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Impact Evaluation of Tertiary Canals

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Abstract Under the commission from JICA, we conducted a four-round household survey from 2009 to 2010 to estimate the impacts of Kaeng Khoi-Ban Mo (KKBM) Pump Irrigation scheme. Total of 826 households were selected and interviewed. As primary and secondary canals were already in operation at the time of survey, we focused on the impacts of tertiary canals.

It is well known that impact evaluation of infrastructure is difficult. This is due to difficulty in randomization and broad spillover of program impacts that effectively wipes out the control group. Our focus on the tertiary canal was strategically determined in light of these difficulties: First, tertiary canals are partially constructed and we could expect to employ plot-level difference-in-differences (DID) estimator. Ordering of tertiary canal construction was deternmined administratively, started from the closest area to the pump to the furthest. This ordering is expected to be uncorrelated with farmer ability, and provides credible ground for implementing DID estimator. Second, smaller program impacts due to limited capacity of tertiary canals to serve plots simultaneously allow us to find the control group within the irrigation scheme. The availability of control group in the neighborhood of the treated group lends support for credible impact evaluation.

We will examine the impact heterogeneity in the coming rounds of additional surveys.

Keywords Impact evaluation, infrastructure, irrigation, water users group, Thailand.

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All comments reflect our own views and not of affiliating organizations. All the errors are ours.

Glossery of terms

ATT	average treatment effects on the treated
DID	difference-in-differences
DOAE	Department of Agricultural Extension
FE	fixed effects
FE-DID	fixed effect difference-in-differences
GPS	global positioning system
IE	irrigation efficiency
JICA	Japan International Cooperation Agency
KKBM	Kaeng Khoi Ban Mo
PN	Pattananikom
RID	Royal Irrigation Department
PSM	propensity score matching
RCT	randomized control trial
RDD	regression discontinuity design
WUE	water use efficiency
WUG	water users group

1 Introduction

Over the past half a century, substantial resources and considerable efforts have been devoted to the development of irrigation infrastructure in many countries. The total farm area equipped for irrigation in the world increased from 167.9 million hectare in 1970 to 300.9 million hectare in 2009, indicating the unprecedented increase in water available for agriculture. The most significant change was seen in Asia where the farm area equipped for irrigation increased from 116.2 million to 211.8 million hectare, which accounted for above 70 percent of the total expansion of irrigation during this period (FAO, 2010).

A well functioning irrigation system plays a key role in the growth of agricultural production and farmers' income. Irrigation can extend cultivable farmland and at the same time promote multiple cropping in the field which otherwise should be dependent on rain fed farming. Irrigation systems are also thought to be effective in improving crop yield through the better control of water usage along with increased inputs such as fertilizer and pesticide. It is expected that these benefits to be large in the case of paddy crops, because they require a lot of standing water with the need of proper control over its level to grow. In fact, in Thailand, 84.9 percent of the harvested irrigated area was paddy field in 2007 and paddy production during the dry season has steadily increased since the mid-1990. In a peri-urban area that we study, the benefits of irrigation can go beyond paddy, as proximity to consumers encourages diversified crop production. We will therefore analyze how crop production as a whole, not just paddy production, changes with irrigation investments.

Despite the importance of irrigation, however, rigorous impact evaluation of this infrastructure has been surprisingly rare. One primary reason behind this gap comes from the fact that it is difficult to find the appropriate control group of farmers without irrigation that can be compared to the treated group of farmers with irrigation. To obtain the better control group is a central issue in applying the rigorous evaluation framework. Due to the infeasibility of random assignment of large-scale infrastructure, an evaluator should choose comparison areas which have similar characteristics, except for the presence of irrigation, to that of interested irrigation areas. The comparison areas should be selected from regions far from any irrigation projects, since irrigation have wide-reaching effects. However, geographically distant areas possibly have very different agronomic environments as well as different economic conditions. Therefore, it is practically difficult to find the desired control group in the evaluation of irrigation systems.

In this study, instead of evaluating irrigation systems as a whole, we examine the effects of tertiary irrigation canals using detailed plot-level data from area with large pump-irrigation systems in central Thailand. Although an apparent limitation arises from our narrow scope of study, focusing on the effects of tertiary canals has one clear advantage. By the nature of low level canals, a tertiary canal affects the water use conditions of contiguous plots locally and only in a confined way. Therefore, if there are variations in timing of the construction of tertiary canals within the project area, we can find both the treated and control group of farmlands that are geographically close each other. As we will describe later, it is indeed the case in the study area where tertiary irrigation systems were constructed gradually over the past several years. A four-round survey we conducted includes the treated farmlands that were provided with tertiary canals during the survey period, in addition to the control group that have yet to be provided. We evaluate the impacts of tertiary canals on yield and farmers' income, employing the deference-in-differences estimator that is increasingly popular among policy evaluation literature.

It is expected that the productivity impacts of tertiary canals are not as large as those of high level canals, if high level canals can provide a reasonable degree of water control. But one should not misunderstand that impacts of tertiary canals need not be studied. There are two reasons why a policymaker in the development community should care about them. First, in theory, tertiary and lower level canals are usually cited as a labor saver. It is therefore crucial in a rapidly growing economy which faces continuous wage growth, or in an aging economy which may also face sustained wage growth, to know how physical infrastructure supplements farmers' managerial efforts in staying profitable. Second, when a donor government finances an irrigation scheme, it is rarely the case that they provide funding for the low level canals. There is an obvious rationale for this, as low level canals require finer design which involves negotiations and adjustments among neighboring farmers. In a country with weak governmental capacity, however, it is reasonable that donor governments may be requested to provide assistance to low level canals. Understanding impacts of tertiary canals will clarify if such assistance is justified on an efficiency ground. To the best our knowledge, this study is one of the first attempts to answer these questions by using rigorous evaluation methods.

In the following sections, we will discuss how we can undertake the impact evaluation study. In Section 2, we describe our study area. We also show the principles of impact evaluations and propose the estimation strategy for this study. In Section 3, we explain the survey and data details. In Section 4, we examine the estimated results and discuss possible economic mechanisms behind them. In Section 5, concluding remarks and the future agenda

Figure 1: Lateral and Tertiary Canals

are provided.

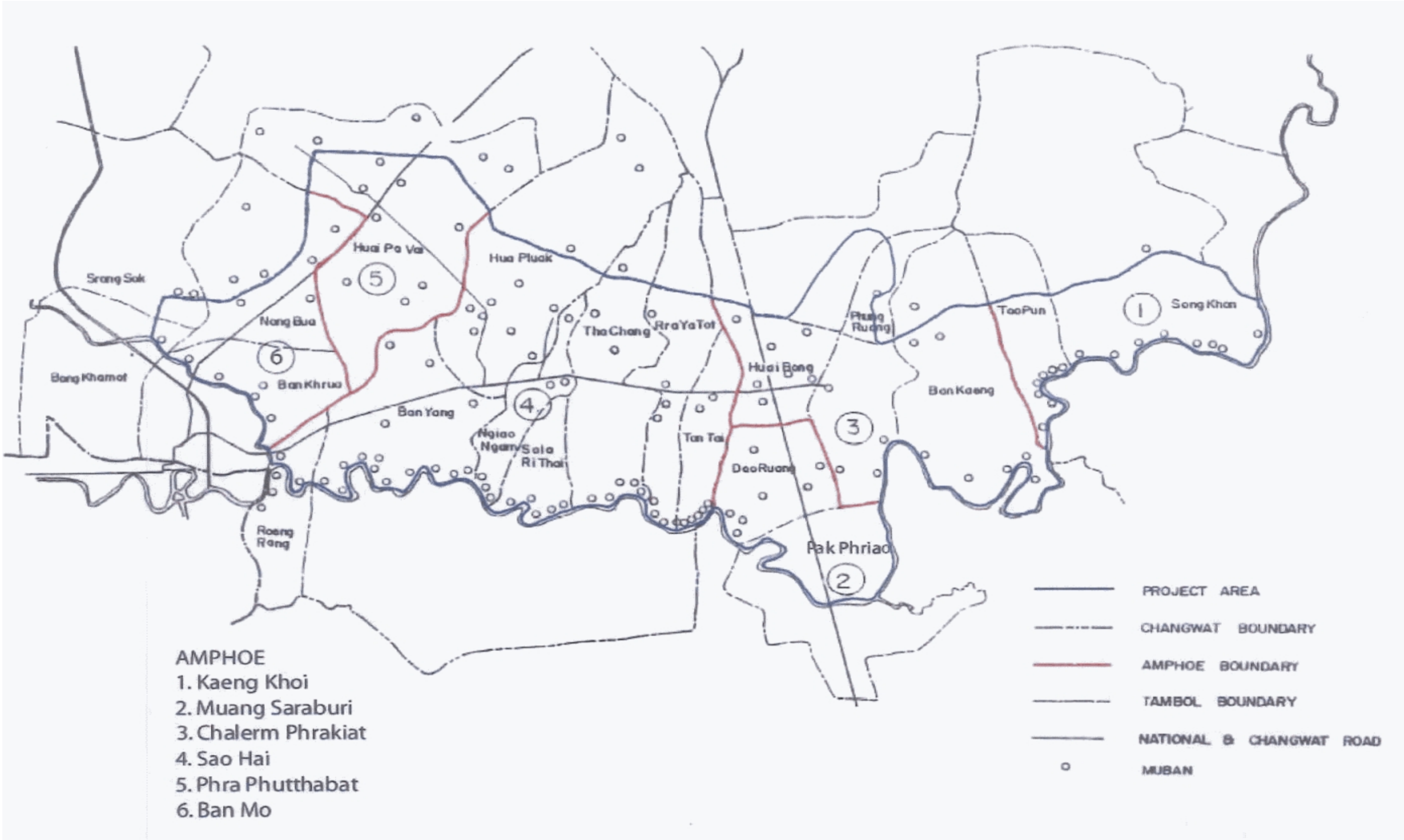
2 Study Area and Evaluation Framework

2.1 Study Area

Our study area is located in Saraburi province in central Thailand. The town of Saraburi is around 100 kilometers from Bangkok and the province has experienced relatively rapid industrialization. The study area benefits from the Kaeng Khoi - Ban Mo (KKBM) Pumping Irrigation Project which was first planned by the Royal Irrigation Department (RID) in 1976. Japan International Cooperation Agency (JICA) initiated a feasibility study (F/S) in 1982, and agreed on a loan for project design in 1985. Due to construction of Pasak Cholasit Dam in the upper stream of Pasak River, the project had come to a stop. In 2001, the project was restarted with a loan from JICA. The loan financed the construction of main (primary), lateral (secondary) and sub-lateral (sub-secondary) canals, and have ended in 2005. Construction of tertiary canals and maintenance of the irrigation scheme are designed and financed by the Thai Government, namely the RID.

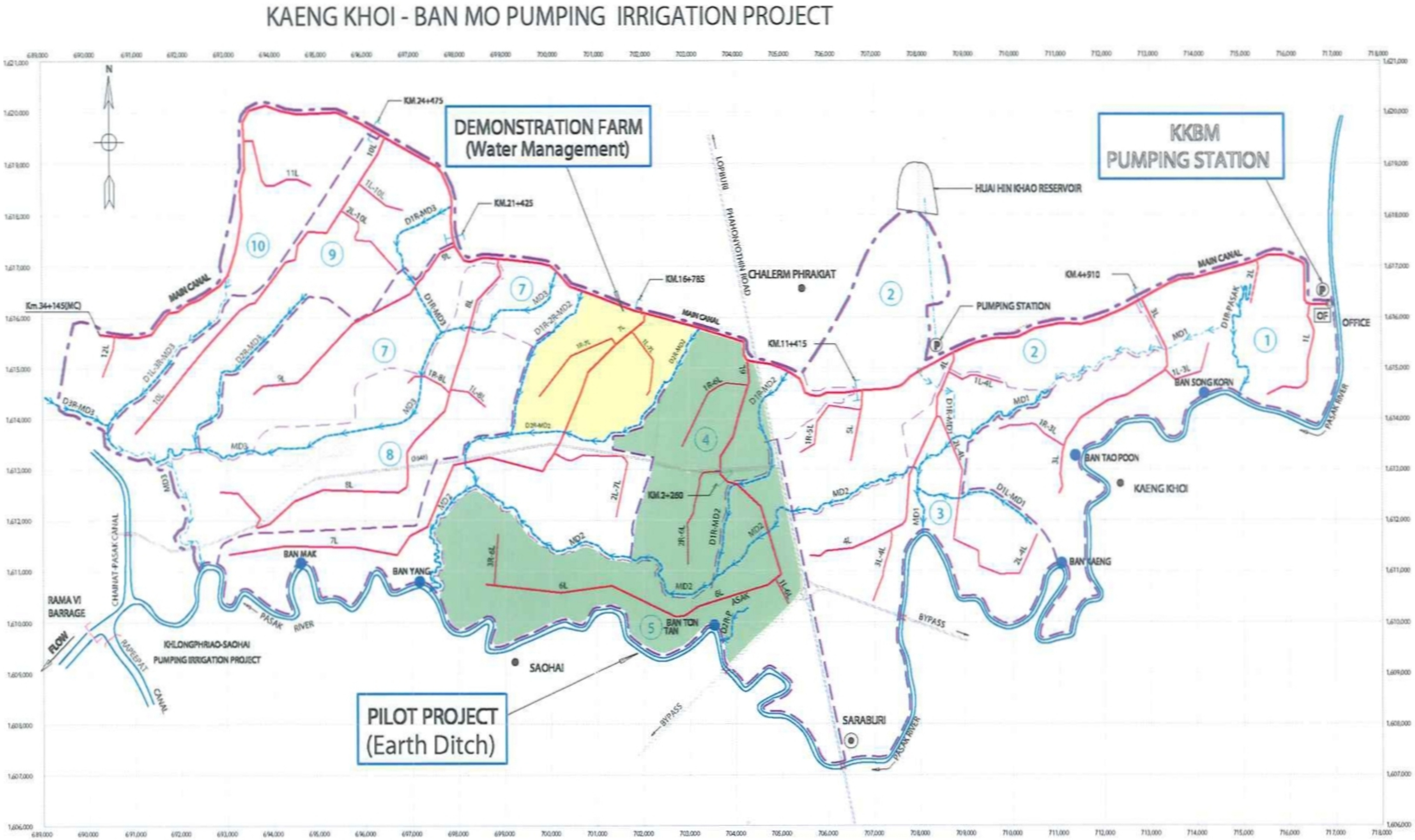
The project aims at increasing agricultural productivity and land utilization. It is therefore important to understand project's impacts on these outcomes. In 1982 when JICA conducted an F/S, the project also eyed at crop diversification as another aim. However, our research found that policy goal has lost in a way, and was not shared when the project began in 2001. It is observed that paddy production is currently prevailing in the project area. We will show the crop choice by farmers in our sample later.

Figure 2: KKBM Administrative Map



Source: RID document.

Figure 3: KKBM Irrigation Map



Source: RID document.

The project involves 6 districts. Figure 2 shows the administrative boundary in the project area. The project was originally designed to have 1 main canal and 12 lateral canals. However, a lateral canal called 2L, the second closest to the pumping station, has never been created because its beneficiary farmlands were eventually converted to industrial use during the construction period. The system is finally equipped with 11 lateral canals (i.e. 1L and 3L to 12L). Figure 3 depicts the water distribution system of the KKBM irrigation project. The main canal has length of 34 kilometers and 11 lateral canals have total length of slightly less than 100 kilometers.

There are substantial variations in the scale of irrigation projects in Thailand. Irrigation schemes are classed as large-scale if they can irrigate at least 80,000 rai or there is a store capacity of more than 100 million cubic meters. Thailand had 83 large-scale irrigation projects by the year 2002 (FAO, 2010). The KKBM project was also classified into this large-scale group in the planning phase as its irrigation area was projected to be 85,695 rai in the wet season (see Box). However, its actual irrigation area has shrunk to 36,311 rai by the year of 2008 due to the massive conversion of agricultural land. These facts taken together imply that the scale of the KKBM project is not extraordinary large in Thailand and its current capacity of water supply is abundant at least in the wet season. One should be careful, therefore, when extending our results to other projects.

During each agricultural season, wet and dry, irrigation water is distributed on the basis of rotating supply to different laterals and the irrigation interval is typically 7 days. The timing and order of irrigation should be agreed upon among whole Water Users Groups (WUGs) and the RID at the beginning of each season. The amount of water distributed to each lateral is determined based on the cropping area associated with it. The RID obtains information on cropping area from the plan submitted every season by WUGs. In this respect, WUGs play important roles in formulating and supporting the rule in which irrigation water can be distributed without serious conflicts between different laterals. A WUG is formed also in order to facilitate coordination of water use among its members. Each lateral usually has more than one WUG. The number of WUGs was initially 15 and it increased to 21 as of year 2008. After the first survey was conducted, the number of WUGs has further increased and reaches to 26 as of year 2011. Another important role of WUGs is to collect lateral maintenance fee as well as electricity fee for pumping in the dry season for the RID. It is worth pointing that farmers are charged nothing for electricity during the wet season. The collection rate of electricity fee in the dry season has been almost 100 percent. At least in this sense, the WUGs are well organized and play the desired roles.

Box: Summary of KKBM Operation Information

- Feasibility studies (F/S): 1982, 1985, 1991-1993
- Construction of main and lateral canals: September, 1995 - June, 2005
- Budget: 2.607 billion yen, of which 1.799 billion yen was financed by ODA
- Irrigated area (rai):

season	projected	actual (2008)
wet	85,695	36,311
dry	27,900	20,121
dry/wet	0.326	0.554

- Irrigation efficiency (2005-2009, water volume demanded / supplied): wet seasons  dry seasons 
- Per rai profits (2005 - 2008, Bahts): wet seasons  dry seasons 
- Canal length: 34 km (main), approximately 100 km total length (lateral)
- Number of Laterals: 11
- Number of water users group (WUG): 26 (2011)
- Fee collection: no fees in wet seasons, 100% collection in dry seasons

Source: Japan International Cooperation Agency (2011), summarized by authors.

When we started the evaluation of the KKBM irrigation scheme in 2009, the main, lateral, and sub-lateral canals were already constructed. This eliminates the control group for impact evaluation of these canals. So we decided to focus on estimating the impacts of tertiary canals which had not been fully constructed. A tertiary canal is a low level canal drawing water from high level canals, and its width is about 30 to 50 centimeters in the KKBM area. A tertiary canal usually serves contiguous plots that share the dikes, and can exert finer control on water utilization and drainage than high level canals. Even without tertiary canals, water is available over ancestor plots that receive water from high level canals (plot-to-plot irrigation). The construction process of tertiary canals starts with discussions between the RID and land owners to decide which part of land is given up for canal construction. Then Ditch and Dike Section of the RID draws a blueprint and dispatches a construction team.

The construction of tertiary canals was initiated from the upper stream of 7L in 2004 as a small demonstration phase. In addition, in a part of 9L and 10L, there had already been tertiary canals constructed through the old project other than KKBM. They were easily integrated into the KKBM irrigation systems in 2006. Except for these cases, the RID began with the construction of tertiary systems along 1L which was at the eastern end of the project area and afterward proceeded westbound. In 2009, lateral canals up to 5L and a part of 6L, 7L, 9L and 10L had completed their tertiary canal construction.

All the tertiary canals that the RID has constructed are concrete ditch. However, in order to accelerate the realization of benefits from tertiary canals, some farmers around 6L were encouraged to construct earth ditch by farmers' efforts through a pilot project before concrete ditch was to be provided by the RID. In total 154 farmers were involved with this pilot project. After observing this project, there were similar efforts by other farmers on different laterals, whereas a large number of earth ditch have been replaced by concrete one as the RID has expanded the construction of tertiary canals following the original plan. Nevertheless, there still remain a non-negligible number of tertiary canals of earth ditch in the project area.

2.2 General principle of impact evaluation

In evaluating a policy on an outcome y_{it} of an individual i in period t, a general framework can be defined as below:

$$TE_{it} = (y_{it} \mid D_{it} = 1) - (y_{it} \mid D_{it} = 0). \tag{1}$$

TE_{it} is what is called as a treatment effect by policy, and $y_{it} \mid D_{it} = 1$ is an outcome of individual i under the policy in period t and $y_{it} \mid D_{it} = 0$ is an outcome of individual i in the absence of the policy in same period. D_{it} is an indicator variable of the policy, or a treatment status indicator, so $D_{it} = 1$ is under the policy and $D_{it} = 0$ is not. People with $D_{it} = 1$ are called the *treated* group, and $D_{it} = 0$ are called the *control* group. TE_{it} is the change in the potential outcomes between with and without the policy.

The fundamental problem in impact evaluation is that (1) is never possible to observe, because an individual is either under the policy or not, not both at the same time. One way out is not to estimate the individual treatment effect, but to estimate an effect for a group of individuals that resembles with each other. In this way we can use the outcome of a different individual under different treatment status as a counterfactual outcome.

Naturally, the most important care is that one needs to choose the counterfactual that resembles very closely with i. If we use a very different individual for a counterfactual of i, then the estimated treatment effect for i can be grossly different from the true treatment effect. So *credibility* of evaluation depends crucially on the precision of counterfactual that the evaluator uses for each individuals. The primary challenge of an evaluation study is to convince readers that its choice of counterfactual is precise.

An evaluation study that employs very similar individuals as counterfactual is said to satisfy *internal validity*, whose estimated results are perceived as highly credible. It is now a general concensus in development community that an evaluation study should pursue internal validity as best as one can (under feasibility and ethical constraints, Evaluation Gap Working Group, 2006). This follows because it is almost meaningless to do an evaluation study whose conclusion is based on errorneous assumptions on the choice of counterfactual.

The "gold standard" of an evaluation method is randomized control trials (RCTs), because, in large sample data, an evaluator can always find precise counterfactual by the virtue of randomization. Unfortunately, RCT is not always possible due to political and feasibility constraints. Infrastructure projects are a well known example of policies that are difficult to conduct RCT, because one cannot expect infrastructure, say, dams, to be randomly placed or access to it is given to random individuals. It is also well known that impacts of a big project may spillover to control groups, which violates the oft used stable unit treatment value assumption (SUTVA) in statistics (Rubin, 1974) or the policy invariance assumption in econometrics (Hurwicz, 1966).

So evaluation of infrastructure has rarely been studied rigorously, with an exception of Duflo and Pande (2007). They use district level data of India to estimate dam construction impacts on economic activity levels, by observing river gradient is strongly correlated with the former but not with the latter, thus satisfying the assumptions of instrumental variables estimator. Their estimate gives impacts at the district level, whose size is as big as prefectures in Japan. In light of SUTVA, their choice of unit is consistent with the expected impacts of dam construction.

In our study, the impacts we would like to estimate are at the household level, much disaggregated than Duflo and Pande (2007). This requires us to collect data at household level, and also seek for a different estimation strategy, because river gradient is almost identical in the Pasak river basin in the KKBM area and cannot be used as an instrumental variable. The feasible estimator choice includes propensity score matching (PSM), regression discontinuity design (RDD), and difference-in-differences (DID). PSM and RDD allow estimation using cross-section data while DID requires panel data. For PSM estimates to be credible, it should satisfy a common support condition which requires sufficient overlap of propensity score distributions between treated and control groups. It in turn implies that the probability of getting tertiary canals in the control group should be strictly greater than zero. However, the RID has followed the deterministic schedule of tertiary construction and therefore the probability for access to tertiary canals was exactly zero in the control group during survey periods. It should also be noted that conditional exogenous program assignment (no omitted variables) must be satisfied for the PSM estimator to be consistent, and there is rarely a case in convincingly showing exogeneity to hold, except when treatment status is randomly assigned, which is what the developer of this methodology had in mind. The failure of a common support and conditional exogenous treatment assignment precludes the use of PSM in this study. RDD requires finding a boundary between serviced and unserviced areas. Although the boundary is not difficult to define, RDD effectively shrinks the sample size to a few dozen households, which leads to unreliable estimates. So DID is the only feasible choice.

2.3 The Difference-in-Differences estimator

The framework of difference-in-differences estimator can be well understood with a linear parametric model. For a household i, suppose output y_{it} is explained by availability of irrigation services $D_{it} \in \{0, 1\}$ in period t. In a reduced form, it can be written as:

$$y_{it} = a + bD_{it} + \boldsymbol{z}_i'\boldsymbol{\eta} + \boldsymbol{x}_{it}'\boldsymbol{\beta} + \lambda_t + u_{it}. \tag{2}$$

The constant vector z_i captures the contribution of plot i's time-invariant traits, such as farmer's characteristics, number of household members, asset ownership, unobservable land fertility, and most importantly the location of the plot. The vector $\boldsymbol{x}_{it}$ represents time varying observables. λ_t captures the season fixed effect which is common to all plots. b is the parameter of interest, as it measures the contribution of tertiary canal construction on y_{it}. As production choices can be correlated with any element in z_i, failing to include all elements in (2) will result in inconsistent estimates on all parameters. However, as we have a panel data, we can eliminate any fixed effects by taking a deviation from household means:

$$y_{it} - \bar{y}_i = b(D_{it} - \overline{D}_i) + (\boldsymbol{x}_{it} - \overline{\boldsymbol{x}}_i)'\boldsymbol{\beta} + (\lambda_t - \overline{\lambda}) + u_{it} - \overline{u}_i. \tag{3}$$

For b in (3) to be estimable, we need some households' D_{it} to change through time. In our irrigation construction context, the change must be from 0 to 1. So we need some households whose data is collected before (as baseline) and after (as follow-up) tertiary canal construction. For the remainder of the households, it can be collected from any lateral whose D_{it} does not change.

If we can assume the correlation between $(D_{it} - \bar{D}_i)$ and $u_{it} - \bar{u}_i$ are zero, then we can estimate b consistently. Zero correlation with $u_{it} - \bar{u}_i$ means that irrigation is not placed systematically according to low or high disturbance deviation areas. For example, a policy maker may want to enhance productivity of farmers of certain lateral who are known to have negative productivity shocks more often than others. By targeting these farmers, it induces a negative correlation between $D_{it} - \bar{D}_i$ and $u_{it} - \bar{u}_i$. After discussions with farmers, RID officials, and WUG leaders, we confirmed that the order of tertiary canal construction was administratively determined from areas closest to furthest of canal intake, or from 1L (eastmost) to 12L (westmost). There was no targeting of farmers in canal construction. Because major productivity shocks are considered to be uniform in KKBM, and even if residual shocks are not uniform, they are not correlated with location. So we can safely assume zero correlation between $(D_{it} - \bar{D}_i)$ and $u_{it} - \bar{u}_i$, giving credibility to our estimation strategy.

The beauty of DID estimator is that it can safely exclude the effects both of time-invariant factors specific to each plot and of time-variant factors which are common to all. The latter advantage in DID rests on the assumption of common time trend (parallel shift). One important deviation from (2) is taking into account the heterogeneous treatment effects. This is easily done with the inclusion of interaction term between treatment status and other variables of interest. We include $z_i(D_{it} - \bar{D}_i)$ and $\mathbf{1}(t = \tau)(D_{it} - \bar{D}_i)$, where $\mathbf{1}(t = \tau)$ is indicator variable that takes a value 1 if $t = \tau$ and 0 otherwise, in order to take into account the possibility that the treatment effect varies depending on time period and plot i's time-invariant traits.

Having successfully addressed the identification strategy of irrigation impacts, we may also want to ask a different question: how likely can we expect the estimated impacts to be applicable to surrounding areas? This is a question of *external validity* which considers the extent of generality of estimated results. As JICA is actively engaged in development assistance in many countries, an evaluator is asked the applicability of lessons of an evaluation study to other areas. In responding to this request, one needs to compare the characteristics of KKBM to other areas. This can be accomplished by two means, comparison of KKBM and surrounding districts using district level data, and conducting another household survey in surrounding areas. In this report, we will take the second approach and compare household characteristics of KKBM and Pattananikom areas, where a part of latter area is under another major pump-irrigation scheme.

3 Data and Descriptive Statistics

3.1 Survey design

3.1.1 KKBM1 (2008 wet), KKBM2 (2009 dry), KKBM3 (2009 wet), KKBM4 (2010 dry)

As noted, we are interested in the treatment effect of tertiary irrigation system on farming productivity in the KKBM project area. To implement the DID estimator, we need panel data on agricultural production by farmers both with and without changing treatment status during survey periods. Fortunately, the distinction between the treated and control can be largely attributed to the construction policy by the RID and thus is exogenous for farmers. Except for the upper stream of 7L, 9L and 10L, the construction of tertiary irrigation canals was to begin at eastern part and to sequentially move westward within the project area. In this schedule, 12L (a lateral canal, or the 12th lateral canal, at the western boundary of the project area) is last to be provided with tertiary canals. As already noted earlier, while there are some earth ditch used as tertiary canals in the project area, the majority of tertiary canals are concrete ditch constructed by the RID.

As of the wet season 2008, the tertiary canals have been completed up to 5L. In addition, the upstream of 6L, 7L, 9L and 10L have also been partially equipped with tertiary irrigation canals. Based on this observation, we focus on two districts (Sao Hai and Phra Phutthabat) under 6L to 11L to estimate treatment effect by taking the advantage of the different timing in tertiary canal construction. In other words, we expected that part of farmers from 6L to 11L would get access to tertiary canal immediately after the baseline survey and thus becoming the treated group.

The list of agricultural farmers is available from the Department of Agricultural Extension (DOAE). The DOAE database contains farmers who have registered themselves to be eligible for receiving financial as well as technological assistance by the Ministry of Agriculture and Cooperatives. We have 2,431 farmers who reside in our targeted districts (i.e. Sao Hai and Phra Phutthabat) as of November 2008.

For our sampling purpose, however, there are two caveats to be aware of when using the DOAE database. Firstly, while we easily find farmers' name and addresses from the database, actual location of their farming plots cannot be known *a priori*. Since the land rental markets are highly active in Thailand, we suppose that some farmers outside our targeted districts may have farming plots in the area. Similarly, it is quite possible for some farmers in our targeted districts to cultivate plots outside the area. We omit non-resident farmers from the sample population simply because we cannot identify them in advance. On the other hand, for sampled farmers in our targeted districts, we collect information on every farming plot, irrespective of its location. Secondly, the DOAE database possibly includes currently inactive farmers due to infrequent updating. The concerns for inactive farmers prompted us not to undertake simple random sampling of farmers in the DOAE database.

To avoid inefficiency associated with picking up many inactive farmers, we employ stratified random sampling. One stratum consists of WUG members of the KKBM irrigation scheme and another stratum consists of Non-WUG members. We compiled an integrated list from the DOAE database and the membership information of related WUGs by matching social identification numbers. WUG members are formal beneficiaries of the KKBM scheme, in which their farming plots are irrigated either through a main canal, (sub) lateral canals, tertiary canals or plot-to-plot system. They are expected to be active farmers with a high degree of certainty, as one must pay a due to be a member to get water in a dry season. Non-WUG members are the farmers who either lack access to any kind of irrigation or have access to irrigation other than the KKBM scheme. We did not have any prior information whether a Non-WUG member is currently active or inactive in agricultural production.

The compiled list contains 621 WUG members and 1,810 Non-WUG members. We have tried to survey all the WUG members (i.e. 621 farmers) and obtained 562 responses from this stratum. Additionally, 999 Non-WUG members were randomly selected and were visited. However, as mentioned above, we discovered a considerable number of them were currently inactive in agricultural production and therefore only 264 Non-WUG members were identified as active farmers. We retain these 826 farmers in total for our main analysis.

The high proportion of inactive farmers and resulting selection of samples may raise concerns. This is valid if the inactive farmers have exited from production due to smaller irrigation impacts on their plots. However, one should note that our aim of estimation is to assess the impacts of tertiary canal construction, not the impacts of KKBM irrigation construction in general. In line with our limited scope of consideration, our population is a group of farmers who operate or have operated under KKBM system with and without tertiary canals. In other words, farmers who have exited before the construction of lateral canals are excluded. Still, it is possible, in the control area where tertiary canal construction had completed before our survey, that farmers with low impacts may have exited already, hence we are picking up only farmers with relatively high impacts. This indicates that our estimates may be downwardly biased and thus may justifiably be content with small or marginally significant impact estimates.

The survey was conducted in four rounds. The first round was carried out from January to April, 2009, for collecting data on the wet season 2008. Subsequently, the second round was carried out from July to October, 2009, for collecting data on the dry season 2009. In both surveys, data pertain to household characteristics, land area, cropping pattern, agricultural output as well as input at each plot level, financial transactions, and other non-agricultural activities. The data on wet season 2009 and dry season 2010 were collected through the third and fourth round, respectively, using the same questionnaire. The third round was carried out from June to August, 2010, and the fourth round was done during from November, 2010, to January, 2011. We finally obtain a unique four-round panel dataset for the impact evaluation of tertiary canals in the KKBM project area.

4 Plans for next year

It is found in our recent field trips that irrigation impacts differ by location. We will incorporate GIS information to proximate water availability. We have also found that RID has delayed the construction of tertiary canals in 8L-12L. Thus we will conduct another round of follow up survey to increase the sample size.

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