Rising Real Wages, Mechanization and Growing Advantage of Large Farms

Evidence from Indonesia

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Abstract

This paper examines dynamic patterns of land use, capital investments and wages in agriculture using farm panel data from Indonesia. The empirical analysis shows that with an increase in real wages that prevailed in both agricultural and non-agricultural sectors in rural areas, relatively larger farmers increased the size of operational farm land by renting in land as well as used more hired-in machines through machine rental and/or service providers, which induces the substitution of labor by machines. Machines and land are complementary and, consistently, the inverse farm size -productivity relationship tends to be reversed among relatively large holders. The results support growing (diminishing) advantage of large (small) farms in the presence of rapidly rising real wages and have food security policy implications to many Asian countries where real wages are rapidly rising and small farms are predominant.

Key words: Wage growth, farm size, mechanization, Indonesia

JEL Classifications: J31, Q12, Q15

1.Introduction

It has been increasingly recognized that rapidly-growing Asia is becoming a driving force of economic growth in the world but also a growing concern in the global food economy due to its large share of grain imports in the world.¹ Economic growth, urbanization and transformation of the economic structure in Asia have been the fastest in the world, which has induced increasing real wages not only in urban and non-agricultural sectors but also in many parts of rural and agricultural sectors in Asia. Although the above transformation contributed to reducing poverty in the region, it also created a challenge to farming which depends on small-scale and family based operations. In this paper, I examine whether an increase in real wage induces a realization of scale economies and the use of machines that substitutes for labor, using farm panel data from Indonesia.

Family labor tends to be more intensively used on smaller farms in the absence of efficient labor markets, which, in turn contributes to the inverse relationship between farm size and crop yield (Feder 1985; Berry and Cline 1979; Benjamin and Brandt 2002).² In fact, Asian agriculture has been dominated by labor-intensive small farms mainly relying on family labor. However, such an inverse relationship could be altered with fast economic growth, often accompanying a rising wage rate, because labor-intensive production becomes costly. The wage growth may have significant adverse effects on the efficiency of small-scale farming in Asia and potentially more generally in developing countries.³

¹ Low self-sufficiency is evident in Japan, Korea, Taiwan and more recently becoming a serious concern in China, where imports of certain commodities increased very rapidly. Though exporters such as Thailand, Brazil, and Argentina can enjoy such a trend, it is possible that the above trend observed in Asia will destabilize the supply-demand balance in the global food economy.

² It is, however, possible that highly fertile land tends to be inherited to the next generation (therefore divided by children), which leads to higher land productivity in smaller farm land. In this mechanism, an increase in real wages caused by migrations out of agriculture reduces the demographic pressure on farm land.

³ Jayne et al. (2014) synthesized recent evidence and discussions on the impact of increased population pressures on agricultural land in Africa. In contrast to Africa, many Asian countries have relatively strong non-agricultural sectors that absorbed surplus labor from agriculture. In other words, as Liu and Yamauchi (2014) emphasized in their paper (in the same special edition), agriculture and non-agricultural sectors are well integrated and thus migration from agriculture to non-agriculture plays an important role in adjusting population pressures in agriculture in many Asian countries.

The following intuition shapes the key hypothesis. An increase in real wages increases the production cost of labor-intensive farming system and thereby decreases comparative advantage in agriculture based on the labor-intensive production methods widely observed in many parts of Asia. To restore comparative advantage, at least partially, farm size expansion and (large-scale) mechanization must take place to save high-cost labor. However, the introduction of large-scale mechanization is difficult if farm size is constrained by, for example, total land endowment, high population density and a relatively high value of non-agricultural land use. All the above factors render a potential advantage to large farmers. If an expansion of farm size is easy for larger farmers, it may create a divergence in production efficiency and profitability between large and small farmers. Under the above circumstances, the inverse size-productivity relationship can be reversed among relatively large holders.

As Otsuka (2013) summarizes in his paper, increasing real wages (and transformation of occupational structures in labor markets) challenge Asian agriculture in which the majority of farmers are smallholders, because of the increasing need (i) to reduce the labor force in agriculture (as the opportunity cost of farming increases), (ii) to increase the average farm size (to reduce labor use by introducing labor-saving production methods) and (iii) to generate enough income to retain parity with non-agricultural workers. If land markets and/or institutional mechanisms are imperfect, major inefficiencies in the allocation of farm land will be bound to arise.⁴

In the recent literature, Foster and Rosenzweig (2010, 2011) also show some evidence to support the second point in India. More recently, Wang et al. (2014) showed that land rental market and machine service providers (as well as machine rental) contributed to the expansion of operational land size and (to some extent) mechanization in China. A rapid increase in the relative price of agricultural labor to machines led to the substitution of labor by machines in major crops (Wang et al., 2015).⁵ The findings

⁴ Useful insights also come from the history of agricultural development. The British enclosure movement during its industrial revolution played a role in consolidating farm lands to thus suppress wages and release labor to non-agricultural industries. Labor cost and supply in the labor market could be critically linked to landownership and land consolidations in rural areas.

⁵ Their estimates of the Morishima Elasticity of Substitution show relatively large substitutability in rice and cotton.

of this paper are quite similar to those in Wang et al.(2014). In a slightly different approach, Liu et al. (2014) and Singh et al. (2014) show that the inverse size-productivity relation has been becoming weaker recently along with an increase in real wages in Vietnam and India, respectively. These studies are also synthesized as part of the literature review by Otsuka, Liu and Yamauchi (2015). Using cross-country panel data, Otsuka, Liu and Yamauchi (2013) present evidence consistent with the above conjectures. That is, rising real wages tend to lower farm productivity if the average farm size remains small.

The key idea of this paper is related to an important line of thought in the literature. Developing the concept of induced innovations proposed by Hicks (1932), Hayami and Ruttan (1985) introduced the idea of induced institutional changes in agriculture. An increase in real wages may induce a technical change to save labor, i.e., mechanization, but also could lead to an institutional arrangement that saves labor and/or reduces user costs of machines on farm even without land consolidation. For example, if machines can be rented relatively cheaply, even small farmers may be able to effectively save labor by utilizing machines through rental markets.⁶ In this context, I examine whether changes in relative factor prices altered productivity through labor-capital substitutability that can be constrained by the initial land distribution. But it remains possible that (i) land reallocation could happen through land rental markets and (ii) institutional arrangements such as emergence of machine rentals and machine service providers can facilitate the substitution of labor by machines.

To empirically investigate the above issue, Indonesia provides an interesting setting in which relatively abundant and scarce land endowments coexist. Land is immobile across islands, while labor is mobile. Demarcation between macro-regional islands offers us an ideal experimental ground, when real wages rise, to learn about differences in the consequence of wage growth between relatively land-

⁶ This will be the case in some areas, e.g., lowland agriculture. However, it is more difficult in hilly areas including terraced rice production.

abundant and land-scarce regions.⁷ Land endowments are relatively large outside Java, whereas the majority of farmers are small landholders within Java.

The data used in the analysis come from 98 villages in 7 provinces (5 macro-regional islands) that represent the major agro-climatic zones in Indonesia. Substantial variations in wage growth across villages (while the average growth is high) also offer an appropriate setting to test the main hypothesis.⁸ This paper shows that wage growth in recent years led to an introduction of labor saving practices among relatively large farmers. That is, larger farmers tend to acquire more land by renting in land and use machines if real wages increase. In response to an increase in real wages, relatively large farmers are more likely to hire in machines somehow through machine rental and/or service providers than purchase machines (i.e., investments).⁹ The empirical findings also show that land and machines are complementary among relatively large landholders. Consistently, the inverse land-productivity relationship tends to be reversed among relatively large holders.

The paper is organized as follows. Section 2 describes the empirical strategy. Section 3 explains the panel data collected in 7 provinces in Indonesia and shows some descriptive findings. The main empirical findings are summarized in Section 4, followed by concluding remarks.

2. Empirical Strategy

⁷ Indonesia has traditional harvest arrangements by traders who purchase products before harvest time (thus, reducing price risk to farmers) or bring laborers to farm yards to harvest, called Ijon and Tebasan, respectively. Casual observations in the field suggest that machines are rarely brought to harvest in the practice of Tebasan concentrated in Java, which may imply that an increase in labor costs has not been excessively high, i.e., there are still sufficient low-cost laborers available to harvesting. However, the empirical findings of this paper point to the emerging phenomenon of relatively large farmers having started scaling up their operations by using machines. Therefore, it appears that Indonesian farming is reaching a cross-road, potentially resulting in divergences in efficiency across differently endowed regions.

⁸ One shortcoming of this paper is lack of machine price (and rental price) data. The analysis assumes that its growth rate is unique within a province (controlled by province dummies or fixed effects), and/or it is more or less similar to the province-specific consumer price index (CPI). It seems at least reasonable to assume that machine prices are homogeneous within a province as the retails are usually available only in relatively large cities and towns (including its provincial capital).

⁹ This finding is very similar to that of Wang, et al. (2014).

This section describes specifications and estimation strategy used in the analysis. Land transactions and machine investments are analyzed in the following first-differenced equation,

$$\Delta y_{ij(0,1)} = \alpha + \beta_1 \Delta w_{j(0,1)} + \beta_2 \Delta w_{j(0,1)} land_{ij0} + \beta_3 land_{ij0} + x_{ij0}' \delta + province + \Delta \varepsilon_{ij(0,1)} \quad (1)$$

where $\Delta y_{ij(0,1)}$ is change in self-cultivated land, rent-in land¹⁰, or the payments for hired-in machines (through machine rental and/or service providers) or the value of machine investments in the period (0,1) for household i in village j, $\Delta w_{j(0,1)}$ is the village-level real wage growth rate (agricultural and non-agricultural wages, computed separately) between 2007 and 2010, $land_{ij0}$ is the self-cultivated land size in time 0, x_{ij0} is a vector of initial household characteristics, *province* is a province dummy, and $\Delta \varepsilon_{ij(0,1)}$ is the difference in shocks (assume that ε_{ijt} is an ex-post shock after household decisions are made).

Note that β_1 is the effect of change in the village-level real wage rate on the dependent variable, and β_2 captures how the initial land-holding affects the impact of change in the village-level real wage rate. The estimated village-level real wage growth rate is interacted with the initial self-cultivated land size. We hypothesize that $\beta_2 > 0$. That is, facing rising real wages, relatively large holders tend to increase their operational size and invest in machines.

The crop income equation is also estimated in the first differenced form:

$$\Delta \ln \pi_{ij(0,1)} = \phi + \gamma_1 \Delta land_{ij(0,1)} + \gamma_2 \Delta mach_{ij0} + \gamma_3 \Delta land_{ij(0,1)} \Delta mach_{ij(0,1)} + village_j + \Delta \eta_{ij(0,1)} \quad (2)$$

¹⁰ The survey data used in this paper do not have information on rented-out land.

where $\Delta \ln \pi_{ij(0,1)}$ is the crop income growth (that is, the difference in log of crop income between time 1 and 0), $\Delta land_{ij(0,1)}$ is change in the self-cultivated land, $\Delta mach_{ij0}$ is machine investment or change in machine services purchased, $village_j$ is village fixed effects, and $\Delta \eta_{ij(0,1)}$ is the difference in ex-post shocks. The variable $\Delta land_{ij(0,1)}$ can be decomposed into changes in owned land and rent-in land. Our interest is in the parameter γ_3 measuring the complementarity between land and machines ($\gamma_3 > 0$) especially among relatively large holders.

$$\Delta \ln \pi_{ij(0,1)}^* = \phi' + \gamma_1' \Delta land_{ij(0,1)} + \gamma_3' \Delta land_{ij(0,1)} land_{ij,0} + village_j + \Delta \eta_{ij(0,1)}$$

(3)

To investigate (in a reduced form) the relationship between crop productivity and farm size, per-ha crop income growth $\Delta \ln \pi_{ij(0,1)}^*$ (crop income normalized by the self-cultivating land size) is regressed on change in self-cultivated land size and its interaction with the initial land size. Eq (3) examines whether the effect of change in land size (say, by renting in land) can differ by the initial land size. Through the complementarity between land and machines, the marginal effect of farm size may change by the initial land size ($\gamma_3' > 0$) as relatively larger holders can find it easier to introduce machines that improve land productivity.

3. Data

3.1 Household Survey

The data come from two rounds of household survey conducted in rural areas of Indonesia. The primary source of our data is the village and household level surveys that we conducted in 2007 and 2010 for 98 villages in seven provinces (Lampung, Central Java, East Java, West Nusa Tenggara, South

Sulawesi, North Sulawesi, and South Kalimantan) under the Japan Bank for International Cooperation (JBIC) Study of Effects of Infrastructure on the Millennium Development Goals in Indonesia (IMDG). Figure 1 shows the locations of surveyed villages. In 2010, we revisited all of the 98 sample villages to re-interview sample households and their splits after the 2007 survey. Out-migrants were tracked through either direct or phone interviews.

Figure 1 to be inserted

The 2007 survey was designed to overlap with villages in the 1994/95 PATANAS [Panel Petani Nasional (National Farmer Panel Survey)] survey sample. The 1994/95 PATANAS survey is representative for the major agro-climatic zones in the country, with a focus on agricultural production activities, so the 2007 survey is also representative in the above sense. The sample also included households in fishery villages and laborer households. In 2007, we visited those villages to expand the scope of research as a general household survey under the IMDG survey (see Yamauchi et al. 2011)

In the 2007 round, we also added 51 new villages in the same seven provinces. These new villages were selected using the following criteria. First we chose the same districts where PATANAS villages are located. We listed villages that had received relatively large amounts of government infrastructure projects during the period 1995 to 2005, funded by either the Japan Bank for International Cooperation or the World Bank. Finally, the new villages were randomly sampled from the list.

In the revisited villages in 2007, we re-sampled 20 households per village from the 1994/95 sample (using a proportional sampling based on landholding size) and followed the split households. In the new villages, we sampled 24 households from two main hamlets in each village. Since one of the 48 villages in the 1994/95 PATANAS was not accessible for safety reasons in the 2007 survey (in West Nusa

Tenggara province), we have the total of 98 villages that are available for various research objectives. (The 2010 survey followed sample households and their split households in all 98 villages).¹¹

Some household members split from the 2007 original households to start their new households or to join other households. In the household-level panel analysis, for households that split between the two rounds of data collection in 2007 and 2010, incomes of original household and split households are aggregated by using the 2007 household unit as the base in the following way. The analysis includes new households if an original household member became a new household head and lives *in the same village* (called split households). Household members who moved outside the original village or joined other households within the village (both called out-migrants) are excluded from our analysis.¹² Then, incomes are aggregated from both original and split households in 2010 to be comparable with the 2007 original households.¹³

3.2 Agricultural Production, Landholding and Machines

Agricultural production was recorded with detailed information but rather differently in the two rounds. In 2007, the survey collected information on outputs and inputs for each crop by crop season, using management units defined by irrigated and un-irrigated lands. The 2010 survey collected plot-level information for each crop and crop season. In the analysis, I use crop income deducting input costs, i.e., crop profit before including family labor costs.

The 2007 and 2010 rounds captured payments for hired-in machines through machine rental and/or service providers. However the data do not show the number of hours or days in which machines were used, so the unit cost (price) is not computable. The analysis below assumes that the price is rather

¹¹ Examples of works using the 2007-2010 panel data include Yamauchi (2015), which looks at the impact of increased transportation speed on labor supply and wages. Seasonality of birth weights and its impacts on human capital formation are analyzed by using the 2007 survey data (Yamauchi, 2012).

¹² Potential attrition-related bias in the current analysis is small since the dynamics of crop income is its focus, not household income in general, which includes non-agricultural employment and remittance incomes.

¹³ The food price crisis of 2008-10 may be correlated with split (and migration) decisions, which raises an additional concern that supports the aggregation of incomes from the 2007 original household and its splits in the period 2007 – 2010.

homogeneous within a province. On the other hand, the total value of machine investments by types in the period of 2007 to 2010 was captured in the 2010 survey. The analysis uses total values of investment such as tractors, threshers, etc., which function to substitute for farm labor.

Land is aggregated at the household level, but can be categorized into three types: self-cultivated own land, self-cultivated rented-in land and rented-out land. The analysis focuses on the self-cultivated own land and the self-cultivated rented-in land since rent-out land is not recorded in the survey. This is not a shortcoming as the farm cultivation decision is the main issue of this paper. However, the panel analysis cannot use a change in “net” rent-in land

Table 1 to be inserted

Table 1 shows the average farm size (self-cultivated own and rented-in) for the whole sample as well as for each province. The second column shows the average land size in the sample of farmers who had non-negative crop incomes in both years. It is clear in the table that farm size is smaller in the Java provinces than outside Java. The average farm size is extremely small, i.e., less than 0.5 ha, in the Java provinces (Column 2), in contrast to outer-Java islands where the average farm size is above 1 ha.¹⁴ By using the sample of farmers who had non-negative crop incomes in both sample years, the average size increases marginally, except for North Sulawesi in our sample.

3.3 Labor Markets and Wages

Village-level wages for both agricultural and non-agricultural works are estimated from individual-level employment data in 2007 and 2010. Both rounds used the identical module to record job type, wage rate, number of days worked, duration, contract type, etc. for each individual employment experience in the past year. Individual frequently had several employment spells in the previous year and this method was applied to both agricultural and non-agricultural employment.

¹⁴ In addition to the observed difference in farm size, it is possible that soil quality significantly differs between Java and non-Java islands.

The data processing followed a few steps. First, we computed the daily wage for agriculture and the monthly wage for non-agricultural work at the individual level. Second, the distribution of the household-level average wages was obtained. Third, we compared the average wages at the village level – both agriculture and non-agriculture – between 2007 and 2010. The analysis uses growth rate of the village-average wages by sector after being converted into real term using the province-specific consumer price indices.

Table 2 to be inserted

Table 2 shows the sample averages and standard deviations of real non-agricultural and agricultural wage growth. Except for agricultural wage in South Sulawesi and both wages in Central Java, real wages increased substantially over 3 years. In Lampung, East Java, South Kalimantan, and North Sulawesi, real agricultural wages increased faster than real non-agricultural wages. It is also noteworthy that variations in wage growth (measured by standard deviations) are large in all provinces.

Figures 2 and 3 to be inserted

Figure 2 shows the relationship between agricultural and non-agricultural wages separately for 2007 and 2010. They are positively correlated in both years, but the positive relationship is slightly clearer in 2010 than 2007. Figures 3a and 3b show the relationship between the initial wage level and the subsequent wage growth for agriculture and non-agriculture respectively. As expected, wage growth is large when the initial level is low, in both agriculture and non-agriculture, implying that wage levels are converging over time.

3.4 Farm Size and Land Rental Transactions

Simple observations are presented on wage growth and land transactions, both of which motivate the analysis below. First, Figure 4 shows the relationship between change in rent-in land and the initial size of self-cultivated land under two different conditions: high and low wage growth areas.¹⁵ For the

¹⁵ The sample of villages is split into two groups: (i) real non-agricultural wage growth rate was above 20%, and (ii) less than 20%. Note that the average growth rate is around 20%.

relationship between change in rent-in land and the initial operational land size, the conventional wisdom is that tenants are likely to be small holders.

Figure 4 to be inserted

In contrast to this view, the figure shows that (i) very small holders did not change their rent-in behavior, (ii) for about 4 to 7 ha, farmers tend to reduce the rented-in land, and (iii) from 7 to 10 ha, they tend to rent in more land in villages where real wages are rising rapidly. More land is rented from medium holders to large holders in villages where real wages are rising fast. This observation is consistent with the main hypothesis.

4. Empirical Results

This section summarizes the empirical results. The analysis uses real agricultural wage growth, not non-agricultural wage growth, since the former directly measures the labor cost in agricultural production and the latter rather measures the opportunity cost and may also introduce income effects in some of the analyses performed below. Machine investments can be increased if farmers have incomes from non-agricultural employment.

Table 3 shows the results on self-cultivated land using the full sample. Columns 2 to 4 include interaction terms of real agricultural wage growth with the initial self-cultivated land size. In Column 1, agricultural wage growth significantly increases the size of self-cultivated land. In Column 2, the above result is altered; the interaction term of real agricultural wage growth and the initial land size is positive, while the direct effect of the wage growth is negative (both are insignificant). Column 3 and use farmers holding larger than 0.6 ha and 1.2 ha, respectively. In these specifications, marginal and/or small farmers are omitted. Interestingly, the interaction term of real agricultural wage growth and the initial land size is

significantly positive in both cases. That is, relatively large holders tend to increase their operational size in response to an increase in agricultural wages. The above results also suggest that the main finding comes from relatively large farmers (consistent with Figure 4).

Age, female, and years of schooling are all defined from the age 20-55 members of the household in 2007. Thus, they are the average age, the proportion of female members, and the average years of schooling completed in the 20-55 age group. Similarly, the number of household members counts only those in the age 20-55 group. The number of household members (in age 20 to 55) has a significantly positive effect in all the specifications. Labor endowment seems to be a factor that constrains the operational size. In contrast, the initial land size has a significantly negative effect in all specifications, implying that, despite the effect of rising real wages, large holders generally tend to decrease their operational size.

Tables 3 and 4 to be inserted

Next, Table 4 shows estimation results on change in rent-in land, i.e., not-owned self-cultivated land. The analysis uses the same specifications as in Table 3. In Column 1, the effect of real non-agricultural wage is insignificant but the introduction of interaction terms of real agricultural wage growth with the initial self-cultivated land size makes the effect of the wage growth significantly positive (Column 2). In contrast to Table 3, the average years of schooling (among the members aged 20 to 55) significantly reduces change in rent-in land, which implies that farm households that are endowed with high level of human capital (measured by educational attainment) tend to reduce rent-in land (or tend to rent out) because they have more employment opportunities in non-agricultural sectors. Columns 3 and 4 restrict the sample to farmers holding larger than 0.6 ha and 1.2 ha respectively. In the former case, the effect of real agricultural wage growth remains significantly positive, while in the latter, it is insignificant probably due to a smaller sample size. It might be because holders in the range of 0.6 to 1.2 ha are playing a more important role than those in greater than 1.2 ha. Combined with the previous results in Table 3, it is

reasonable to conclude that, when real wages increase, the size of operational farm land tends to expand among relatively large holders.

Table 5 to be inserted

Table 5 show the results on machine hire-in expenses and machine investments. In Columns 1 to 4, the dependent variable is change in the total payment for hired-in machines through machine rental and/or service providers from 2007 to 2010. Province fixed effects control for province-specific changes in the unit cost of machine use. The specifications follow those in Tables 3 and 4. Strikingly, the results in Table 5 resemble those in Table 3, that is, an increase in real agricultural wages induces the use of machines but the effect is significantly large among relatively large farmers. The interaction term of real agricultural wage growth and the initial self-cultivated land size is significantly positive in Columns 2 to 4. This result remains qualitatively the same even if the sample is restricted to farmers who hold greater than 0.6 ha or 1.2 had. Interestingly, the initial land size does not affect the use of machines, which implies that an increase in machine use is neutral to the initial land size.

In contrast, machine investments are not related to wage growth (Columns 5 and 6).¹⁶ The analysis uses Tobit model to estimate marginal effects. The initial land size significantly positively affects the decision to invest in machines most likely due to the liquidity constraint and the possibility that land is used as collateral to borrow credit, and/or scale advantage among large holders. The initial land size effect was not observed in the hired-in machine use. Interestingly, the proportion of female members in the prime age group has a significantly negative effect on machine investments.

¹⁶ The dependent variable is the total investment value in the period of 2007 to 2010, recorded in the IMDG-2 survey, not calculated from capital stocks from the two survey years.

Table 6 to be inserted

Table 6 summarizes the estimation results on crop income and productivity growth. In Columns 1 to 4, the dependent is the growth of crop income (after deducting all costs except family labor) taking the difference in log crop incomes between 2007 and 2010. Thus, negative income observations were dropped from the sample. The first three columns use all farmers with positive crop incomes in both years. Three results emerge. First, self-cultivated land, both owned and rent-in, has significant positive effects on crop income (Column 1). Second, machine investment also has a marginally significant effect on crop income (Column 2). Third, if we include the interaction term between cultivated land and machine investment (Column 3), the effects of land and machine investment remain robust, and the interaction has a positive effect on crop income, but this is marginally insignificant.

Next, Column 4 uses the sample of farmer holding greater than 0.6 ha. Thus, marginal farmers are not included in the analysis. In this group, we find that land acquisition and machine investments are complementary, mutually augmenting crop income. Though the above complementarities are supported, the marginal effects of land and machines become insignificant. That is, a combination of land and machines as an investment package is profitable for the group of farmers who have relatively large land endowments.

Finally, Columns 5 to 7 examine land productivity growth by using a change in log of per-hector crop income from 2007 to 2010. Log transformation, once combined with village fixed effects, makes the analysis unit-free under the assumption that price change is village specific. Given the results in Columns 3 and 4, an increase in the operational land size is expected to raise productivity only among relatively large farmers who also tend to use machines. The interaction of change in self-cultivated land and the initial self-cultivated land size in Column 6 captures the possibility that the farm size - productivity relationship can be non-monotonic. Interestingly, the effect of an increase in the self-cultivated land is positive (still insignificant) if the initial land size is relatively large. If I use the sample in which changes

in machine expenses are non-negative, the interaction term becomes significant (t value = 2.66), which indicates that the inverse farm size - productivity relationship can be revised among relatively large farmers when machines are used more over time. The above finding is also consistent with complementarities between machine and land.

5. Conclusions

This paper showed that an increase in labor costs has been inducing relatively large farmers to expand their operational farm land by renting in land and substitute labor by machines through machine rental and/or service providers. The effect of rising real agricultural wages is significant only for hired-in machine use but not for machine investments. The empirical results also show that machine investments and land are complementary. Consistently, crop productivity has increased along with an expansion of operational farm size among relatively large farmers.

The introduction of large-scale mechanization is generally challenging if farm size is constrained by some factors, such as total land endowment, high population density and a relatively high value of non-agricultural land use. However the results indicate that both land transfer and machine use are not seriously constrained in the current empirical setting largely because, in both transactions, rental markets seem to function relatively smoothly. In response to an increase in wages, both land transfer and machine use are observed in the manner consistent with price theory.

In the context of Indonesia, the above findings may imply a possible divergence in production frontier by macro-regional islands, in particular, between Java and outer-Java regions as farm land endowment significantly varies across the islands. Agriculture in favorably endowed outer-Java islands may stay on the frontier by promoting mechanization on the basis of the initial scale advantage, while smaller farmers in Java can be trapped in high-cost agriculture due to rigidity of land markets.

Historically land reforms in developing countries have typically aimed to create small farmers by redistributing land from landlords to tenants. Successful land reforms contributed to promoting equity as well as efficiency in agriculture but could impose a historical constraint on production efficiency when labor shortage becomes serious. While small farmers find it difficult to maintain family-labor intensive production, it is also politically challenging to re-redistribute land to enlarge operational land sizes by taking land out of small holders, say, through land consolidation programs. In the current empirical setting, land rental market as well as machine rental market seems to be functioning to support an expansion of operational farm size to some extent, which is also observed in some other countries such as China (Wang et al., 2014). Activating roles of rental markets and transactions looks like a socially cost effective solution to the problems of small farms in Asia under the surge of rising real wages.

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Figure 1 Locations of surveyed villages

Figure 2 Daily agricultural wage vs monthly non-agricultural wage

Figure 3a Agricultural wage growth vs the initial level

Figure 3b Non-agricultural wage growth vs the initial level

Figure 4 Change in rent in land and the initial landholding: High vs low wage growth villages

Table 1 Average land size (ha) in 2007

		Crop income>0 in 2007 and 2010
All sample provinces	1.088 (1.429)	1.170 (1.417)
Lampung	1.324 (1.256)	1.342 (1.213)
Central Java	0.366 (0.448)	0.401 (0.535)
East Java	0.519 (1.499)	0.471 (0.410)
NTB	1.005 (1.125)	1.120 (1.271)
South Kalimantan	1.249 (1.264)	1.267 (1.024)
North Sulawesi	1.626 (2.472)	2.201 (2.816)
South Sulawesi	1.063 (1.068)	1.111 (1.098)

Numbers in parentheses are standard deviations.

Table 2 Average real wage growth (%)

	Non-agricultural	Agricultural
All sample provinces	18.32 (51.27)	23.13 (71.52)
Lampung	12.46 (66.96)	51.95 (60.86)
Central Java	6.163 (39.62)	5.733 (35.80)
East Java	27.13 (37.37)	40.02 (125.1)
Nusa Tenggara Barat	24.62 (59.56)	14.71 (48.48)
South Kalimantan	14.43 (51.22)	23.91 (56.76)
North Sulawesi	31.22 (25.60)	63.94 (53.19)
South Sulawesi	16.59 (60.06)	-20.70 (70.45)

Provincial CPI is used for the conversion into real terms. Numbers in parentheses are standard deviations.

Table 3 Estimation: Self-cultivated land

Dependent: Change in self-cultivated land				
Sample:	All	All	Land>0.6 ha	Land>1.2 ha
Real wage growth: Agriculture	0.1152 (3.01)	-0.0269 (0.44)	-0.1300 (1.23)	-0.3720 (1.79)
Real wage growth: Agriculture * Self-cultivated land 2007		0.1472 (1.69)	0.1967 (2.02)	0.2802 (2.56)
Years of schooling (age 20-55 in 2007)	0.0013 (0.07)	-6.27E-06 (0.00)	0.0029 (0.08)	-0.0122 (0.26)
Age (age 20-55 in 2007)	-0.0051 (1.01)	-0.0067 (1.42)	-0.0127 (0.83)	-0.0141 (0.63)
Female (age 20-55 in 2007)	-0.0588 (0.18)	0.0144 (0.04)	0.1365 (0.25)	0.1461 (0.18)
Number of hh members (age 20-55 in 2007)	0.1271 (2.84)	0.1391 (3.23)	0.2147 (4.46)	0.1487 (2.48)
Self –cultivated land 2007	-0.3720 (2.45)	-0.4737 (2.98)	-0.5629 (3.16)	-0.6222 (2.90)
Positive crop income in 2007	0.0822 (0.78)	0.0998 (0.98)	-0.0183 (0.15)	-0.1291 (0.56)
Province fixed effects	yes	yes	yes	yes
R squared (within province)	0.1029	0.1180	0.1373	0.1438
Number of observations	1196	1189	638	359

Numbers in parentheses are absolute t values using robust standard errors with province clusters.

Table 4 Estimation: Rent-in land (Not-owned self-cultivated land)

Dependent: Change in rent-in land				
Sample:	All	All	Land>0.6 ha	Land>1.2 ha
Real wage growth: Agriculture	0.0331 (1.19)	0.0858 (2.24)	0.1244 (2.52)	0.0956 (0.71)
Real wage growth: Agriculture * Self-cultivated land 2007		-0.0330 (1.42)	-0.0506 (1.42)	-0.0366 (0.65)
Years of schooling (age 20-55 in 2007)	-0.0249 (2.37)	-0.0246 (2.30)	-0.0439 (2.22)	-0.0492 (2.05)
Age (age 20-55 in 2007)	-0.0026 (0.57)	-0.0021 (0.44)	-0.0056 (0.53)	0.0052 (0.32)
Female (age 20-55 in 2007)	-0.0841 (0.53)	-0.0934 (0.56)	-0.0910 (0.31)	-0.2131 (0.47)
Number of hh members (age 20-55 in 2007)	0.0107 (0.37)	0.0086 (0.28)	0.0059 (0.16)	-0.0666 (1.61)
Self-cultivated land 2007	-0.0311 (1.22)	-0.0123 (0.35)	-0.0242 (0.59)	-0.0209 (0.36)
Positive crop income in 2007	-0.0305 (0.56)	-0.0328 (0.60)	-0.1480 (1.86)	-0.2178 (2.07)
Province fixed effects	yes	yes	yes	yes
R squared (within province)	0.0091	0.0112	0.0252	0.0267
Number of observations	1196	1189	638	359

Numbers in parentheses are absolute t values using robust standard errors with province clusters.

Table 5 Estimation: Machine hire-in expenses and investments

Dependent: Sample:	Change in machine hire-in expenses #				Machine investments +	
	All	All	Land>0.6 ha	Land>1.2 ha	All	All
Real wage growth: Agriculture	6.6843 (1.27)	3.0011 (0.62)	4.6784 (0.54)	6.3106 (0.49)	0.1734 (0.05)	1.8345 (0.65)
Real wage growth: Agriculture * Self-cultivated land 2007		10.798 (3.00)	11.884 (2.83)	11.892 (2.92)		-1.2462 (1.19)
Years of schooling (age 20-55 in 2007)	-0.7435 (1.44)	-0.7710 (1.28)	-0.9287 (0.74)	0.0378 (0.02)	1.0058 (1.32)	1.0017 (1.30)
Age (age 20-55 in 2007)	0.1620 (0.91)	0.1417 (0.70)	0.1175 (0.21)	0.6875 (0.86)	0.2204 (1.25)	0.2239 (1.24)
Female (age 20-55 in 2007)	-21.024 (1.38)	-20.589 (1.40)	-16.834 (0.69)	-34.794 (1.01)	-14.370 (2.70)	-14.780 (2.65)
Number of hh members (age 20-55 in 2007)	5.4071 (1.35)	5.9501 (1.50)	10.948 (1.48)	16.198 (1.55)	2.9747 (1.64)	2.9637 (1.63)
Self-cultivated land 2007	5.9065 (1.54)	-0.3637 (0.10)	-1.7174 (0.36)	-1.4273 (0.27)	2.3744 (1.68)	3.0685 (1.90)
Positive crop income 2007	-3.1121 (0.65)	-2.8338 (0.54)	-6.1867 (0.55)	-7.8274 (0.74)	4.5317 (1.59)	4.5404 (1.52)
Province fixed effects	yes	yes	yes	yes		
R squared (within province)	0.0253	0.0428	0.0535	0.0696		
Province dummies					yes	yes
Pseudo R squared					0.0235	0.0240
Number of observations	1074	1071	580	325	1181	1181

Numbers in parentheses are absolute t values using robust standard errors with province clusters. # Divided by 1,000. + Divided by 1,000,000.

Table 6 Estimation: Crop income and productivity growth

Dependent: Sample:	Change in log of crop income				Change in log of per-ha crop income		
	All	All	All	Land>0.6 ha	All	All	Using machines +
Change in self-cultivated farm land		0.2932 (2.75)	0.2661 (2.46)	0.1351 (1.11)	-0.0264 (0.28)	-0.1504 (1.14)	-0.1797 (1.21)
Change in self-cultivated farm land owned	0.3392 (3.15)						
Change in self-cultivated farm land not own	0.1983 (1.18)						
Machine investment #		0.3238 (1.47)	0.4213 (1.67)	0.0933 (0.38)			
Change in self-cultivated farm land * Machine inv #			0.0004 (1.85)	0.0005 (2.58)			
Change in self-cultivated farm land * Self-cultivated land 2007						0.0512 (1.48)	0.0853 (2.66)
Village fixed effects	yes	yes	yes	yes	yes	yes	yes
R squared (within village)	0.0191	0.0195	0.0220	0.0126	0.0001	0.0028	0.0072
Number of observations	844	843	843	476	765	765	635

Numbers in parentheses are absolute t values using robust standard errors. # Divided by 10,000,000. + The sample consists of farmers who experienced a non-negative change in hired-in machine expenses from 2007 to 2010.