

**Evolution of agricultural mechanization in Vietnam:  
Insights from a literature review and multiple rounds of a farm household survey**

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**Abstract:** Despite the reportedly rapid growth of mechanization, as well as its unique history in economic and social systems, information on the patterns of agricultural mechanization growth in Vietnam has been limited. Through an extensive review of existing literature and several rounds of nationally representative household survey data, we document the evolution of mechanization (particularly tractors and combine harvesters) in Vietnam, including the heterogeneity across regions and farm sizes, and the emerging roles of the private sector in the supply of machinery and hiring services. The historical growth pattern of mechanization in Vietnam had been non-linear, characterized by somewhat high tractor-use prior to 1975 followed by a decline in the 80s before a resurgence in the 90s, with considerable variations in adoption patterns across regions. Since the economic and social reform in the late 80s, the private sector has rapidly emerged as the major player in meeting the demand for greater farm power uses, including the domestic manufacturing of power tillers, the introduction of larger combine-harvesters, and individual machine owners emerging as the primary suppliers of hiring services. While machinery use has gradually spread from larger farms to smaller farms, there are some signs that the comparative advantage has been shifting towards larger farms.

**Keywords:** mechanization; mechanization growth; tractors; combine-harvesters; hiring service providers; Vietnam

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## **1 Introduction**

Vietnam has reportedly experienced rapid growth in agricultural mechanization lately; particularly in the use of tractors and combine-harvesters (Pingali 2007; Reardon et al. 2014). The recent growth in mechanization has been similar to other developing countries in Asia. However, in the long term, the historical growth of agricultural mechanization has been unique due to the considerable changes in the political and economic systems in Vietnam, which few other countries in South East Asia or South Asia have experienced.

Documentations of the key agricultural mechanization patterns in Vietnam are limited and large knowledge gaps exist. There has been little information on the actual extent of mechanization prior to 1975; in particular the use of tractors in Vietnam. Understanding such historical patterns is important in assessing how the early exposures to tractors might have contributed to their spread in later decades. There is also little information available regarding the sub-national variations of machine adoptions; including tractors and combine-harvesters. Lastly, little documentation exists on how the supply of machines and hiring services are emerging in Vietnam. Understanding such supply-side development is important in assessing how the public-sector policies and the private sector have contributed to the mechanization growth.

This paper fills such knowledge gaps and documents the evolution of the growth of mechanization in Vietnam based on an extensive review of the existing literature and several rounds of a nationally representative household survey. The available evidence suggests that the level of tractor use in Vietnam had been relatively high in the 1970s and the early-1980s, but declined through the late-1980s before it started taking off again in the 1990s. The relatively high level of tractor uses up to the early-1980s were partly due to political and military reasons, as both the West and the Soviet Union gave substantial support in providing heavy machinery, including tractors. We also find that the mechanization growth pattern has been heterogeneous within the country, with distinctions between the relatively smallholder-dominated deltas and the land-abundant Central Coast. Based on the literature review, we also find that the private-sector led hiring services have been increasingly taking over the public or the cooperative-based service providers; consistent with the patterns elsewhere in Asia including countries like China with relatively stronger Socialist structures of the economy (Zhang et al. 2017).

This paper contributes to the literature on agricultural mechanization by providing a more focused in-depth description of the evolutionary pattern of agricultural mechanization in Vietnam and its sub-regions. It builds on the past and emerging literature that focuses on providing holistic perspectives on the spread of agricultural mechanization and the development of relevant sectors, rather than an analysis of specific causal mechanisms (IRRI 1978; 1983; 1986; Kienzle et al. 2013; Mandal et al. 2017). The paper also provides important historical perspectives and contexts to studies that focus on the more recent agricultural mechanization issues in Vietnam (e.g., Liu et al. 2016).

The paper is structured in the following way. Section 2 describes in detail the historical pattern of the growth of agricultural mechanization in Vietnam. Section 3 provides qualitative analysis of the factors driving the spread of mechanization and the variations across the regions within the country. Section 4 briefly describes the emerging patterns in the supply of machinery and mechanization service. Lastly, section 5 provides concluding messages.

## **2 Historical background of the evolution of mechanization in Vietnam**

The evolution of agricultural mechanization in Vietnam has not been linear. The significant changes in the levels of mechanization, particularly in the use of tractors and combine-harvesters,

are partially associated to key historical events that changed the political and economic systems in the county over the last half-century. Table 1 shows a back-of-the-envelope approach to estimating the levels of mechanization based on a detailed review of existing literature that has not been widely chronicled in the existing mechanization literature. It also summarizes rough indicators of the economy and agricultural transformation. Vietnam's recent history of agricultural mechanization can be roughly grouped into four phases: (1) ~ 1975 (before re-unification); (2) 1975 ~ 1980s: Collectivized production; (3) 1990 ~ 2010: Liberalization and take-off of power-tiller uses and medium-size 20-35 horsepower (hp) tractors; (4) 2010 ~: deepened mechanization growth through large tractors and combine-harvesters.

[Insert Table 1]

### **Phase 1: ~ 1975 (before reunification)**

Before the reunification of Vietnam in 1975, the uses of draft animals had been fairly common. In 1968, draft animals accounted for about 50 percent of all farm power used in Southern Vietnam<sup>1</sup>, followed by manual power (Khalil 1981). While tractors were used on only a fraction of farms, mechanical horsepower per hectare in Vietnam (0.023 hp/ha) was higher than India (0.008), Korea (0.003), Pakistan (0.013) in the late 1960s (Khalil 1981).

The North and the Southern Vietnam had seen divergent patterns in the transformation of the agricultural sector. In the Northern Vietnam, collective farms had already accounted for a majority of farming production by the mid-1960s. Both the USSR and China had provided increasing support on mechanization through tractor provisions to these collective farms, among other things (Smith 1985; Rangarao 1969). In some areas, demand for mechanization was partly driven by the war. For example, in Thanh Oai District near Hanoi, 30 percent of the land had been plowed by tractors by 1970. This was possibly due to the out-migration of a large portion of the young male labor force to the war in the late 1960s (Wiegersma 1988). However, in Nam Hong district, the area of land plowed by tractors increased from 5 to 14 percent from 1965 to 1970 (Wiegersma 1988). Although the area cultivated by tractors was likely less than 10 percent overall, the number of tractors in the North increased from around 400 in 1960 to 2,666 in 1970 and 7,468 in 1975 (Trần 1998).

In Southern Vietnam, farming systems had already been relatively modernized by the 1960s, particularly in the Mekong Delta. By 1945, the Mekong Delta had several large plantations, including those operated by the French, with relatively advanced technologies like machinery, motorized water pumps, and tractor-mounted plows. These fields were also lent out to neighboring farmers who would plow the land with water buffalos (Biggs 2012). In the 1960s and the early-1970s, tractors were supplied by the United States. Some USD 15 million worth of farm machinery was imported into Southern Vietnam in 1970 (Logan 1971), primarily financed by US Government grants and the US military. By the end of 1971 there were nearly 40,000 tractors in Southern Vietnam (Braddock 1988), although some were used for military purposes rather than for farming. Four-wheel tractors (4wt) were more common than two-wheel tractors (2wt) in the Mekong Delta as supplies came from the USSR and the US (Xuan 1975). Although Korea started exporting power tillers to Vietnam in 1965, the importation of power tillers had been relatively small (Lee 2007).

Furthermore, various programs contributed to the increasing share of are cultivated by

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<sup>1</sup>In this paper, we refer to "Northern Vietnam" as areas that belong to one of the four regions, North East, North West, North Central Coast, and Red River Delta regions. Similarly, we refer to "Southern Vietnam" as areas that belong to one of Central Highland, South Central Coast, South East and Mekong River Delta regions.

tractors. The military had conducted the largest land-clearing operation ever undertaken, employing teams of commercial track-type tractors with commercial land-clearing accessories (Uthus 1973), in the tropical vegetation of Vietnam throughout the 1960 and early 1970s. Additionally, the “Land to the Tillers” program initiated in 1970, gave agricultural land to the farmers that were tilling the land. By 1975, approximately 2 million farmers become landowners, each obtaining between 1 to 3 ha of rice land free of charge (Xuan 1975). By the mid-1970s, the share of area cultivated by tractors reached 16 percent in Northern Vietnam and 30-40 percent in Southern Vietnam (Young et al. 2002).

During the 1960s and the early 1970s, economic structures and employment shares across sectors had also diverged between Northern Vietnam and Southern Vietnam (Table 1). In Northern Vietnam, the agricultural sector had continued to account for more than 40 percent of national income and employed more than 70 percent of the workforce. In contrast, Southern Vietnam had been more affected by the ongoing war. The share of agriculture declined from 40 percent in 1960 to 25 percent in 1970 and the share of the workforce employed in agriculture had also declined from 71 percent to 56 percent (even lower if the share of army recruitment was added). Meanwhile, the share of service industry had grown from 41 percent to 59 percent during the same period, in part due to the growing presence of the US military (Dacy 1986). While the economic structure during this period was substantially influenced by external factors associated with the war, the underlying structures were somewhat consistent with the growth of the use of mechanization in Vietnamese agriculture, particularly in the South.

### **Phase 2: 1975 ~ 1980s: Collectivized production**

After the victory of the National Liberation Front and reunification under the Socialist regime in 1975, Vietnam implemented a policy of agricultural collectivization and the strategy for investing in agricultural mechanization was dictated by the concept collective large-scale, mechanized production throughout the country (Khiem 1998). The Soviet Union was a key partner in the mechanization of Vietnam during this phase. Between 1976 and 1980, the Soviet Union provided USD 3.5 billion of economic aid and USD 2 billion of military aid to Vietnam (Trung 1990); partly in the form of tractors, together with large trucks and cars (Gough 1977; Võ 1990). The 1978 Treaty on Friendship and Cooperation between the Soviet Union and Vietnam made Vietnam a full-fledged partner of the Soviet bloc (Quang 1990 in Trung 1990), and by 1990, Vietnam had received 15,000 agricultural tractors from the USSR, in addition to thousands of Austrian Steyr 65-hp tractors and French Renault 55-hp tractors. Given that 20 – 50 hp 4wt had been commonly produced in the Soviet Union during this period (Andreev 1967), it’s likely that most tractors provided to Vietnam were to have been of this type. Moreover, five combines (11t, tracklayers) were also imported from USSR in 1977 (Gummert et al. 2013).

However, the growth of tractor use was generally stagnant throughout the 1980s. The shares of area cultivated by tractors declined from 27 percent in 1980 to 21 percent in 1990 (Table 1). This was particularly evident in Southern Vietnam. The number of functioning tractors in the Mekong Delta declined by as much as 76 percent between 1975 and 1983 (Raymond 2008; Bui & Preechametta 2016). Draft power shortages in Southern Vietnam had become more severe than in the Northern Vietnam (Pingali & Xuan 1992). Various factors could explain such declines. First, tractor supplies from USSR had declined after 1980. Second, the share of the workforce in agricultural sector at the national level rose back to around 70 percent in 1980 and generally remained unchanged throughout the decade (Table 1) as workers who were formerly engaged in the service sector (including the military during the war) had moved back to the farming sector.

Third, as is described in the later section, ownership of machinery, including tractors, and mechanization service provisions had largely fallen into the public sectors domain.

For instance, machinery owners were forced to sell their farm machinery to the collective or to form a “farm machinery team” under state direction in 1983 and upper-middle-class peasants were subjected to steeply progressive taxation that took more than 80 percent of their incomes (Porter 1993 p.60). Such measures generally did not lead to a substantial increase in tractor use throughout the 1980s. Although, the stagnation in mechanization was not entirely due to the collectivization that had been pushed under the Socialist regime. The collectivization had been rather incomplete particularly in Southern Vietnam and despite the aforementioned measures, many private tractor owners remained in custom hiring business (Van Luong & Unger 1988) and the private market for water buffalo plowing or tractor plowing remained active, parallel to the formal system of centrally controlled input provisions (Pingali & Xuan 1992).

Importantly, since the transition into the Socialist regime in 1976, the Vietnamese government’s support of agriculture had been substantial. The share of state investment in agricultural sector had remained between 15 - 20 percent until 1988 (Tuan 2006), including 1 - 2 percent for investment in tractors. While the share of state investment declined after 1988, investment remained between 7 - 15 percent between 1989 and 2000 (Tuan 2006) with a significant investment in agricultural R&D for varietal development and irrigation infrastructure. Consequently, rice yield increased substantially in Southern Vietnam during the 80s (2.3 tons/ha to 3.4 tons/ha), and in Northern Vietnam during the 90s (2.8 tons/ha to 4.6 tons/ha). The potential effects of such a technology build-up on the growth of mechanization in the liberalized systems in the 1990s and afterward should not be ignored.

### **Phase 3: 1990 ~ 2010 (Liberalization and take-off of tractor uses)**

The period between 1990 and 2010 in Vietnam saw a substantial growth in the use of both 2wt and 4wt (Figure 2). The area cultivated by tractors (2wt and 4wt combined) increased from 21 percent in 1990 to 30-40 percent in 2000, and to 70 percent in 2010 (Table 1). Although exact figures are not available, 2wt and 4wt might have contributed to the growth in area cultivated at a ratio of 1/3 and 2/3 respectively. While 2wt account for about 2/3 of the increase in the number of tractors during this period. The growth in tractor use was largely a result of the growth in custom hiring services by tractor owners, who constitute 1 - 2 percent of all farm households (Tsukada 2011; Viet 2014; Takahashi 2014). Still, by 2007, Vietnam had the highest number of tractors per cultivated area of rice in Southeast Asia (Pingali 2007). Domestic manufacturing of 2wt also grew during the period and largely supplied the increase in demand for 2wt within the country rather than imports. By 2000, domestic production reached 5000 - 6000 2wt annually and the country began exporting in 2001.

[Insert Figure 2]

The overall agricultural output and yield growth since the 1990s and the growth in tractor use associated with these gains was likely induced by public investment in agriculture and infrastructure. Adoption of hybrid rice varieties has been increasing since 1992, when the first hybrid rice variety, imported from China, was introduced. By 2013, the share of rice varieties domestically bred had reached 46 percent, surpassing the share of varieties imported from China or the International Rice Research Institute (IRRI) (Dung 2013); indicating a substantial rise in the effectiveness of the public-sector R&D. Public investments in irrigation remained high in the

1990s, approximately 5 percent of total government spending and 50 percent of government agricultural spending (Barker et al. 2004). Public investments into irrigation accounted for 28 percent of the agricultural output growth between 1991-99 (and facilitated public investments into pumps<sup>2</sup> accounting for additional 6 percent), while investment in agricultural research accounted for another 27 percent (Barker et al. 2004). Investment in infrastructure in the 1990s improved price response of agricultural production (Minot & Goletti 2000) and trade (World Bank 2007 p.120), with the investment in road accounting for another 11 percent of agricultural output growth (Barker et al. 2004). The increase in yield potential induced by these public investments may have raised the demand for more intensive land preparation or transportation, and thus increased the use of tractors.

A broader economic transformation also progressed since the 1990s. Between 1993-98, the Vietnamese economy grew by 8.9 percent annually, the fourth fastest in the world (Nguyen et al. 2007; Haughton et al. 2001). The shares of the industrial sector and service sector in the economy had risen during the 1990s and 2010s, and the relative share of agriculture declined from 31 percent to 17 percent of GDP and from 72 percent to 54 percent of employment (Table 1). While the declining share of agriculture was partly the result of the widening urban-rural income gap (Nguyen et al. 2007) and the employment share in agriculture remaining above 50 percent in 2010, the decline since 1990 was consistent with the growth of tractor use during this period.

The effects of these conditions were also magnified through reforms, such as “Doi Moi”, that started in the late 1980s. The pillars of the reform consisted of: decollectivization, allocation of secure land use rights to farm households (1993 Land Law) (Ravallion & van de Walle 2008),<sup>3</sup> and elimination of internal barriers to trade, among others. The reforms also dismantled the cooperatives and formally allowed individual ownerships of agricultural machines (Young et al. 2002) and all production inputs except land, and the free marketing of agricultural outputs and inputs, as well as equipment (Castella et al. 2001). Finally, a legal framework for private economic activity in agriculture, manufacturing, and services was established (Nguyen et al. 2007). The liberalization of the agriculture sector in the early 1990s partly facilitated the rapid increase in the adoption of modern rice technologies, including power tillers (Pingali et al. 1997).

#### **Phase 4: 2010~ (deepened mechanization growth through four-wheel tractors and combine-harvesters)**

The 2010s were characterized by the growing shift from small to large tractors and from reapers to combine-harvesters. Between 2006 and 2015, the share of tractors above 12 hp (which are mostly 4wt) to all tractors in Vietnam increased from 30 percent to almost 50 percent, with the share of power tillers relatively declining (CSAM 2014; Viet 2014). In 2016, there total of 532,600 tractors, among which 294,600 were 2wt with less 15 hp, 221,300 were 4wt with 15-35hp, and 16,700 were 4wt with more than 35 hp (Nguyen-Duc-Ban. 2016). In 2014, 50 percent of the land was cultivated by 4wt, compared to 30 percent by 2wt (CSAM 2014). In 2015, about 70% of paddy in Mekong Delta had been mechanically dried, using the flat-bed dryer developed by Faculty of Agricultural Engineering and Technology (FAET) in Nong-Lam University (NLU) and the Center for Agricultural Energy and Machinery (CAEM) (Hien 2010). Mechanization of rice harvesting had also progressed substantially. The area of rice harvested by combine-harvesters increased from

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<sup>2</sup>Unlike in South Asia, pumps in Vietnam are predominantly used with surface water, mostly canals (AQUASTAT).

<sup>3</sup>The law introduced official land titles and permitted land transactions for the first time under communist rule. The state continued owning the land, but granted usage rights that could be legally transferred and exchanged, mortgaged and inherited by households (Ravallion & van de Walle 2008).

15 percent in 2006 to 35-45 percent at the national level, and 60 percent in Red River Delta in 2013 (Tam 2015; Soni 2015). In Mekong River Delta, the share increased from 15 percent in 2011 (Viet 2011) to 60 percent or more in 2014 (Viet 2014; Reardon et al. 2014). As described in the later section, most of these emerging combine-harvesters have 35 ~ 70 hp. The government also played important promotional roles on the growth of mechanization during this period, including several combine contests organized by the Vietnamese Ministry of Agriculture where the performance of several domestically-made smaller combines and larger European combines were assessed (Hien et al. 2007). However, unlike tractors, the spread of combine-harvesters was relatively slower in the 2000s. While the government promoted their adoption through sensitization, including a series of combine contests organized by the Ministry of Agriculture since 1998 (Gummert et al. 2013), and many brands tried, demand was not sufficient to develop after-sales services.

It's important to note that the rate of growth for mechanization has been faster within the rice sector in Vietnam. Other agricultural sectors in Vietnam, such as upland crops where all operations (seeding, cultivation, harvesting, etc.) are done manually except land tillage, has been slower to incorporate mechanization in the production of those crops.

The economic structure has not drastically changed in Vietnam since 2010 (the agricultural sector share to GDP has remained around 17 percent), but rural wages have continued rising. Daily earnings for rural workers increased from \$12.93 (constant 2010 US dollar, PPP) in 2007 to \$17.35 in 2012 (Wiggins & Keats 2015). In addition to the rising rural wages, a relatively large, wealthier farmer class has emerged, cultivating 3 ha or more since the since the 1993 Land Law (Ravallion & van de Walle 2008) and since the 2000s particularly in Mekong River Delta (Takahashi 2014). These changes may have resulted in more investments in combine-harvesters (in 2014, 75 percent of combine-harvesters in Vietnam were located in Mekong River Delta (Viet 2014)).

Furthermore, the government's increasing concern of post-harvest losses led to the promulgation of a series of decisions (particularly Decision No. 63/2010/QD-TTg of 2010 and Decision No. 65/2011/QD-TTg in 2011, and No. 68/2013/QD-TTg in 2013) that included public support through government-provided loans (Viet 2014; MARD 2012). These actions may have created additional demand for modern harvesting and post-harvesting processing machines like combine-harvesters, however such effects must be investigated more formally in future studies.

### **3 Descriptive analysis of the growth pattern of mechanization**

This section provides more detailed descriptive evidence of the growth pattern of mechanization in Vietnam between more recent period, using several rounds of Vietnamese Living Standard Survey (VLSS). For a detailed description of VLSS, see Liu et al. (2016).

#### *Sub-national variations in machine rental and ownership*

The recent machinery use patterns in Vietnam have been consistent with the hypothesis that mechanization growth tends to be faster in areas with favorable agricultural environments (e.g., lowland areas like deltas). Table 2 reports proportions of farm households that rented machinery by region and their changes between 1992 and 2008.<sup>4</sup> The Mekong and Red River deltas are the

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<sup>4</sup>While VLSS does not report the detailed descriptions of how machines were used by the households, tractors in Vietnam have typically been used for land preparation and transportation.

For example, tractors are used for land preparation on rice plots in the following way. For the first rice crop, before sowing the germinated seeds, farmers muddy and level the land because the soil of land is wet after the flooding season. For the second rice crop, if only two rice crops are being planted in that year, they plow, muddy,



main regions of rice production and the most populated areas in Vietnam. The Mekong River delta had the highest machinery rental rate (49 percent) in 1992 and has remained one of the most mechanized areas since. However, the Red River Delta became the most prevalent machinery rental region from 2004-2008 (80-85 percent). Machinery rental has also grown substantially in the Central Highlands, increasing to 55 percent in 2008 (Table 2). This region has the lowest population density and it is the main production area for cash crops (Table 3). The pattern in the Central Highlands has been consistent with the hypothesis that mechanization helps the growth of larger-farms in relatively land-abundant areas where market access is good. Unsurprisingly, the mountainous Northwest region had the lowest rate at 27 percent in 2008.

[Insert Table 2]

[Insert Table 3]

Table 4 reports the proportion of households that owned tractors by region from 1992 to 2008. Tractor ownership was consistently low except for the Central Highlands where about 13 percent households owned tractor in 2008. In other regions, the tractor owning households accounted for less than 2 percent in 2008. There are also slight variations in the major types of tractors across regions (Table 5). While the majority of tractors owned in 2007 were 2wt with less than 12 horsepower for all regions, the South Central Coast, Central Highland, and the Mekong Delta were relatively more populated with 4wt with greater than 12 horsepower. In particular, 7.5 out of 1,000 farm households in the Mekong Delta owned larger 4wt with horsepower greater than 35. This was substantially higher than the national average of 1.7 out of 1,000 farm households.

[Insert Table 4]

[Insert Table 5]

Table 2 and Table 4 together indicate that a significant share of tractor adoptions has been achieved through rentals rather than ownership. This has applied to not only to the expensive 4wt, but also the relatively cheaper 2wt. The high user-owner ratios for 2wt have also been observed in countries like Bangladesh, where the ratio has been as high as 36 users to owners (Diao et al. 2014). The growth of machine rentals has been observed across many regions, including Northern Vietnam where the use of rented 2wt was less common than in Southern Vietnam in the 1990s (Minot & Goletti 2000 p.14).

Importantly, the growth in tractor use in Vietnam since the 1990s is likely to have been the result of rising demand for overall farm power use, rather than the substitutions of manual farm power. Figure 3 plots the proportion of households that owned tractors, rented machinery, or hired

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and level the land. However, if they are planting three annual rice crops, they may not plow the land and may instead burn the rice straw left in the field because land preparation is very short in this rice season. Then, if there is a third rice crop, they again plow, muddy, and level the land (Tuyên 2013).

For transportation, 4wt and 2wt are typically used in the following way. In Vietnam, tractors used for transportation are often called “xe cay” for 4wt, and “Công nông” for 2wt. 2wt with trailers (Công nông) are often used to ship around 2 tons of goods per trip, to a trading hub at the commune center that are as far as 10 km away, although for distance of more than 500m, farmers may use motorbikes or animal traction (horses, buffalos) rather than 2wt (Lançon et al. 2014) (Lançon et al. 2014). Many village collectors reportedly own 2wt with such 2-ton capacity trailer (Lançon et al. 2014). Transport costs in districts like Krông Nô district, are generally around 10 VND per kg per km (0.04 cent), although some farmers in the more remote area pay around 40 VND per kg per km (Lançon et al. 2014).

labor from 1992 to 2008. While we do not see much change in tractor ownership, the percentage of cultivating households that rented machines more than tripled, from 19 percent in 1992 to 63 percent in 2008. The percentage of households that hired labor also increased sharply from 32 percent in 1992 to 55 percent in 2008.

[Insert Figure 3]

#### *Farm size and machinery use*

Another important pattern of mechanization is the considerable spread among smallholders. Such patterns have been reported for other Asian countries, but not in Vietnam.

Based on rice planting area, we categorize farmers into two equal groups: smaller-holders cultivating less than 5,760 square meters of rice areas and larger-holders cultivating more than 5,760 square meters of rice areas. Figure 4 plots tractor ownership and machine rental from 1992-2008 for these two groups. Larger-holders and smaller-holders have similarly low levels of machine ownership, compared to the levels of machine use through rentals, indicating that, not only smaller-holders but also most larger-holders in Vietnam have relied on rented machines rather than owned machines. While larger-holders have had higher propensity to rent machines throughout the period, the difference between the two groups has decreased over time, especially in the late 2000s, indicating that smaller-holders have also been able to benefit from machine rentals.

[Insert Figure 4]

Figure 5 shows the relationship between tractor ownership and rice planting area for 1992 and 2008, estimated through a non-parametric regression. The dotted lines show the 95 percent confidence intervals around the point estimates. In 1992, tractor ownership had been mostly concentrated among very large farms cultivating more than 20,000 square meters (approximately 10 in the natural log), although the large confidence intervals suggest the estimation was not precise. In 2008, while large farms still exhibited a slightly higher rate of tractor ownership than small farmers, the tractor ownership seemed to spread relatively more evenly across farms of different sizes. While tractor ownership remained low as mentioned above, Figure 5 suggests its relatively increased among small farms lately.

[Insert Figure 5]

Figure 6 illustrates a similar trend as Figure 5, but in the case of machine rentals. Machine rentals are significantly positively associated with farm size in both rounds. This indicates that the complementarity between land and machines have remained important. However, the slope of the curve for 2008 is flatter than the slope of the curve for 1992, suggesting that machine rental has increased more among small farms.

[Insert Figure 6]

It is important to note that the complementarity between land and machines remains potentially influential. This is because, during 1992 and 2008 when tractor use grew considerably, the production intensity of rice, which is often the most mechanized crops among smallholders in Asia, had also risen more relative to the production of other crops.

Figure 7 depicts the mean and median of the total land cultivated per household and the total annual crop land cultivated per household from 1992 to 2008. Although the mean of landholdings was relatively stable over time, the median reduced slightly at a steady pace over this period, suggesting a change in the landholding distribution. Figure 8 and Figure 9 depict the distribution of total cultivated land and annual crop land, for 1992 and 2008. Both figures show similar patterns of distributional change in comparison to 1992: the percentage of medium-sized farms reduced and there is a slight increase in percentage for both the small farms and large ones. In contrast, the total rice planting area increased for all percentiles over this period, showing different patterns from total cultivated areas across all crops (Figure 10). This difference may be attributed to increased intensification in rice production. Indeed, the proportion of irrigated annual land increased from 57 percent in 1992 to 81 percent in 2008, allowing for rice to be planted in more crop seasons within a year. Similarly, in one of the most mechanized region, the average farm size among their sample households increased from 1.0 hectare in 1996 to 1.4 hectares in 2009 in the Mekong Delta.

[Insert Figure 7]

[Insert Figure 8]

[Insert Figure 9]

[Insert Figure 10]

Relatedly, Liu et al. (2016) shows that, while rice yield was significantly negatively associated with farm size (inverse-relationship of farm size and land productivity) in the early 1990s, such relationship had largely disappeared by 2008, indicating that the complementarity between land and machine has started becoming more effective. This finding is consistent with the patterns in many other Asian countries (Foster & Rosenzweig 2011; Yamauchi 2016). While the spread of tractor use has benefited smallholders as much as larger farms, further intensification of mechanization may gradually shift the comparative advantages to larger farmers and have serious implications on the future of smallholders in Vietnam.

#### *Wages and mechanization growth*

As mentioned above, increased machinery uses in Vietnam is likely to have been the results of increased overall demand for farm power, as is indicated by the positive associations between the share of farm households using machines and hiring labor (Figure 3). Nevertheless, it is important to note that rising wages have also been important drivers of the growth of mechanization.

Figure 11 plots the median female and male real agricultural wages from 1992 to 2008. Real wages increased significantly from 1992 to 1998<sup>5</sup> and 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 6 reports the median male real wage by region from 1992 to 2008, using VLSS and VHLSS commune survey data. Although real wages were consistently lower in the northern regions than in the southern regions, regional wage differences narrowed considerably by 2008. This indicates an increasingly spatially integrated national labor market and fast transmissions of wage increases

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<sup>5</sup>This period in Vietnam also saw an increasingly share of rural-urban wage gap explained by the returns to skills (Nguyen et al. 2007), and also marked the beginning of the decline in the agricultural share of employment (Table 1).

in certain regions on the increases in the cost of labor in other regions.

[Insert Figure 11]

[Insert Table 6]

### *Determinants of machine uses*

The descriptive analysis above provides several indicators that the growth of mechanization between 1992 and 2008 had been driven by multiple factors. To more formally identify the determinants of machine use, we estimate the following fixed-effects panel equation:

$$d_{mit} = \delta_{0,mi} + \delta_1 \ln w_{mt} + \delta_2 \ln a_{mit} + \delta_4 z_{mit} + \delta_5 D_t + \epsilon_{mit}, \quad (1)$$

where  $d_{mit}$  is a dummy variable indicating machine use for household  $i$  in commune  $m$  and year  $t$ . It takes a value of 1 if the household owned any tractors or spent on machine rentals and 0 otherwise.  $\ln w_{mt}$  is log male agricultural wage (in real terms);  $\ln a_{mit}$  is log rice planting area,  $\delta_{0,mi}$  is a household fixed effect which captures time-invariant household and location-specific effects such as land quality and weather;  $z_{mit}$  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 uniformly across communes); and  $\epsilon_{mit}$  is the error term. We cluster standard errors at the commune level. Equation (1) is estimated using the 1992/98 panel, 2002/04 panel, and 2006/08 panel of the VLSS separately. The results are reported in Table 7. The estimation found that larger farmers are more likely to use machines in all three panels. Machine use did not respond to real agricultural wage in the 1990s' or the early 2000s' panel. In contrast, machine use significantly increases the real wage in the 2006/2008 panel, suggesting efficiency improvements in rural factor markets.

[Insert Table 7]

## **4 Market institutions of mechanization service provisions**

This section briefly summarizes the evolving modes of machinery supplies and mechanization service provisions in Vietnam. Overall, recent patterns suggest that the private sector has been transforming both markets.

### **4.1 Agricultural machinery manufacturing**

As was mentioned above, the growth of the supply of power tiller in the domestic market during the 1990s had been led by the growth in domestic manufacturing, although some power tillers had also been imported. By the end of the 1990s, 5,000-6,000 power tillers were already being domestically manufactured annually by major manufacturers like VIKYNO and VINAPRO (JICA 2000), who were leading manufacturing of diesel engines and other machinery (Hien et al. 2007). Some power tillers were domestically manufactured using a diesel engine fitted into a scrap chassis (Starkey et al. 2002 p.57)<sup>6</sup>. By 2001, Vietnam had started exporting tractors (mostly power tillers) (FAO 2016).

While there is no direct evidence, the importation of power tillers in the 1980s may have resulted in the local adaptations and eventual manufacturing. For example, since the late 1980s,

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<sup>6</sup>In Vietnam, the use of the small engine for multiple small types of machinery started indigenously by domestic engineers who saw the potential of changing the use of the equipment for power boats and axial flow pumps in the 60s (Sansom 1969; Stewart 1974; Biggs & Justice 2015), and later on power tillers.

Daedong Industry Co. in Korea started exporting power tillers and farm engines to Vietnam via barter trade – gaining a foothold in communist countries (Lee 2007). Similarly, Tongyang Moolsan Co. supplied power tillers and farm engines to Vietnam and was recognized by the Vietnamese government for its technology (Lee 2007).

Domestic manufacturing also accounts for 30 percent of combine-harvesters (MIT 2015), which are mostly the domestic production of Kubota combines by Kubota Vietnam Ltd (the rest were often manufactured in China and exported to Vietnam). Direct evidence on how industrial policy in Vietnam has led to their growth is scarce, but anecdotal evidence suggests that domestic manufacturing of harvesters and reapers originally promoted by the Vietnamese government had gradually declined.<sup>7</sup>

Rice milling machines are mainly manufactured in the country by companies such as Bui Van Ngo, Lamico, etc., with rice processing lines of 4- 40 ton/hr capacity, and grain dryer arrays of 30 to 200 ton per batch. Bui Van Ngo's product quality is of world-class (comparable to Japanese Satake, which is one of the major suppliers of modern rice milling machines globally and Asia region) and Bui Van Ngo has exported rice equipment to about 20 countries in Asia, the Americas and Africa.

Manufacturing of engines in Vietnam has also grown. Today, diesel engines from 5 to 30 HP can be produced domestically, with an annual production capacity of 40,000 units, approximately 30% of domestic market share. In addition, about 2,000 provincial medium or small-size mechanical workshops deal with fabrication, trial, sale, and repair of machines. The leading manufacturer, Viet Nam Engine and Agricultural Machinery Corporation (VEAM), has also exported engines. VEAM is a large state-owned company with reported assets around USD 600 million in 2014 and was recently converted into a Joint Stock entity in 2016. VEAM has 7 large factories throughout Vietnam and has set up a national network of dealers for its 2wt, engines and other machinery. It inherits the old-time support for heavy industries and has some advantages over private companies in terms of loans and investment. However, to be competitive in the manufacturing of machines, the company should have a solid basis in modern metallurgy, which is severely lacking in Vietnam. Thus, even with a large inventory of machine-tools and production capacity, VEAM has just played a modest role in supplying machinery for agriculture.

## **4.2 Machinery supply**

In Vietnam today, tractors are largely marketed by the private sector, which supplies both new and used machines, provides repair / maintenance services as well as some extension / training and credit services for prospective machine owners. Vietnamese-manufactured power tillers (VIKYNO, VINAPRO, etc.) have been substituting imported power tillers since the 1990s. Domestic manufacturers have been expanding their supply networks and likely providing spare parts. The Japanese company, Kubota, has been making inroads into the Vietnamese market for 4wt and combine-harvesters. In fact, new Kubota 4wt are competing against old Kubota tractors (Global Index 2011). Kubota tractors sold in Vietnam are, however, modified to be much stronger and durable than those used in Japan. This is because while there is only one production season

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<sup>7</sup>Before the growth of combine-harvesters in the 2010s, manufacturing of reapers and mini-combines had grown temporarily (Hien et al. 2007). Reaper manufacturing in Vietnam peaked in 1988 with about 15 manufacturers, but had gradually declined to three by 2000, producing 100-200 units per year each (Hien et al. 2007). Mini-combine-harvesters that could harvest around 1 ha per day had been developed in a public-private partnership between Philippine Rice Research Institute (PhilRice) and Briggs & Stratton (B&S). Around 700 machines were produced by VINAPRO in Vietnam until 2009 (Pandey et al. 2010 p.338). Most of these mini-combines were bought by private farmer-contractors with their own money.

per year in Japan, while Vietnam typically has two or three production seasons per year and tractors are used extensively throughout the year.

The private sector has also largely been supplying combine-harvesters. While harvesters originally promoted in Vietnam generally did not spread quickly, Chinese combines have been increasingly adopted; particularly between 2006 - 2009, as these Chinese companies also provided after-sales services and spare parts. Gradually, the Japanese Kubota combine, with a generally smaller harvest loss rate,<sup>8</sup> has overtaken the Chinese combines. By 2013, Kubota's share in the Vietnamese combine-harvesters market had reached 75 percent. Concurrently, the number of Vietnamese manufacturers reduced from 15 to 3 with 15 percent market share (Gummert et al. 2013). Kubota's dealers and network have grown to supply machines, after-sales services, and repair and maintenance services.

### **4.3 Custom hiring service provisions**

Historically, three major types of tractor / combine-harvester owners and service providers have existed in Vietnam; (1) individual ownership; (2) government-run; and (3) cooperatives-run systems.

#### *(1) Individual ownership*

In Southern Vietnam, individual ownership and service provisions had been the most common form of ownership before 1975. In the 1960s, larger farmers who had received increased income from using water pumps and new varieties were then able to invest in further labor-saving technical innovations such as roto-tillers and tractors (Wiegersma 1988).

In the late 1970s, after the reunification of the country, individual ownership of tractors, tillers, threshers, pumps and draft animals was abolished and were sold to the province at values below market prices (Pingali & Xuan 1992), with the intent of making the local governments and cooperatives the major providers of services.

However, such measures had been relatively incomplete and many individual owners remained in business in Southern Vietnam. The diffusion of cooperatives in Southern Vietnam was generally limited; only 6 percent of farmers in Mekong Delta belonged to cooperatives in 1986, compared to over 90 percent in Northern Vietnam (Pingali & Xuan 1992). Despite the law, villagers still owned substantial stocks of non-land capital, such as water pumps or small tractors, and provided services to lower middle and poor peasant cultivators, or to the agricultural cooperatives on a contractual basis (Van Luong & Unger 1988; Gorman 2014).

After Resolution No. 10 was instituted in 1988, which initiated the process of de-collectivization,<sup>9</sup> tractor plowing services were privatized, although in some cases the services had remained the responsibility of the collectives (Kirk & Tuan 2009). The individual ownership began growing again in Southern Vietnam, as well as in Northern Vietnam. Initially, tractors were purchased from the cooperatives that used to own them. These new individual tractor owners often had diverse backgrounds. For example, individuals in Quang Binh Province purchased tractors from cooperatives, using the private savings accumulated through various activities like a duck-raising business (Quan 2009). Households studied by Quan (2009) in Quang Binh had invested 21

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<sup>8</sup>Currently, three-types of Kubota combine-harvesters with the typical cutting width of 1.5 ~ 2m are popular (MIT 2015); "DC - 35" (35hp) which harvest 0.1 ~ 0.3 ha / hr, and "DC - 60" (60hp) or "DC - 70" (70hp) which harvest 0.3 ~ 0.7 ha / hr.

<sup>9</sup>Resolution 10 obliged the agricultural cooperatives to contract land to peasant households for 15 years for annual crops and 40 years for perennial crops (Kirk & Tuan 2009).

million VND (about USD1,400) from their own savings on a small tractor in 2004, which was primarily used for moving the mobile saw used for wood processing. While the tractor was also used for land preparation for about 15 days a year, income from the land preparation was negligible. In some cases, tractor owners provide transportation services to other farmers, in exchange for labor to harvest their rice crops (San 1989). Manure collectors also purchased tractors and gradually replaced human and buffalo carts (Peters et al. 2004).

By 1999, tractors were predominantly owned by individual farming households – 88 percent for large tractors, 97 percent for power tillers, and 98 percent for diesel engines (JICA 2000) – further deepened in 2007 (94 percent of > 35 hp, 98.5 percent of 12-35hp, and 99.7 percent of < 12 hp tractors) (Viet 2014). In Vietnam today, 2wt are widely used and account for the majority of tractors. The low cost of 2wt suggests that ownership is not solely restricted to wealthy households, but also affordable to middle-income households. As a result, the roles of cooperatives that allow joint ownership of tractors may be less significant. There has also been a significant decrease in the price of land preparation services after small tractors (12 hp) were introduced and replaced big tractor (50 hp).

Figure 12 plots the probability that a farm household provides tractor rental services, conditional on rice planting area, among 789 tractor owners aggregated from three rounds (2004, 2006, and 2008) of the VLSS. Larger rice farmers are more likely to provide rental services. This is primarily because larger farmers are generally still more likely to own tractors (albeit with relative growth of tractor ownership among smaller farms, as illustrated in Figure 5), for use on their own farms, but also for earning profits from hiring out to neighboring farms.

[Insert Figure 12]

## *(2) Government-run system*

Government-run agricultural machine stations were set up under the communist party in the 1980s, with the aim of providing affordable mechanization services to farmers and cooperatives. By 1983, agricultural machine stations were set up in 200 districts throughout the country, which could potentially handle 30 percent or more of the tilling of the arable lands in the country (US Department of Commerce 1983); slightly more than the actual area tilled by tractors in 1980 (27 percent). Additionally, 120 stations for minor repairs of tractors and 45 maintenance workshops were created throughout the country with Soviet assistance. By May 1983, 200 “machine collectives” and 100 “machine cooperatives” had been set up in Southern Vietnam, with a fleet of 3,200 tractors (Marr & White 1988 p.167). In 1984, at the Sixth Plenum of the Central Committee (Fifth Congress), a plan was developed to transfer control of agricultural support stations and agencies dealing with tractor operations, irrigation, farm implement factories, etc. from the provinces to the districts (Vasavakul 2015). By 1985, there were about 300 district-level agricultural machine stations (previously called tractor stations) with a fleet of approximately 20,000 tractors of various sizes and more than 20,000 tractor operators – primarily tasked with providing tilling service for agricultural cooperatives (US CIA 1985).

In the early 1980s, some cooperatives still found it cheaper to hire draft animals from contractors rather than hiring tractors from district hiring station (White 1982). The incentive structures for station workers, as prescribed in the Government’s Directives in 1982, had not been properly implemented and workers were poorly incentivized, insufficiently compensated, and not provided with adequate protective equipment (US CIA 1985). The efficacy of these government-run systems was evident in the resulting closure of all the district tractor stations in Vietnam by

1990 after the market reforms of the late 1980s (Tan 2011).

### *(3) Collectives / Cooperatives*

Since the decollectivization that started in 1988, collectives gradually transferred the ownership of tractors to individuals (though some cooperatives still owned tractors), but these cooperatives still played important roles in coordinating land preparation. In the early 1990s, cooperatives in Northern Vietnam often provided primary plowing and harrowing services to groups of villagers using riding tractors, who would then apply secondary plowing using private animals or tractors from individual contractors (Kono & Doan 1995).

Under the New cooperative law, many former ‘agricultural production collectives’ had been converted to ‘service cooperatives’ (Scott 2008). This process was mostly complete by 2005 (Quan 2009). The main services of new cooperatives include the management of the irrigation systems and the electricity-generating facilities, the supply of farm inputs, field preparation, extension and the marketing of outputs. (Wolz 2000; Quan 2009).

These newly converted cooperatives provided hiring service through their own tractors or acted as an intermediary between farmers and individual tractor owners (often called contractors) (Takahashi 2015). Contractors were usually a local group serving households within their commune with members contributing capital to their own tractors<sup>10</sup> and some receiving government support to purchase tractors. When contracting individual tractors or buffalo owners, cooperatives often rely on competitive bidding, with a ceiling price for the land preparation service pre-determined by the representatives of the members of the cooperatives (Quan 2009). In other cooperatives, several board members jointly invested in tractors and received dividends from the profit earned through hiring (Takahashi 2015).

### *Combine-harvester service providers*

The information of combine-harvester ownership and service provision is generally limited. However, anecdotal evidence suggests that individual farmer-to-farmer model is quite common in Mekong River Delta where 75 percent of combine-harvesters in Vietnam were located as of 2014 (Viet 2014), the most common being the Japanese Kubota. Many Kubota combine owners are wealthy large farmers, cultivating 20-100 ha annually. In the Mekong Delta, 20 percent of Kubota combine owners cultivate more than 100 ha (Global Index 2011). These combine-owners hire out their services earning several hundred million Vietnamese dong (10,000 USD or more) per year after deducting costs (Global Index 2011).

## **4.4 Relatively weak government involvement during mechanization growth phase since the 1990s**

In Vietnam, as in some other Asian countries, the government’s direct policies towards mechanization followed the growth rather than led it for the period up to the 1990s when the mechanization substantially took off. For example, information of subsidies in Vietnam up to the 2000s is limited, suggesting that subsidies were not widely provided. Only in 2009 did the government take a proactive policy on mechanization through Resolution 48/NQ-CP that aimed at reducing rice post-harvest losses from the current 11-13 percent loss down to a 5-6 percent loss by

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<sup>10</sup>Communes are the lowest governmental administrative units in Vietnam. A commune is usually a homogeneous community in terms of topography and livelihood activities. The concept of a modern commune relates more to the term ‘community’ than to the term ‘collective ownership’. Typically, there are between 15 and 35 communes in a district, and within a commune there are typically 5 to 10 villages or ‘hamlets’ (Quan 2009).



2020 (Nguyen-Le-Hung & Hien 2014), Decision 68/2013/QD-TTg<sup>11</sup> in 2013, and Decision 08/2014/TT-BNNPTNT to deal with credit policies to reduce postharvest losses and to improve mechanization in post-harvest operations, aiming for providing the subsidies on interest rates for selected machines and equipment, provided to Cooperatives, farmers' groups, households and individuals (listed in that priority order).

Other policies had been implemented in the past, but had relatively limited effects on the growth of mechanization. For example, the National Center for Testing of Agricultural machinery issued permits for locally mass-produced or imported equipment. However, after 1990, this agency became self-financed with a reduced role and scope (no longer in charge of Southern Provinces) and was renamed Center for Evaluation of Machines and Equipment. The agency liberalized the applications of diverse machinery in agriculture, but it also allowed for more low-quality imported second-hand machines that were unsuitable for production and resulted in losses to farmers using these machines.

## 5 Conclusions

Vietnam has reportedly experienced rapid growth in agricultural mechanization lately. However, available information about the historical growth patterns of mechanization in the country has been rather vague. Significant knowledge gaps exist regarding the actual extent of mechanization, heterogeneity of adoption patterns across regions and farm sizes, and the characteristics of emerging suppliers of machines and hiring services.

As far as tractors are concerned, available evidence indicates that tractor adoption rates in Vietnam reached moderately high levels by 1980 (close to 30 percent of the entire country and even higher in Southern Vietnam), albeit very different socio-political systems than today. Future studies must investigate how such exposures might have contributed to the resurgence of tractors in the 1990s.

Substantial public investments including those in agricultural R&D and irrigation infrastructure, as well as the acceleration of the economic transformation in the county, are likely to have stimulated the demand for increased farm power use after the economic and social reforms in the late 1980s. The mechanization patterns have been highly divergent across regions, characterized by the growth in the smallholder-dominated deltas and the land-abundant regions of Central Coast. Machine use has been largely enabled by rentals rather than ownership. While machinery use and tractor ownership was originally concentrated among larger farmers, they have gradually spread to smaller farms, enabling many smallholders to stay competitive in the face of rising farm wages. However, the past few decades have also seen an increase in the areas cultivated for crops such as rice annually through increased production frequency enabled by the expansion of irrigation infrastructure. Mechanization growth is likely to shift the comparative advantage of farming toward larger farms, where land market development may become increasingly important.

Since the economic and social reform in the late 1980s, the private sector has rapidly emerged as the major player in meeting the demand for greater farm power use in Vietnam. The fast pace of growth of the power tiller manufacturing industry during the 1990s and the shift from smaller combines to larger combine-harvesters in the last several years, is largely consistent with the predictions in earlier literature (eg., Binswanger 1986) that the supply side is generally

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<sup>11</sup> Downloaded from:

[http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?class\\_id=1&mode=detail&document\\_id=170904](http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?class_id=1&mode=detail&document_id=170904)

not a major constraint for mechanization growth in developing countries, compared to the demand side constraints even in the transition countries like Vietnam.

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**Table 1. Mechanization level and economic structure in Vietnam<sup>a</sup>**

	Year	1960	1970	1980	1990	2000	2010
% mechanized land preparation <sup>b</sup>	Nation			27	21	30-40	70
				(North - 16, South - 35 in 1977)			
% rice harvesting by combine-harvesters <sup>c</sup>						15 (2006)	35 (2013) (Mekong River Delta > 60°)
Domestic production / year <sup>d</sup>	Power tillers	0	0	0	0	~ 5000 / 6000	
GDP share (%) by economic sector <sup>e</sup>	Agriculture	North – 42 South – 40	North – 43 South – 25		35	31	23
	Industry + mining	North – 18 South – 19	North – 24 South – 16		18	19	26
	Service + others	North – 41 South – 41	North – 33 South – 59		47	50	51
Agricultural employment share (%) <sup>f</sup>		North – 83 South – 88	North – 71 South – 56		71	72	69
% of area irrigated <sup>g</sup>		22	22	31	52	61	71
% of rice area irrigated <sup>g</sup>	North			46	61	80	
	South			39	50	73	
Rice yield <sup>g</sup>	North	1.9	2.0	2.2	2.8	4.6	5.3
	South	1.9	2.2	2.3	3.4	4.1	5.2

Source: Authors' compilations from various sources.

<sup>a</sup>Regional classifications of “North” and “South” are made to capture the regional heterogeneity, even though these classifications are no longer official after the reunification in 1975.

<sup>b</sup>The approximate share (%) of land preparation done by tractors is obtained from the following sources; US Department of Commerce for 1960, Young et al. (2002) for figures in 1977, Tan (2011) for 1980 and 1990. For 2000, it is calculated based on the interpolations of various sources. These are not meant to be the exact share, but rather shown to provide some ideas about the extent of tractor uses. Specifically, it is calculated assuming the following: 10,000 power tillers cover 1% of area, 10,000 small 4wt (12-35hp) cover 2% of area, and 10,000 large 4wt (> 35hp) cover 6% of area, given the size of arable land in Vietnam, which has stood around 6 million ha. For 2000, the figure is 54% if limited to rice area (Tan 2011).

<sup>c</sup>Tan (2011) for 2006, Soni (2015) for 2013; For Mekong River Delta in 2013, Viet (2014); Reardon et al. (2014).

<sup>d</sup>JICA (2000).

<sup>e</sup>Northern Vietnam – Nguyen Tien Hung (1977) and Beresford (1989) for 1960 and 1970 (share of National Income), with the figures for 1970 the averages of 1968 and 1971; for figures from 1990, World Bank (2016). For the sector share of GDP; Southern Vietnam - Dacy (1986) for 1960 and 1970 (share of Net Domestic Product). For the Northern Vietnam, “service + others” include commerce and service, construction, transport and communications, and others. For North and Southern Vietnam in 1960 and 1970, “mining” is not included in Industry. National figures from 1986 onward are McCaig & Pavcnik (2013). Figures for 1980 are replaced by those for 1986, as the reliable figures for the early 1980s are generally unavailable.

<sup>f</sup>Employment shares; Southern Vietnam – Beresford (1986) for 1960 and 1970 (substituted for 1974). Northern Vietnam - Vickerman (1985) for 1960 and 1970 (average of 1965 and 1975). National: Ronnås (1992) for 1980 and 1990. McCaig & Pavcnik (2013) for 2000 (substituted for 1999) and 2010 (substituted for 2009).

<sup>g</sup>The share of area irrigated and rice yield is calculated using Ut & Kajisa (2006), FAO (2016) and World Rice Statistics (2016).



**Table 2. Proportion of machine rental by region, 1992-2008**

Regions	1992	1998	2002	2004	2006	2008
Red river delta	0.130	0.577	0.705	0.803	0.816	0.853
North East	0.005	0.269	0.210	0.305	0.383	0.421
North West	0.110	0.168	0.190	0.230	0.288	0.272
North Central Coast	0.260	0.300	0.585	0.659	0.679	0.727
South Central Coast	0.114	0.457	0.629	0.675	0.702	0.761
Central Highlands	0.033	0.380	0.376	0.588	0.535	0.546
South East	0.063	0.489	0.431	0.507	0.444	0.459
Mekong river delta	0.491	0.699	0.713	0.742	0.690	0.668

Source: Authors' estimations based on VLSS and VHLSS.

**Table 3. Median total land cultivated per household (in square meters) by region, 1992-2008**

Regions	1992	1998	2002	2004	2006	2008
Red river delta	2442	2376	2160	2052	1980	1946
North East	3700	3394.5	3600	3310	3314	3240
North West	8899	7400	7840	7351.5	9000	8200
North Central Coast	2701	2558.5	2800	2773	2825	2545
South Central Coast	2565	2847	2500	2474	2500	2500
Central Highlands	8500	9700	10000	10000	10200	10350
South East	7000	7775	7100	8000	8000	7000
Mekong river delta	7800	7400	6400	6435	6000	6000

Source: Authors' calculations based on VLSS and VHLSS.

**Table 4. Tractor ownership by region, 1992-2008**

Regions	1992	1998	2002	2004	2006	2008
Red river delta	0.001	0.002	0.008	0.010	0.006	0.008
North East	0.003	0.004	0.009	0.012	0.011	0.012
North West	0.000	0.000	0.006	0.000	0.003	0.000
North Central Coast	0.002	0.002	0.010	0.006	0.009	0.002
South Central Coast	0.003	0.012	0.007	0.010	0.010	0.009
Central Highlands	0.099	0.212	0.099	0.116	0.125	0.128
South East	0.014	0.069	0.025	0.025	0.025	0.020
Mekong river delta	0.016	0.028	0.014	0.021	0.018	0.020

Source: Authors' estimations based on VLSS and VHLSS.

**Table 5. Tractors per 1000 farm households by regions in Vietnam, 2007**

Regions	< 12 hp	12 – 35 hp	> 35 hp
Red River Delta	14.9	3.1	0.3
North East	28.3	3.3	0.3
North West	9.0	1.1	0.4
North Central Coast	12.3	3.4	0.9
South Central Coast	9.2	4.6	4.0
Central Highland	97.8	56.8	5.8
South East	23.2	10.6	3.5
Mekong Delta	21.8	7.5	7.5
Total	24.3	8.8	1.7

Source: Tsukada (2012 Table 3).

**Table 6. Real median daily wage of male agricultural labor (000 VND), 1992-2008**

Regions	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

Source: Authors' calculations based on VLSS and VHLSS

**Table 7. Regression results on machine use**

Variables	(1) 1992/98	(2) 2002/04	(3) 2006/08
Log total area of rice (all varieties)	0.00234 (0.0258)	0.0968*** (0.0317)	0.0540** (0.0235)
Log male real ag wage (VND in 1992)	-0.0729 (0.101)	0.0730 (0.0513)	0.103** (0.0436)
male household head	-0.0675 (0.0447)	-0.0308 (0.0776)	-0.0221 (0.0197)
age of household head	-0.000305 (0.00110)	-0.000135 (0.00205)	-0.000412 (0.000565)
highest education of household members	-0.0000498 (0.00749)	0.00359 (0.00851)	-0.00202 (0.00637)
number of male members	0.0403* (0.0215)	-0.0114 (0.0286)	0.00208 (0.00824)
household size	-0.0282** (0.0138)	0.00489 (0.0190)	0.00609 (0.0103)
Year dummy	0.319*** (0.0600)	0.0720*** (0.0167)	0.00906 (0.0160)
Observations	4766	2777	3780

Source: Authors' calculations based on VLSS and VHLSS.

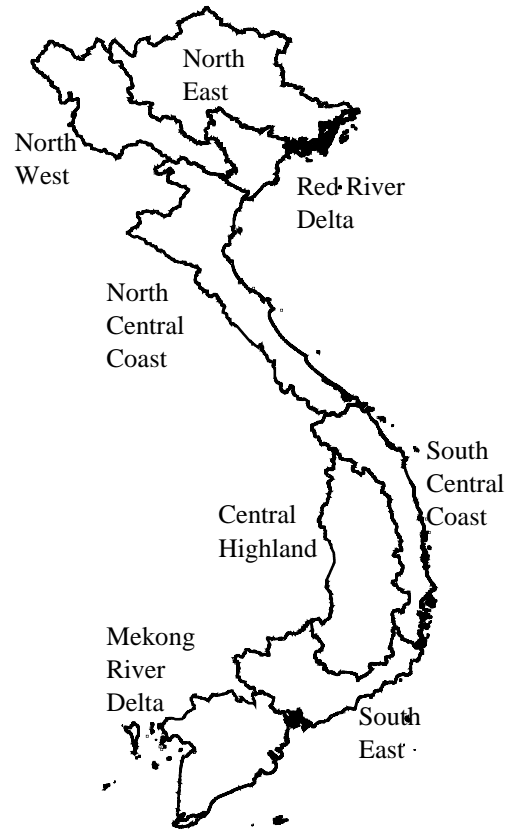
Asterisks indicate the statistical significance: \*\*\* 1%

\*\* 5%

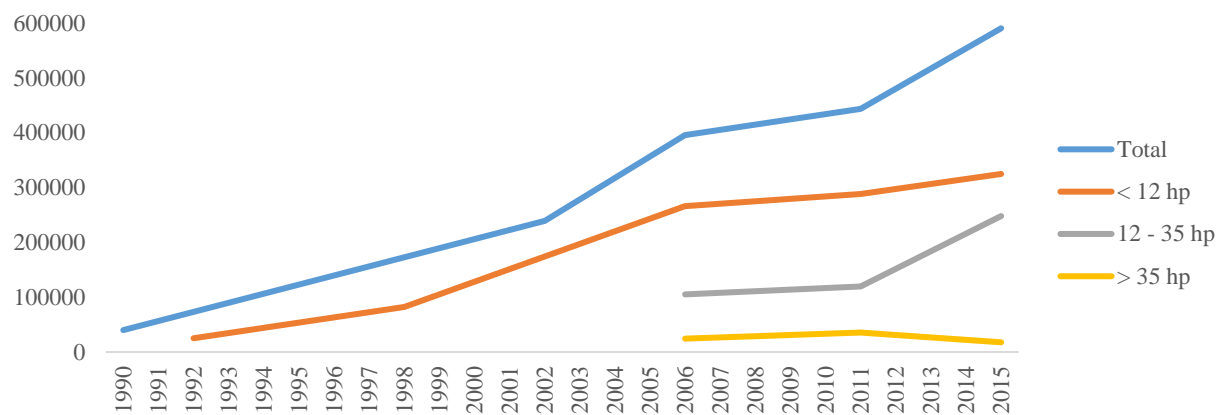
\* 10%.

Standard errors in parentheses.

## Figures



**Figure 1. Agricultural Regions in Vietnam**  
Source: Authors.

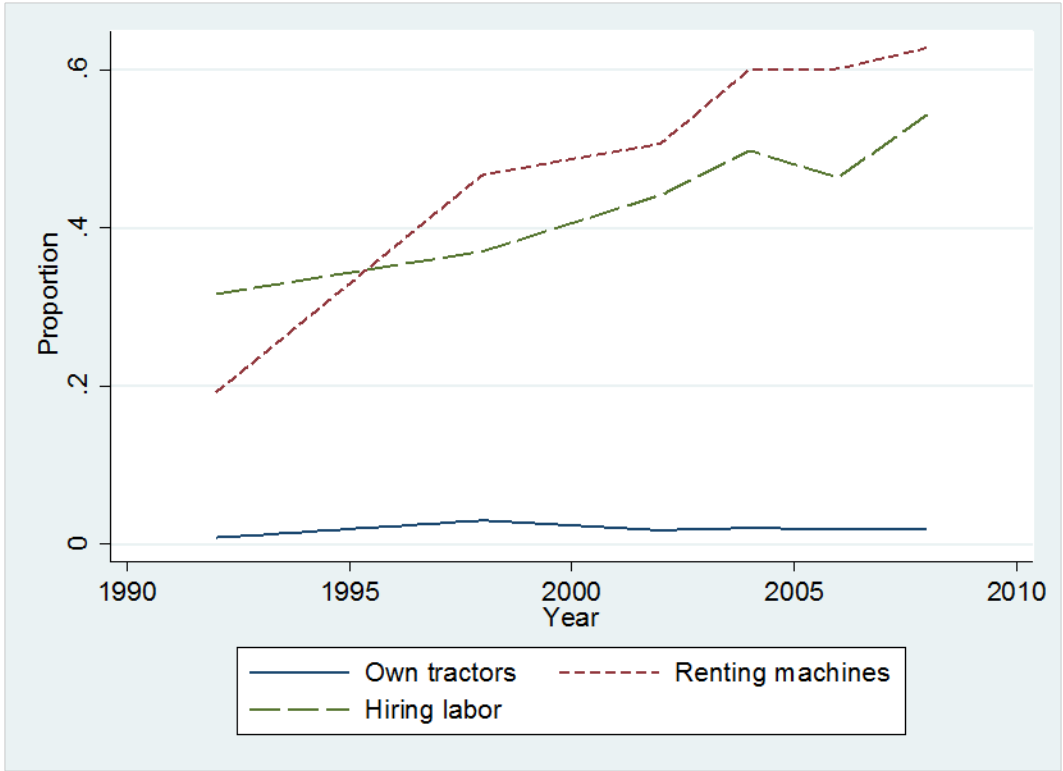


**Figure 2. Number of tractors of different horsepower in Vietnam<sup>a</sup>**

Source: Figures other than FAOSTAT (2015); figures for 2002 and 2006 are from CSAM (2014); Figures for 2011 are Viet (2011); figures for 2015 are assessed from the total figures for 2015 (Haque et al. 2016) as well as breakdowns of different horsepowers in 2014 (Viet 2014). Total in 1989 is based on Campbell (1989).

<sup>a</sup>Figures of tractors below 12hp in 1992 and 1998 are estimated assuming 2/3 of tractors in Vietnam are of this type, based on the author's assessment of VLSS.

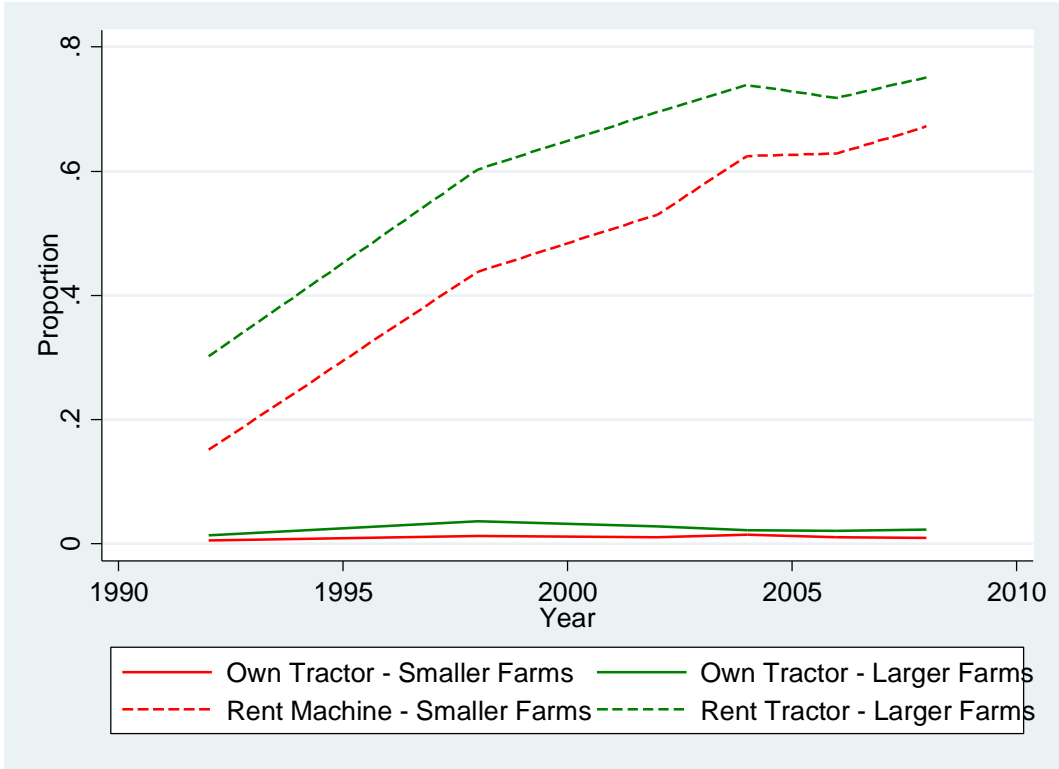




**Figure 3. Trend of tractor ownership, machine renting, and labor hiring for all farming operations in Vietnam, 1992-2008**

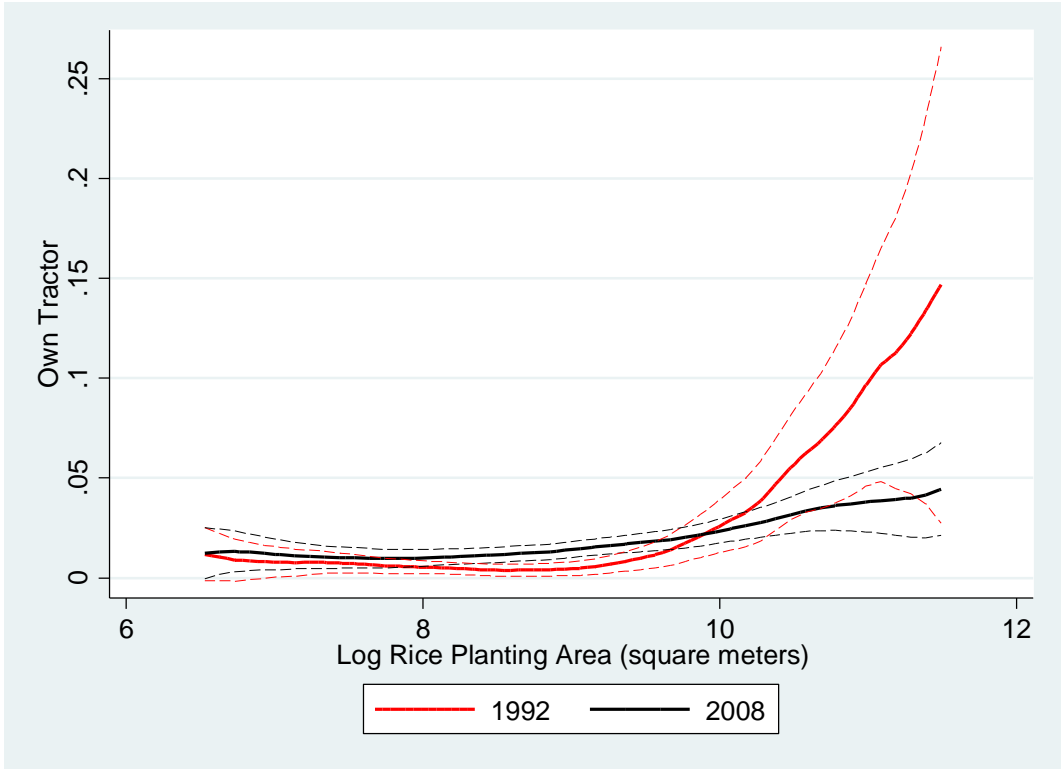
Source: Authors' calculations based on VLSS.

<sup>a</sup>Proportion is in terms of households, and not weighted by areas.



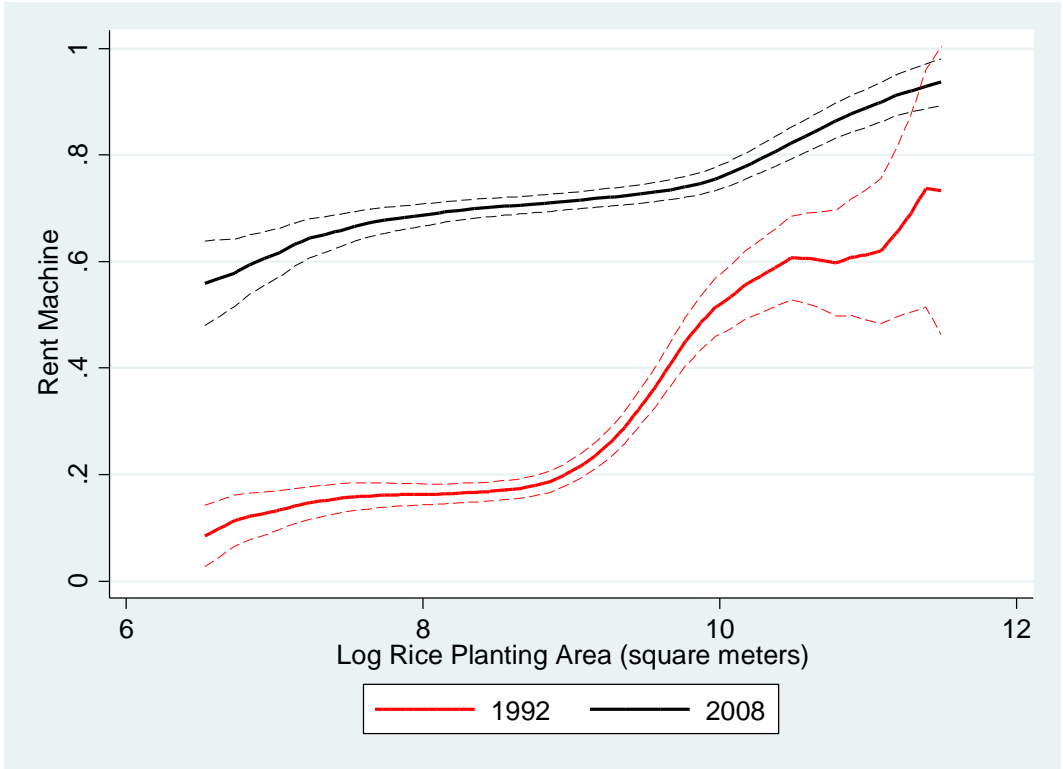
**Figure 4. Tractor ownership and machine rental for larger and small holders, based on rice planting area, 1992-2008**

Source: Authors' calculations based on VLSS.



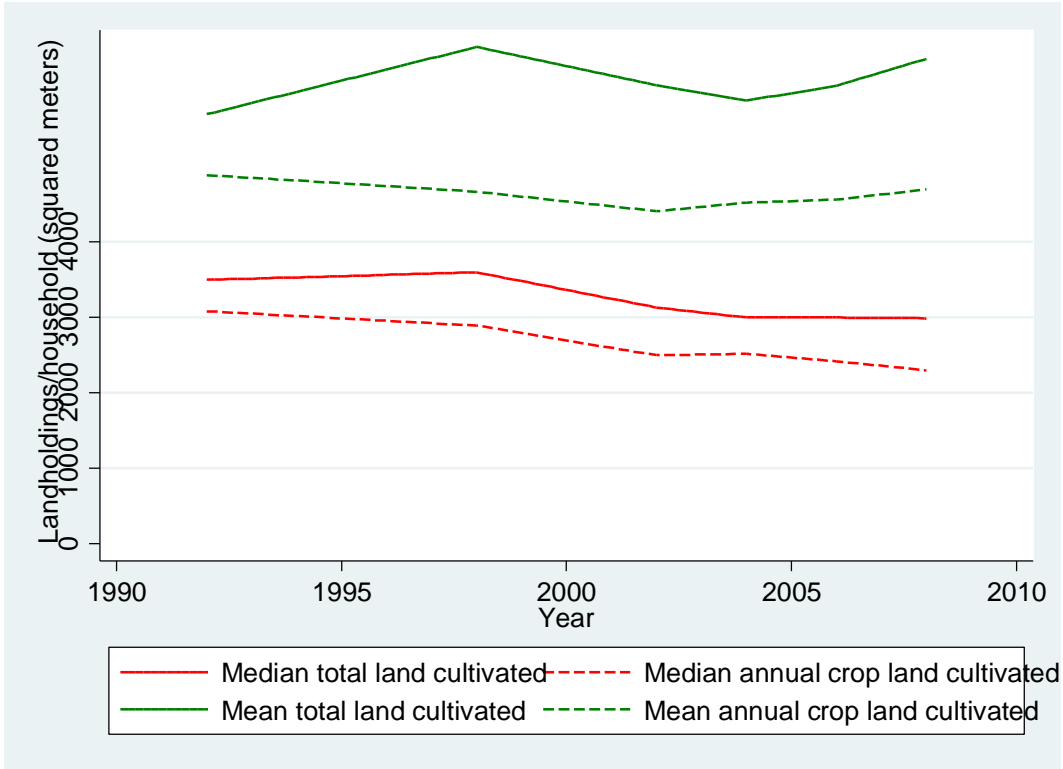
**Figure 5. Relationship between tractor ownership and rice planting area for 1992 and 2008**

Source: Authors' calculations based on VLSS.



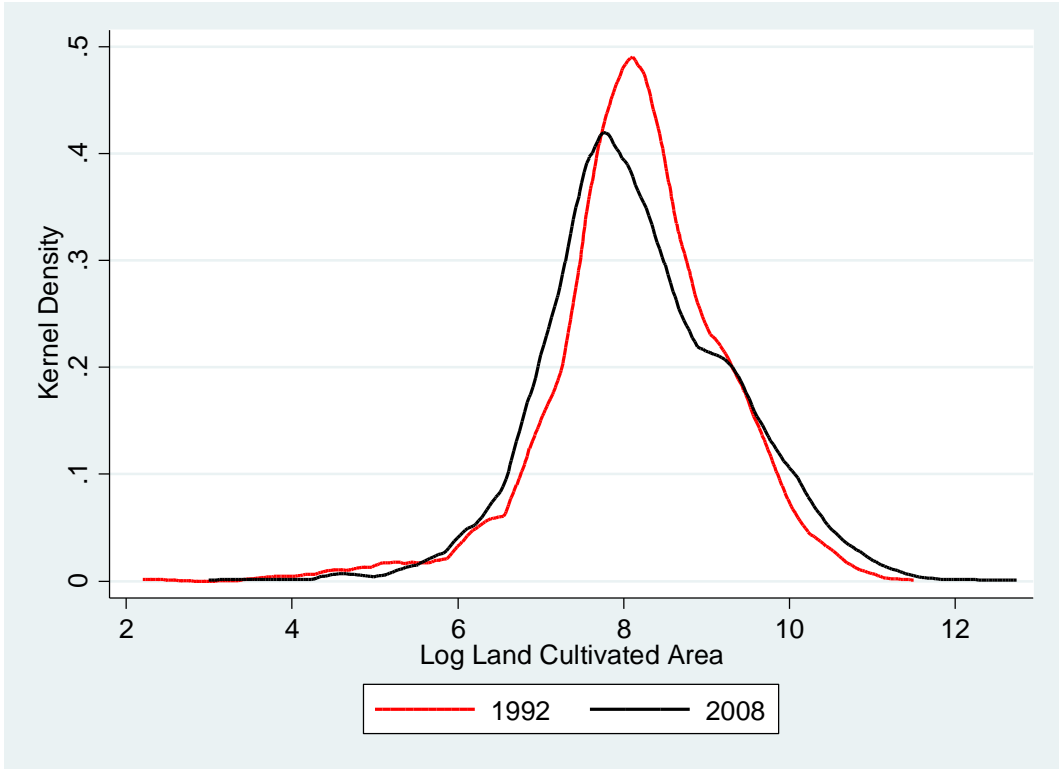
**Figure 6. Relationship between machine rental and rice planting area for 1992 and 2008**

Source: Authors' calculations based on VLSS.



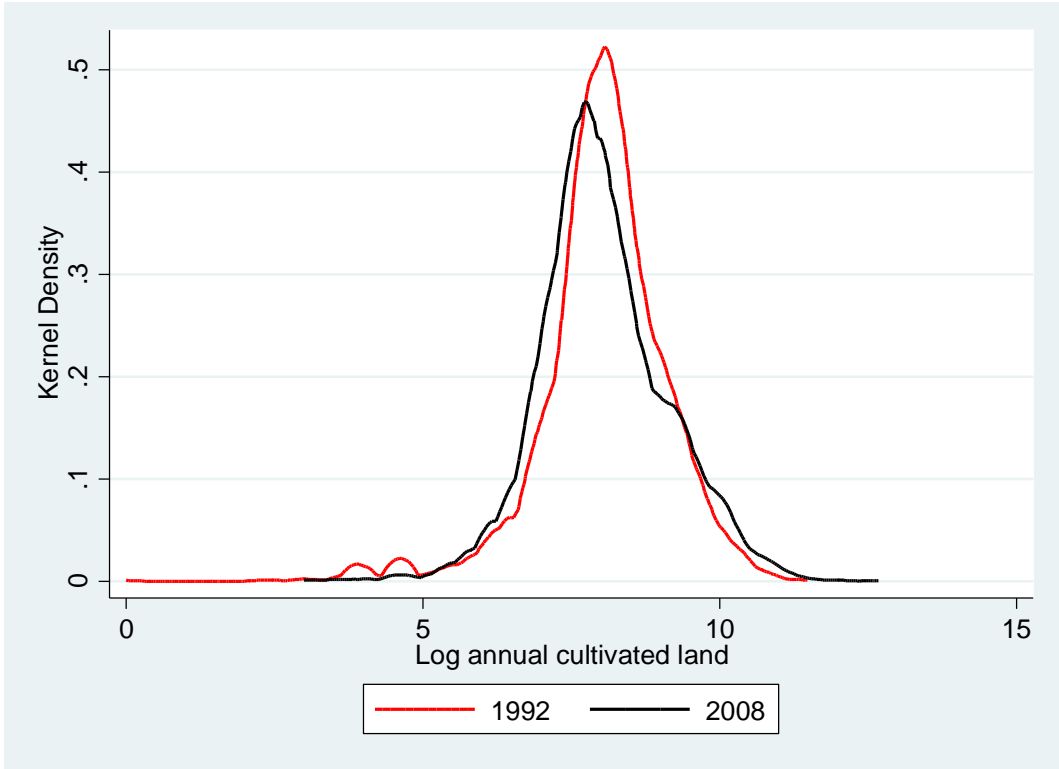
**Figure 7. Trend of total land cultivated per household and total annual crop land cultivated per household, 1992-2008**

Source: Authors' calculations based on VLSS.



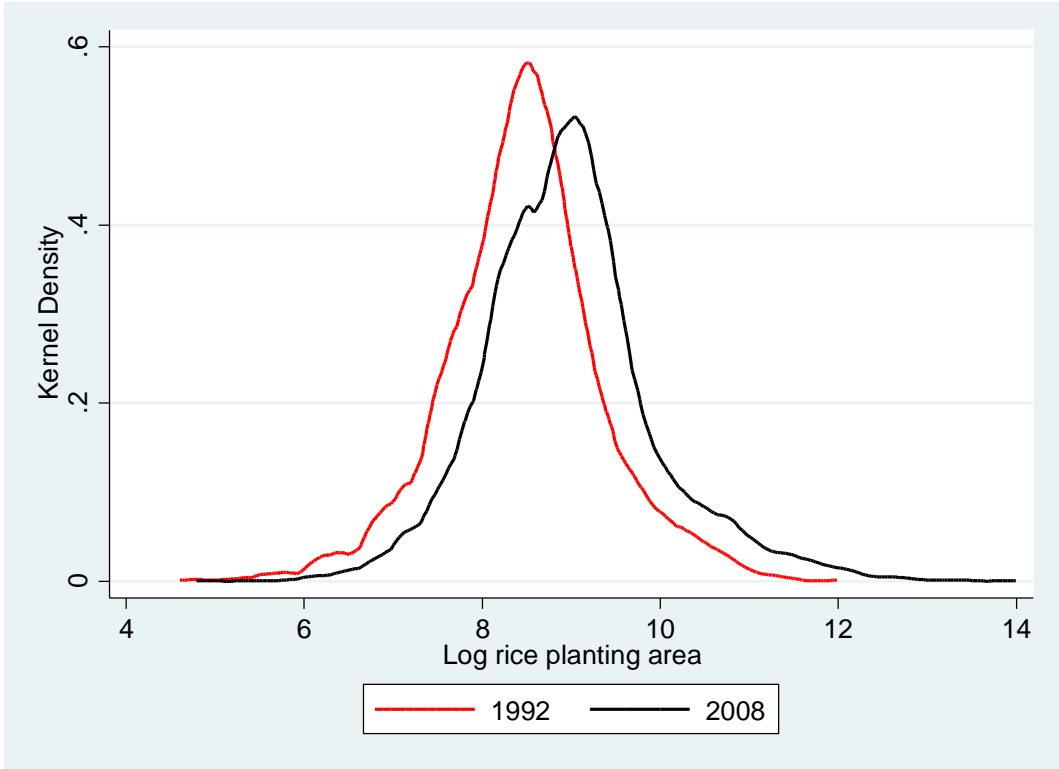
**Figure 8. Kernel density of total cultivated area in 1992 and 2008**

Source: Authors' calculations based on VLSS.



**Figure 9. Kernel density of total annual crop land in 1992 and 2008**

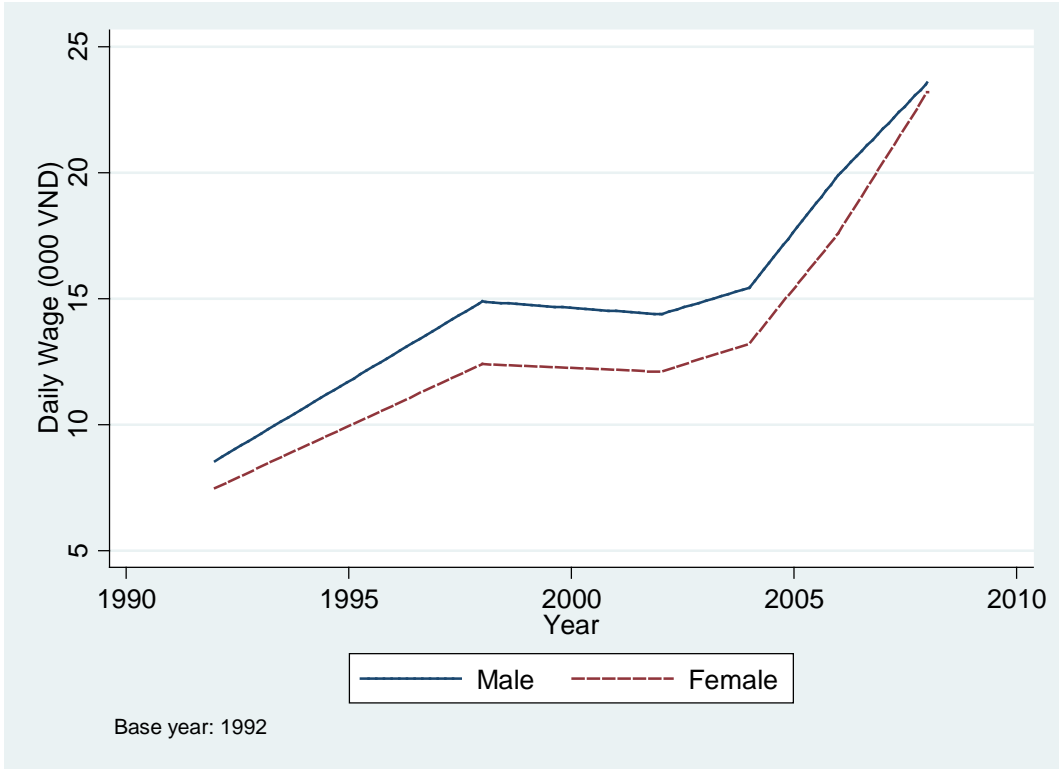
Source: Authors' calculations based on VLSS.



**Figure 10. Kernel density of rice planting area in 1992 and 2008**

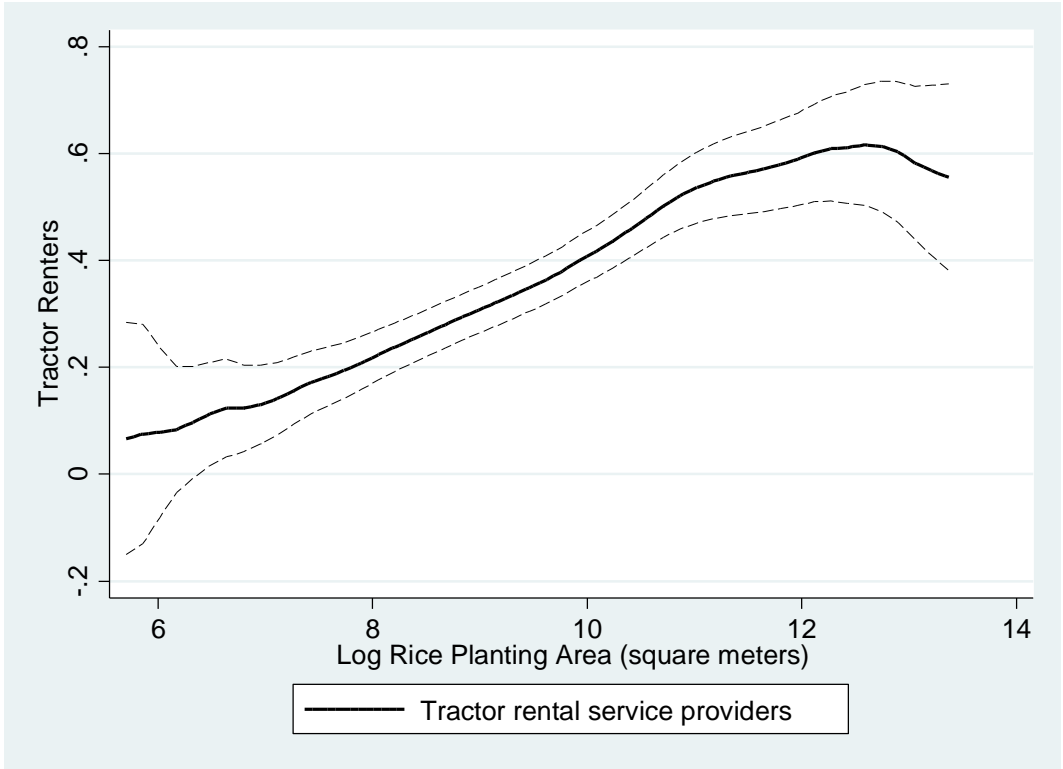
Source: Authors' calculations based on VLSS.





**Figure 11. Median daily real male and female agricultural wage, 1992-2008**

Source: Authors' calculations based on VLSS.



**Figure 12. Probability of provision of tractor rental services conditional on rice planting area among tractor owners from 2004-2008**

Source: Authors' calculations based on VLSS.