Title: State-Community Cooperation in the Commons and Its Contribution to Environmental Outcomes: Evidence from Thailand's Community Forest

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Abstract: The paper contributes to a much discussed research question that whether and when it improves matters, in this case, environmental outcomes, to vest ownership in public entity or collectivities. It, both theoretically and empirically, offers a new solution that ownership can be shared, as forests cover a wide range of resources. Some resources can be vested under public ownership and some can be vested under the local community. With cooperation, this can solve hold-up problems and create an incentive for human capital sharing that ultimately leads to optimal human capital investments and hence better environmental outcomes. Empirically, the paper takes Thailand's "forest community registration" programme as a measure for such cooperation. Although the registration does not give *de jure* common property rights to the communities, it marks the cooperation and the sharing of knowledge and human capital between the state and communities in protecting the forests. Based on both baseline fixed effect and instrumental variable strategy estimations, it is found that at the province level, an increase in the degree of cooperation is associated with (i) a reduction in the occurrence of forest fires, (ii) a decrease in air pollution, and (iii) lower level of forest deterioration and an improvement in forest regeneration.

Keywords: Relationship-specific investment, common property rights, community forest, environmental degradation

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I. Introduction

The management and the institutional arrangement of a common-pool resource such as the forest, in particular as to how to avoid the so-called tragedy of the commons, has long been a subject of interest for economists and other social and environmental scientists. Many schemes such as introducing punishment levied by the state authorities and the common-pool resource privatisation have been devised by policy makers in attempt to solve the problem. Nonetheless, in her seminal work (for instance, see E. Ostrom, 1990), E. Ostrom has suggested that the common-pool resource can be efficiently owned by a group of individuals, or the community. When property rights over the resource are well and clearly defined, community ownership can serve as an alternative tool to avoid the "tragedy of the commons" or environment degradation. A number of community ownership and community forests have, since, been put into practice, gained support from official authorities, and won legal recognition. A number of studies have tried to investigate factors and rules, as well as to devise the schemes, which are essential for the success of community land ownership. However, while there is a movement towards community ownership in governing the commons, the role of the state in providing expertise and services that are also important for the common-pool resource protection are gradually ignored. State ownership and community ownership are often viewed as the two systems that exist in separate spheres.

This paper applies the incomplete contract theory of non-verifiable information and relationship specific investment (for example, see Hart, 1995; and Hart and Moore, 1990) to the problem of the common-pool resource management. It proposes that state and community co-ownership of the common resource can, in fact, lead to a desirable outcome. This is when each party's rights are exclusively and well defined over the spectrum of resources (e.g. forest stock and forest flow) in the unified common pool (e.g. forest as a whole).Unlike under the system that the whole spectrum of rights over the common is owned by one party, co-ownership can lead to a desirable outcome because it can lead to coordination and the sharing of human capitals between the two parties. More specifically, the paper shows that given that cooperation can be achieved and human capitals are shared, cooperation between the state and the local community in protecting the forest can yield a better outcome than under the decentralisation of forest management to the locals or under the pure government ownership.

In the empirical part, the paper exploits a unique institution of Thailand's community forests where well-defined rights to the spectrum of forest resource are shared between the state and the community. It has been documented that under such arrangement, the state has provided essential human capital and non-physical support that otherwise would have been absent under the community ownership. In addition, the community complements the state's human capital with its locally-based human capital, mainly by strengthening protection, and monitoring the forest use by the local groups of volunteers. The coordination and the resulting human capital sharing have led to better environmental outcomes. In particular, in this paper, with the use of the province-level panel data, both the

baseline and instrumental variable (IV) results show that the extent of the forest community registration, which represents the coordination between the state and the local forest community, is associated with (i) lower level of forest deterioration and an improvement in forest regeneration, (ii) a reduction in the frequency of forest fires, and (iii) a decrease in air pollution.

Such findings complement the existing literature on governing the commons. Co-ownership, when rights belonged to each party is well defined, can lead to a more desirable outcome. In the age that privatisation and decentralisation of rights from the state to local communities are a common practice, this paper provides both theoretical underlying and empirical evidence that the government and the local communities can cooperate and share the ownership. This, as a consequence, generates incentives and behaviours that lead to the sharing of human capitals – an important yet often ignored in the common-pool resource literature - in yielding better environmental outcome.

The rest of the paper is organised as follows. Section II covers a brief account of the so-called community forests in Thailand. Section III illustrates a theoretical framework. Section IV discusses the data. While section V presents baseline empirical analysis, section VI covers instrumental variable estimation. Section VII concludes.

II. The so-called community forests in Thailand: a brief account

Despite (i) an international movement towards community-forest management, where the management of the forests are decentralised and transferred from the government to the local, and (ii) a domestic movement, supported by the 1997 constitution, towards increased participation of communities and local organisation in managing natural resources (*item 46*); still, Thailand's forest communities do not possess legally supported status. When the movements had culminated in early 2002, the House of Representatives passed the bill that recognised the legal status of the communities, which lived in and around the National Forest Reserves, and initiated the establishment of forest communities, the Senate rejected the bill.

Such rejection ignored the fact that there exist more than 80,000 communities residing in and around the forests all over Thailand. These local communities have relied on the forests as a major source of food and energy. Even though in the *de facto* fashion, they have used, protected and managed the forests for a long time and over several generations (Daniel, 2002). Nevertheless, despite the rejection of the bill, the Royal Forest Department (RDF, hereafter) has decided to carry on with its "forest-community registration" project, which started in 1999. The registration has marked and enabled the cooperation and the sharing of knowledge and technology, in using and protecting the forests, between the government and the locals.

It is often noted in the literature (for example, see Salam et. al., 2006) that the community-forest management is often initiated by the local people and already in use prior to the registration. However, once the local communities are registered as the forest communities with the RFD, they are legally recognised and their locally organised activities are supported by the RFD. Even though the registered communities possess no legal rights, the RFD informally allows the communities to protect the forests and support the communities through its local staffs. In turn, the local communities complement the RFD's work on the protection usually by forest patrol organised by voluntary rotating groups. Such patrol can help detect forest fires as well as illegal logging by the outsiders. Nonetheless, such simple patrols lack support from "hard-technology" such as fire extinguishers and guns

that are usually used by the RFD's staffs. This is because both parties lack the legal rights to do so. In other words, without the bill, the forest-community registration only allows the transfer of soft but not hard technology from the government to the locals.

While the local communities supply the above human capital towards forest usage and forest protection; the roles of the RFD's staffs under the forest-community registration include the following points. First, they informally recognise the *de facto* rights and authority of the communities to forest protection. Second, they motivate the local communities to take up further protection through a variety of auxiliary programmes. For instance, the RFD occasionally initiates tree-planting programmes, and soil-conservation programmes, in conjunction with the local communities and interested outside parties. In addition, in order to create a clear physical boundary of rights in the forests, the RFD staffs also facilitate the demarcation of the significant forest areas in the vicinity of the local communities. Importantly, the RFD's staffs either take or support penal actions against offenders, in the disputes and cases that have been brought to them by the villagers. Such supports strengthen the credibility of the local community role and complement its extended activities. Moreover, the staffs can permit or overlook the selective felling of trees that is proposed by the local communities. Even if such practice is subject to the staffs' discretion, it creates a degree of flexibility and compromise in the local forest usage, which can help strengthen the coordination between the two parties. Lastly, the RFD's staffs have to facilitate the formation of the local executive committees in relation to forest protection.

According to the above account, the forest-community registration programme has brought about a close coordination and the sharing of non-physical resources between the state and the local communities in using and protecting the forests. In absence of the registration, the local human capital would have not been fully recognised and utilised. In absence of the registration, the use of state's authority and its staffs' expertise would have been confined within the *de jure* context. With the coordination and the sharing of non-physical resources, the opportunity set of the use of both parties' human capitals has expanded. Following this, the next section shows how such coordination can theoretically lead to desirable environmental outcomes.

III. Relationship-specific investment and property right in the forest

The theoretical part applies the incomplete contract theory. Specifically, the simplest possible version of the incomplete contract theory of firms with the relationship-specific investment (Hart, 1995; Hart and Moore, 1999, and 2006) is applied to show how co-ownership of the forests, between the state and the local communities, can solve the hold-up problem in non-physical capital investment that is relevant to forest protection, and, in turn, can lead to an improvement in the forest condition and the environmental outcomes. To my knowledge, it is the first time that this type of incomplete contract theory has been applied to common resource and environmental economics literature.

The setup and assumptions:

Assume that there are two parties concerning forest protection; the Royal Forest Department (P1) and the local community (P2). Forests are the combination of two assets; (i) the stock of forests (f1) – the forests as a whole environmental unit, and (ii) the flow of forests (f2) – the products of the forests including timber and non-timber products such as fruits and mushrooms. Suppose that in order to "produce" forest maintenance and protection, P2 in combination with f2, supplies a single unit of input, called *a local forest*

protection, to P1. P1 in combination with f1, then use this *local forest protection* to produce output, *environmental outcomes related to the forest conditions,* which have the value to the public or the so-called market.

Assume also that this economic relationship lasts for two periods. *Ex ante* relationship-specific investments by the two parties are made at period 0, and the *local forest protection* is supplied at period 1. P1 makes relationship-specific investment in its staffs' training on technological knowledge and official protocols, and in using technology that can help forest protection. P2 makes relationship-specific investment in the local knowledge and practice, and village social capital that are essential for forest maintenance and protection. Both forest stock and flow are already in place at period 0, so that the investments taken by both agents will make forest stock and flow more "productive" with respect to improving environmental outcomes.

The model also assumes that the state and the local community have symmetric information throughout, and there is no uncertainty about each agent's costs and benefits. Nevertheless, there is uncertainty about the quality of the *local forest protection* that P1 requires. Only in period 1, the quality or type of the *local forest protection* becomes known. This, as a consequence, creates the ineffective long-term contract between the two parties. This is because the quality of the *local forest protection* cannot be specifically described in the written contract in period 0 according to every contingency occurring in the future period 1. In other words, contract is incomplete. Thus, possible negotiation only occurs in period 1.

In addition, suppose that it is too costly for P1 and P2 to specify particular uses of f1 and f2 in period 0 contract. For example, from case to case, the local staffs permit selective tree-felling by the local community, however, this cannot be officially specified in the rule and largely depends on the staffs' discretion. Consequently, the owner(s) of asset f1 and f2 has not only residual rights of control, but all control rights over the stock and flow of forest.

There exist 4 possible types of ownership or property right in the forest structures.

(i) *Full cooperation or Co-ownership:* P1 owns f1, and P2 owns f2, with both being able to access both human capitals. This type of ownership represents Thailand's existing non-official community forest, which has come into place after the introduction of the forest-community registration programme. As outlined in the background section, the RFD still holds the ownership of the stock of forests, and the local communities can possess the flow of forest products.

(ii) *Non-integration:* P1 owns f1, and P2 owns f2, but with no access to the other party's human capital. This type of integration can describe the state of forest ownership in Thailand before the introduction of the forest-community registration programme. Similar to the co-ownership type, the RFD has an access and owns the stock of forests and the local communities use the flow of the forests. However, without the registration, the rights of the local communities are not formally recognised and, as a result, are threatened from time to time by local staffs. In addition, without the mark of registration, there is no cooperation or the sharing of human capitals between the official staffs and the locals. Under such circumstances, they do not cooperate in protecting and using the forests, but competing in owning the forests.

(iii) *Type 1 integration:* P1 owns both f1 and f2, but P1 has no access to P2's human capital. Type 1 integration can be thought of as the Nationalised public forest, where the forests are owned, used and managed solely by the State.

(iv) *Type 2 integration:* P2 owns both f1 and f2, but P2 has no access to P1's human capital. This type of integration can capture typical community forests where the ownership, the use and the management of the forests are decentralised from the government to local people.

Relationship-specific investments and payoffs:

Let us denote P1's relationship-specific investment by *i.* Such investment affects the state's payoff both if the RFD deals or "trades" with the local community and if it does not. In other words, investing in its staffs' human capital relating to forest protection would pay off, although to a lesser extent, even if the RFD does not deal with the locals. If "trade" happens, P1's will have an access to both P2's physical and human capitals in addition of its own physical and human capitals and , hence, gain G(*i*) and its *ex-post* payoff is G(*i*) – *r*, where *r* is the agreed return P1 gives to P2 for the local forest protection service P2 supplies. If "trade" does not happen, P1 can arrange with an outsider who supplies "non-specific" local forest protection at rate, $\bar{r}$. Assume that this "non-specific" local forest protection potentially leads to lower-quality protection. P1's payoff will be *g(i;F) -*$\bar{r}$ in this case. The lower-case *g* denotes the absence of P2's human capital and *F* denotes the set of assets P1 has access to, where

$$F = \{f1\}\ under\ full\ cooperation\ and\ non-integration,$$
$$F = \{f1, f2\}\ under\ type\ 1\ integration,$$
$$F = \emptyset\ under\ type\ 2\ integration.$$

Similarly, P2's relationship-specific investment in period 0 is denoted by *e.* As mentioned above, this includes investing in local knowledge and practice, as well as social capital that is essential for forest protection. If "trade" occurs with P1, P2's payoff is *r-C(e),* where *C(e)* is the cost of relationship-specific investment. Likewise, if "trade" does not occur, P2's payoff is $\bar{r}$ *−c(e;V)* and *V* denotes the set of assets P2 has access to*,* where

$$V = \{f2\}\ under\ full\ cooperation\ and\ non-integration,$$
$$V = \emptyset\ under\ type\ 1\ integration,$$
$$V = \{f1, f2\}\ under\ type\ 2\ integration.$$

If "trade" occurs, the total *ex-post* surplus is $G(i) - r + r - C(e) = G(i) - C(e)$. Following this, if "trade" does not occur is $g(i; F) - c(e; V)$. Following Hart (1995), assume that there are always *ex-post* gain from trade, whether the RFD ends up dealing with the local communities or not, such that:

Condition 1:

$$G(i) - C(e) > g(i; F) - c(e; V) \geq 0, for\ all\ i\ and\ e, and\ for\ all\ F\ and\ V,$$
$$where\ F \cap V = \emptyset\ and\ F \cup V = \{f1, f2\}.$$

Condition 1 implies that the investment by P1 and P2 are relationship-specific and they pay off more if "trade" occurs. This relationship-specificity also applies to marginal return from each investment, such that:

Condition 2:

$$\frac{\partial G(i)}{\partial i} > \frac{\partial g(i; f1, f2)}{\partial i} \geq \frac{\partial g(i; f1)}{\partial i} \geq \frac{\partial g(i; \emptyset)}{\partial i}, for\ all\ 0 < i < \infty,$$

and

Condition 3:

$$\left|\frac{\partial C(e)}{\partial e}\right| > \left|\frac{\partial c(e; f1, f2)}{\partial e}\right| \geq \left|\frac{\partial c(e; f2)}{\partial e}\right| \geq \left|\frac{\partial c(e; \emptyset)}{\partial e}\right|, for\ all\ 0 < i < \infty.$$

Notice that *i* is specific to forest stock but not to forest flow, whereas *e* is specific to forest flow but not to forest stock. Both parties observe the above gains and cost, however outsiders cannot verify them. Conditions 2 and 3 also emphasise again the role of human capital investment, which is an important element in achieving desirable environmental outcomes, yet often ignored in the common-pool resource literature.Both investments are in human capital. It enhances the final payoff, but, unlike physical capital, cannot be owned or transferred to the other's party. This is why, for example, although P1 owns both *f1* and *f2,* with no access to P2's human capital, P1 earns a strictly smaller payoff, i.e. $G'(i)$ is strictly greater than $g'(i; f1, f2)$.

Period 1 division of surplus:

As both parties possess symmetric information, we can assume that bargaining occurs in period 1 such that the gain from trade is divided equally as in the Nash bargaining solution, such that it yields the following results.

Full Cooperation:

Similar to rights under typical community forests, rights to flow are parceled and rights to stock remain intact. Nonetheless, unlike typical community forests where both rights are held by the community, the two types of rights, under full cooperation, are vested in different bodies. In particular, while rights to flow are purely vested in the local community, rights to stock are owned by the State. In addition, both have reached the agreement that by sharing such a structure of ownership over the unified forest, they also have access to each other's human capital. By allowing full cooperation and full human capital access, the net present value of their "trading" relationship is

$$G(i) - i - C(e) - e,$$

which yields the optimal *ex-ante* relationship-specific investments, *i** and *e*.* In other words, by optimisation,

$$\frac{\partial G(i^*)}{\partial i} = 1,$$
$$\left|\frac{\partial C(e^*)}{\partial e}\right| = 1.$$

Non-Cooperation:

This represents a situation when the RFD and the local community choose their human capital investments non-cooperatively in period 0. P1's and P2's payoff are, thus, as the following.

$$\pi_1 - i = -\bar{r} + \frac{1}{2}G(i) + \frac{1}{2}g(i; F) - \frac{1}{2}C(e) + \frac{1}{2}c(e; V) - i,$$
$$\pi_2 - e = \bar{r} - \frac{1}{2}C(e) - \frac{1}{2}c(e; V) + \frac{1}{2}G(i) - \frac{1}{2}g(i; F) - e.$$

By differentiation with respect to investments and following necessary and sufficient conditions for a Nash equilibrium;

$$\frac{1}{2}\frac{\partial G(i)}{\partial i}+\frac{1}{2}\frac{\partial g(i;F)}{\partial i}=1,$$
$$\frac{1}{2}\left|\frac{\partial C(e)}{\partial e}\right|+\frac{1}{2}\left|\frac{\partial c(e;V)}{\partial e}\right|=1.$$

Consequently, it yields the following equilibriums.

Non-integration equilibrium:

$$\frac{1}{2}\frac{\partial G(i_0)}{\partial i}+\frac{1}{2}\frac{\partial g(i_0;f1)}{\partial i}=1,$$
$$\frac{1}{2}\left|\frac{\partial C(e_0)}{\partial e}\right|+\frac{1}{2}\left|\frac{\partial c(e_0;f2)}{\partial e}\right|=1.$$

Type 1 integration equilibrium:

$$\frac{1}{2}\frac{\partial G(i_1)}{\partial i}+\frac{1}{2}\frac{\partial g(i_1;f1,f2)}{\partial i}=1,$$
$$\frac{1}{2}\left|\frac{\partial C(e_1)}{\partial e}\right|+\frac{1}{2}\left|\frac{\partial c(e_0;\emptyset)}{\partial e}\right|=1.$$

Type 2 integration equilibrium:

$$\frac{1}{2}\frac{\partial G(i_2)}{\partial i}+\frac{1}{2}\frac{\partial g(i_2;\emptyset)}{\partial i}=1,$$
$$\frac{1}{2}\left|\frac{\partial C(e_2)}{\partial e}\right|+\frac{1}{2}\left|\frac{\partial c(e_0;f1,f2)}{\partial e}\right|=1.$$

Proposition 1:
Full cooperation yields the highest relationship-specific investments. Other ownership structures yield underinvestment and hence sub-optimal environmental outcomes. In other words,

$$\frac{\partial G(i)}{\partial i}>\frac{1}{2}\frac{\partial G(i)}{\partial i}+\frac{1}{2}\frac{\partial g(i;F)}{\partial i}=1$$
$$\left|\frac{\partial C(e)}{\partial e}\right|>\frac{1}{2}\left|\frac{\partial C(e)}{\partial e}\right|+\frac{1}{2}\left|\frac{\partial c(e;V)}{\partial e}\right|=1,$$

by assuming negative second derivatives. Alternatively,

$$i^*>i_1\geq i_0\geq i_2,$$
$$e^*>e_2\geq e_0\geq e_1.$$

Choice of forest ownership structure:

Under full cooperation, the two types of rights are vested in different bodies. In particular, while rights to forest flow are parceled and purely vested in the local community[1], rights to forest stock are intact and owned by the State. In addition, both have reached the agreement that by sharing such a structure of ownership over the unified forest, they also have access to each other's human capital. As such, cooperation and

[1] The paper assumes away any possible internal collective-action problem. It simply focuses on the local community as a unit which can be represented by an agent.

human capital sharing in the forest yields the highest relationship-specific investments in both parties' human capital ($i^*$and e^*) and the highest resulting environmental outcomes.

Under Type 2 integration or a typical community forest where both forest flow and stock are held by the local community, by ignoring possible internal collective-action problem, we assume that by sharing rights within the local community, the local can monitor each other's use and can band together to patrol the entire forests to protect them from outsiders' invasion. Rights to flow of forests are parceled among the local community members, whereas rights to stock of forests are intact. Nevertheless, the local will not have an access to the RFD's technical assistance, which can be essential in maintaining and protecting the forest.

For Type 1 integration or nationalised public forests, property rights or ownership are entirely transferred from the local user groups or local community to the state. This eliminates an incentive for the local community to monitor and restrain use. It converts owner-protectors into poachers. Both rights to flow and rights to stock of forests are intact under such public property rights.

The advantage of full cooperation over Type 2 integration is that although both divide the resources into two groups, by allowing the stock to be owned by an additional party who also has an interest in protecting the forests as a whole, full cooperation gives an incentive to that party (the RFD) to contribute its human capital, which is not possessed by the local community, in forest protection. This is likewise in the case of the advantage of full cooperation over Type 1 integration. Co-ownership can solve the problem occurred in the nationalised public forests that the government rarely possesses enough money or personnel to enforce their rules and laws. Under the coordination, the local communities will contribute their human capital on personnel that otherwise could be absent under a single state-ownership. Unlike the locals, the RFD staffs have a smaller incentive to patrol frequently, as the benefits resulting from their employment are not closely tied to their enforcement of the Forest laws. The locals, on the other hand, benefit from an access to forest products in return for their monitoring duties.

Although the model covered in this paper is abstracted from discussing about forest privatisation, the existing literature on the commons often exerts that due to the indivisibility of the forests, stocks should not be parceled as typically occurs under privatisation. Forests may become unable to produce some products and benefits if we try to divide them into small parcels under individual private property rights regime. This is because forests are not only valuable for their products but also for their protection of water, soil and local climate (McKean, 2000). As a consequence, they should be managed in very large units.

In addition, although it has been acknowledged that the internal relation and actions within the local group, to a certain extent, determine the outcomes of natural-resource management (Gibson et. al., 2000), this aspect of the issue is not the subject of interest in this paper. The paper does not open up the local group into several units of group members, but takes the local group as a unified unit which can be represented by a single agent. The paper focuses on the relationship between a group of the locals and the state, and not the organisation within the local communities. It ignores the issues concerning factors and conditions that lead to successful management and organisation within the local community. By doing so, it analyses the option and aspect of the possible co-ownership and coordination between the state and local community that have been largely ignored in the literature.

IV. Data

To capture the cooperation between the State and the local communities, the paper makes use of the province-level registration of the forest communities recorded at the Community Forest Office, the Royal Forest Department. The record spans from the first year of the registration, 1999, to 2011. Three measures; (i) the number of forest-community villages, (ii) the number of forest-community projects[2], and (iii) total forest-community area, are used to represent the extent of the cooperation which varies from province to province, and from year to year. The summary statistics are covered in Table 1.

There are three measures of environmental outcomes that are related to the state of forests; (i) forest fire, (ii) air pollution, and (iii) forest deterioration. Forest fire is captured by both its frequency of occurrence and the area each incident covers. The forest fire data are obtained from the records collected by the RFD in conjunction with its provincial offices. Air pollution data are obtained from the Public Health Department. Two measures that are seen to be related to the use and the state of forests are selected. The mean of average carbon monoxide in 8 hours, measured in ppm or parts per million, is used to capture the general state of air quality in each province. Another measure of air pollution is PM10 or particulate matter of 10 micron diameter, which forest fires usually emit (Junpen et. al., 2011). According to the Public Health Department, if PM10 in 24 hours exceeds 120 micron/cubic metre (the standard level), the air is considered to be dangerously polluted. The last measure of environmental outcomes – forest deterioration- is the share of forest area in each province interpreted from the satellite pictures since 1961. The summary statistics of the three measures are in Table 1.

[2] The difference between forest-community villages and forest-community projects is derived from the fact that in some cases, a project can cover more than one village.

TABLE 1: PROVINCE-LEVEL SUMMARY STATISTICS (1999 - 2011)

	observations	Mean	minimum	maximum
Forest communities				
Number of forest-community villages	909	65.67	0	347
		[64.95]		
Number of forest-community projects	909	60.65	0	382
		[59.55]		
Total forest-community area (*rai*)	909	18711.98	0	272290
		[30801.3]		
Forest communities normalised by forest area (%)				
Number of forest-community villages	896	0.017	0	0.553
		[0.055]		
Number of forest-community projects	896	0.016	0	0.554
		[0.055]		
Total forest-community area	896	2.27	0	29.38
		[4.13]		
Forest fire				
Forest-fire frequency	801	152.39	1	2664
		[342.49]		
Forest-fire area (*rai*)	801	2262.67	2	48841
		[4063.79]		
Pollution				
Mean of average carbon monoxide in 8 hours (ppm)	252	0.545	0.2	1.4
		[0.188]		
% of average PM10 in 24 hours greater than the standard level	253	3.368	0	42.44
(120 micron/cubic metre)		[6.463]		
Forest deterioration				
Share of forest area from satellite picture interpretation	1066	29.639	0.243	100
(From 1961)		[22.571]		

Note: Standard deviations are in parentheses.

V. Baseline empirical analysis

Empirical strategy

With the use of province-level panel data, the following baseline specification based on the fixed effects are used as the main empirical strategy

$$y_{it} = \alpha_i + \beta_t + \gamma CF_{it} + \theta' x_{it} + u_{it} ,$$

where y_{it} is the variable measuring environmental outcomes of province *i,* in year t. CF_{it} represents the cooperation between the RFD and the local communities in using and protecting the forests, which is captured by three measures of the registration of the forest communities, namely (i) the number of forest-community villages, (ii) the number of forest-community projects, and (iii) total forest-community area. α_i includes unobserved time-invariant province-level characteristics, such as the geographic variation of forest condition, e.g. the elevation, that could potentially determine the success of forest use and protection (for example, see Schweik, 2000 for the case of southern Napal). β_t captures the nationwide events that could affect the environmental outcomes of each province in the same way in year t. u_{it} is clustered at the province level.

One of the advantages of the empirical strategy, considered in this paper, is the use of sub-national panel data that can capture the essence of both community forest management and environment outcomes. This not only allows us to look at the effects over time, but the use of the panel data with the fixed effects also allows the paper to control for any time-invariant characteristics at the province level that could have otherwise been omitted variables and led to the endogeneity problem under the simple cross-section data.

CF_{it} - the number of forest-community villages, projects, or area – can be seen, with reference to the theoretical part, as the extent of moving towards *Full Cooperation*. Prior to the registration, the RFD had already taken an official responsibility of protecting forest resources, however it lacked the coordination and cooperation with the local communities which, in some parts of Thailand, had long devised some kinds of local management in order to protect the forests. Thus, for some parts of Thailand, CF_{it} can, according to the theoretical part, be a proxy of a movement from *Non-Integration* to *Full Cooperation.* On the other hand, in places that the local communities did not have interest in forest protection, registration can be seen as moving from *Type 1 Integration* to *Full Cooperation.* On the other hand, in places that the RFD had extremely limited access to the forests but the local communities had devised their own forest protection and management, registration can be seen as moving from *Type 2 Integration* to *Full Cooperation.* All of which movements represent an increase in the cooperation that enhances the sharing of knowledge and human capital in using and protecting the forests between the two parties.

Baseline empirical results

Forest fires:

Table 2 considers the effect of the cooperation on the occurrence of the forest fires, whereas table 3 considers the effect on the average area of forest fires. While the number of community-forest projects and community-forest area exert negative and statistically significant relationships with the occurrence of forest fires, none of the measures for the registration (cooperation) exerts statistically significant relationship with the forest fire area. At first, this may seem highly puzzling. However, once we consider the theoretical implication on the sharing of human capital, coupled with the background of Thailand's so-called community forests, the results are, indeed, reasonable. Whilst the occurrence of the forest fires can be prevented by simple patrolling organised by the villagers, in order to

control the area of forest fires, ones need some instruments such as fire extinguishers. Although under the cooperation, the local RFD staffs recognise the *de facto* rights and authority of the local communities to forest protection, formally motivate them to take up further protection, and facilitate their activities such as patrolling; under the existing laws, the staffs cannot supply them with physical instruments such as fire extinguishers or guns (Salam et. al., 2006). Consequently, human resources but not physical resources are shared between the two parties. Following from this, it is the occurrence of the forest fires, and not the area of the forest fires, that has been statistically significantly reduced after the introduction of the registration.

The results in table 2 also exert some economic significance in addition to statistical significance. In particular, a one standard deviation increase in the number of the community-forest projects (59.55 projects) decreases the frequency of forest fires by 30 times, which is 45.6% of the mean forest fire frequency in this data set.

TABLE 2: Cooperation in community forest and the frequency of forest fire

	FE	FE	FE	FE	FE	FE
	[1]	[2]	[3]	[4]	[5]	[6]
Community-forest village	-0.249	-0.249				
	[0.176]	[0.176]				
Community-forest project			-0.515	-0.515		
			[0.268]**	[0.268]**		
Community-forest area					-0.0015	-0.0015
					[0.0007]**	[0.0007]**
Announced forest area		-0.000027		-0.000025		4.22E-06
		[7059247]		[3620481]		[6221763]
Year dummies	YES	YES	YES	YES	YES	YES
Province dummies	YES	YES	YES	YES	YES	YES
Observations	801	801	801	801	801	801
Number of groups	65	65	65	65	65	65
Adjusted R-squared	0.856	0.856	0.857	0.857	0.861	0.861

Note: Standard errors are in parentheses. *, **, *** denote significant levels at 10%, 5%, and 1%.

TABLE 3: Cooperation in community forest and the average area of forest fire

	FE [1]	FE [2]	FE [3]	FE [4]	FE [5]	FE [6]
Community-forest village	-1.698	-1.698				
	[3.169]	[3.169]				
Community-forest project			-3.906	-3.906		
			[3.127]	[3.127]		
Community-forest area					-0.015	-0.015
					[0.01]	[0.01]
Announced forest area		-0.0007		-0.0007		1.00E-04
		[1.65e+08]		[1.15e+08]		[1.82e+08]
Year dummies	YES	YES	YES	YES	YES	YES
Province dummies	YES	YES	YES	YES	YES	YES
Observations	801	801	801	801	801	801
Number of groups	65	65	65	65	65	65
Adjusted R-squared	0.533	0.532	0.534	0.533	0.537	0.537

Note: Standard errors are in parentheses. *, **, *** denote significant levels at 10%, 5%, and 1%.

Air pollution:

In table 4, the number of community-forest villages registered is found to be negative and statistically significantly correlated with the province-level mean of average carbon monoxide in 8 hours[3]. As forests are found to also provide environmental services beyond the forests themselves, in particular, they help clean and purify the air (Gibson et al., 2000), proper use and better protection of the forests facilitated by the cooperation between the RFD and the local communities, marked by the forest community registration, should, in turn, lead to better forest condition and, to a certain extent, cleaner air in the surrounding area.

[3] Note that the number of observations is lower than that of in tables 2 and 3 due to the fact that although some provinces have more than one weather/ air pollution stations, not every province is endowed with the station. In the province with more than one station, the average of the measured pollution among different stations is taken.

TABLE 4: Cooperation in community forest and the mean of average carbonmonoxide in 8 hours

	FE	FE	FE	FE	FE	FE
	[1]	[2]	[3]	[4]	[5]	[6]
Community-forest village	-0.0013	-0.0013				
	[0.0006]**	[0.0006]**				
Community-forest project			-0.001	-0.001		
			[0.0008]	[0.0008]		
Community-forest area					-2.01E-06	-2.01E-06
					[1.27e-06]	[1.27e-06]
Announced forest area		-1.47E-07		-1.28E-07		-1.56E-07
		[30989.9]		[28563]		[29877.36]
Year dummies	YES	YES	YES	YES	YES	YES
Province dummies	YES	YES	YES	YES	YES	YES
Observations	251	251	251	251	251	251
Number of groups	26	26	26	26	26	26
Adjusted R-squared	0.674	0.673	0.662	0.66	0.66	0.66

Note: Standard errors are in parentheses. *, **, *** denote significant levels at 10%, 5%, and 1%.

Furthermore, table 5 shows that all of the measures of the cooperation between the state and the local communities statistically and significantly relate to a reduction of the percentage of average PM10 in 24 hours that is greater than the standard level. Such results can be seen as following directly from the results in table 2. Junpen et. al. (2011), for example, emphasise the link between forest fires and its PM10 emission. PM10 is found to be both environmental harmful and health-threatening both to the local communities and the people in the surrounding area. As a result, additionally, although not formally addressed in the theoretical part, by sharing the ownership in the forests, the local communities potentially internalise what would have been externalities to them in the public forest regime. This may also contribute to the findings about the reduction of both forest fire frequency and PM10.

TABLE 5: Cooperation in community forest and % of average PM10 in 24 hours greater than the standard level

	FE [1]	FE [2]	FE [3]	FE [4]	FE [5]	FE [6]
Community-forest village	-0.339	-0.339				
	[0.014]**	[0.014]**				
Community-forest project			-0.04	-0.04		
			[0.016]**	[0.016]**		
Community-forest area					-8.00E-05	-8.00E-05
					[0.00002]***	[0.00002]***
Announced forest area		8.55E-07		4.66E-07		3.18E-07
		[621851]		[650351]		[386822]
Year dummies	YES	YES	YES	YES	YES	YES
Province dummies	YES	YES	YES	YES	YES	YES
Observations	252	252	252	252	252	252
Number of groups	28	28	28	28	28	28
Adjusted R-squared	0.638	0.636	0.696	0.636	0.638	0.636

Note: Standard errors are in parentheses. *, **, *** denote significant levels at 10%, 5%, and 1%.

Forest deterioration:

The state of the forests is measured as the share of the forest in each province, interpreted from the satellite pictures, recorded since 1961. As the registration of "forest communities" has only begun in 1999, from 1961 to 1999, the measure of cooperation takes the number zero.

To control for the time element, the specification, which table 6 is based on, considers the time trend instead of the year dummy. This is, firstly, because the share of forest area generally follows a certain trend and does not usually suddenly fluctuate according to the annual events. More specifically, in Thailand, during the period of study, it is found that the forests tend to deteriorate as opposed to regenerate over time. Thus, if the year dummies were, instead, considered, the study would have potentially omitted a significant trend that determines the share of the forest area. Secondly, following from the first argument, by considering the time trend, the model presents a better fit, and thus, is more likely to be a true model, compared to the model that considers the year dummies. From table 6, in all columns, it is found that there is a negative and statistically significant relationship between the time trend and the share of forest area. This confirms the above conjecture that the share of province-level forest is, indeed, on average, deteriorate over time, during our period of study.

In columns 1, 3, and 5, when the time trend is controlled for, the measure of cooperative forest communities exert a positive and statistically significant relationship with the share of forest. This implies that despite the general trend of forest deterioration occurring overtime, the cooperation between the state and the local communities, which is marked by registered forest communities, can statistically and significantly contribute to forest regeneration. In addition, a huge difference in the magnitudes between the community-forest village (project) and area potentially implies that it is the activity and

human resources at the community level, and not merely the area that the community forest covers, that is at the heart of forest regeneration.

Moreover, in columns 2, 4, and 6, when the interaction between the share of community-forest measure and the time trend are additionally considered, a negative and statistically significant relationship between the interaction term and the share of forest is found. It means that for a given deterioration that occurs over time, an increase in community forest reduces the degree of such deterioration. This implies that by generating forest regeneration, the existence of the cooperation between the state and the local communities also slows down the deterioration of the forests.

TABLE 6: Cooperation in community forest and forest deterioration

Share of forest from the satellite pictures	FE	FE	FE	FE	FE	FE
	[1]	[2]	[3]	[4]	[5]	[6]
Share of community-forest village	7.152	33.102				
	[1.276]***	[6.446]***				
Share of community-forest project			7.367	41.537		
			[1.459]***	[8.28]***		
Share of community-forest area					0.016	0.105
					[0.005]***	[0.045]**
(Share of community-forest village)*(time trend)		-0.572				
		[0.121]***				
(Share of community-forest project)*(time trend)				-0.751		
				[0.155]***		
(Share of community-forest area)*(time trend)						-0.002
						[0.0009]***
time trend	-0.658	-0.665	-0.646	-0.657	-0.565	-0.571
	[0.077]***	[0.077]***	[0.076]***	[0.077]***	[0.067]***	[0.068]***
Province dummies	YES	YES	YES	YES	YES	YES
Observations	1066	1066	1066	1066	1066	1066
Number of groups	66	66	66	66	66	66
Adjusted R-squared	0.837	0.837	0.834	0.835	0.826	0.827

Note: Standard errors are in parentheses. *, **, *** denote significant levels at 10%, 5%, and 1%.

VI. Robustness check

Instrumental variable strategy

It could be possible that the baseline estimation is tempered wtih the possibility of endogeneity concerns. For example, there could be reverse causality problem, where better environmental outcomes encourage and facilitate more cooperation and greater registration. On the other hand, there could be omitted variable such as local environmental value that could drive both environmental outcomes and the degree of cooperation. If such omitted variable is time-invariant, the baseline fixed effect estimation can mitigate such problems. Nonetheless, if the omitted variable also varies with time, the problem will remain.

To address such endogeneity concerns, this section makes use of the instrumental variable strategy. In particular, two measures of community social capitals, (i) village participation rate, and (ii) village group-formation rate, are used as the instrumental variables for community-forest registration. The Community Development Department has collected the data on various aspects of problems faced by the villagers in Thailand every other year. Since 2003, it has started collecting data on asocial capital aspect. The database identifies the number of villages that face high, medium, and low/no levels of problems concerning the social capital. The author then selects two social capital variables that should be associated with registered community-forest villages[4], and constructs (i) village participation rate, and (ii) village group-formation rate, at the province level. More specifically,

$$village\ participation\ rate = \frac{number\ of\ villages\ with\ low\ or\ no\ problems\ concerning\ the\ participation}{number\ of\ villages\ in\ the\ province}, \text{ and}$$

$$village\ group - formation\ rate = \frac{number\ of\ villages\ with\ low\ or\ no\ problems\ concerning\ group\ formation}{number\ of\ villages\ in\ the\ province}.$$

Table 7 gives the summary statistics for both IV variables.

TABLE 7: IV Variable summary statistics

	observations	mean	minimum	maximum
Village general social capital				
Participation rate	355	0.911	0.529	1
		[0.094]		
Group-formation rate	355	0.764	0.152	1
		[0.152]		

Note: Standard errors are in parentheses.

Variables are measured at province-level over the years 2003, 2005, 2007, 2009, 2011.

Table 8 illustrates the results based on the instrumental variable estimation, where the dependent variable is the occurrence of forest fire. Due to the availability of the IV variables, the estimation only covers the years 2003, 2005, 2007, 2009, and 2011. Since the air pollution variables do not available for every province, and out of the above 5 years, the forest area from the satellite picture is only available for the year 2005; the number of observations when air pollution and forest area are considered become extremely

[4] As the participation and group-formation rates are based on the number of villages within each province that faces low or no problem; to enable the matching and the fitness, community-forest village, instead of project or area, is used as the measure of cooperation in this instrumental variable estimation.

negligible. As a result, only the estimation with the occurrence of forest fire as the dependent variable is considered in this section.

From column 1, the first-stage estimation shows that the measures of village social capital can statistically and significantly explain the registration of community-forest village. In particular, village participation rate is highly positively and statistically significantly associated with the cooperation between the community and the state. This could be explained by the fact that the participation rate measures the villagers' participation in community activities as well as in the activities in conjunction with outside parties, including government agencies. Thus, high participation rate also leads to greater cooperation. However, village group-formation rate has a negative and statistically significant relationship with the registration of community-forest village. High group-formation rate potentially represents strong internal group-bonding. Such strong bonding may discourage the willingness of the villagers to form coalition and to coordinate with the outsiders. Strong internal group-bonding could, in addition, help ensure successful forest management and, as a result, could reduce the dependency on and the cooperation with the outsiders in order to achieve better environmental outcomes. In addition, according to the F-test, both village social capital measures are also statistically significant in jointly determine the registered community-forest village.

The second-stage estimation confirms that cooperation between the state and the local community, measured by registered community-forest village, significantly reduces the environmental hazard such as the frequency of forest fire. Compared with the baseline estimation of the same number of observation, although the standard errors are different, the coefficients are highly similar. In addition, not only the IV variables are highly correlated with the endogenous regressor; according to the overidentification test, they are also proved to be uncorrelated with the error process. Thus, the validity of the IV variables is statistically ensured. In addition, intuitively, such general social capitals although matter for the coordination with the outside parties, they are too general to directly and specifically determine or associate with environmental aspect and outcomes.

TABLE 8: IV results

Cooperation in community forest and the frequency of forest fire

First-stage Estimation		**Second-stage Estimation**		**Baseline estimation**
Community-forest village	FE	**The frequency of forest fire**	IV	FE
	[1]		[2]	[3]
Village participation rate	107.314	Community-forest village	-0.263	-0.259
	[24.272]***		[0.163]*	[0.271]
Village group-formation rate	-70.206	Anounced forest area	0.00012	YES
	[37.212]*		[1.92e-6]***	
Announced forest area	YES	Year dummies	YES	YES
Year dummies	YES	Province dummies	YES	YES
Province dummies	YES	Observations	305	305
Observations	347	Number of groups	70	70
Number of groups	70	Overidentification test: p-value	0.875	
F(6,69)	19.03	Adjusted R-squared		0.819
Prob > F	0			
Adjusted R-squared	0.908			

Note: Standard errors are in parentheses. *, **, *** denote significant levels at 10%, 5%, and 1%.
Due to collinearity, announced forest area, although being controlled for, is omitted when FE regressions are performed

VII. Conclusion

The paper contributes to a much discussed research question that whether and when it improves matters, in this case, environmental outcomes, to vest ownership in public entity or collectivities. It, both theoretically and empirically, offers a new solution that ownership can be shared, as forests cover a wide range of resources. Some resources should be vested under public ownership and some should be vested under the local community. With cooperation, this will create an incentive for human capital sharing that ultimately leads to optimal human capital investments and hence better environmental outcomes. Empirically, the paper takes Thailand's "forest community registration" programme as a measure for such cooperation. Based on both baseline fixed effect and instrumental variable strategy estimations, it is found that at the province level, an increase in the degree of cooperation is associated with (i) a reduction in the frequency of forest fires, (ii) a decrease in air pollution, and (iii) lower level of forest deterioration and an improvement in forest regeneration.

However, it should be noted that the theoretical part does not attempt to study the mechanism that leads to the cooperation between the two parties. It, instead, in line with the baseline empirical part, takes cooperation as exogenously given and compares its outcome to that of other types of arrangements. Nevertheless, under the instrumental variable estimation, local community social capitals, in particular the participation rate and group-formation rate, are shown to be significant determinants of the degree of cooperation. Given that in this paper, an improvement in environmental outcomes is found when the cooperation is introduced, further and more specific exploration on the

mechanism that leads to the cooperation between the state and the local community could potentially offer an interesting future research topic.

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