Structural Transformation and Intertemporal Evolution of Real Wages, Machine Use, and -Farm Size - Productivity Relationships in Vietnam

Yanyan Liu, William Violette and Christopher B. Barrett[1]

April 2017 revised version

Abstract

This paper explores the evolution of real agricultural wages, machinery use, and the relationship between farm size and productivity in Vietnam during its dramatic structural transformation over the course of the 1990s and 2000s. Using six rounds of nationally representative household survey data, we find strong evidence that the inverse relationship between rice productivity and planting area attenuated significantly over this period and that the attenuation was most pronounced in areas with higher real wages. This pattern is also associated with sharp increases in machinery use, consistent with a substitution effect between machinery and labor. The results suggest that rural factor market failures are receding in importance, making land concentration less of a cause of concern for aggregate food production.

[1] Yanyan Liu (corresponding author) is a senior research fellow in the Markets, Trade and Institutions Division of the International Food Policy Research Institute (IFPRI), Washington, DC. Her email is y.liu@cgiar.org. William Violette is a PhD candidate in the Department of Economics at Brown University, Providence, RI, US. Christopher B. Barrett is a professor in Dyson School of Applied Economics and Management at Cornell University, Ithaca, NY, US.
This paper was undertaken as a part of, and partially funded by, Bill and Melinda Gates Foundation and the CGIAR Research Program on Policies, Institutions, and Markets (PIM) led by IFPRI. The opinions expressed here belong to the authors, and do not necessarily reflect those of PIM, IFPRI, or CGIAR.

1. Introduction

The structural transformation of low-income agrarian economies is both cause and consequence of the steady amelioration of rural factor market imperfections that have led to intersectoral and interhousehold heterogeneity in shadow prices of land, labor, and capital (Timmer 1988, 2007). Urbanization, the rise of modern industrial and service sectors, and a declining share of agriculture in gross domestic product (GDP) and employment go hand in hand with economic growth and diminution of market failures that obstruct factor price equalization among production units. In low-income agrarian economies, household-specific market failures appear commonplace (de Janvry, Fafchamps, and Sadoulet 1991, Dillon and Barrett 2017). When multiple markets fail, factor (shadow) prices vary across units, leading to heterogeneous input application rates and partial productivity measures, the most common of which is the oft-observed inverse relationship between farm size and crop yields per unit area cultivated (Feder 1985). The existence of any relationship between farm productivity and farm size—negative or positive—has attracted much scholarly and policymaker attention, as perhaps indicative of key market failures that motivate agricultural and rural development policy interventions. Examples of such interventions include progressive land reform and smallholder agricultural credit subsidies that might generate both efficiency and equity gains. If economic transformation were to improve factor market performance, this might shift the farm size–productivity relationship and the economic rationale for concerted intervention to address rural market failures.

In the past twenty-five years, Vietnam has undergone some of the most rapid transformation of any low-income agrarian nation. During that time, the country experienced rapid real GDP growth of 4–8 percent annually, mainly driven by the development of nonfarm sectors and the activation of markets for credit, labor, land, machinery, and other factors of production throughout the country (McCaig and Pavcnik 2013). As the nonfarm sectors provided more job opportunities, people moved out of farming, resulting in increased agricultural real wages and shrinkage in the wage gap between agricultural and nonagricultural sectors, as predicted by dual economy models (Lewis 1954; Gollin 2014).

Such changes likely have important implications for agriculture. It has long been observed that, in developing country agriculture, smaller farms are typically more productive per unit area cultivated than larger ones (Chayanov 1926/1986; Sen 1962; Berry and Cline 1979; Carter 1984; Barrett 1996; Benjamin and Brandt 2002; Barrett, Bellemare, and Hou 2010; Carletto, Savastano, and Zezza 2013). The evidence of such an inverse farm size–productivity relationship has often justified land policies supporting small landholders and deterring farm size expansion, as well as agricultural credit policies to promote smallholder access to commercial inputs.

However, as a low-income agrarian economy undergoes rapid structural transformation, do factor markets for agricultural labor and machinery become more active, driving up real wages and attenuating the inverse relationship? Conceptually, Otsuka (2013) suggested that increasing real wages would reduce demand for agricultural labor, promote the use of machinery as a substitute for labor, and decrease the disadvantage of larger farms—perhaps even flipping the inverse relationship to a direct relationship—due to scale economies in machine use and access to financing. Similarly, using nationally representative household data from India, Foster and Rosenzweig (2011) estimated an increase in optimal farm size due to the substitution of machinery for labor.

This paper explores the evolution of real agricultural wages, machinery use, and the relationship between farm size and productivity in Vietnam during its dramatic structural transformation over the course of the 1990s and 2000s. This inverse farm size productivity relationship (IFSPR) has been most commonly attributed to imperfections in multiple factor markets, especially for land, labor, and credit (Sen 1966; Feder 1985). Even without significant changes in land policy, if the inverse relation had been partially driven by imperfect credit or labor markets, improved factor market functioning through structural transformation, as manifested in increased real wage rates and more active machinery rental markets, may have lessened or may even have reversed the long-standing inverse farm size–productivity relationship. Because the IFSPR has long served as a powerful metaphor for pervasive rural factor market failures that motivate government interventions, any such evolution has powerful implications for policy. Yet to date there has been little exploration of how the IFSPR has changed with the structural transformation of an agrarian economy.

This paper uses six rounds of nationally representative household survey data from Vietnam, from 1992 through 2008, to examine whether and the extent to which increasing real wages and increased machinery rentals are associated with change in the IFSPR between rice productivity and cultivated area.[2] To our knowledge, this study is the first to look at intertemporal change in the inverse farm size–productivity relationship over such a long period. We find strong evidence that the IFSPR between rice productivity and planting area attenuated significantly over this period. Such results are consistent with the findings in a subsequent study in India which shows the inverse size-productivity relationship reduced over the period from 1982 to 2008 (Deininger et al. 2016). We find those attenuations are most pronounced in areas with higher real wages, which are also associated with sharp increases in machinery use, consistent with a

[2] Vietnam Living Standards Surveys (VLSS) was changed to Vietnam Household Living Standards Surveys (VHLSS) in the rounds in 2000s. However, the survey instruments and sampling framework are virtually unchanged.

substitution effect between machinery and labor that reduces the small farm advantage in labor supervision relative to the larger farm advantage in capital access, leading to attenuation of the IFSPR. The empirical results of this study suggest that, in Vietnam, larger farmers' disadvantage in land productivity, compared to smaller farmers, has lessened sharply, which is probably attributable to improved labor and machine rental markets.

2. Data and Descriptive Evidence

This study uses data from the 1992 and 1998 Vietnam Living Standards Surveys (VLSS) and from the 2002, 2004, 2006, and 2008 Vietnam Household Living Standards Surveys (VHLSS) (General Statistics Office of Vietnam). VLSS and VHLSS use similar survey instruments and are nationally representative. The survey instruments include a household questionnaire and a commune questionnaire. VLSS used the 1990 census in its sampling framework. VLSS 1998 intended to interview all households from VLSS 1992. VHLSS sampled based on the 2000 census. Each round in the VHLSS survey, except for 2002, re-interviewed some households sampled in the previous round and added some newly sampled households.[3] Any two or more rounds of VHLSS 2000s can form a household panel, though the sample size decreases as more rounds are included in the panel.

We merge the data from household and commune surveys to construct three rural household panel data sets: VLSS 1992/1998, VHLSS 2002/2004, and VHLSS 2006/2008. The VLSS 1992/1998 panel contains 3,034 households from 103 rural communes; the VHLSS 2002/2004 panel, 2,303 households from 794 rural communes; and the VHLSS 2006/2008 panel, 2,346 households from 956 rural communes.

[3] The 2002 round was based off a new sample according to the 2000 census.

The commune survey provides information on local agricultural wage by gender and by task (land preparation, planting, tendering, and harvesting). We generate median wage by gender, combining across all tasks for each commune for each panel round. To calculate the real wage, we deflate local nominal wage rates by the national consumer price index (CPI), which captures intertemporal inflation, and by the regional CPI, which captures spatial price variation.[4] Figure 1 plots the median female and male real agricultural wages from 1992 to 2008. The real wage increased significantly from 1992 to 1998. It leveled off from 1998 to 2004, probably reflecting the lagged effects of the Asian financial crisis of 1997/1998. From 2004 to 2008, the real wage again picked up rapidly, at a rate even faster than seen during 1992–1998. Table 1 reports the median male real wage by regions from 1992 to 2008, using VLSS and VHLSS commune survey data.[5] Although the real wage was consistently lower in the northern regions than in the southern regions, regional wage differences narrowed considerably by 2008, indicating an increasingly spatially integrated national labor market. This pattern is consistent with the stylized facts of structural transformation (Timmer 2007).

The household survey data provide information on household demographics, rice output by type of rice, rice planting area, landholdings, labor hiring, and machinery ownership and hiring cost. Figure 2 plots the mean and median area of land cultivated per household from 1992 to 2008. A median farm household cultivated 0.35 ha and 0.30 ha in 1992 and 2008, respectively, while the mean cultivated area increased from 0.57 ha to 0.64 ha from 1992 to 2008. The cultivated area of annual crops dropped from 0.31 ha in 1992 to 0.23 ha in 2008 for the median farm household while the mean cultivated area of the annual crops only slightly dropped from 0.49 ha to 0.47 ha during

[4] The regional CPIs are provided in the data set.

[5] We cannot generate a population-weighted national average because the wage data come from the commune survey and commune-level weights are not available for these data sets.

the same period. No major changes in rural land policy occurred during the study period. Land sales were virtually zero. Figure 3 plots the proportion of households participating in land rental markets. Land rental transactions are at stably low level throughout this period: about 3% of farm households rented out land and 8-14% rented in land.

Figure 4 plots the proportion of households that owned tractors, rented machinery, or hired labor from 1992 to 2008. We do not see much change in tractor ownership; the rate remains almost zero, which is not surprising given the rather low median landholdings in Vietnam (Figure 2). The percentage of cultivating households that rented machines more than tripled, however, from 19 percent in 1992 to 63 percent in 2008. This observation mirrors recent findings from China (Yang et al. 2013). The percentage of households that hired labor also increased sharply, from 32 percent in 1992 to 55 percent in 2008.

Figure 5 plots the locally weighted polynomial regression result of log rice yield against log planting area for 1992, 1998, 2002, 2004, 2006, and 2008.[6] The figure shows point estimates with solid lines and the 95 percent confidence intervals with dotted lines of the same color as the corresponding point estimates. The sharp upward displacement of the yield curves between each successive survey round, especially the first three, demonstrates the rapid growth in rice productivity. Although the curve is downward sloping throughout, pointing to the presence of an inverse farm size–productivity relationship, it flattens considerably in 2006 and 2008, suggesting that productivity advantage for small farmers had decreased. Such changes perhaps resulted from the more efficient labor and machine rental market (as shown in Figure 1, Table 1, and Figure 3), given the land rental and sales market was stagnant.

[6] The procedure we use is the "lpoly" in Stata 13 SE with default optimal bandwidth.

3. Empirical Method

The descriptive evidence suggests that the size-productivity relationship may have attenuated over time. In this section, we empirically test if this is the case. We estimate rice production equations using three panels (1992/98, 2002/04, 2006/08) separately to look at the evolution of the IFSPR. If this relationship indeed attenuated over time, we then examine if such attenuation is linked to higher wage, as suggested by Otsuka (2013) and Otsuka, Liu and Yamauchi (2016). As the substitution of labor by machine induced by higher wage is a likely channel of such attenuation, we also explore whether higher wage was associated with higher machinery usage.

To examine the evolution of the IFSPR, we first estimate a rice yield equation using the three panels separately:

$$\ln y_{ict} = \beta_i + \beta_1 \ln h_{ict} + \beta_2 z_{ict} + \beta_3 D_t + \varepsilon_{ict}, \quad (1)$$

where *i*, *c*, and *t* index farm/household, commune, and year, respectively; β_i is a household fixed effect which captures time invariant household and location-specific effects such as land quality and weather; $\ln y_{ict}$ is log rice yield (in kilogram per hectare); $\ln h_{ict}$ is log rice planting area (in hectare); z_{ict} is a vector of household-specific time-varying characteristics; D_t is a year dummy which captures period-specific fixed effects (including interest rates, which are assumed uniform across communes); and ε_{ict} is an iid, mean zero, normally distributed random error term.

The main coefficient of interest, β_1, is elasticity of rice yield with respect to planting area. A negative β_1 estimate will point to the presence of IFSPR. If such relationship lessened over time, the absolute value of β_1 will be smaller in a later panel than in an earlier panel. If such relationship is reversed, the β_1 estimate will be positive.

To examine whether the attenuation, if observed in equation (1), is larger in locations with higher wage, we explore the spatial variation of real wage. We include wage and its interaction with planting area as explanatory variables in the expanded specification:

$$\ln y_{ict} = \xi_i + \xi_1 \ln h_{ict} + \xi_2 \ln \mathrm{w}_{ct} \times \ln h_{ict} + \xi_3 \ln \mathrm{w}_{ct} + \xi_4 z_{ict} + \xi_5 D_t + v_{ict}, \quad (2)$$

where $\ln \mathrm{w}_{ct}$ is log real wage of male agricultural labor; ξ_i is a household fixed effect; all other variables are the same as in equation (1). We demean the variables $\ln h_{ict}$ and $\ln \mathrm{w}_{ct}$ around the sample means, so the coefficients ξ_1 and ξ_3 can be interpreted as the mean partial effects.

By testing the hypothesis that ξ_1 and ξ_2 change over the course of structural transformation in the economy, we can explore whether any initial relationship between size and productivity is indeed attenuated by increased factor market activity (proxied by real wage), as theory would predict. Similar to equation (1), a negative ξ_1 estimate suggests the presence of IFSPR. A positive ξ_2 estimate combined with a negative ξ_1 estimate then suggests that higher wages attenuate the IFSPR.

To look at the association between wage and machine use, we estimate the below equation:

$$d_{mit} = \delta_{0,mi} + \delta_1 \ln \mathrm{w}_{mt} + \delta_2 \ln a_{mit} + \delta_4 z_{mit} + \delta_5 D_t + \epsilon_{mit}, \quad (3)$$

where d_{mit} is a dummy variable indicating machine use for household *i* in commune *m* and year *t*. It takes value 1 if the household owned any tractors or spent on machine rental and 0 otherwise.

[7]ln a_{mit} is log total cultivated land area of the household.[8] If higher wage rates drive substitution of machinery for labor, the δ_1 estimate will be positive.

Each of these regression models – equations (1) – (3) – only estimate the associations that describe the relationships observed in the data. We caution against interpreting these estimates as the causal effects of farm size on crop yields. Those descriptive parameter estimates nonetheless convey significant information about the evolution of the agricultural economy over the course of structural transformation.

4. Results

4.1 Does the inverse relationship change over time?

Columns (1)–(3) of Table 2 report regression results of equation (1) for the three panels, 1992/98, 2002/04, 2006/08. The dependent variable is rice yield aggregated over all rice varieties. We have two main findings. First, the coefficient estimate on planting area is statistically significantly negative in all panels, suggesting the existence of an inverse farm size–productivity relationship throughout the study period. This result is consistent with most of the published literature.

Second, with a value of –0.061, the estimated coefficient of planting area in the 2006/2008 panel is lower than that in the 1992/1998 panel (–0.149) and in the 2002/04 panel (–0.156). We

[7] Large farms are likely to face a lower price of machine use. It is thus inappropriate to use spending on machine rental to proxy for time of machine use due to heterogeneous pricing. In addition, if we use spending on machine rental as proxy for the actual machine use, we will underestimate machine use of the farm households that use their own machines. Dropping machine-owning households would also create a sample selection bias which is difficult to address without a credible instrument that affects machine purchase but does not affect machine rental. We thus only look at the extensive margin by generating a dummy variable indicating machine use.

[8] The questions on the machine rental and ownership are asked at the household level. Therefore we use household landholdings instead of rice planting area on the right hand side of equation (2).

next test for the statistical significance of the differences in the coefficient estimates between the panels. To do such tests, we pool the three panels, interact all the control variables with panel dummies, and run the same regression with the pooled dataset.

The results are reported in Columns (4)-(6) of Table 2. The coefficient estimate of the planting area is not significantly different between the 1992/1998 panel and the 2002/2004 panel, suggesting that the IFSPR did not change significantly between the two periods. The result is not surprising, given the fact that the real wage growth was stagnant from 1998 to 2004 as shown in Figure 1. In contrast, the effect of planting area was statistically significantly lower for the 2006/2008 panel than for either of the earlier two panels, concurrent with the rapid increase in real wage from 2004-2008 (Figure 1). The result is consistent with the theoretical prediction that the inverse farm size–productivity relationship attenuates as the labor and machine rental markets become more active and spatially integrated.

4.2 Are higher wage rates associated with attenuation of the inverse relationship?

The results of equation (2) are presented in Columns (1)-(3) of Table 3, for 1992/1998, 2002/2004, and 2006/2008 panels, respectively. The differences in coefficient estimates (and their standard errors) are reported in Columns (4)-(6) of Table 3. Consistent with the results from equation (1), the coefficient estimate of planted area is negative throughout but its absolute value is significantly smaller in the 2006/2008 panel than in the earlier two panels, pointing to attenuation of the IFSPR in late 2000s.

Second and more interestingly, the coefficient estimate on the interaction term of planting area and real wage is statistically significantly positive in the 2006/2008 panel, though it is insignificant in the 1992/1998 and 2002/2004 panels. This suggests that the IFSPR attenuates most quickly in areas where the real wage rate is higher, creating greater incentives to substitute machinery for labor. The statistically insignificant estimate from 1992/1998 and 2002/2004 is consistent with the existence of imperfect factor markets in the earlier years in the survey, before wages began to reach a level at which substituting capital for labor began to appear potentially profitable to farmers.

Together with findings from equation (1), these results reinforce the story that in the late 2000s, increasingly active rural factor markets significantly reduced the inverse farm size–productivity relationship, and these effects were most pronounced in areas with higher real wages. The point estimates for the 2006/2008 panel (Column (3) of Table 3) suggest that an 80 percent increase in the real wage for male workers offsets the effect of doubling farm size. A third finding from equation (2) is that real wage is insignificant in the rice yield equation in all the panels, suggesting that higher wage rates did not reduce rice yields, on average.

4.3 Are higher wage rates associated with higher machine use?

The results of equation (3) are presented in Table 4. For all the three panels, larger farmers are more likely to use machines. Machine use did not respond to real agricultural wage in the 1990s or the early 2000s panel. In contrast, machine use increases significantly in real wage in the 2006/2008 panel, suggesting efficiency improvements in rural factor markets. This result is consistent with the earlier finding that the IFSPR attenuated most quickly in areas where the real wage rate is higher in late 2000s, supporting that machine substitution for labor is a channel through which this attenuation is observed.

4.4 A robustness check

In Tables 2 and 3, the dependent variable is land productivity of rice aggregated over all rice varieties. These results may be biased if the choice of rice varieties is correlated with farm size and if the productivity differs across rice varieties.[9] We thus run the same regressions for spring ordinary rice and autumn ordinary rice separately as a robustness check. The 2002 VHLSS does not distinguish between these rice varieties; therefore, the 2002/2004 panel is left out of these analyses. The results, reported in Tables 5 and 6, are similar to those reported in Tables 2 and 3, showing a significantly decreasing IFSPR for both spring and autumn rice over 1992/1998 and 2006/2008. The interaction term between wage and plant area is significantly positive for both spring and autumn rice from the 2006/2008 panel, in line with the result from Table 3. For the 1992/1998 panel, the interaction is insignificant for spring rice but significantly positive for autumn rice.

5. Conclusion

This study uses three household panel data sets from the 1990s and the 2000s from the same survey to explore the changing relationship between land productivity and rice planting areas in Vietnam. The findings show that the IFSPR attenuates considerably over the course of those two decades. This change is associated with rising real wages and increasingly active machine rental and agricultural labor markets in rural Vietnam. In addition, the inverse relation attenuated most in areas with higher agricultural real wages by the mid-2000s, as real wages reached levels sufficiently high enough to induce some substitution of machinery for labor. As a result, the long-standing productivity advantage assumed to exist among smaller farmers appears to have

[9] The rice varieties include winter-spring ordinary rice, summer-autumn ordinary rice, tenth-month or autumn-winter rice, ordinary rice planted in terraced field, year-round ordinary rice, year-round glutinous rice, and year-round specialty rice.

diminished or disappeared altogether by the latter part of the period. Indeed, as real wages keep increasing, the IFSPR may be reversed, leading to increased land concentration among farmers increasingly likely to employ machinery, without adverse effects on aggregate food production or prices.

References

Barrett, C.B. (1996). "On Price Risk and The Inverse Farm Size-Productivity Relationship," Journal of Development Economics, 51(2):,193-215.

Barrett, C.B., S.M. Sherlund, and A.A. Adesina, (2008). "Shadow Wages, Allocative Inefficiency, and Labor Supply in Smallholder Agriculture," Agricultural Economics, 38(1): 21-34.

Barrett, C.B., M.F. Bellemare, and J.Y. Hou, (2010). "Reconsidering Conventional Explanations of the Inverse Productivity-Size Relationship," World Development, 38(1): 88–97.

Benjamin, D., and Brandt, L. (2002). "Property rights, labor markets, and efficiency in a transition economy: The case of rural China," Canadian Journal of Economics, 35(4): 689–716.

Berry, R. A., and Cline, W. R. (1979). "Agrarian structure and productivity in developing countries," Baltimore: Johns Hopkins University Press.

Carletto, C., S. Savastano, and A. Zezza, (2013). "Fact or artifact: The impact of measurement errors on the farm size–productivity relationship," Journal of Development Economics, 103: 254-261.

Carter, M. (1984). "Identification of the Inverse Relationship between Farm Size and Productivity," Oxford Economic Papers, 36: 131-145.

Chayanov, A. V. (1926/1986). "The Theory of Peasant Economy," Madison: University of Wisconsin Press.

de Janvry, A., M. Fafchamps, and E. Sadoulet, "Agrarian Structure, Technological Innovations and the State," in The Economic Theory of Agrarian Institutions, Edited by P. Bardhan, Oxford University Press, 1991.

Deininger, K., S. Jin, Y. Liu, and S. Singh, (2016). "Can Labor Market Imperfections Explain Changes in the Inverse Farm Size-Productivity Relationship? Longitudinal Evidence from Rural India," unpublished manuscript.

Dillon, B. and C.B. Barrett, (2017) "Agricultural Factor Markets in Sub-Saharan Africa: An Updated View with Formal Tests for Market Failure," *Food Policy* 67: 64-77.

Feder, G. (1985). "The Relation between Farm Size and Farm Productivity," Journal of Development Economics, 18: 297-313.

Foster, A., and M. Rosenzweig, (2011). “Are Indian Farms Too Small? Mechanization, Agency Costs, and Farm Efficiency,” Brown University, Providence, RI, US.

Gollin, D. (2014). “The Lewis Model: A Sixty-Year Retrospective,” Journal of Economic Perspectives, 28(3): 71-88.

Lewis, W.A. (1954). “Economic Development with Unlimited Supplies of Labor,” The Manchester School, 22(2): 139–191.

McCaig, B. and N. Pavcnik, (2013). “Moving out of agriculture: Structural change in Vietnam,” NBER Working Paper 19616. Forthcoming in “Structural change, fundamentals, and growth,” eds. M. McMillan and C. P. Sepulveda.

Otsuka, K. (2013). “Food insecurity, income inequality, and the changing comparative advantage in world agriculture,” Agricultural Economics, 44: 7–18.

Otsuka, K., Y. Liu, and F. Yamauchi, (2016). “Growing advantage of large farms in Asia and its implications for global food security,” Global Food Security, 11: 5-10.

Sen, A. K. (1962). “An Aspect of Indian Agriculture,” Economic Weekly, 14: 243–266.

Sen, A. K. (1966). “Peasants and Dualism with or without Surplus Labor,” Journal of Political Economy, 74(5): 425–450.

Timmer, C. P. (1988). “The agricultural transformation,” In H. Chenery and T.N. Srinivasan (Eds.), Handbook of Development Economics, Volume 1 (Part II), 8: 276-331. Amsterdam: North Holland.

Timmer, C. P. (2007). “The Structural Transformation and the Changing Role of Agriculture in Economic Development,” Wendt Lecture, American Enterprise Institute.

Yang, J., Z. Huang, X. Zhang, and T. Reardon, (2013). “The rapid rise of cross-regional agricultural mechanization services in China,” American Journal of Agricultural Economics, 95(5): 1245-1251.

Table 1: Real median daily wage of male agricultural labor (000 VND)

	1992	1998	2002	2004	2006	2008
Red river delta	7.49	14.41	13.59	15.28	19.90	28.06
North East	5.16	11.17	11.00	13.00	15.78	22.22
North West	6.96	9.05	9.28	9.38	14.48	18.66
North Central Coast	7.67	12.12	12.96	13.22	19.95	23.58
South Central Coast	7.34	15.56	14.39	16.17	17.60	23.51
Central Highlands	9.21	13.40	13.38	13.89	18.46	26.53
South East	11.44	15.70	17.26	17.14	21.60	25.63
Mekong river delta	15.01	18.69	17.51	19.04	22.41	25.53

Table 2: Regression results on land productivity of rice (all varieties included), equation (1)

	(1)	(2)	(3)	(4)	(5)	(6)
	1992/98	2002/04	2006/08	(2)-(1)	(3)-(1)	(3)-(2)
Log total area of rice (all varieties)	**-0.149*** **	**-0.156*** **	**-0.0609*** **	**-0.00788**	**0.0877*** **	**0.0956*** **
	(0.0293)	(0.0305)	(0.0159)	(0.0422)	(0.0332)	(0.0343)
Male household head	0.00550	0.0309	0.00568	0.0254	0.000178	-0.0253
	(0.0299)	(0.0391)	(0.00921)	(0.0491)	(0.0312)	(0.0401)
Age of household head	0.000858	0.0000337	0.000202	-0.000824	-0.000656	0.000168
	(0.00117)	(0.00132)	(0.000303)	(0.00176)	(0.00120)	(0.00135)
Highest education of household members	0.0232**	0.000856	0.000375	-0.0224**	-0.0229**	-0.000482
	(0.00958)	(0.00568)	(0.00402)	(0.0111)	(0.0104)	(0.00696)
Number of male members	0.0150	-0.0184	-0.00281	-0.0333	-0.0178	0.0155
	(0.0159)	(0.0172)	(0.00453)	(0.0234)	(0.0164)	(0.0178)
Household size	0.00897	0.0200*	0.00493	0.0110	-0.00404	-0.0151
	(0.00847)	(0.0120)	(0.00589)	(0.0146)	(0.0103)	(0.0133)
Year dummy	0.312***	0.0522***	0.0229***	-0.260***	-0.289***	-0.0292**
	(0.0615)	(0.00997)	(0.00597)	(0.0621)	(0.0615)	(0.0116)
Observations	4944	3037	3864			
R-squared	0.221	0.093	0.031			

Standard errors in parentheses: * p<0.10 ** p<0.05 *** p<0.01.

Table 3: Regression results on land productivity of rice (all varieties included), equation (2)

	(1)	(2)	(3)	(4)	(5)	(6)
	1992/98	2002/04	2006/08	(2)-(1)	(3)-(1)	(3)-(2)
Log total area of rice (all varieties)	**-0.150*** **	**-0.119*** **	**-0.0607*** **	**0.0307**	**0.0894*** **	**0.0587***
	(0.0296)	(0.0309)	(0.0152)	(0.0427)	(0.0332)	(0.0344)
Log total area of rice X log male real ag wage	**0.00554**	**-0.00384**	**0.0758*** **	**-0.00938**	**0.0702***	**0.0796***
	(0.0355)	(0.0365)	(0.0212)	(0.0508)	(0.0412)	(0.0421)
Log male real ag wage (VND in 1992)	**-0.0235**	**0.0218**	**0.0223**	**0.0453**	**0.0458**	**0.000566**
	(0.0793)	(0.0225)	(0.0248)	(0.0821)	(0.0828)	(0.0334)
Male household head	0.00126	0.0430	0.00506	0.0417	0.00381	-0.0379
	(0.0328)	(0.0400)	(0.00925)	(0.0516)	(0.0339)	(0.0410)
Age of household head	0.000920	0.000606	0.000243	-0.000313	-0.000676	-0.000363
	(0.00125)	(0.00128)	(0.000301)	(0.00179)	(0.00128)	(0.00132)
Highest education of household members	0.0239**	-0.00155	-0.000449	-0.0255**	-0.0243**	0.00110
	(0.0106)	(0.00586)	(0.00398)	(0.0121)	(0.0113)	(0.00708)
Number of male members	0.0172	-0.0221	-0.00258	-0.0393	-0.0198	0.0195
	(0.0175)	(0.0169)	(0.00455)	(0.0243)	(0.0180)	(0.0175)
Household size	0.00903	0.0194*	0.00489	0.0103	-0.00414	-0.0145
	(0.00902)	(0.0111)	(0.00600)	(0.0143)	(0.0108)	(0.0126)
Year dummy	0.334***	0.0499***	0.0178*	-0.284***	-0.316***	-0.0321**
	(0.0611)	(0.0106)	(0.00921)	(0.0618)	(0.0616)	(0.0141)
Observations	4744	2777	3780			
R-squared	0.226	0.069	0.045			

The variables, "Log total area of rice" and "Log male real ag. wage", are centered around their sample means.
Standard errors in parentheses: * $p<0.10$ ** $p<0.05$ *** $p<0.01$.

Table 4: Regression results on machine use, equation (3)

	(1) 1992/98	(2) 2002/04	(3) 2006/08
Log total land cultivated	**0.0786*** **	**0.0884*** **	**0.0652*** **
	(0.0234)	(0.0207)	(0.0191)
Log male real ag wage (VND in 1992)	**-0.0586**	**0.0712**	**0.104** **
	(0.0929)	(0.0530)	(0.0409)
Male household head	-0.0591	-0.0388	-0.00998
	(0.0442)	(0.0660)	(0.0191)
Age of household head	-0.0000823	0.000860	-0.000592
	(0.000910)	(0.00184)	(0.000517)
Highest education of household members	0.00146	0.0112	-0.000869
	(0.00660)	(0.00810)	(0.00599)
Number of male members	0.0324	-0.00196	0.00496
	(0.0197)	(0.0277)	(0.00827)
Household size	-0.0292**	0.00822	-0.00363
	(0.0123)	(0.0177)	(0.0106)
Year dummy	0.298***	0.0610***	-0.00168
	(0.0529)	(0.0159)	(0.0145)
Observations	5241	3378	4431
R-squared	0.193	0.036	0.014

Standard errors in parentheses: * p<0.10 ** p<0.05 *** p<0.01.

Table 5: Regression results on land productivity of spring ordinary rice, equations (1) and (2)

	(1) 1992/98	(2) 2006/08	(3) (2)-(1)	(4) 1992/98	(5) 2006/08	(6) (5)-(4)
Log total area of spring ordinary rice	**-0.131*** **	**-0.0508*** **	**0.0802*** **	**-0.129*** **	**-0.0550*** **	**0.0743*** **
	(0.0262)	(0.0130)	(0.0291)	(0.0256)	(0.0131)	(0.0287)
Log total area of spring ordinary rice X log male real ag. wage				**-0.00845**	**0.0552*** **	**0.0636* **
				(0.0326)	(0.0209)	(0.0386)
Log male real ag. wage (VND in 1992)				**0.0679**	**-0.00214**	**-0.0700**
				(0.0665)	(0.0235)	(0.0702)
male household head	0.0170	0.0148	-0.00218	-0.00877	0.0116	0.0204
	(0.0414)	(0.0106)	(0.0426)	(0.0448)	(0.0110)	(0.0459)
age of household head	0.000160	0.0000934	-0.0000667	-0.000110	0.0000715	0.000181
	(0.00110)	(0.000359)	(0.00115)	(0.00120)	(0.000365)	(0.00125)
highest education of household members	0.0115**	0.000106	-0.0114	0.0119*	-0.0000726	-0.0119
	(0.00558)	(0.00558)	(0.00787)	(0.00638)	(0.00570)	(0.00853)
number of male members	0.000300	0.00311	0.00281	0.00510	0.00493	-0.000172
	(0.0191)	(0.00483)	(0.0196)	(0.0207)	(0.00491)	(0.0212)
household size	0.00681	-0.00220	-0.00901	0.00431	-0.00259	-0.00691
	(0.0109)	(0.00621)	(0.0125)	(0.0115)	(0.00627)	(0.0131)
Year dummy	0.291***	-0.0130*	-0.304***	0.268***	-0.0118	-0.279***
	(0.0422)	(0.00705)	(0.0426)	(0.0559)	(0.00875)	(0.0564)
Observations	4148	3097		3952	3035	
R-squared	0.242	0.017		0.249	0.024	

The variables, "Log total area of spring ordinary rice" and "Log male real ag. wage", are centered around their sample means.
Standard errors in parentheses: * p<0.10 ** p<0.05 *** p<0.01.

Table 6: Regression results on land productivity of autumn ordinary rice, equations (1) and (2)

	(1) 1992/98	(2) 2006/08	(3) (2)-(1)	(4) 1992/98	(5) 2006/08	(6) (5)-(4)
Log total area of autumn ordinary rice	**-0.216*****	**-0.0873*****	**0.129*****	**-0.216*****	**-0.0893*****	**0.126*****
	(0.0420)	(0.0209)	(0.0467)	(0.0406)	(0.0212)	(0.0456)
Log total area of autumn ordinary rice X log male real ag wage				**0.181****	**0.115****	**-0.0661**
				(0.0751)	(0.0542)	(0.0923)
Log male real ag wage (VND in 1992)				**-0.200**	**0.0125**	**0.213**
				(0.218)	(0.0473)	(0.223)
male household head	-0.0491	0.0137	0.0628	-0.0321	0.0111	0.0432
	(0.0514)	(0.0154)	(0.0534)	(0.0567)	(0.0161)	(0.0587)
age of household head	0.000171	0.000778	0.000606	-0.000106	0.000804	0.000911
	(0.00208)	(0.000495)	(0.00213)	(0.00227)	(0.000508)	(0.00232)
highest education of household members	0.0262**	-0.00270	-0.0289**	0.0236*	-0.00417	-0.0277*
	(0.0125)	(0.00651)	(0.0140)	(0.0125)	(0.00677)	(0.0141)
number of male members	0.0334	0.00617	-0.0273	0.0341	0.00703	-0.0271
	(0.0241)	(0.00729)	(0.0251)	(0.0242)	(0.00728)	(0.0251)
household size	0.0137	0.00984	-0.00386	0.0206	0.0100	-0.0106
	(0.0129)	(0.00819)	(0.0153)	(0.0142)	(0.00842)	(0.0165)
Year dummy	0.268***	0.0583***	-0.209***	0.358***	0.0563***	-0.302***
	(0.0762)	(0.0105)	(0.0766)	(0.104)	(0.0166)	(0.105)
Observations				3520	2413	
R-squared				0.150	0.076	

The variables, “Log total area of autumn ordinary rice” and “Log male real ag. wage”, are centered around their sample means.
Standard errors in parentheses: * p<0.10 ** p<0.05 *** p<0.01.

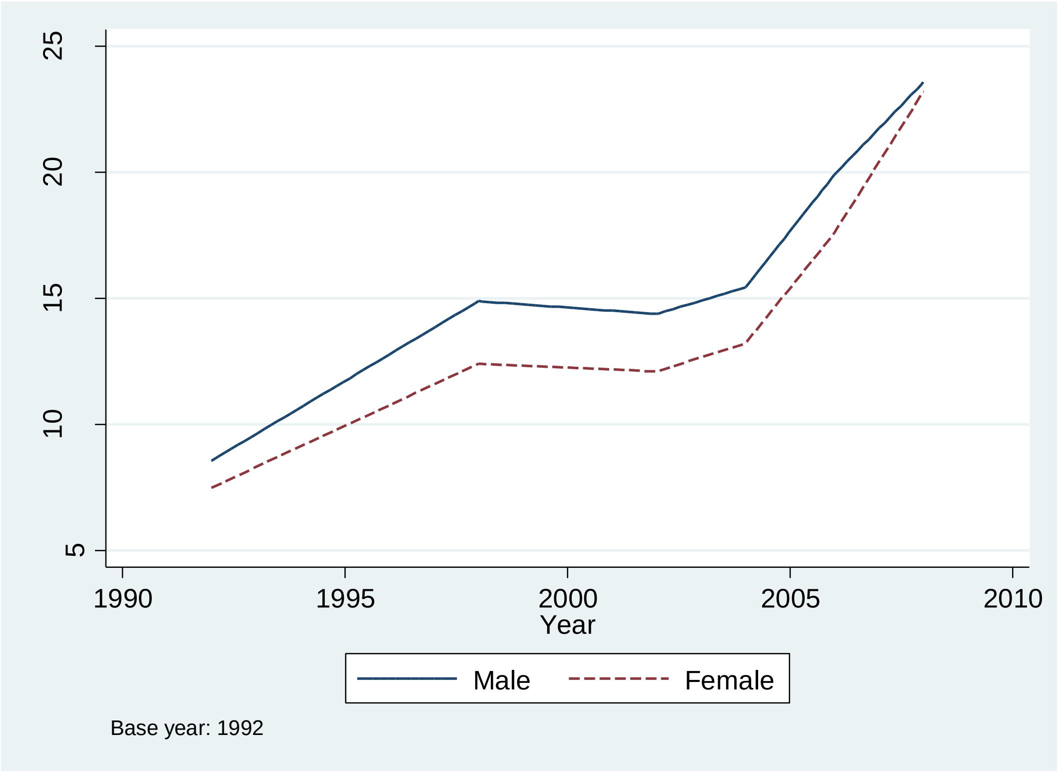

Figure 1: Median daily real male and female agricultural wage, 1992-2008

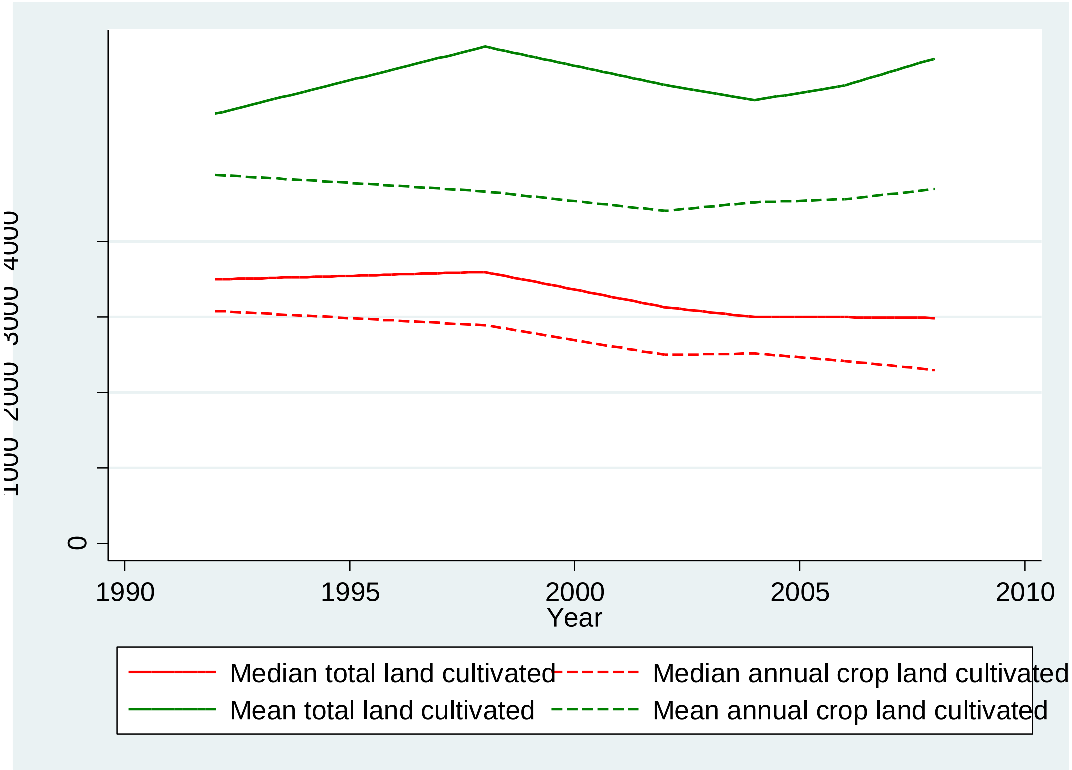

Figure 2: Trend of total land cultivated per household and total annual crop land cultivated per household, 1992-2008

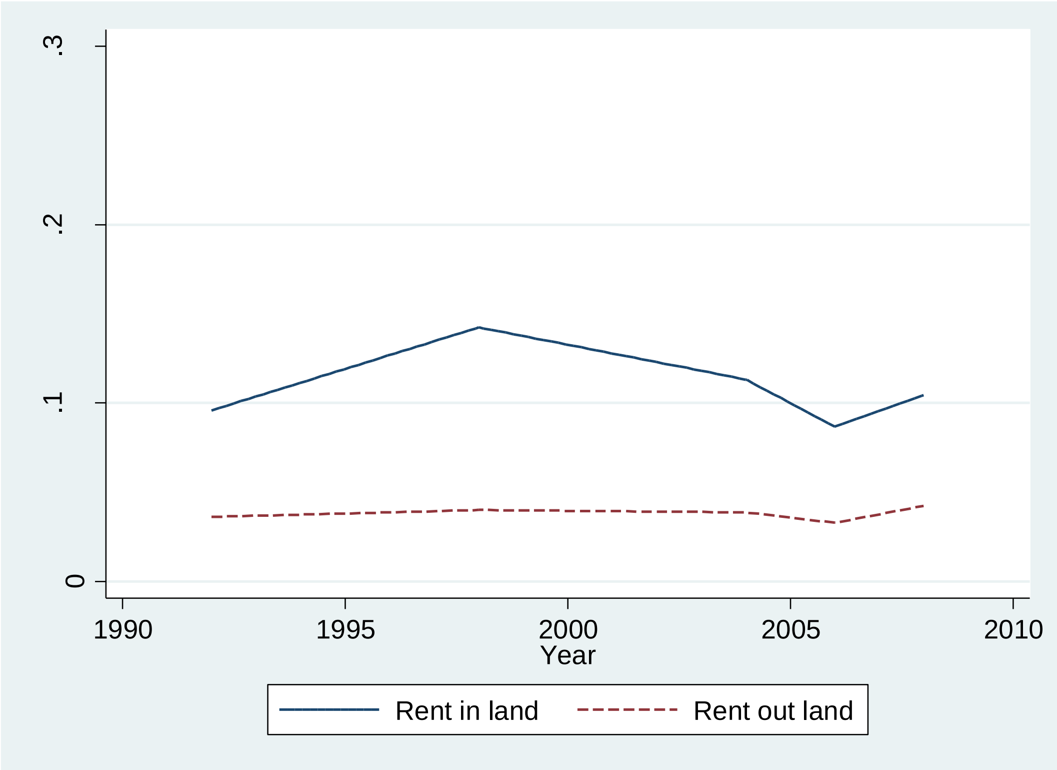

Figure 3: Trend of land rental, 1992-2008

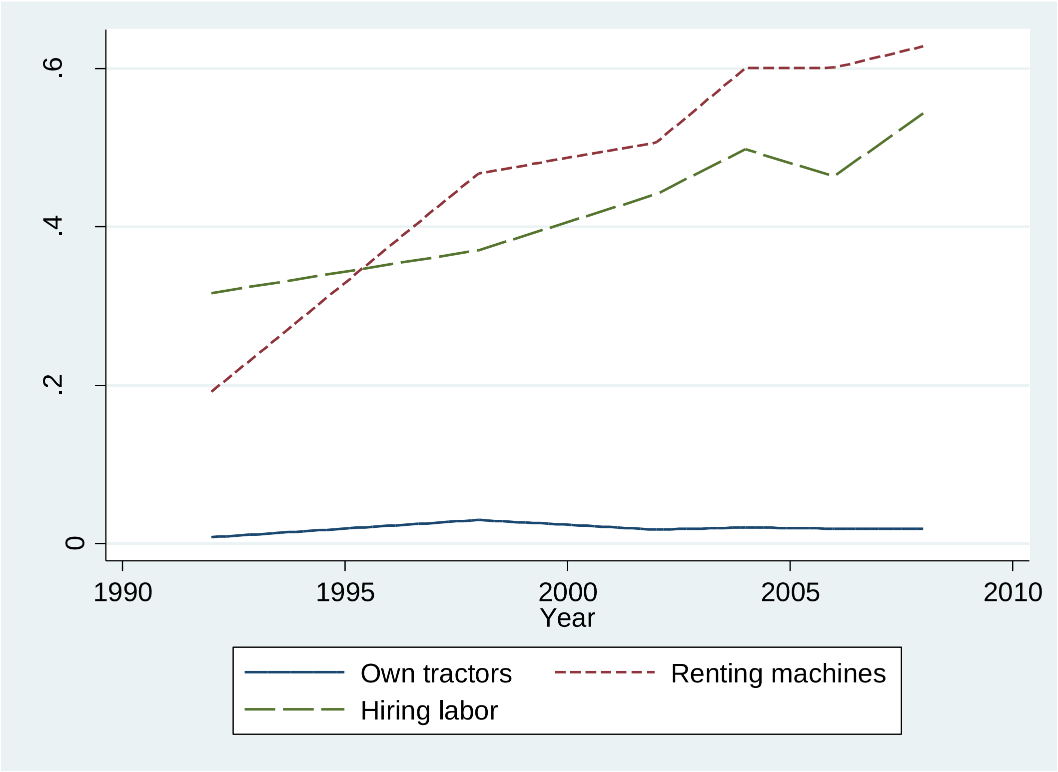

Figure 4: Trend of tractor ownership, machine renting, and labor hiring, 1992-2008

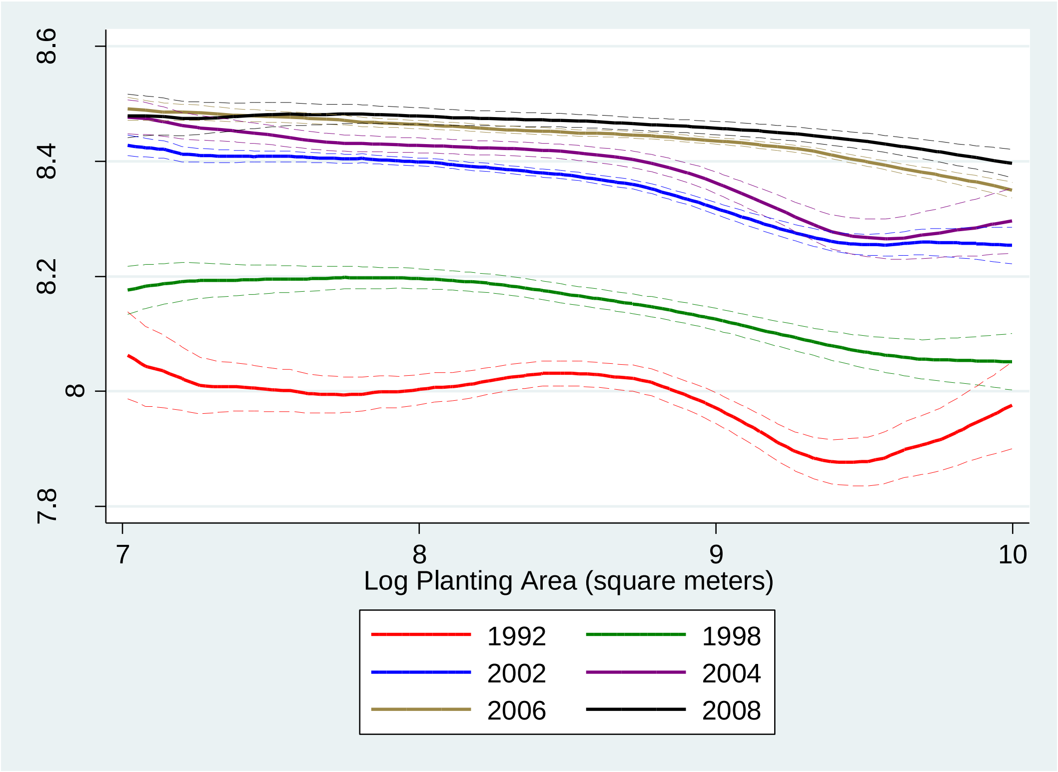

Figure 5: Rice yield versus planting area, 1992-2008