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Empirical Study of Growth and Poverty Reduction in Indonesian Farms: the Role of Space, Infrastructure and Human Capital and Impact of the Financial Crisis

Risk, Infrastructure, and Rural Market Integration: Implications of Infrastructure Provision for Food Markets and Household Consumption in Rural Indonesia

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Risk, Infrastructure, and Rural Market Integration:
Implications of Infrastructure Provision for Food Markets and Household Consumption in Rural Indonesia

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Abstract
Utilizing original panel data collected in 2007 and 2010 in rural Indonesia for 2261 households located in 98 villages in 7 provinces, this paper investigates the food markets' functions with different extents of integration, and aims to interlink three important factors in the process of economic development — risk, infrastructure and welfare — of the rural poor. Focusing especially on irrigation systems and local paved roads, we explore the potential effect of infrastructure in relation to the global food price crisis that occurred in 2007–08 and thereafter affected poor households in rural Indonesia. The most important finding from our empirical analysis can be seen in the villages with relatively low integration to the surrounding markets, but which had access to irrigation systems. In those villages food prices, and in particular the price of rice, were kept lower, even when rural Indonesia experienced a spike in food prices. This implies that, although the implication is contrastive to rice producers (net sellers), irrigation facilities offset the negative effects for rural households by maintaining a relatively abundant food supply in local markets. Along with this investigation, the threshold estimation examines whether there exists a certain threshold for the proportion of local paved roads that divides villages according to either lower or higher spatial connectivity. Our results clearly indicate the existence of such a threshold. These findings suggest that when evaluating the potential role of irrigation and the effectiveness of irrigation development and management, it is important to pay more attention to the functions of the surrounding markets as related to rural road conditions, in addition to the direct impact of irrigation on agricultural productivity as it affects households.

Keywords: risk, infrastructure, market integration, food price crisis, Indonesia

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1. Introduction

The relationship between infrastructure and risk has attracted growing attention by international societies (World Bank 2014). Whereas risk disrupts economic development and adversely affects people's welfare the construction of infrastructure is expected to be an effective measure against risk. Therefore, examining how infrastructure strengthens people's ability to cope with risk and prevents a decline in their welfare has been a central concern among policy makers and development practitioners. This paper aims to connect three important factors in the process of economic development for the rural poor — risk, infrastructure and welfare — through an investigation into the functioning of local food markets with varying levels of integration to surrounding markets. Focusing especially on irrigation systems and local paved roads, we explore the potential effect of infrastructure in relation to the global food price crisis that occurred in 2007–08 and thereafter affected poor households in rural Indonesia.

In the world food markets, wheat prices rose rapidly in May 2007, which was followed by a sharp increase in corn prices later in the same year, after grain prices had gradually grown for several years (Timmer and Dawe 2010). After that, while wheat prices peaked in February 2008 and corn prices peaked in June, while rice prices started rising sharply as well and reached a higher peak in May 2008. This international surge in the price of agricultural commodities increased domestic food prices in Indonesia and had some influences on the welfare of rural Indonesian households. The rise in food prices had two contrastive direct impacts (Yamauchi and Dewina 2012). On one hand, higher prices of agricultural commodities increased profits from agricultural production and income levels of food producers. On the other hand, higher food prices curtailed the purchasing power of consumers and decreased the welfare level of those who had to buy food commodities from the market.

This study focuses on the potential effect of two different kinds of infrastructure, irrigation systems and rural paved roads, in relation to the food price crisis. Irrigation facilities are expected to enhance agricultural productivity and lower the risk of crop failure, and also yield some indirect benefits to the broader population (Hussain and Hanjra 2004). Rural paved roads, by reducing transportation costs, are expected to enhance economic activities in local areas (Khandker et al. 2009), and in addition are regarded as a major factor determining the extent of the connection between the local and surrounding markets (Cirera and Arndt 2008). In this study, we hypothesize that the potential effect of irrigation during the food price surge should differ depending on the extent of rural market integration. We examine this hypothesis by utilizing our original survey data collected in rural Indonesia.

In the past literature, extensive macro- and micro-level analyses have been conducted to explore how infrastructure contributes to economic development (Jimemez 1995; Esfahani and Ramirez 2003; Fan and Zhang 2004; Straub 2011). Likewise, the link between infrastructure and poverty alleviation, has also been explored in a variety of developing countries (Van de Walle 1996; Zhang and Fan 2004; Lokshin and Yemtsov 2004; Lokshin and Yemtsov 2005; Khandker and Koolwal 2010). However, the relationship between infrastructure and risk has not yet been thoroughly examined, and the interactions between different types of infrastructure facilities in estimating their impacts on welfare are still in question. This study, by taking into consideration two different types of infrastructure facilities simultaneously, tries to understand the important implications of the infrastructure on the food markets' functions and the growth of household consumption per capita in rural Indonesia during the food price crisis.

The organization of this paper is as follows. Section 2 reviews the relevant literature, clearly states the research agenda, then postulates specific research hypotheses by showing theoretical models. Section 3 provides explanations about out datasets and Section 4 discusses our empirical strategies. The estimation results are shown in Section 5, and the summary of our findings and some policy suggestions are presented in Section 6.

2. Risk, infrastructure, and rural market integration

Risks (or shocks as their revealed form) affect the welfare of the poor in a variety of ways. In their flagship report, World Bank (2001) attempted to introduce a categorization of risks based on the extent to which they are either idiosyncratic or covariate, then further subdividing risks into six types based on their characteristics: natural, health, social, economic, political, and environmental. In their recent publication, moreover, World Bank (2014) argues comprehensively for the heterogeneity of the channels through which risks affect the economies and societies in the developing countries. Among their arguments, it is worth emphasizing that the majority of the working poor population is in agriculture sector, where they are faced with risks and uncertainties such as natural hazards and volatile price fluctuations (see also Dercon 2004 and Collins et al. 2009).

Starting with an influential work by Morduch (1994), the nexus of the economics of poverty dynamics and the economics of risk or uncertainty has been widely and intensively investigated. Krishna (2007), for example, emphasizes the dynamic characteristics of poverty by illustrating the significant percentage of the population who fell into and escaped from poverty in several developing countries. The severity of this hardship and its dynamic characteristic have brought the relationship between risk and poverty to the forefront of development studies.

A number of surveys have attempted to categorize effective risk-related measures. Alderman and Paxson (1992), for example, use a dichotomy. Their first category, risk management actions, aims to reduce the variability of income, or risk per se, while the second, risk coping, enables intertemporal consumption smoothing. Morduch (1995) emphasizes that coping with risk can occur at two stages: income smoothing and consumption smoothing. The above two categories are closely related to the notions of ex-ante and ex-post measures, which are argued in Rosenzweig and Binswanger (1993).

The construction of infrastructure, in both ex-ante and ex-post ways, is expected to be one of the effective measures against risks. A variety of public interventions that apt to strengthen the risk coping abilities of rural households have been widely studied and infrastructure development seems to have the potential for success (World Bank 2014). A recent publication, for example, emphasizes the importance of ex-ante risk coping measures by pointing out that prevention of natural hazards is more feasible and more cost-effective than ex-post measures (World Bank and United Nations 2010). The study reiterates the effectiveness of constructing infrastructure that will prevent greater devastation in the wake of a natural disaster, as well as for introducing software components such as early warning systems.

Among various infrastructure, irrigation facilities and rural road construction—both infrastructure doubtlessly influential to the rural households' welfare—have been studied rigorously. Duflo and Pande (2007), for example, conduct an impact evaluation of large scale irrigation dams in India by utilizing a random experiment. Dillon (2011) evaluates the secondary impacts of irrigation on asset accumulation and informal risk sharing mechanisms in Mali. Any rigorous impact evaluation of agricultural projects, however, is generally speaking very difficult (Winters et al. 2011). In particular, quantifying the magnitude of the indirect effects of irrigation development and management projects is still a challenge (Hussain 2007). Impact analysis of road construction, on the other hand, is plentiful (Gibson and Rozelle 2003; Jacoby and Minten 2009; Mu and Van de Walle 2011; Van de Walle 2002), with most studies suggesting that investments in road construction, which lower transportation costs, positively contribute to economic development and poverty reduction.

Although the past literature has intensively investigated the relationships between risk, infrastructure, and welfare, to the best of our knowledge few studies have paid attention to the links between all three of these factors. In other words, few studies have sufficiently examined the potential role of infrastructure in mitigating the loss of welfare when risk is materialized. In order to link risk, infrastructure, and welfare, our research strategy focuses on the functions of the food markets. There are some crucial agricultural risks — for example, the fluctuation of food prices or crop failures due to natural hazards — which are supposed to affect the quantities and/or prices of agricultural products. Food markets are the most important channels through which these risks would affect the welfare of rural poor households because their livelihoods are mainly dependent on agriculture and food is doubtlessly crucial commodity for them as well.

The complexity of this process should be carefully examined however, to take into consideration how foods markets affect both the losses and gains a shock brings to households in the area. Therefore, attention should be drawn to the extent of market openness in order to understand the extent of market integration, which is in part determined by roads that bridge markets and affect transportation costs. A number of researches have investigated the relationship between roads, transportation costs, and market integration. Cirera and Arndt (2008), for example, following a spatial efficiency approach based on Baumol (1982), conduct a survey in Mozambique and argue that road rehabilitation has a positive impact on spatial efficiency. Roads affect the extent to which price changes (or shocks) are transmitted among markets. These findings can be paraphrased to conclude that some infrastructure can affect the ways markets function. This study therefore, by taking the food markets' functions (and the extent of market integration which would affect those functions) into consideration, aims to propose an implication of the links between the aforementioned three factors — risk, infrastructure, and welfare — thereby making a modest contribution to the existing literature.

2.2 Theoretical models

As discussed by Barrett and Li (2002), there are problems surrounding the concept of "market integration," Conceptualizations of market integration should focus both on tradability and efficiency, with the extent of market integration to be measured by price, transfer costs, and trade flow data. This paper, due to constraints of available data, does not intend to rigorously measure the extent of market integration, but to draw out implications regarding differences in the impact of a shock, by categorizing villages with lower spatial connectivity and those with higher spatial connectivity. This categorization based on spatial connectivity can also be defined as two economic regimes: locally independent economies and integrated market economies. For the construction of theoretical models this study specifically focuses on rice, as rice is the dominant staple food in the country and price, quantity of supply, and consumption of rice significantly affects the welfare of households. Then, theoretical models for these two distinct economic regimes can be written as follows:

(1) For locally independent economies (or villages with lower spatial connectivity), utility maximization can be expressed:

$$\max_{x_{1i}, x_{2i}, x_{3i}} u(x_{1i}, x_{2i}, x_{3i})$$

s.t.

$$p_1^* x_{1i} + p_2 x_{2i} + p_3 x_{3i} \leq y_i + Y_i \quad \text{(Budget constraint)}$$

$$y_i = p_1^* f_i(X_i; A_i) - pX_i \quad \text{(Profit from rice production)}$$

$$\sum_i x_{1i} \leq \sum_i f_i(X_i; A_i) \quad \text{(Market clear condition of rice or demand=supply)}$$

(2) For integrated market economies (villages with higher spatial connectivity):

$$\max_{x_{1i}, x_{2i}, x_{3i}} u(x_{1i}, x_{2i}, x_{3i})$$

s.t.

$p_1 x_{1i} + p_2 x_{2i} + p_3 x_{3i} \leq y_i + Y_i$ (Budget constraint)

$y_i = p_1 f_i(X_i; A_i) - pX_i$ (Rice production)

$\sum_i x_{1i} \leq \sum_i f_i(X_i; A_i) + M - X$ (Market clear condition or rice or demand=supply)

where x_{1i} is household i's rice consumption, x_{2i} is other food consumption, and x_{3i} is non-food expenditures. While p_1 is price of rice, p_2 is price of other food items, and p_3 is price of non-food items. y_i is household i's profit from rice production, Y_i is income from other sources, X_i is input for rice production, p is price of the input, and A_i is production endowment such as land and irrigation facilities. M is rice inflow and X is its outflow.

Obviously, the difference between the two economic regimes is the existence of M-X, or the trade volume of rice. By assuming the difficulty in trading rice with the surrounding markets due to limited connectivity, an endogenous rice price is the most salient feature of locally independent economies in which the rice price is determined by the supply and demand for rice in the local market. In contrast, people in integrated market economies behave as a price taker. In reality, every local market is to a certain extent integrated to the surrounding markets, and there are neither perfectly independent local markets nor any perfectly integrated markets. Yet, the purpose of presenting these two extreme cases in this section is to illustrate the distinct features of each regime. Later, we empirically examine whether there exists a threshold level of market integration that could spilt our sample villages into two categories.

The extent of market integration is closely related to the road conditions. This study applies the argument in Yamauchi and Dewina (2012) and adopts the average road quality at the sub-district level in order to measure the connectivity, or the extent of market integration. The reasons are as follows. As described in the following section, this study covers the households in seven provinces in rural Indonesia, where the authors conducted field surveys and found that some market characteristics may be unique. The food prices vary from one village to another, and the extent of variation across villages may suggest different levels of market integration in each village. Therefore in our study, analysis of tradability among the villages is of the most importance, and it is meaningful to average inter-village road quality within a sub-district to proxy tradability at the inter-village level.

It is also worth mentioning here that for a village, impacts brought by market integration can be asymmetric between goods it can produce and those it can only import, as under certain circumstances, the quantity of endogenous production may also influence the price. In the context of rural villages in developing countries, where the vast proportion of rural areas are still disconnected from the surrounding are due to insufficient roads, it is very important to take into consideration the market of each commodity in each village, although this study only focuses on the rice market.

2.3 Hypothesis

The main objective of this study is to investigate the role of irrigation facilities in conjunction with rural paved roads in relation to a food price surge. Variations in food prices are typical in low-income countries, and the magnitude of price fluctuations brought by a shock depends on the extent to which villages are integrated in the outside markets (Fafchamps 1992; Minten and Kyle 1999). As Goodwin and Piggott (2001) pointed out, a large amount of empirical research has evaluated the extent to which spatially separate markets are integrated, by testing the extent to which shocks are transmitted among spatially separate markets. Moser et al. (2009) also indicates that rice markets in Madagascar are well integrated up to the sub-regional level and the factors that restrict competition are high crime rates, remoteness, and a difficulty transmitting information. Together with the argument of Cirera and Arndt (2008), these studies suggest that investments in road construction and/or rehabilitation will lower transportation costs, and by proxy the extent of market integration and the degree of food price variation.

Taking the arguments above, we first hypothesize that there should be a threshold level of average road quality at the sub-district level that distinguishes through different degrees of rural market integration locally independent economies from integrated market economies. Then we postulate our second hypothesis that the effect of irrigation in the face of a food price surge should be different depending on the extent of rural market integration. To examine these hypotheses, we utilize the threshold estimation methodology developed by Hansen (2000) and test if there exists a certain threshold level of the proportion of local paved roads that splits villages into two economic regimes in which the provision of irrigation systems and farming status, i.e., rice producers or non-producers, interact differently. The distinct consequences of the risk for rice producers and non-producers could be explained by their access to irrigation systems and the characteristics of local markets with different degrees of market integration. The threshold estimation methodology can examine these two hypotheses simultaneously, but specifically for the second hypothesis we introduce the following two comparisons in each economic regime, i.e., villages with low spatial connectivity and the ones with high spatial connectivity:

(1) irrigated villages and non-irrigated ones;

(2) rice producers (net sellers) and consumers (net buyers).

Since 2007 Indonesia has experienced a surge in food prices compared to other consumption goods, which in turn has expectedly affected rural poor households more adversely because they spend a higher share of their income on food consumption (Nose and Yamauchi 2014). However, for those villages with access to irrigation systems, it is expected that this adverse effect could be offset for villages with only limited spatial connectivity by maintaining a relatively abundant food supply in local markets and then subsequently stabilizing food prices at a lower level. When villages have high spatial connectivity, on the other hand, we expect that neither irrigation nor rice farming status correlates with the growth of consumption. Because income sources in spatially well-connected areas or more developed areas were more diverse, employment incomes and private transfers rather than agricultural incomes seemed to contribute to the growth of consumption (Yamauchi and Dewina 2012).

3. Data

3.1 Household and village surveys

The data set utilized in this study is original panel data collected in rural Indonesia in 2007 and 2010. In 2007 there were 2261 sampled households located in 98 villages in 7 provinces (Lampung, Central Java, East Java, West Nusa Tenggara, South, Sulawesi, North Sulawesi, and South Kalimantan). Some households were split into smaller households as some household members became independent. Yet, such split households were traced in the 2010 survey and included as part of the original households when household panel data were constructed. These surveys were conducted under the Japan Bank for International Cooperation (JBIC)'s "Study of Effects of Infrastructure on Millennium Development Goals in Indonesia (IMDG)". Figure 1 shows the locations of surveyed villages.

In addition to the two rounds of household surveys, two rounds of village surveys were also conducted. The village surveys collected fundamental information about socio-economic characteristics of the villages such as their locations, history, employment opportunities, and their access to local markets, education, and health facilities. The village surveys also include some information about the conditions of infrastructure. With respect to irrigation systems, the surveys asked if there was any system of irrigation in the village (Yes or No), and also collected some basic information on irrigation projects implemented in the village. In 2007, 64 villages were equipped with irrigation systems and 34 villages were not, and there was no significant change in these figures as of 2010.[1] Information about intra-village roads was also collected, revealing the the most common road surfaces to be asphalt roads (35 villages), roads paved with other materials (34 villages), dirt roads (26 villages), and "water" surfaces (3 villages) in 2007. There also was no significant improvement in the intra-village road conditions between 2007 and 2010.

3.2 Village survey and census

Another source of village-level information is the 2008 PODES village census implemented by the Indonesian government, which confirmed the type of road surface of the widest road in each village: asphalt/concrete, pebble, land, and other. We use this information to construct our key variable that determines the degree of spatial connectivity in each village. In doing so, the proportion of asphalt/concrete roads at the sub-district level is calculated and used as a proxy for accessibility to higher levels of transportation networks and also to gauge efficiency of transportation within the sub-district. The mean of the proportion of local paved roads is 68.8 percent and the median is 78.5 percent with the minimum value of 0 (3 villages) and the maximum value of 1 (24 villages).

3.3 Consumption

The household survey questionnaires gather information about the quantity and the value of weekly food consumption and item-by-item expenditures, which is aggregated to calculate the total food consumption expenditures. Regular non-food expenditures in the past one month and occasional non-food expenditures in the past one year are also captured. By converting these expenditures into a monthly expense and totaling them, we calculate the total consumption

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[1] Among our sample villages with access to irrigation systems, nearly 80% of villages reported that they had either technical or semi-technical irrigation facilities. The basic structure of these irrigation facilities includes main/secondary canals from a water source such as a dam to each village, and tertiary canals reaching to agricultural land. The other villages reported that they had either a simple or pump irrigation facility.

expenditures, which is further adjusted to the per-capita term by applying an adult equivalence scale.

Table 1 compares the levels of per-capita monthly total consumption expenditures between 2007 and 2010 by the status of infrastructure conditions. First, in Panel A, two simple comparisons are shown: the villages with or without irrigation, then those with lower or higher spatial connectivity. In order to divide the villages into those with lower spatial connectivity and those with higher spatial connectivity, we used the median of the proportion of local paved roads. Panel A shows that, while villages with higher spatial connectivity indicate more developed areas, the placement of irrigation facilities suggests that irrigation projects might be implemented in less developed areas. Then, in Panel B, two factors above — accessibility of irrigation facilities and spatial connectivity are put together, and shown in matrices. Among the villages with lower spatial connectivity, total consumption expenditures in the villages with irrigation were lower than those in the villages without irrigation, but the villages with irrigation experienced a slightly higher growth rate than those without irrigation. These differences, in contrast, cannot be seen among the villages with higher special connectivity. It thus seems that irrigation facilities in the villages with lower spatial connectivity could play a role during the food price crisis.

Table 2 provides a further comparison by taking into account rice farming status, i.e., whether the households are rice producers (net rice sellers), or non-producers (net rice buyers). By using the rice farming status, Table 2 compares the levels and the growth rates of total consumption expenditures by adopting three dichotomies: households in villages with low or high spatial connectivity, those in villages with or without irrigation, and those that are rice producers or non-producers. It is striking to note that the influences of irrigation facilities on the average growth rates of total consumption expenditures, as presented through the comparison of irrigation status in Table 1, are more evident among non-producers residing in the villages with lower spatial connectivity. Facing limited spatial connectivity, non-producers with access to irrigation experienced higher growth rates compared to those without access to irrigation. Rice producers in the villages with lower spatial connectivity enjoyed higher growth rates regardless of their access to irrigation, although the growth rate was slightly lower for those in the villages with irrigation. The existence of the irrigation systems does not seem to make any significant difference in the villages with higher connectivity.

Before we go into more detailed analysis of these tentative findings, it's important to compare rice prices so that we can have some ideas about what is going on in the local markets (Table 3). The structure of Table 3 is same as Table 1. In Panel A, there are two comparisons: the villages with or without irrigation then those with low or high connectivity are shown, while the matrices taking both into consideration are shown as Panel B. The average rice prices in the villages with irrigation are significantly lower among the villages with lower connectivity in both years. This suggests that, even when rural Indonesia experienced a surge in food prices, these prices, and particularly rice prices in villages with access to irrigation systems, were kept lower because the local supply of rice was relatively abundant with limited spatial connectivity and lower degrees of market integration.[2] In contrast, no significant variation in rice prices among the villages with higher spatial connectivity can be seen. Bearing these findings in our mind, our specific research hypotheses are examined more rigorously in the following sections.

[2] Note that even though rice prices in the villages with lower spatial connectivity were kept to be lower during the crisis, the absolute level of rice prices increased significantly. This means that even the villages with lower spatial connectivity were not free from high inflation. According to BPS, the nation-wide CPI in 2010 was 121.74 (the base year is 2007). The increase in rice prices can be explained by increases in production-factor prices such as wages for casual agricultural workers, rental rates for farm land, and other inputs for crop production, e.g., fertilizers.

4. Empirical models

4.1 Consumption growth

In order to more rigorously examine our hypotheses, the threshold estimation methodology developed by Hansen (2000) is utilized. A pair of growth models is formulated below.

(1) $$y_{ijk} = \gamma_1^1 \cdot rice_{ijk} + \gamma_2^1 \cdot irrigation_{jk} + \gamma_3^1 \cdot rice_{ijk} \times irrigation_{jk} + X_{ijk}\beta^1 + \alpha_k + \varepsilon_{ijk}$$

(up to threshold),

(2) $$y_{ijk} = \gamma_1^2 \cdot rice_{ijk} + \gamma_2^2 \cdot irrigation_{jk} + \gamma_3^2 \cdot rice_{ijk} \times irrigation_{jk} + X_{ijk}\beta^2 + \alpha_k + \varepsilon_{ijk}$$

(above threshold),

where the dependent variable y_{ijk} is the average annual growth rate of total consumption expenditures per capita between 2007 and 2010 for household *i* residing in village *j* in province *k*. The explanatory variables $rice_{ijk}$ and $irrigation_{jk}$ are dummy variables (the former takes the value of 1 for rice producers and 0 for non-producers, and the latter takes the value of 1 if the household *i* resides in the villages having access to irrigation and 0 otherwise). The term of $rice_{ijk} \times irrigation_{jk}$ is an interaction between the two dummy variable that takes the value of 1 for rice produces in villages with irrigation facilities. X_{ijk} is a vector of other explanatory variables. The other explanatory variables used in this model are a set of household characteristics in 2007 with a couple of household head characteristics that reflect changes between 2007 and 2010. βs and γs are the parameters to be estimated and our focus will be on γs. α_k is the province level fixed effects and ε_{ijk} is assumed to be an i.i.d. error term. Since the dependent variable is the growth rate, time-invariant unobservable factors are taken care of and this model investigates a correlation between the consumption growth and the explanatory variables.

In examining our hypothesis, the threshold variable is the average proportion of local paved roads at the sub-district level, and we assume that there exists a threshold that splits villages into two categories: villages with lower spatial connectivity and villages with higher spatial connectivity. An advantage of utilizing the threshold estimation is to rigorously examine the existence of the threshold along with the estimation of the parameters. Our first hypothesis postulates that the accessibility to irrigation systems and rice farming status have a more significant influence in the villages with limited spatial connectivity because the supply of rice in such villages is more susceptive to local rice production.

The list of explanatory variables is shown in Table 4. Three dummy variables are used to capture changes in household head characteristics. The first dummy variable takes the value of 1 when the household head is female in both years and 0 otherwise. The second dummy variable takes the value of 1 when a male-head household in 2007 changes into a female-headed household in 2010, and the third dummy variable take the value of 1 when a female head in 2007 is replaced by a male head in 2010. In addition to these three dummy variables, the household head's age and level of education achieved are controlled for as household head characteristics. Other household characteristics included in the empirical model are the log of household size, a dummy variable for a landless household based on farm land ownership, and the log of agricultural land size in hectors. Village characteristics are also included in the model. Additionally, a set of province dummy variables is used to control for fixed-effects at the province level.

4.2 Rice price

In addition to the consumption growth model described above, because rice price plays a central role to determine the welfare level of rural households, we explicitly investigate factors associated with rice prices at the village level and examine whether our hypotheses are empirically supported.

(3) $$price_{jkt} = \gamma_t \times irrigation_{jk} + X_{jkt}\beta_t + \alpha_{jk} + \alpha_k + \varepsilon_{jkt},$$

where $price_{jkt}$ is the price of rice in village *j* in province *k* in year *t*, and $irrigation_{jk}$ is a dummy variable representing the village *j* has irrigation. X_{jkt} is a vector of other explanatory variables and α_k is the province fixed effects. ε_{jkt} is assumed to be an i.i.d. error term. We estimate γs and βs in 2007 and 2010 for villages with lower spatial connectivity and those with higher spatial connectivity separately. Nonetheless, because this model cannot control for time-invariant village-level unobserved factors α_{jk}, which is highly likely to cause omitted variable bias, we estimate the following model as well.

(4) $$\Delta price_{jkt} = \gamma \times irrigation_{jk} + X_{jk}\beta + \alpha_k + \varepsilon_{jk},$$

where the dependent variable is the change in rice prices between 2007 and 2010 and X_{jk} is a vector of explanatory variables that are community characteristics in 2007–08. Similar to the consumption growth model, this model eliminates time-invariant unobserved factors at the village level and examines a correlation between the change in rice prices and the explanatory variables. We estimate γ and β for the villages with lower spatial connectivity and those with higher spatial connectivity separately. With this model, we can test whether irrigation facilities could keep rice prices significantly lower during the food price crisis.

5. Estimation results

Before showing the estimation results, Table 5 compares the household characteristics in the sample villages by the presence of irrigation systems, and then compares the household characteristics between rice producers and non-producers. The characteristics of rice producers are intuitively understandable. The proportion of female-headed households among rice producers is less than that among non-producers and rice producers are more likely to be a larger household, which implies that a larger labor force is necessary for rice production. The proportion of landless households is also lower among rice producers. In contrast, the characteristics of households in the villages with irrigation are a little counter-intuitive. An interesting finding is that while the proportion of rice producers in the villages with irrigation is significantly higher, the proportion of landless households is also significantly higher in the irrigated villages. This can be explained by the fact that households that are not involved in rice production and residing in the villages with irrigation are more likely to be landless. Lastly, the average of the highest education level achieved by the household head is higher in the villages with irrigation compared to that in the villages without irrigation systems.

The estimation results by the regression model with all households and the threshold regression model are shown in Table 6. The regression analysis with all households shows that during the food price crisis rice non-producers on average experienced slower consumption growth by 9.3 percentage points compared to rice producers (significant at the 1 percent level). This can be explained by the fact that while increased food prices, particularly rice, raised the agricultural income of rice producers, higher food prices reduced the purchasing power of non-producers. The presence of irrigation facilities nonetheless improved non-produces' consumption growth rate significantly (Column A). As can be seen, rice prices tend to be lower in the irrigated villages, and these lower prices might allow non-producers to spend more on other goods. It thus seemed that for non-producers, irrigation facilities could offset the negative effects of the food price crisis by keeping the food supply in local markets relatively abundant.

The threshold estimation examines if there exists a certain threshold level of the proportion of local paved roads that splits the villages into lower and higher spatial connectivity. As shown in Figure 2, our estimation result clearly indicates the existence of such a threshold. The estimated value of the threshold variable is 0.875, which implies that villages with less than or equal to 87.5 percent asphalt roads at the sub-district level can be regarded as those with limited spatial connectivity. Among the villages with limited spatial connectivity, the offsetting effect of food price crisis for non-producer is more evident (Column B), whereas the influence of the irrigation provision and rice farming status is insignificant in the villages with higher spatial connectivity (Column C). In the villages with lower spatial connectively, the existence of irrigation facilities has a contrasting impact for rice producers and non-producers. Lower rice prices in the villages with irrigation might result in a decrease in the profit from rice production and lead to rice producers' slower growth rate of total consumption expenditures.

Finally, we explicitly investigate factors associated with rice prices. The cross-sectional analyses indicate that rice prices in the villages with irrigation tend to be lower even after controlling for some village characteristics that represent both supply- and demand-side factors of rice production (Table 7). Yet, the difference is only significant within the villages with limited spatial connectivity in 2010 (Column C). These estimation results might be biased due to omitted variables because we control for a limited number of village characteristics in this model. The alternative model with the dependent variable of the change in rice prices between 2007 and 2010 also examines whether irrigation facilities could keep rice prices significantly lower during the surge in food prices. The estimation result shows that in the villages with lower spatial connectivity, irrigation facilities in fact did play such a role (Column E).

6. Conclusion

This paper, focusing on the function of village food markets, aims to shed new light on the link between infrastructure (particularly irrigation facilities and rural roads), risk (food price crisis), and the welfare of the rural households. In our analytical models, we take the average annual growth rate of total consumption expenditures per capita as a welfare indicator. The primary challenge to this paper is that biases caused by the endogenous placement of infrastructure and endogenous decisions to produce rice may still remain, as time-variant unobservable factors could associate with both the endogenous variables and consumption growth. Therefore, our findings may not be causalities, but just correlations. To examine this, the authors will further explore valid instrumental variables or appropriate sample trimming methodologies using the propensity score. It is worth emphasizing, however, that this study does not intend to rigorously evaluate the impacts of infrastructure, but instead to illustrate how influences of the food price crisis were transmitted into rural economies, and how infrastructure facilities worked against the crisis.

In this paper, we specifically investigated differencing effects of irrigation systems depending on the extent of market integration. During the food price crisis, in villages with access to irrigation systems and limited spatial connectivity due to unfavorable road conditions and high transportation costs, food prices were kept lower even when the rest of rural Indonesia experienced a spike in food prices. This suggests that irrigation systems provided a relatively abundant food supply, while low road connectivity did not hamper the lowering prices through general equilibrium effects. As a result, our empirical analysis also shows that, although the implication is contrastive to rice producers (net sellers), irrigation systems offset the negative effects of the food price crisis for rural food consumers (net buyers). Along with this investigation, the threshold estimation examines whether there exists a certain threshold level of the proportion of local paved roads that splits the villages into lower and higher spatial connectivity. Our estimation result clearly indicates the existence of such a threshold. Although the Indonesian government has implemented a series of food price stabilization policies (Saifullah 2010), the existence of fragmented rural food markets may suggest a limit to the effectiveness of their market operations.

A variety of other policy discussions can be made based on the findings of this study. First, in the process of planning infrastructure construction in the field of economic cooperation, links between the infrastructure, risk, and the welfare of the beneficiaries should be carefully examined. For example, although conventionally the concept of Internal Rate of Returns (IRR) has been applied for evaluating the effectiveness of infrastructure investments, this study proposes a new and complementary concept for evaluating them. The IRR method can evaluate the outcomes of infrastructure provisions only by focusing on the *average* increase of outcomes. As argued above, however, fluctuation itself would also severely affect the poor and vulnerable. Our analysis shows that properly designed and constructed infrastructure facilities have the function of mitigating such risk, as well as enhancing average increases. This risk-mitigating function of infrastructure has been underestimated by the conventional evaluation method, though practitioners have been tacitly recognizing them. This function can be interpreted as a potential benefit because this study reveals that some benefits cannot be realized under the ordinary circumstances but only in the face of negative shocks.

Second, our analysis also focuses on the cross-effects between irrigation facilities and rural roads, and shows that road construction may increase risks farmers face, while irrigation facilities work in the opposite direction. Nothing in our results, of course, attempts to question the benefits expected as a result of road construction. As argued above, such benefits have been empirically examined and proven. With limited financial resources, however, policy makers have to choose the most appropriate development programs including, for example, considering sequences: which project comes first and which can come later, or which sectors are complimentary. To do this, policy makers should have more extensive knowledge about the implications of public investments. In addition to this paper, for example, Yamauchi et al. (2011) find that the effects of road construction and educational investment are complimentary in Indonesia. These findings would jointly help policy makers prioritize public investments. To further debate the efficiency of public investments, cost and benefit analysis should be considered. This study suggests that when estimating the return of the irrigation projects, benefits that are realized only when certain types of shock happen have to be taken into account.

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Table 1. Growth of per-capita monthly consumption by infrastructure provision

Panel A	All sample			All sample		
	Without irrigation (n=769)	**With irrigation (n=1416)**	**Diff.**	**With low connectivity (n=1123)**	**With high connectivity (n=1062)**	**Diff.**
	Mean	**Mean**		**Mean**	**Mean**	
	(s.d.)	**(s.d.)**		**(s.d.)**	**(s.d.)**	
2007	421544	414355	-7189*	353101	484334	131234***
	(339890)	(521217)		(304616)	(582211)	
2010	654763	621004	-33759	565942	703673	137731***
	(339890)	(521217)		(304616)	(582211)	
2010-2007	233219	206648	-26571	212842	219339	6498
	(732068)	(639807)		(484953)	(827930)	
Growth rate	0.169	0.186	0.017	0.202	0.157	-0.046***
	(0.263)	(0.267)		(0.268)	(0.261)	

Panel B	With low connectivity			With high connectivity		
	Without irrigation (n=389)	**With irrigation (n=734)**	**Diff.**	**Without irrigation (n=380)**	**With irrigation (n=682)**	**Diff.**
	Mean	**Mean**		**Mean**	**Mean**	
	(s.d.)	**(s.d.)**		**(s.d.)**	**(s.d.)**	
2007	387525	334856	-52669	456369	499916	43547
	(299062)	(306153)		(374344)	(670408)	
2010	606742	544319	-62423	703921	703535	-386
	(299062)	(306153)		(374344)	(670408)	
2010-2007	219217	209463	-9754	247552	203619	-43933
	(569389)	(433985)		(868146)	(804873)	
Growth rate	0.185	0.212	0.027	0.153	0.159	0.006
	(0.268)	(0.267)		(0.257)	(0.264)	

Note: t-test results are shown, * significant at 10%; ** significant at 5%; *** significant at 1%.

1 USD = approximately 8900 IDR in June 2007 and approximately 9000 IDR in June 2010.

Table 2. Growth of per-capita monthly consumption by rice farming status

	With low connectivity			With high connectivity		
	Without irrigation	**With irrigation**	**Diff.**	**Without irrigation**	**With irrigation**	**Diff.**
	Mean (s.d.)	**Mean (s.d.)**		**Mean (s.d.)**	**Mean (s.d.)**	
Rice producers (n=)	131	316		69	230	
2007	317110	328808	11698	384448	392769	8322
	(204250)	(274420)		(261616)	(282850)	
2010	665778	531483	-134295**	601000	620456	19457
	(808944)	(412947)		(442379)	(478283)	
2010-2007	348668	202674	-145993***	216552	227687	11135
	(754728)	(395160)		(470858)	(458726)	
Growth rate	0.259	0.216	-0.043	0.208	0.187	-0.021
	(0.303)	(0.288)		(0.302)	(0.247)	
Non-producers (n=)	258	418		311	452	
2007	423279	339429	-83850***	472326	554438	82112*
	(331834)	(328364)		(393579)	(793220)	
2010	576767	554023	-22743	726756	745810	19054
	(394991)	(552251)		(1111617)	(764179)	
2010-2007	153488	214595	61107*	254430	191373	-63058
	(434107)	(461575)		(934098)	(933221)	
Growth rate	0.147	0.209	0.062***	0.140	0.144	0.004
	(0.240)	(0.251)		(0.244)	(0.271)	

Note: t-test results are shown, * significant at 10%; ** significant at 5%; *** significant at 1%.

1 USD = approximately 8900 IDR in June 2007 and approximately 9000 IDR in June 2010.

Table 3. Comparison of village-level rice prices by infrastructure provision

Panel A	All sample			All sample		
	Without irrigation (n=34)	With irrigation (n=64)	Diff.	With low connectivity (n=50)	With high connectivity (n=48)	Diff.
	Mean	**Mean**		**Mean**	**Mean**	
	(s.d.)	**(s.d.)**		**(s.d.)**	**(s.d.)**	
2007	4201	4022	-179*	3996	4175	179*
	(533)	(487)		(517)	(487)	
2010	5681	5292	-388***	5241	5621	381***
	(533)	(487)		(517)	(487)	
2010-2007	1480	1271	-209*	1244	1446	202*
	(576)	(525)		(541)	(545)	

Panel B	With low connectivity			With high connectivity		
	Without irrigation (n=17)	With irrigation (n=33)	Diff.	Without irrigation (n=17)	With irrigation (n=31)	Diff.
	Mean	**Mean**		**Mean**	**Mean**	
	(s.d.)	**(s.d.)**		**(s.d.)**	**(s.d.)**	
2007	4196	3893	-303**	4205	4159	-46
	(523)	(489)		(559)	(452)	
2010	5532	5090	-442**	5829	5508	-321
	(523)	(489)		(559)	(452)	
2010-2007	1336	1197	-138	1624	1349	-275
	(572)	(528)		(560)	(520)	

Note: Village-level rice price is estimated by calculating the mean of the household-level rice prices in the village. Household-level rice price is defined as the price of rice at which each household purchases rice at the local market. t-test results are shown, * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4. Summary statistics of explanatory variables

	Mean	s.d.	Min.	Max.
Household head characteristics (n=2182)				
Female (=1)	0.072	(0.259)	0	1
Male to female (=1)	0.045	(0.207)	0	1
Female to male (=1)	0.027	(0.164)	0	1
Age	49.33	-13.25	18	92
Education (highest grade completed)	6.040	(3.987)	0	20
Household characteristics in 2007				
log (household size)	1.381	(0.433)	0	2.565
Landless (=1)	0.346	(0.476)	0	1
log (land size in ha)	-0.298	(0.968)	-4.605	2.996
Rice production				
Rice producers in 2010 (=1)	0.341	(0.474)	0	1
Village characteristics (n=98)				
Irrigation facility				
Irrigated (=1)	0.653	(0.478)	0	1
Market access				
Market outside the village (=1)	0.704	(0.459)	0	1
Distance to market with permanent building (km)	7.009	(12.793)	0.100	91.000
Main road condition				
Asphalt (=1)	0.837	(0.372)	0	1
Paved with other materials (=1)	0.071	(0.259)	0	1
Dirt (=1)	0.082	(0.275)	0	1
Intra-road condition				
Dirt (=1)	0.265	(0.444)	0	1
Paved (=1)	0.347	(0.478)	0	1
Asphalt (=1)	0.357	(0.482)	0	1
Other village characteristics				
Population (1000)	4.53	(4.06)	0.44	23.01
Percentage of rice producers (%)	33.2	(27.8)	0	96.43
Average of consumption levels (1000IDR)	385	(150)	140	1068

Note: Mean of log (land size) is the mean among households that have access to agricultural land. Mean of distance to market with permanent building is the mean among villages whose market is located outside the villages.

Table 5. Comparison of household characteristics

	With Irrigation (n=1414)	Without Irrigation (n=769)	Diff.	Rice producers (n=744)	Rice non-producers (n=1439)	Diff.
	Mean	**Mean**		**Mean**	**Mean**	
	(s.d.)	**(s.d.)**		**(s.d.)**	**(s.d.)**	
Household head characteristics						
Female (=1)	0.071	0.075	-0.005	0.042	0.088	-0.047
	(0.256)	(0.264)		(0.200)	(0.284)	***
Male to female (=1)	0.045	0.046	-0.001	0.028	0.054	-0.025
	(0.206)	(0.209)		(0.166)	(0.225)	***
Female to male (=1)	0.024	0.034	-0.010	0.026	0.028	-0.003
	(0.153)	(0.181)		(0.158)	(0.166)	
Age	49.547	48.921	0.627	48.921	49.536	-0.616
	(13.206)	(13.332)		(12.254)	(13.737)	
Education (highest grade completed)	6.268	5.629	0.639	5.904	6.115	-0.211
	(4.099)	(3.745)	***	(3.873)	(4.046)	
Household characteristics in 2007						
Household size	4.354	4.319	0.036	4.495	4.263	0.232
	(1.788)	(1.793)		(1.766)	(1.797)	***
Landless (=1)	0.370	0.303	0.067	0.220	0.411	-0.191
	(0.483)	(0.460)	***	(0.415)	(0.492)	***
Land size in ha	1.271	1.581	-0.310	1.354	1.410	-0.056
	(1.665)	(2.110)	***	(1.552)	(2.030)	
Irrigated (=1)				0.731	0.605	0.127
				(0.444)	(0.489)	***
Rice producers (=1) in 2010	0.385	0.260	0.125			
	(0.487)	(0.439)	***			

Note: t-test results are shown, * significant at 10%; ** significant at 5%; *** significant at 1%.

Mean of land size is the mean among households that have access to agricultural land.

Table 6. Growth of per-capita monthly consumption

Dependent variable: Geometric mean of growth rate between 2007 and 2010	All households (A)	Households with low connectivity (B)	Households with high connectivity (C)
Threshold Estimate		0.875	
95% Confidence Interval		[0.833 , 0.944]	
Rice production & Irrigation facility			
Rice non-producers (=1)	-0.093***	-0.130***	0.006
	(0.031)	(0.029)	(0.084)
Irrigated (=1)	-0.032	-0.059***	0.023
	(0.019)	(0.020)	(0.034)
Rice non-producers * Irrigated (=1)	0.098***	0.155***	-0.033
	(0.033)	(0.031)	(0.088)
Household head characteristics			
Female (=1)	-0.002	0.015	-0.026
	(0.020)	(0.029)	(0.022)
Male to female (=1)	0.001	-0.020	0.022
	(0.029)	(0.025)	(0.066)
Female to male (1)	-0.064**	-0.054	-0.063*
	(0.026)	(0.040)	(0.033)
Age	0.001	0.001	-0.001
	(0.003)	(0.004)	(0.004)
Age squared /1000	-0.005	-0.001	-0.003
	(0.026)	(0.034)	(0.035)
Education (highest grade completed)	-0.002	-0.001	-0.002
	(0.002)	(0.002)	(0.002)
Household characteristics			
log (household size)	0.074***	0.092***	0.048**
	(0.013)	(0.018)	(0.019)
Agricultural landless (=1)	-0.021	-0.027*	-0.031
	(0.013)	(0.016)	(0.024)
log (land size in ha)	0.001	-0.013	0.020*
	(0.007)	(0.008)	(0.011)
Province FE	Yes	Yes	Yes
R-sq.	0.053	0.063	0.058
Number of observations	2182	1343	839

Note: Village-level cluster-robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. For the threshold estimate, the confidential interval is constructed by using the methodology developed by Hansen (2000) and the estimation result is illustrated in Figure 2.

The program for the estimation is downloadable from http://www.ssc.wisc.edu/~bhansen/progs/ecnmt_00.html.

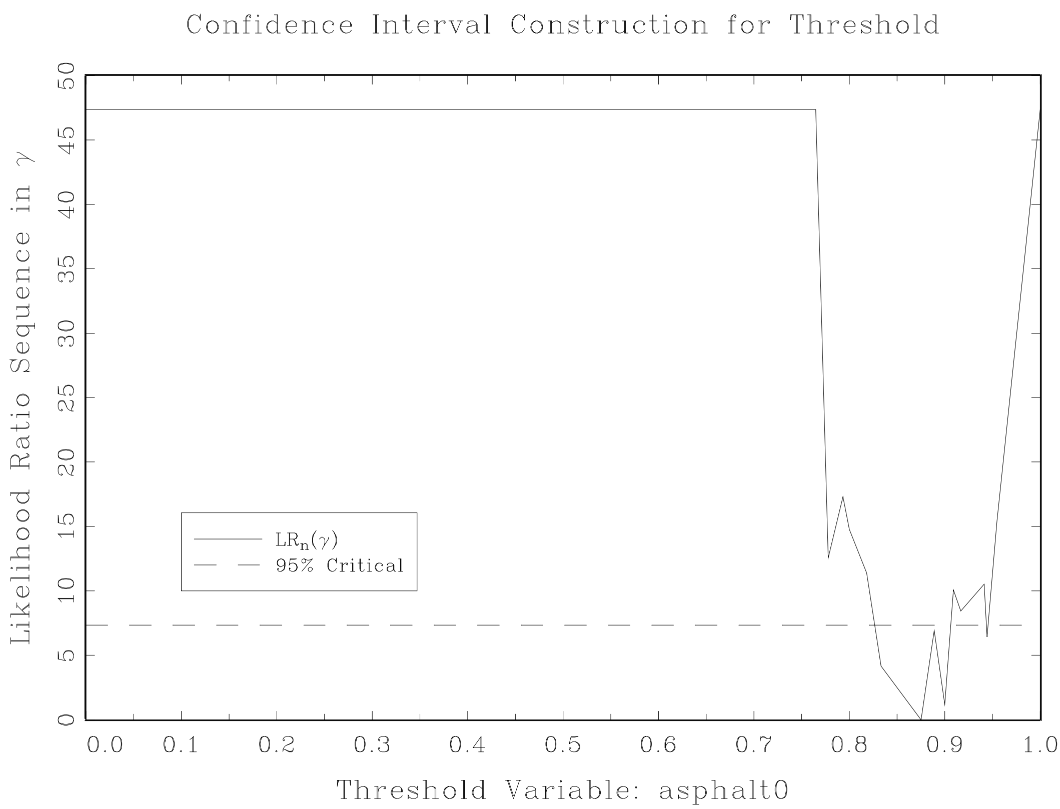
Table 7. Factors associated with rice prices

Dependent variable:	Rice price in 2007		Rice price in 2010		Change in prices	
	With low connectivity	With high connectivity	With low connectivity	With high connectivity	With low connectivity	With high connectivity
	(A)	(B)	(C)	(D)	(E)	(F)
Irrigation facility						
Irrigated (=1)	-73.4	-101.6	-381.1**	134.5	-307.7*	236.1
	(170.7)	(135.8)	(184.8)	(280.2)	(172.0)	(249.4)
Market access						
Market with permanent building outside the village (=1)	54.5	-138.1	185.8	46.9	131.3	185.0
	(171.5)	(162.7)	(185.6)	(335.7)	(172.8)	(298.8)
* Distance to market with permanent building (km)	18.2*	34.2	2.9	30.3	-15.4	-3.8
	(10.7)	(26.2)	(11.6)	(54.0)	(10.8)	(48.0)
Main road (base group is asphalt road)						
Dirt (=1)	-323.2		-283.4		39.7	
	(419.1)		(453.6)		(422.2)	
Paved with other materials (=1)	61.7	-1133.9	117.7	-905.3	56.0	228.7
	(254.3)	(559.2)	(275.2)	(1153.8)	(256.2)	(1027.1)
Intra-road (base group is asphalt road)						
Dirt (=1)	-65.8	234.4	457.6**	43.7	523.4**	-190.7
	(199.3)	(199.0)	(215.7)	(410.6)	(200.8)	(365.5)
Paved with other materials (=1)	-140.2	182.9	128.3	-157.8	268.5	-340.7
	(166.0)	(180.9)	(179.7)	(373.2)	(167.2)	(332.3)
Other village characteristics						
Population (1000)	37.1	-12.9	-29.1	33.9	-66.3***	46.8
	(24.2)	(21.2)	(26.2)	(43.8)	(24.4)	(39.0)
Percentage of rice producers (%)	-7.3**	-6.9**	-6.3**	-17.1**	1.1	-10.2*
	(2.8)	(3.0)	(3.0)	(6.1)	(2.8)	(5.4)
Average of consumption levels (1000IDR)	0.2	0.5	1.3*	-0.4	1.1	-0.8
	(0.7)	(0.4)	(0.7)	(0.8)	(0.7)	(0.7)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
R-sq.	0.392	0.824	0.524	0.647	0.454	0.526
Number of observations	60	38	60	38	60	38

Heterogeneity-robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%.

Figure 1. Locations of Sample Households

Figure 2. Threshold Estimate and Confidence Interval



Abstract (in Japanese)

要約

本論文は 2007/08 年に起こった国際食糧価格の高騰とそれに続くインドネシア国内の食糧価格の上昇という危機に対し、二種類のインフラストラクチャー(灌漑施設と地方舗装道路)がどのような役割を果したのかを検証している。一般に、灌漑施設は農業生産性の向上に寄与し、地方舗装道路は輸送コストを低減させることで村の農作物市場の周辺市場との統合度合いに影響を与えると考えられている。本論文は、食糧価格危機に対し、インフラストラクチャーが家計の消費水準の決定にどのように働いたかを、主食である米の局所的な需給メカニズムに注目し、分析を行っている。分析結果は、地方舗装道路の未整備により周辺市場との統合度合いの低い地域で、灌漑施設を有する村では米の供給が十分に保たれ、米価が比較的安価に抑えられたことを示している。これにより、食糧価格危機の購買者に対する負の影響は緩和された。なお、周辺市場との統合度合いの高い地域では、このような役割を確認することはできない。