that the threshold that determines the principals' behavior negatively depends on the probability to identify a non pro-environmental agent in the population, ϕ. When ϕ is low, the threshold $\tilde{\tilde{q}}$ 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 a strong effort in educating their children to their own trait, because the reward of being non pro-environmental rather than

Figure 2: Dynamics: The Command and Control Policy



pro-environmental is larger the lower is the probability to identify pro-environmental agent.

Even if these results are already know in the literature on cultural transmission, a deep understanding of the long-run dynamics of preferences under a standard principal-agent model is crucial for our analysis. Indeed, this type of policy is less expensive for the public legislator, but it implies a different long-run equilibrium distribution of environmental preferences compared to the case in which knowledge brokers operate as intermediaries to implement the agricultural environmental measures.

4 Brokers Networks and the Public Institution

The decision of the public legislator to invest extra resources to stimulate the emergence of intermediaries rather than directly delegate the AEMs to farmers, is an open and debated argument. One of the main controversy is related to the analysis of benefits and costs of these different policies. The presence of intermediaries requires larger investments for the legislator, that is, the payment for the organisation of the learnings. When a system with brokers emerges, the total amount of resources transferred to put in practice some AEMs is larger compared to the amount under a centralized command

and control policy[21]. However, the public institution might find profitable to invest these extra resources if and only if one of his main objective is the seek of the social benefits of the environmental effectiveness.

Think for instance to the case in which the public institution uses the pooling strategy to offer a light green AEM to everybody. In this scenario, the gain to be pro-environmental rather than non pro-environmental is very small. Therefore, the associated steady state will be characterized by a low share of pro-environmental agents. Moreover, no environmental effectiveness will be generated since no deep green AEMs will be offered to pro-environmental farmers. By contrast, if an institution find profitable to set a separating strategy, then some environmental effectiveness will always be generated. Since pro-environmental agents will be never revealed as no pro-environmental, the public legislator is able to know the total environmental effectiveness generated by a command and control policy in the long run. However, she cannot distinguish non pro-environmental agents behaving pro-environmentally from 'real' pro-environmental agents. At the same time, when knowledge brokers emerge, all pro-environmental agents will be recognized because intermediaries can adjust relatively quickly compared to the change in preferences' distribution. However, also in this scenario, knowledge brokers are not able to identify non pro-environmental farmers. Consequently, in both scenarios, some non pro-environmental farmers will receive the high monetary transfer, y_1, guaranteed by a deep green AEM without putting effort or investing in learning for the implementation of the deep green measure.

Proposition 3 *Under assumptions 1-4, the emergence of a network of knowledge brokers promotes the environmental culture in the farmers' population if and only if* $\psi > \tilde{\psi}$ *with* $\tilde{\psi} = \frac{s[1]\beta\gamma}{(\bar{k}_1-\bar{k}_2)(1-\bar{b}^b)-\bar{b}^b s[\bar{b}^b](1-\beta)-\phi(y_1-y_2)}$.

Proof See Appendix C

Accordingly to the above proposition, the decision of the public legislator to provide a command control policy rather than investing extra resources to finance intermediaries,

[21] Considering that population is normalized to one, the extra cost that the public legislator has to pay when a system with brokers emerges is equal to $\beta s[1]$.

depends on the level of benefits that the environmental effectiveness of the implementation of deep green AEMs can generate. For this reason, we concentrate our attention on the long-run share of pro-environmental agents as a measure of total environmental effectiveness generated by different policies. The theoretical results indicate that the system with intermediaries can promote pro-environmental behaviour if the environmental effectiveness of a deep green AEM is sufficiently high.

Appendices

Appendix A: Proof of Proposition 1

The dynamic system (5) has three steady states admissible in the domain, $q \in [0,1]$ and $b \in [0,1]$. Two of these steady states are trivial $(\bar{b}_0, \bar{q}_0) = (0,0)$ and $(\bar{b}_1, \bar{q}_1) = (1,1)$, while one is non-trivial $(\bar{q}^b, \bar{b}^b)$.

If the cultural dynamics is such that the dynamic system will converge in the long-run to the solution $q = 0$, it is straightforward to observe that the expected return for a knowledge intermediaries of offering project 1, $\bar{q}_0\psi - (\Delta y + \bar{d} + \beta s[\bar{b}_0]$, with $s[\bar{b}_0] = s[0]$,will necessarily be negative. This means that when $q = 0$, no knowledge brokers would offer project 1, so that $\bar{b}_0 = 0$. The Jacobian of the dynamic system (5) close to the fixed point (0,0), is given by:

$$J(0,0) = \begin{vmatrix} \gamma - \bar{k}_2 & 0 \\ \psi & -\beta s^{`}[0] \end{vmatrix}.$$

The two eigenvalues $\lambda_{1,2}$ of the dynamic system evaluated at $(0,0)$ are given by: $\lambda_1 = \gamma - \bar{k}_2$, which is positive by assumption 2, and $\lambda_1 = -\beta s^{`}[0] \leq 0$, given the assumptions on function $s[.]$. It follows that the steady state $(0,0)$ is necessarily unstable[22]

When $q = 1$, the dynamic equation describing the adjustment of knowledge intermediaries reduces to $\psi - (\Delta y + \bar{d} + \beta s[\bar{b}_1]$, with $s[\bar{b}_1] = s[1]$, is positive if assumption 1 holds. It follows that the expected return of the intermediary, $\Pi^{\beta}[b_t] \equiv \Pi_1[b_t] - \Pi_2$, is always positive and all intermediaries will have incentives to offer deep green AEMs to farmers. When $q = 1$, the unique network of knowledge brokers implicitly defined by $\Pi^{\beta}[b_t]$ and admissible in the domain is given by $\bar{b} = 1$. Therefore, the second steady state to consider in our analysis is $(1,1)$. The Jacobian of the dynamic system (5) close

[22]Notice that if $\beta s^{`}[0] = 0$, the other eigenvalue is always positive by assumption 2, so that the origin is unstable.

to the stationary point (1,1) is given by:

$$J(1,1) = \begin{vmatrix} \bar{k}_1 + (\beta + 2(1-\beta) - 1)s[1] & 0 \\ \psi & -\beta s^{`}[1] \end{vmatrix}.$$

The two eigenvalues $\lambda_{1,2}$ of the dynamic system evaluated at $(1,1)$ are given by: $\lambda_1 = \bar{k}_1 + (1 - \beta s[1]) > 0$, and $\lambda_1 = -\beta s^{`}[1] < 0$. The stationary point $(1,1)$ is unstable and is a saddle point, since eigenvalues have always opposite sign.

Since both trivial steady state are always unstable, we expect the internal steady state to be stable. Given the impossibility to derive analytical expressions for the stationary point $(\bar{q}^b, \bar{p}^b)$, we follow the analysis on existence and stability of fixed points developed in Francois and Zabojnik (2005). The objective is to prove the existence of a stable non-trivial value of $b \in]0,1[$, such that the replicator function defined in (4) is equal to zero, i.e. $dq = 0$. To prove this statement observe that $\tau^e(q_t, b_t)$ is increasing in $V^{ee}[b_t] - V^{en}[b_t]$ and $\tau^n(q_t, b_t)$ is increasing in $V^{nn}[b_t] - V^{ne}[b_t]$. It follows that the difference in parents' effort $\tau^e(q_t, b_t) - \tau^n(q_t, b_t)$ has to be increasing in the expression $\gamma - 2[b_t(\bar{k}_1 + (1-\beta)s[b_t]) + (1-b_t)\bar{k}_2] \equiv Q_e(q_t, b_t)$. We can define $\Phi : R \to [-1; 1]$ the mapping from $V^{ee}[b_t] - V^{en}[b_t]$ to the probability difference $\tau^e(q_t, b_t) - \tau^n(q_t, b_t)$ with Φ continuous, $\Phi(0) = 0$ and $\Phi^{'} > 0$. Substituting the mapping into the dynamic equation (4), we derive the replicator dynamics describing the evolution of q_t as a function of the relative expected payoff for e-type relative to n-type agent: $dq = q_t(1 - q_t)\Phi Q_e(q_t, b_t)$. Since the function $Q_e(q_t, b_t)$ is continuous, for any $q \neq \{0, 1\}$ the direction of the replicator dynamics equation depends on the sign of the relative expected payoff for e-type, i.e. $Q_e(q_t, b_t)$. Deriving this latter with respect to b_t, we get $Q_e^{'} = 2(\bar{k}_2 - \bar{k}_1 - (1-\beta)(s[b_t] - b_t s^{'}[b_t]))$. Note that under assumption 3, the sign of the first derivative is ambiguous and depends on b_t and on the fix cost, $\bar{k}_1$, of behaving pro-environmental. However the second derivative of Q_e is always negative: $Q_e^{''} = -2(1-\beta)[b_t s^{''}[b_t] + 2s_1^{'}[b_t]]$ since $s^{'}[b_t] > 0$ and $s^{''}[b_t] \geq 0$. The expected return for a pro-environmental relative to a non pro-environmental agent $Q_e(q_t, b_t)$ is a u-shaped function with a maximum point b^{max}. However, only one value of b solving the replicator dynamic defined by (4) can belong to the domain. Observe that, under assumption 3, when $b_t = 0$ the term $Q_e(q_t, b_t)$ is strictly positive, while when

$b_t = 1$ it becomes strictly negative. It follows that the function describing the expected return for a pro-environmental relative to a non pro-environmental agent slopes upward at $b < 0$ and changes slope at $b = b^{max}$. Continuity implies that there exists only one value of $b \in]0,1[$ such that the net benefit of behaving pro-environmentally relative to non pro-environmentally is equal to zero. This internal solution is stable. Rewriting (4) as $q_{t+1} = f[q_t]$, taking the first derivative of the r.h.s. evaluated at $q_t = \{0,1\}$, allows us to derive $f^{`}[q] = 1 + \bar{k}_2(1-p_t) + p_t(\bar{k}_1 + (1-\beta)s[b]) > 1$. This inequality implies that the trivial steady states are necessarily unstable. It follows from continuity that the internal steady state $(\bar{q}^b, \bar{b}^b)$ is the stable steady state of the system defined in (5).

Appendix B: Proof of Proposition 2

Assumption 4 implies that $\phi < \frac{\bar{k}_1}{\Delta y}$. This restriction guarantees that the incentive compatibility constraint under command and control policy is satisfied. It follows that potentially non pro-environmental farmers always behave non pro-environmentally. Moreover, assumption 4 also implies that $\phi > \frac{\bar{k}_1 - \bar{k}_2}{\Delta y}$. This restriction guarantees that the steady state under separating strategy is always larger than the steady state under pooling strategy. Using the utility matrix in table 1 and 2 when $b_t = 0$, so that $k_1[b_t] = \bar{k}_1$, we can derive the expected utility at time t of a parent of type i having a child of type j. Note that the expected utility when the institution offers a separating strategy, depends on the probability of recognize a non pro-environmental agent, ϕ. More precisely: $V_s^{ee} = V_1^{ee}$, $V_s^{en} = \phi V_2^{en} + (1-\phi)V_1^{en}$, $V_s^{nn} = \phi V_2^{nn} + (1-\phi)V_1^{nn}$ and $V_s^{ne} = V_1^{ne}$. Define $\tau^i[q_t; E[\sigma_t^l]] = \tau^i[q_t; V^{ii}[E[\sigma_t^l]] - V^{ij}[E[\sigma_t^l]]]$ with $i = \{e, n\}$ type of agent and $l = \{p, s\}$ type of strategy (pooling and separating, respectively) decided by the public institution at time t. Solving the dynamic equation (4) when $b_t = 0$, we derive the possible steady states of the economy: $\bar{q} = 0$, $\bar{q} = 1$ and $\bar{q}^l \in (0,1)$. The non-trivial steady state $\bar{q}^l$ is a function of the expected policy decided by the institution in the long run $\bar{q}^l \equiv \bar{q}^l[E[\sigma^l]]$. It follows that the dynamics of the preferences will depend on the institution profitable strategy decided at each period of time $t > 0$.

Using (2) we are able to derive the intensity of the optimal education effort of pro-environmental, $\tau^e[q_t, E[\sigma_t^l]]$, and non pro-environmental parents, $\tau^n[q_t, E[\sigma_t^l]]$, related to the expected policy[23]. Observe that $\tau^e[q_t, E[\sigma_t^l]] > \tau^n[q_t, E[\sigma_t^l]]$ when $q_t < \bar{q}^l[E[\sigma_t^l]]$ with $\bar{q}^l[E[\sigma_t^l]] = \{\bar{q}^s, \bar{q}_2^p\}$, where $\bar{q}^s$ defines the steady states under separating and $\bar{q}_2^p$ under pooling strategy of project 2[24]. In both scenarios the internal steady state will be globally stable in the long run. This statement can be proved given continuity of (4) and observing that the limit of the r.h.s. of the first derivative of the dynamic equation $q_{t+1} = f[q_t, \phi, E[\sigma_t^l]])$ evaluated at $q = 1$, is always larger than one under both strategies under assumption 4. This means that trivial steady states are unstable. It follows that the dynamic equation describing the evolution of preferences, always crosses the 45 degrees line from the left as q_t increase towards the internal steady state.

Depending on the share of pro-environmental agent at time t, the dynamics will depend on the strategy of the public institution. In particular, when $q_t > \tilde{\tilde{q}}[\phi] \equiv \frac{(1-\phi)(y_1-y_2+\bar{d})}{\psi-\phi(y_1-y_2-\bar{d})}$ the public institution will find profitable to offer a separating rather than a pooling strategy. However, if the share of pro-environmental agent is low, $q_t < \tilde{\tilde{q}}[\phi]$, the institution will prefer to opt for a light green AEM to all the farmers.

First, consider the case in which $\tilde{\tilde{q}}[\phi] < \bar{q}_2^p$. By imperfect empathy we derive that $\tau^e[q_t, E[\sigma_t^l]] - \tau^n[q_t, E[\sigma_t^l]] > (<) 0$ if $q_t < (>) \bar{q}^l[E[\sigma_t^l]]$. Suppose that $q_0 < \tilde{\tilde{q}}[\phi]$. In this case the public institution will offer at time $t = 0$ project 2 to all farmers because $\tilde{\tilde{q}}[\phi] < \bar{q}_2^p$. Since $q_0 < \bar{q}_2^p < \bar{q}^s$, pro-environmental farmers will make a larger effort compared to non pro-environmental farmers to protect their trait, that is $\tau^e[q_t, E[\sigma_t^p]] > \tau^n[q_t, E[\sigma_t^p]$. The evolutionary dynamics will increase the share of pro-environmental agents at time $t = 1$. At time $t + k$ we observe that $q_{t+k} > \tilde{\tilde{q}}[\phi]$. When this happens, the institution will find profitable to change policy and offer a separating strategy. In this case, we observe that $\tau^e[q_t, E[\sigma_t^s]] - \tau^n[q_t, E[\sigma_t^s]] > 0$ for all $q_t < \bar{q}^s$. It follows that the share of pro-environmental agents continues to increase until the stable steady state $\bar{q}^s$. Note that if $E[\sigma_t^l] = \sigma^s$ then $\bar{q}^l[E[\sigma_t^l]] = \bar{q}^s$, while if $E[\sigma_t^l] = \sigma_2^p$ then $\bar{q}^l[E[\sigma_t^l]] = \bar{q}_2^p$. Given the expected strategy profile $E[\sigma_t^s] = \{\sigma^s\}_{t+1}^{\infty}$, the institution will find rational to offer always a separating strategy in the long run.

[23]We assume that socialization costs are convex and we consider the standard function used in the literature on cultural transmission, that is: $C(0) = C'(0) = 0$, $C'(\tau^i) > 0$ and $C''(\tau^i) > 0$.

[24]Remember that for the institution is never optimal to offer the pooling strategy of project 1.

If $\bar{q}_2^p < \tilde{\tilde{q}}[\phi] < \bar{q}^s$, the long run steady state will depend on the initial conditions of the dynamic variable q. In this scenario, the expected strategy profile $E[\sigma_t^l]$ of the public institution is always stationary and depends on the effort of parents in the socialization process. In particular, $E[\sigma_t^l] = \sigma_2^p$ if $q_0 < \tilde{\tilde{q}}[\phi]$, while $E[\sigma_t^l] = \sigma^s$ if $q_0 > \tilde{\tilde{q}}[\phi]$. If the initial share of pro-environmental agents is such that the pooling (separating) strategy is chosen, the dynamic of preferences will converge to $\bar{q}_2^p$ $(\bar{q}^s)$.

Finally, if $\tilde{\tilde{q}}[\phi] > \bar{q}^s$, the separating strategy will be offered only when $\tilde{\tilde{q}}[\phi]$. As before $\tau^e[q_t; E[\sigma_t^l]] - \tau^n[q_t; E[\sigma_t^l]] > (<) 0$ if $q_t < (>) \bar{q}^l[E[\sigma_t^l]]$. Since $\tilde{\tilde{q}}[\phi]$ is larger than the steady state under separating strategy, this equilibrium will be never reached. Assume that $q_0 > \tilde{\tilde{q}}[\phi]$. At time $t = 0$ the institution will find profitable to offer the separating strategy. However, since $q_t > \bar{q}^s$ we observe that $\tau^e[q_t; E[\sigma_t^l]] < \tau^n[q_t; E[\sigma_t^l]]$. It follows that at time $t = 1$, we will have $q_1 < q_0$. The reduction in the share of pro-environmental agent will modify the profitability condition of the public institution. If at time $t+k$ the share $q_{t+k} < \tilde{\tilde{q}}[\phi]$, then the public institution will find profitable to offer project 2 to all farmers. The long run equilibrium will be characterized by a share of pro-environmental agents $\bar{q}^p < \bar{q}^s$ in a scenario in which the institution will offer project 2 to all farmers.

Appendix C: Proof of Proposition 3

To prove proposition 3, we should analyse if the net long-run benefits of a policy finalized to generate a network of knowledge brokers are positive. Put differently, we analyse if the benefits in terms of total environmental effectiveness produced in the long run by a system with brokers, are sufficiently high to compensate for the extra monetary investments of financing knowledge activities: $\psi(\bar{q}^b - \bar{q}^s) > \beta s[1]$. Define the equilibrium shares of pro-environmental agents as follow: $\bar{q}^b = \frac{\gamma - \bar{b}^b((1-\beta)s[\bar{b}^b] + \bar{k}_1) - \bar{k}_2(1-\bar{b}^b)}{\gamma} \in]0,1[$ and $\bar{q}^s = \frac{\gamma + \phi(y_1 - y_2) - \bar{k}_1}{\gamma} \in]0,1[$. First, notice that assumptions 1-3 guarantee that an internal steady state with a share of pro-environmental agents $\bar{q}^b$ exists and is stable. Second, assumption 4, implies that the share of pro-environmental agents under a separating equilibrium is always larger than the share under pooling equilibrium. Indeed, in the command and control scenario, if a public institution find profitable to offer a pooling strategy, the environmental effectiveness produced in the long run will be zero, since all farmers will implement a light green AEM. At the same time, if the share of pro-environmental agents in the long run under a system with intermediaries is lower than the share under a separating strategy, then environmental effectiveness will be maximized under a command control policy. For this reason, a necessary condition to have larger environmental effectiveness under brokers' system is that $\bar{q}^b > \bar{q}^s$. However, this condition is not sufficient to guarantee that the environmental effectiveness generated in presence of green knowledge brokers would compensate for the extra investment that the legislator has to do to generate a network of knowledge brokers. If we compare the difference in long run share of pro-environmental agents $\bar{q}^b - \bar{q}^s$ with the extra cost of investing in a system with knowledge brokers $\beta s[1]$, we find that the inequality $\psi(\bar{q}^b - \bar{q}^s) > \beta s[1]$ is satisfied when $\psi > \tilde{\psi}$ with $\tilde{\psi} \equiv \frac{s[1]\beta\gamma}{(\bar{k}_1 - \bar{k}_2)(1-\bar{b}^b) - \bar{b}^b s[\bar{b}^b](1-\beta) - \phi(y_1 - y_2)}$.

References

brokers.bib