Effect of Labour Movement on Agricultural Mechanisation in Cambodia

Chhim Chhun, Buth Bora and Ear Sothy

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CDRI
☞ 56, Street 315, Tuol Kork, Phnom Penh, Cambodia
✉ PO Box 622, Phnom Penh, Cambodia
☎ (855-23) 881384/881701/881916/883603
🖷 (855-23) 880734
E-mail: cdri@cdri.org.kh
Website: www.cdri.org.kh

Edited by: Susan Watkins
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Contents

Figures and Tables

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Abstract

This paper looks at the effect of labour movement on farm mechanisation in rural Cambodia. The study focuses on labour movement from on-farm towards off-farm jobs, and uses investment in agricultural machinery as a proxy for farm mechanisation. Statistics show that in recent years there has been a huge outmigration from rural areas. This has had significant impacts on farming practices across the country. Farmers can no longer depend on a ready supply of labourers, which in turn necessitates more investment in agricultural machinery to maintain production and productivity. Our results are robust to checks around omitted or unobserved variable bias. Using farm wage as the instrumental variable, ivtobit regression analysis indicates that increased off-farm employment has a statistically significant positive effect on the rate of investment in agricultural machinery. Households whose members work off-farm are more likely to make investments in agricultural machinery as a direct substitute for labour. Simply put, an increase in the number of household members working off-farm induces farmers to invest more in agricultural machinery, the core factor contributing to the success or failure of agricultural mechanisation.

1. Introduction

In development, economic transformation from reliance on agricultural production to manufacturing industry and services is one of the many facets of structural change debated in the literature. Lewis (1954) was among the first economists to propound the concept of the persistence of agricultural labour surplus and consequent lower wages in agriculture than outside the sector. This wage differential induces workers to gradually move away from farm work towards employment in other sectors. The emptying out of local rural labour markets exerts greater demands on the remaining workers to increase their productivity, and their wages gradually increase in line with productivity improvements. The agro-economic structure has to shift from heavy reliance on natural resources and the weather towards more modern farming practices. The needs for productivity improvements and agriculture sector development necessitate technological innovation, farm mechanisation, knowledge and technology transfer, and agricultural infrastructure development.

Farm mechanisation is a driving force of agricultural transformation and development. Indeed, it is arguably the most important factor in increasing farm productivity as well as reducing the wage differential between the agriculture and non-agriculture sectors. Ruttan (2002) echoes this theme in his research on agricultural productivity growth, noting the rapid mechanisation of farming during the industrial revolution in the second half of the nineteenth century, especially in Europe, North America and some countries in Asia. In stark contrast, in the last two decades, few developing countries have successfully mechanised their agriculture sectors and made the transition to industrialised economies.

Cambodia is an agrarian country: 80 percent of the population live in rural areas where they rely directly or indirectly on agriculture for their livelihoods (MOP 2009). Over the last two decades, the labour force has been leaving agriculture to work in other (mostly industrial) sectors located in urban areas or shifting from farm to off-farm activities. These labour movements[1] started in the mid-1990s with the United States of America and the European Union granting to Cambodia most-favoured nation status and trade privileges under the Generalised System of Preferences. Since then, the use of machinery in agriculture has accelerated markedly. This raises the question of whether or not the causal relationship between agricultural mechanisation and the labour share in agriculture holds true for Cambodia. That is to say, a shortage of farm labour resultant of labour movement out of agriculture could lead to further expansion of agricultural mechanisation.

This study investigates whether or not labour movements affect the level of farm mechanisation in rural Cambodia. We define labour movement as the movement from on-farm towards off-farm jobs. Number of off-farm working days was used as a proxy for labour movement. We use ivtobit regression to analyse the relationship between off-farm employment and agricultural machinery investment. Investment in agricultural machinery is used as a proxy for farm mechanisation—the more investment in agricultural machinery, the more farming becomes mechanised.

The rest of this paper is structured as follows. Section 2 provides an overview of the literature on other countries' experiences in farm mechanisation while Section 3 reviews the situation of agriculture, migration and farm mechanisation in Cambodia. After describing the econometric models and estimation methods used for analysis, Section 4 looks at the relationship between off-farm employment and farm mechanisation. Empirical findings are presented in Section 5 and the results discussed in Section 6. Section 7 concludes and offers some policy recommendations.

1 "Labour movement" here refers only to that between on-farm and off-farm jobs.

2. Literature review

Most studies of agricultural transformation have focussed on the impacts of farm mechanisation on agricultural productivity and rural labour markets. In the early 1950s, China's scholarly community was divided between two opposing views on agricultural mechanisation (Hsu 1979). Mao Tse-tung argued that there would not be enough capital and labour to mechanise agriculture in the absence of collectivisation, whereas Liu Shao-chiheld that agriculture must be mechanised first. Later, Duff (1978) and Johnston and Kilby (1975) refuted previous studies on farm mechanisation as most of these ignored its indirect impacts, which they believed also played a significant role in development.

Ahammed and Herdt (1983) looked at both the direct and indirect effects of mechanisation in the Philippines. Holding the quantity of irrigation water constant, they found that a 1 percent increase in consumer spending on rice would maximise direct and indirect employment if production switched from traditional buffalo-pulled ploughs to power tillers with gravity irrigation systems; the higher the level of mechanisation, the greater the increase in employment from improvements in irrigation. However, the benefits of mechanisation to households largely depend on how mechanisation has evolved. Tractors and threshers divert income from hired labour to landowners, while power tillers used with hand threshing increase hired labour income. Given that the main objectives were to increase rice production, boost employment and improve income equity, Ahammed and Herdt (1983) concluded that the Philippines should increase the proportion of output produced with intensified irrigation rather than through intensified mechanisation of rice production.

In a similar study, Hamid (1972) recognised both the advantages and disadvantages of mechanisation. On the positive side, he argued that mechanisation helps increase overall production, though optimum yields also depend on other factors such as seedbed preparation, proper planting and seeding rates, proper fertiliser use and timely water distribution. In addition, mechanisation reduces dependence on animal traction for tillage. Apart from low productivity and high costs, draught animals require fodder which takes up land that would otherwise be available for growing food for human consumption. On the negative side, in poor countries where capital is in short supply but labour is abundant, resources should be diverted to labour-intensive industries rather than agriculture. Mechanisation may displace labour. That in turn can lead to social unrest if other sectors cannot absorb displaced rural workers. Hamid (1972) concluded that large tractors displace labour, but smaller ones do not. Small machines such as power tillers (two-wheel tractors) displace only draught animals. In fact, they generate more employment opportunities, help improve small farm productivity and reduce income disparities. Prihar and Sidhu (1984) confirmed these results, reporting that tractor-operated farms use more labour than bullock-operated farms though the latter use slightly more family labour. They concluded that there should be no fear of labour displacement by tractors.

The relationship between mechanisation and farm employment is less clear. Some studies suggest that it is a lack of labour that forces mechanisation, while others argue that it is mechanisation and the associated increase in productivity per worker that lead farmers to substitute machines for labour, thereby swelling the movement of workers out of rural areas. Reimer (1984) found little direct evidence to suggest that individual farm households experience decreased demand for labour following increased mechanisation. Indeed, Ramsay (1985) discovered that mechanisation appears to have greatly increased demand for agricultural labour in Thailand. Sison, Herdt and Duff (1985) reached contradictory results, however. They contended that the

major effect of the adoption of mechanical power in rice-growing areas of the Philippines has been a significant reduction in labour requirements. Family labour and/or hired labour inputs fell with the use of two-wheel tractors in land preparation, whether singly or in combination with animal draught power.

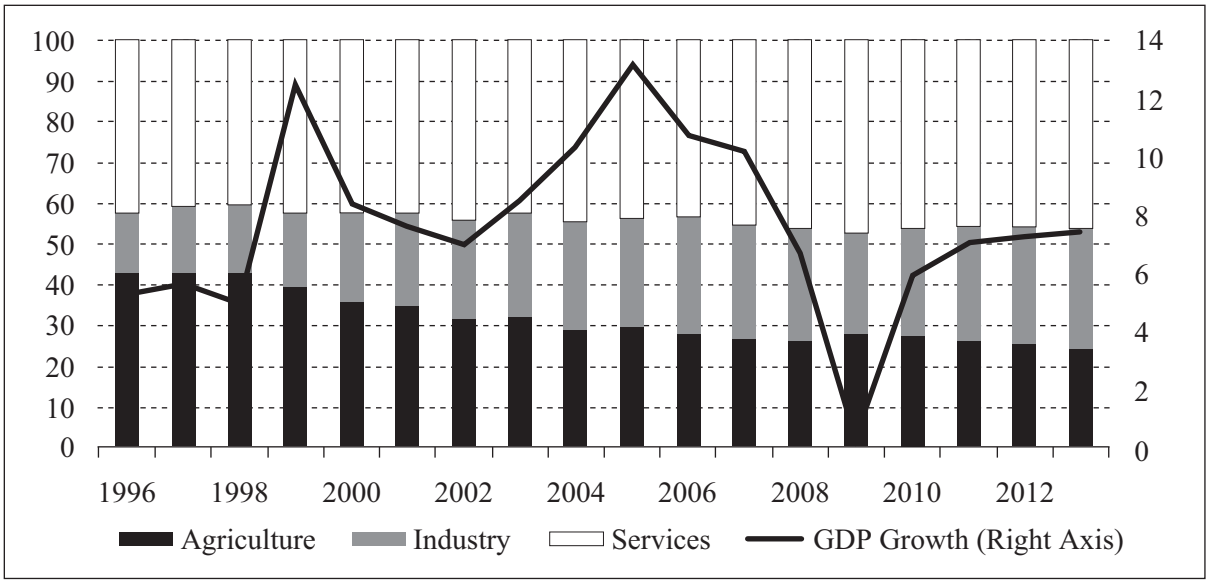
In contrast, Oshiro (1985) found a reverse causal direction. He claimed that the rapid mechanisation of rice production in Japan during the 1960s and 1970s started initially as a response to labour scarcity and only then did it begin to replace labour on all size classes of farms. The mechanisation of small-scale rice production has changed the demographic structure of farm households. Because of the difficulty of expanding paddy holdings, the labour saved from mechanisation has resulted in the movement of farm household members towards non-agricultural employment.

3. Agriculture, migration and farm mechanisation in Cambodia

3.1 Overview of agriculture

Cambodia is going to reach lower-middle-income status within the next few years and is expected to attain upper-middle-income status by 2030 (RGC 2014). Annual GDP growth rate averaged 8 percent over the decade 2003 to 2013, peaking at 13.3 percent in 2005. Hit hard by the global financial crisis, growth plummeted to almost zero in 2009 before rebounding to 6 percent in 2010. Robust economic growth has led to rapid structural change. Industry's share of GDP doubled from only 15 percent in 1996 to almost 30 percent in 2013, while that of agriculture steadily decreased from nearly 43 percent to about 24 percent. The service sector's share of GDP has remained steady, hovering around the 40 percent mark (Figure 1).

Figure 1: Output by sectors and annual GDP growth rate, 1996 to 2013 (percent)

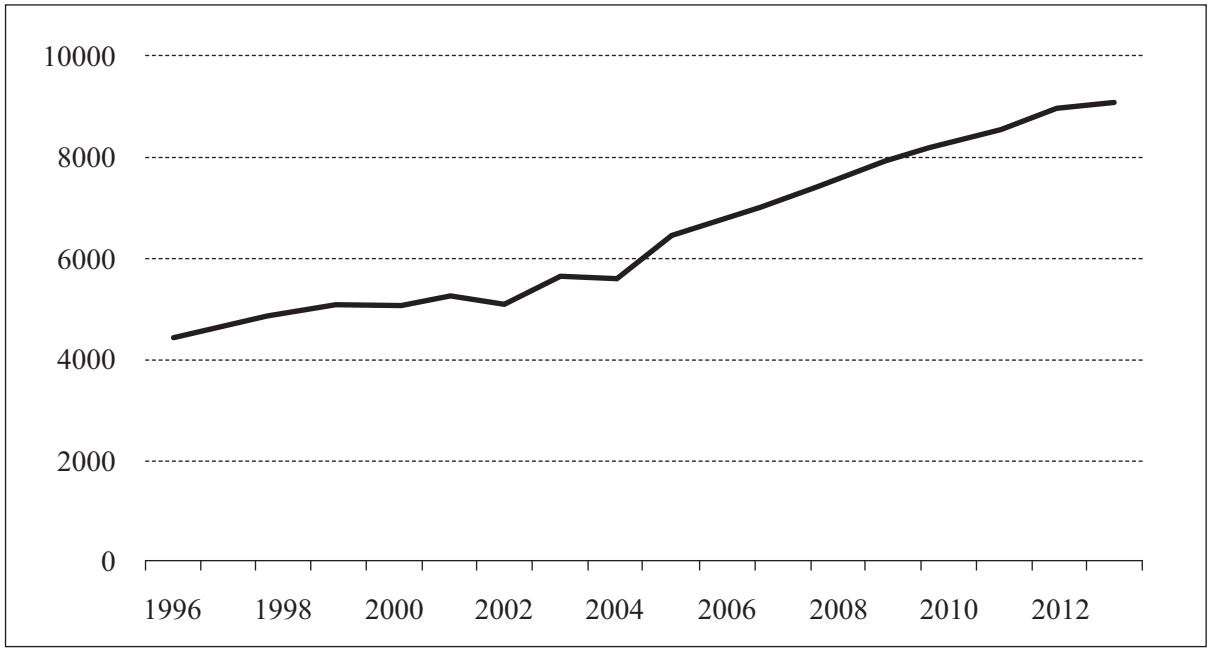


Source: Key indicators for Asia and the Pacific (ADB 2014)

Despite its relative decline in the last 20 years, agriculture is still considered the key driving force and critical foundation for building a strong and resilient economy. The sector's value added increased considerably from about KHR4500 billion in 1996 to almost KHR9100 billion in 2013 (Figure 2). Remarkably, agricultural growth remained strong (at around 5.4 percent) throughout the global financial crisis while industry was hit hard (with negative growth of up to

9.5 percent). Since then, the Cambodian government has paid special attention to agricultural development with a policy focus on making the country a key exporter of milled rice, called Cambodia's "white gold", in the global market.

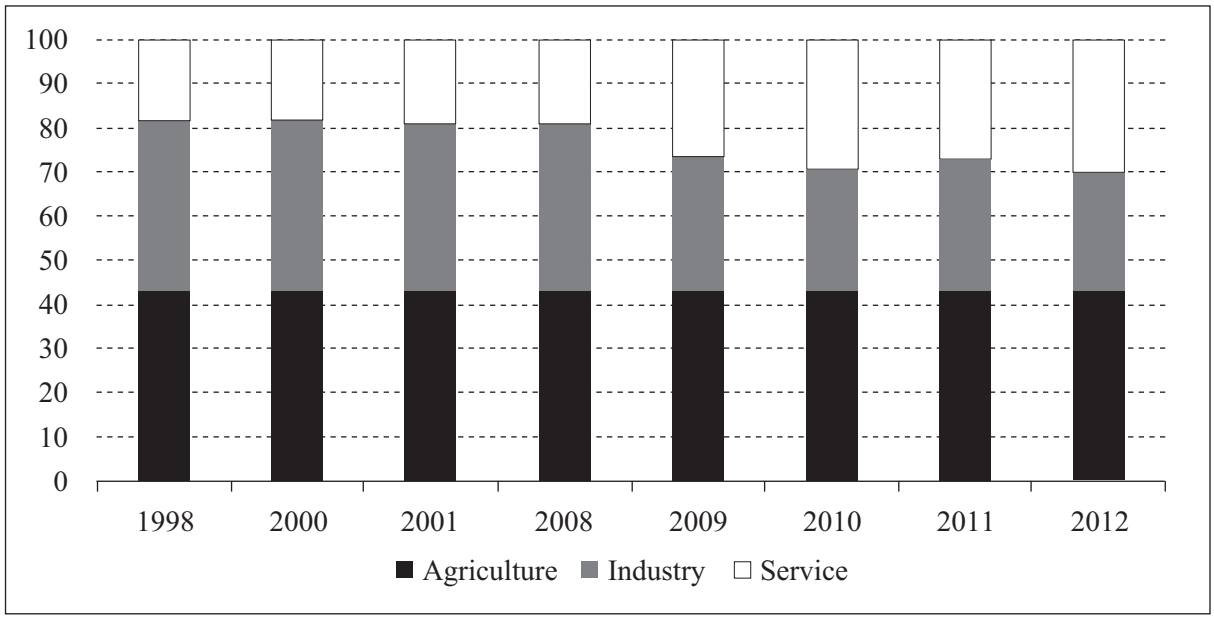
Figure 2: Agriculture value added, 1996 to 2013 (KHR billion, constant prices 2000)



Source: Key indicators for Asia and the Pacific (ADB 2014)

Figure 3 illustrates the changes in Cambodia's employment structure. Although agriculture has retained its important role as the absorber of the largest share of the labour force, this share decreased markedly from around 78 percent in 1998 to around 51 percent in 2012 while the shares of industry and services kept increasing. Employment in industry rose from only 4.2 percent in 1998 to around 19 percent in 2012 and that in services from about 18 percent to around 30 percent.

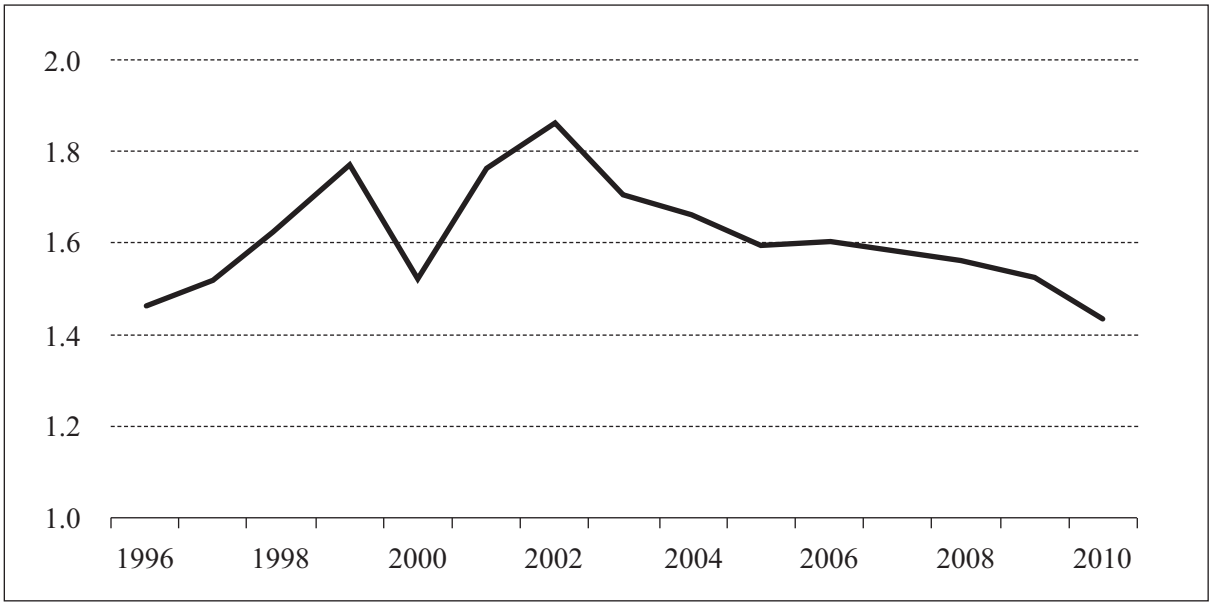
Figure 3: Employment by sector, 1998 to 2012 (percent)



Note: Data is not available for every single year over this period
Source: Key Indicators for Labour Market (ILO 2013)

As Figure 4 shows, agricultural labour density dropped continuously from 2002, from nearly two workers per ha in 2002 to 1.4 workers per ha in 2010.

Figure 4: Agricultural employment, 1996 to 2010 (workers per hectare of cultivated land)



Source: Key Indicators for Asia and the Pacific (ADB 2014); Statistical Yearbook (NIS 2011a)

The constant decrease in agriculture's employment share and employment density in tandem with the rising share of agricultural value added reflects the vast out-migration of agricultural labour and improvements in agricultural labour productivity. Largely due to the rapid and sustained growth of industry and service sectors, rural people have been leaving villages where they were mostly engaged in agricultural activities to work in urban areas, especially Phnom Penh and overseas, where industry and service enterprises are mainly located. This phenomenon has reduced the number of people employed in the agriculture sector, pushing farms to become more productive and efficient in order to sustain and increase production. Increased agricultural mechanisation is considered the best option for replacing the annual loss of labour. Consequently, more farmers have been buying farm machinery and equipment such as tractors, hand tractors and water pumps; others who cannot afford to buy their own rent machines in the farming season.

3.2 Migration

The 2008 population census records massive and rapid internal migration to Phnom Penh, particularly from rural villages. The following are some key highlights of the census results: only 30 percent of Phnom Penh residents and 54 percent of non-Phnom Penh urban residents were originally born there; 40 percent of the internal migrants in Phnom Penh and 36 percent of those in other urban areas arrived within the last five years; and, in 2008, one in 12.5 Phnom Penh residents had been living there for less than one year. Census data clearly indicates a huge influx of people into Phnom Penh over a short period of time.

More recently, in 2011, the Ministry of Planning conducted a country-wide survey of rural-urban migration aiming to identify the reasons for migration and the characteristics (urban and rural) and destinations of migrants (MOP 2012). The survey discovered a moderately high negative net migration rate in rural areas. Shown in Table 1, the average annual net migration

rate for rural villages in 2011 was minus 40 (i.e. an average of 40 migrants per 1000 rural villagers). Put another way, overall, rural villages lost some 4 percent of their population, and around 5 percent of rural people migrated out of their village to live in other places. Further, the distribution of net migration rates for rural villages was skewed. Majority (91 percent) of the rural villages fell into the net migration loss category while the populations in the remaining 9 percent stayed stable or increased. Basically, 12 percent of the surveyed rural villages lost more than 10 percent of their population (MOP 2012).

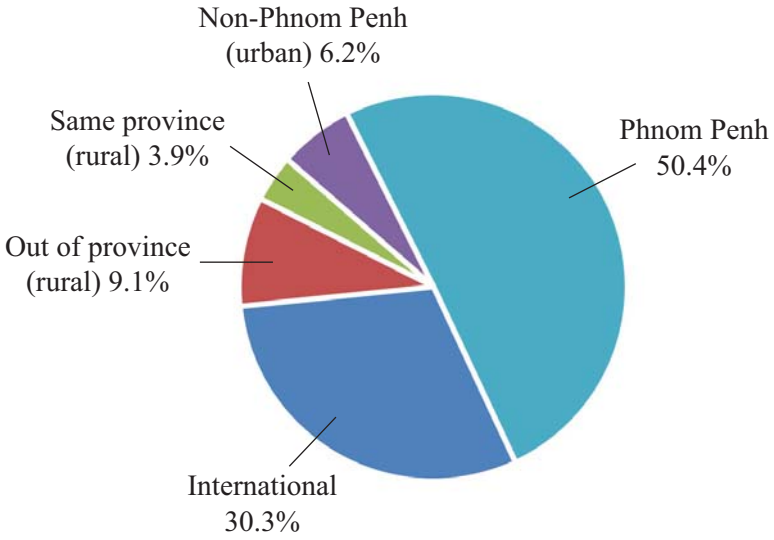
Table 1: Descriptive statistics of rural-urban migration, 2011 (per 1000 rural people)

	Out-migration	In-migration	Net-migration
Average rate	48.1	8.1	-40.0
Standard deviation of average rate	46.4	18.7	51.2
Median rate	32.7	4.6	-25.8

Source: Adapted from Report of the Cambodia Rural Urban Migration Project (MOP 2012)

Figure 5 illustrates the main destinations of rural migrants in 2011. Phnom Penh was the most popular, accounting for 50.4 percent of the total number of rural migrants, followed by international (30.3 percent), another rural province (9.1 percent) and non-Phnom Penh urban areas (6.2 percent). Few migrants (3.9 percent) moved to another rural area within the same province.

Figure 5: Rural migrants by destination, 2011 (percent)



Source: Adapted from Report of the Cambodia Rural Urban Migration Project (MOP 2012)

The main reasons for rural migration are shown in Table 2. Work-related reasons remained the dominant factor behind migration, accounting for 87 percent of the total. This result is consistent with the continual drop in agricultural labour density and agriculture's share of total employment (see Figures 3 and 4). On top of that, of the international migration, 97.1 percent was work-related while only 0.8 percent was for education and 1.9 percent for marriage. Notably, up to 13.2 percent of the migration to Phnom Penh and 20 percent of that to non-Phnom Penh urban areas was for education. The percentage of migration within the same province due to marriage was also high, accounting for 15.2 percent of the total. Essentially, work was the main single factor encouraging rural people to migrate, either to Phnom Penh or overseas.

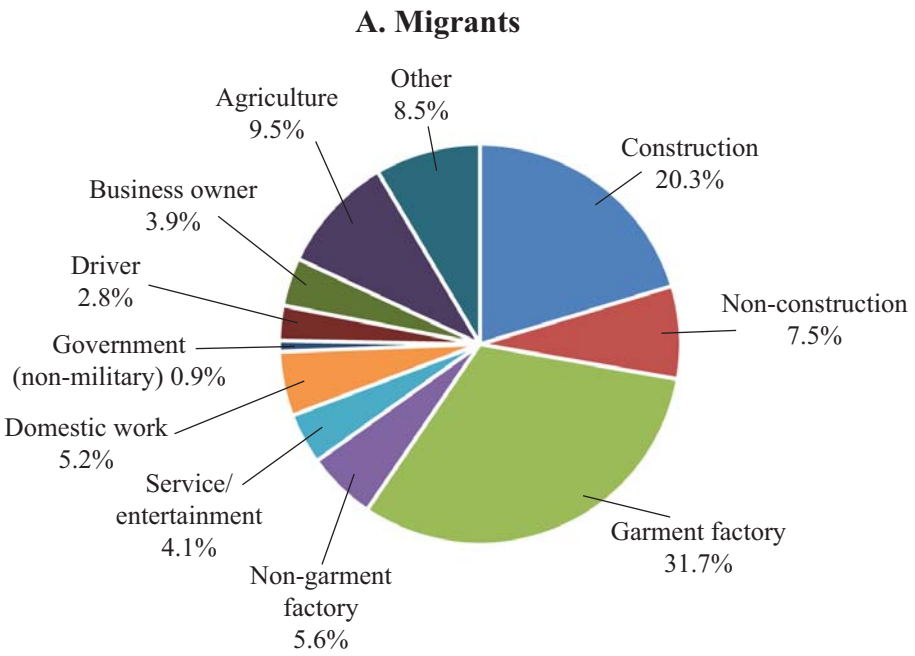
Table 2: Rural migration by destination and reason, 2011 (percent)

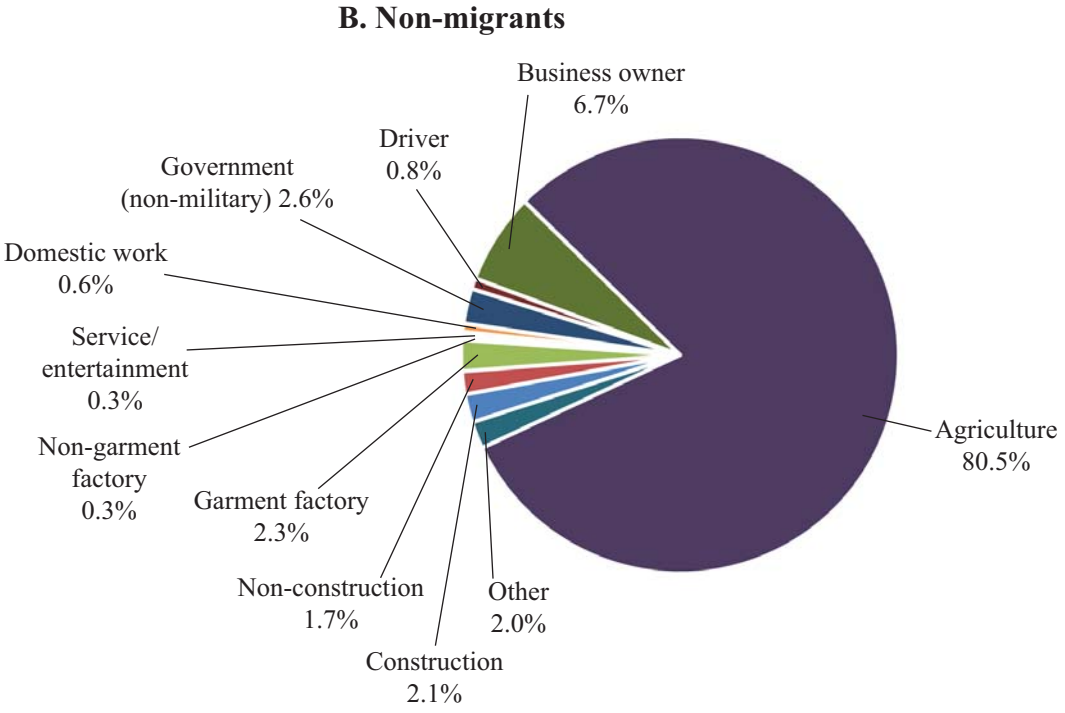
Reasons	Total sample	Phnom Penh	Non-Phnom Penh urban	Same province rural	Out of province rural	International
Work-related	87.0	85.0	75.1	72.4	79.4	97.1
Education	9.2	13.2	20.0	10.2	7.0	0.8
Marriage	3.2	1.5	4.2	15.2	11.0	1.9
Other	0.6	0.3	0.7	2.2	2.6	0.2
Total	100	100	100	100	100	100

Source: Adapted from Report of the Cambodia Rural Urban Migration Project (MOP 2012)

Figure 6 illustrates significant differences in the distribution of migrants and non-migrants by occupation. The majority of migrants took up work in the two main industrial subsectors—garment manufacturing (31.7 percent) and construction (20.3 percent), while 9.5 percent were employed as agricultural workers and 7.5 percent as non-construction workers. Not surprisingly, the dominant occupation was agriculture for 80.5 percent of non-migrants, followed a long way behind by business owner (6.7 percent).

Figure 6: Migrants (A) and non-migrants (B) by occupation, 2011 (percent)





Source: Adapted from Report of the Cambodia Rural Urban Migration Project. (MOP 2012)

All in all, the survey data indicates massive migration from rural areas. The largest population flows in 2011 were from rural villages to Phnom Penh and overseas, representing 80.7 percent of total migration. Majority of those migrants took up jobs in the garment and construction sectors.

3.3 Agricultural mechanisation

As discussed earlier, the persistent decline in agricultural labour emphasised the need to increase production and productivity through improving or increasing the use of agricultural machinery to substitute for loss of labour. As Figure 7 shows, between 2001 and 2012 the numbers of agricultural machines—tractors, power tillers, water pumps and threshers—climbed year after year. The number of tractors escalated by 244 percent, water pumps 260 percent and threshers 327 percent. But the shift to using power tillers led the way with an astounding 1365 percent increase from around 8800 in 2001 to almost 129,000 in 2012.

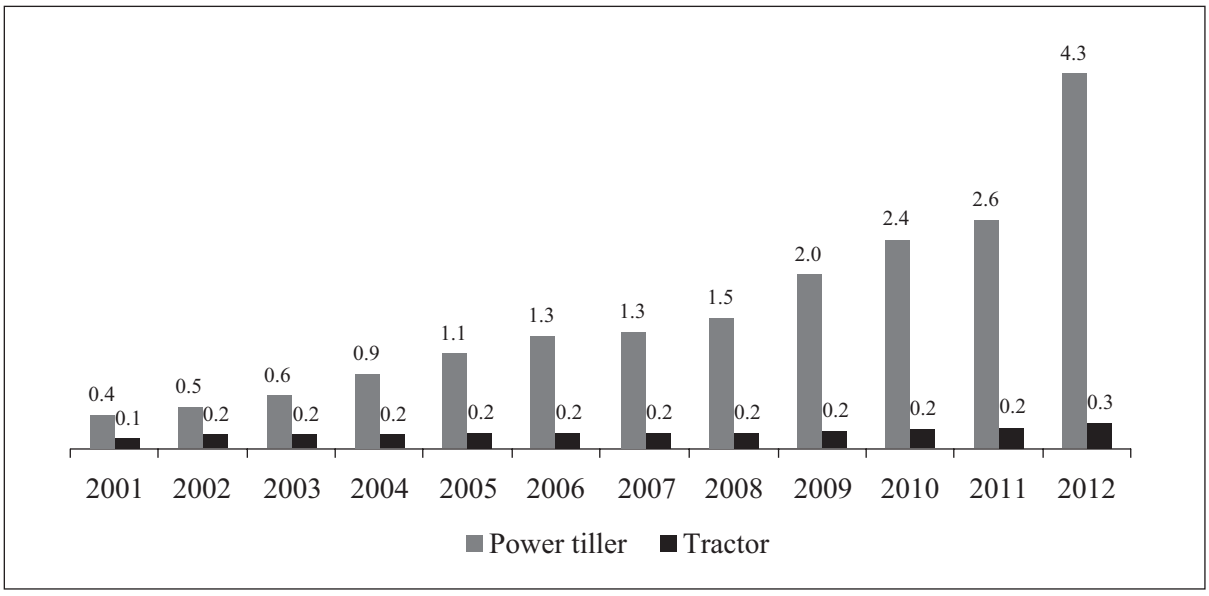
Figure 8 illustrates changes in the density of tractors and power tillers per 100 ha of riceland between 2001 and 2012. Specifically, the number of tractors rose from almost zero to 0.3 per 100 ha while the number of power tillers increased drastically from 0.4 per 100 ha to around 4.3 per 100 ha. Given the small size of farms, investment in agricultural machines has been skewed towards buying power tillers rather than tractors, suggesting a possible relationship between farm size and tractor density.

Figure 7: Agricultural machinery by type, 2001 to 2012

Year	Tractors	Power tillers	Water pumps	Threshers	Rice mills
2001	2602	8789	64406	3780	30542
2002	3293	9782	82622	4199	31507
2003	3640	13693	99825	4967	32752
2004	3857	20279	106569	6220	36531
2005	4166	26504	120969	7338	38606
2006	4215	32485	127610	7765	38618
2007	4475	34639	131702	8036	38680
2008	4611	38912	136061	8237	39429
2009	5495	54163	164932	13936	48020
2010	6202	66484	152289	13922	47960
2011	786	77421	183502	15210	48753
2012		128806	231942	16146	54428

Source: Compiled by authors based on Annual Reports (MAFF 2001-14)

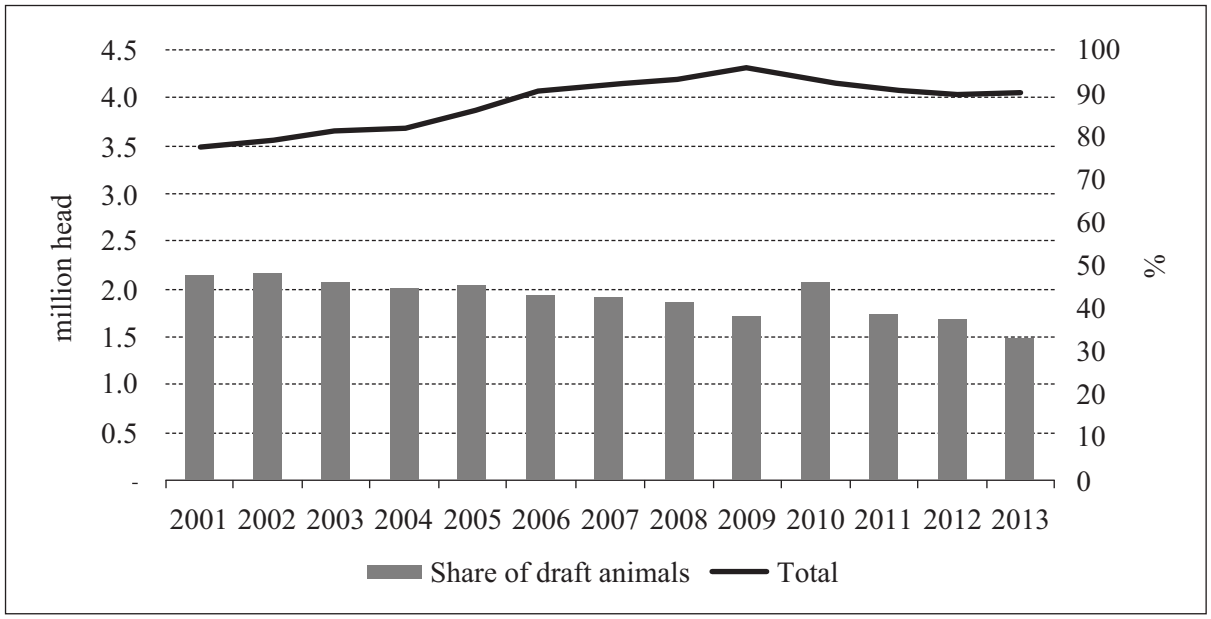
Figure 8: Power tillers and tractors per 100 ha of rice land, 2001 to 2012 (number)



Source: Compiled by authors based on Annual Reports (MAFF 2001-14) and Statistical Yearbook (NIS 2011a)

As machine use and density increased, the use of animal power declined. Figure 9 shows the declining number of draught animals versus the growing number of cattle between 2001 and 2013. Except for 2010, the share of draught animals in the national herd dropped year after year from 47 percent in 2001 to 33 percent in 2013, while cattle numbers grew from 3.5 million head in 2001 to 4.3 million head in 2009 before tailing off to around 4 million head in 2013.

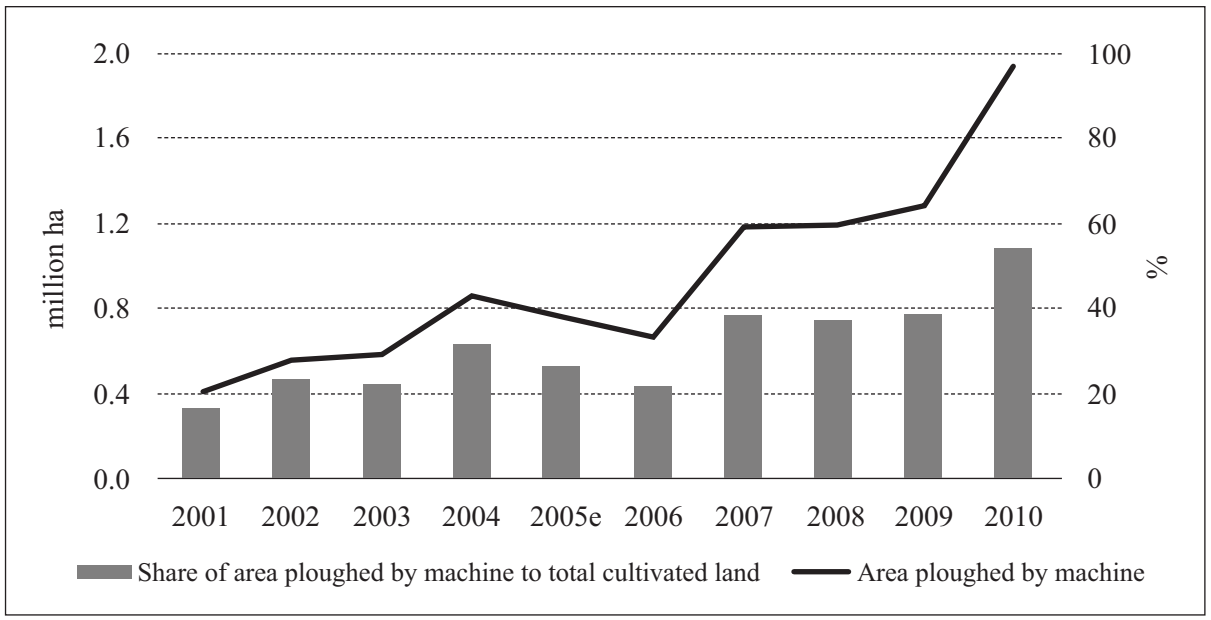
Figure 9: Number of cattle and share of draught animals in national herd, 2001 to 2013



Source: Compiled by authors based on Annual Reports (MAFF 2001-14)

The spread of farm mechanisation increased the area of cultivated land, as depicted in Figure 10. The area of land ploughed mechanically increased from about 500,000 ha or 16 percent of total cultivated land in 2001 to almost 2 million ha or 54 percent of total cultivated land in 2010.

Figure 10: Area ploughed by machine and its share to cultivated land, 2001 to 2010



Source: Compiled by authors from Annual Reports (MAFF 2001-14) and Statistical Yearbook (NIS 2011a)

4. Methodology

4.1 Data

This study used data from Cambodia Socio-Economic Survey (CSES) 2011, undertaken by the National Institute of Statistics under the auspices of the Ministry of Planning (NIS 2011b). It is a nationally representative survey of 3600 households in 360 villages across the country. The CSES records household-level data about housing conditions, education, economic activities, household production, income, consumption, health, and victimisation. For the purposes of our study, only rural households were taken into account.

Few types of agricultural machinery are used in Cambodia. Hence this study focuses on tractors, water pumps, threshers and hand-tractors (*kou yon*): 26 percent of surveyed households possessed at least one of these machines in 2011.

4.2 Econometric models and estimation methods

Estimates of the effects of off-farm employment on investment in agricultural machinery are based on cross-sectional regressions. This approach is expressed in the following two-equation system:

$$l_i = x'_i\pi + \mu_i \qquad (1)$$

$$y_i = x'_i\beta + \alpha l_i + \varepsilon_i \qquad (2)$$

where y_i is the total amount of money (KHR million) a household has invested in agricultural machinery (hereafter investment); l_i is off-farm employment defined as the number of days a household spent on off-farm activities[2] in the previous month; and x_i, with the property $E(x_i\mu_i) = E(x_i\varepsilon_i) = 0$ denotes a vector of observed determinants of investment, which may also determine employment decisions. This exogenous vector may include household characteristics, household head characteristics, household assets and farm size. The unobserved components of investment and off-farm employment level are captured by ε_i and μ_i, respectively, and subscript *i* represents individual sample households.

The coefficient α is the effect of off-farm employment on machinery investment. The coefficient α estimated by ordinary least squares (OLS) is not appropriate when the dependent variable is censored, as OLS provides inconsistent estimates. To overcome this censoring issue, we employ Tobit model (Wooldridge 2002, 2003; Cameron and Trivedi 2009; Hill, Griffiths and Lim 2011). The two-equation system can then be rewritten:

$$y_i = max\ (0, x'_i\beta + \alpha l_i + \varepsilon_i) \qquad (3)$$

Although the censoring issue has been addressed, consistent estimation of α by Tobit model requires that $E(l_i\varepsilon_i) = 0$, or that unobserved components of investment in agricultural machinery do not correlate with the level of off-farm employment (after accounting for all observed attributes). In other words, Tobit estimation gives a consistent estimate of α if and only if l_i and ε_i are uncorrelated (i.e. if l_i is econometrically exogenous in Equation 2). The most likely case to have this condition hold is when employing individuals on-farm or off-farm is randomly

2 The number of days a household spent on off-farm activities is the sum of the total number of days each labourer of the household spent.

assigned to households. If otherwise (i.e. off-farm employment correlates with unobserved components of investment), α will not be consistently estimated by Tobit.

Employment decisions in Cambodia (and most likely elsewhere as well) are not randomly assigned across the population; rather, the employment decision is self-selected on the basis of the individual's or household's unobserved characteristics. Depending on how choices are made, measurement of the differences or similarities in investment decisions between households with different levels of off-farm employment may overstate or understate the true effect of off-farm employment on investment in agricultural machinery.

There could be a variety of reasons for why employment decisions may be correlated with unobserved components of investment decisions. One convincing example is that households with more access to information might be more likely to push members to work away from the farm as they might be convinced by the media that returns in farming are lower than in non-farm jobs. In the meantime, access to information may be negatively correlated with the decision to invest in agricultural machinery. Households with more access to information may have learned that returns to investments in non-farm enterprises are better than those in farming. As a consequence, the more information farm households can access, the lower their investments in farming. Because access to information is not observed, we fail to incorporate it into the estimation framework. The Tobit estimation of Equation (3) will then produce a downward bias in the estimates. A similar negative bias is arrived at if the true effect of off-farm employment varies across the population and if households with low levels of off-farm employment have large effects (see Card 1993).

The identification of causal effects of off-farm employment on investment using Tobit could also be impaired by the selection issue due to observable and unobservable differences between households with high levels of off-farm employment and those with low levels of off-farm employment. Households that strongly encourage members to take off-farm jobs might, for example, experience low levels of investment in agricultural machinery to begin with. In this case, the Tobit estimate of α is likely to be upwardly biased.

A consistent estimate of the effect of working away from the farm on the level of farm machinery investment can be obtained if there is a component of vector z_i that affects the employment decision but does not affect the level of investment in agricultural machinery. For example, if either working on-farm or off-farm were randomly assigned, then the realisation of the random process could be used to estimate the two-equation system regression model using instrumental variables (Cameron and Trivedi 2009) as it is clear that randomisation affects only where employment should be, but does not directly affect the investment decision.[3] However, because "pure" randomisation (i.e. randomly assigned on-farm or off-farm jobs) is absent in Cambodia, it is necessary to identify a causal determinant of off-farm employment that can be legitimately excluded from the investment equation. Using this determinant in the Ivtobit (ivtobit) model estimation, we can obtain a true estimate of α. More formally, Equation (1) is replaced with the following:

$$l_i = x'_i\pi + z'_i y + \mu_i \qquad (4)$$

3 For example, draft lottery was used to generate IV estimates of the effects of military service during the Vietnam war (Angrist 1990).

We then substitute the predicted value of l_i from the estimation of Equation (4) in the fitting of Equation (3) to obtain an estimate for α_{iv}. In this IV framework, α_{iv} is identified from the variation in off-farm employment levels that is due to the variation in z_i.

In equation form, z_i is eligible to serve as IV for off-farm employment if the two following conditions are satisfied.

(i) $\text{Cov}(z_i, l_i) \neq 0$

(ii) $\text{Cov}(z_i, \varepsilon_i) = 0$

The first condition ensures that the vector z_i actually captures at least some of the variation in the level of off-farm employment (l_i). If it does not, then it is of no use in estimating the effect of off-farm employment on investment. If it does, but weakly, then z_i is viewed as a weak IV, and consequently the results could be debatable.

The second condition, which is called "exclusive restriction", ensures that z_i is uncorrelated with unobserved components of investment. If this condition was violated (i.e. z_i was actually correlated with the error term), it should be included as a covariate in Equation (1).

While it is not problematic to identify whether a particular regressor is strongly correlated with instrumental variables,[4] it is, unfortunately, not feasible to account (econometrically) for possible correlation between these instruments and the unobserved determinants of the variables of interest (Wooldridge 2006). In practice, the only way to test for correlation is to use economic theory and economic scenarios.

In labour market theory, the wage rate is the main determinant of the employment decision. People will naturally move to work in areas where wages are higher, holding all other conditions constant. One could also reasonably expect that wage does not affect agricultural machinery investments directly. Based on this economic scenario, we expect households to respond strongly to the wage rate in making employment decisions (i.e. household members will move to take up off-farm jobs if wages are high, or work on-farm if otherwise). The movement of labour, which is due to the variation in the off-farm wage, may ultimately affect household choices and levels of investment in farm machinery. If the inputs of machinery and labour are substitutes, we expect that a rise in the off-farm wage will increase investment in machinery. In contrast, if the two inputs are complements, we expect the opposite effect.

Off-farm employment involves a variety of sectors and different kinds of jobs, making it difficult to define a unique wage that can represent the whole non-farm sector. For example, the average wage of low-skill workers in the construction sector could be significantly different from the average wage of high-skill workers in the hotel industry. One way of overcoming the challenge to identifying the off-farm wage rate is to use mirror data.[5] Simply put, instead of the off-farm wage, we use the farm wage as an instrument of off-farm employment to estimate the true effect of off-farm employment on investment in agricultural machinery. The off-farm employment of households is likely to increase if the farm wage decreases. The farm wage of household *i* is denoted as w_i, and Equation (4) rewritten as:

$$l_i = x'_i\pi + yw_i + \mu_i \qquad (5)$$

4 Just see how statistically and economically significant the coefficient in the first stage equation is (Eq. 4).

5 This is not exactly mirror data as used in trade analysis, but the concept is the same.

CSES 2011 collected data on the daily wage of 10 low-skill jobs[6] at the village level, assuming that the wage does not vary across households within the same village. The average daily wage over the year was collected separately for males and females. For simplicity, we use the average wage of males and females as the single daily wage that each household earns. Farm wage refers to the wage of the following four farming activities: ploughing (animal traction), transplanting seedlings, caring for crops and harvesting.

5. Empirical findings

The variables used for empirical analysis are described in Table 3. Twenty-six percent of sample rural households own at least one farm machine, and average annual household investment in agricultural machinery is around KHR0.81 million (includes censored data); if we exclude censored data (investment>0), average household agriculture machinery investment is KHR3.02 million. Households engage in off-farm activities[7] for 39.5 days every year. On average, household size is 4.54 people, household head schooling is 4.34 years (primary school only) and household head age is 47 years. Each sample household has one migrant member. The daily farm wage is KHR14,269. Average household agricultural landholding is 1.47 ha, of which 0.68 ha is under irrigation.

Table 4 presents the results of Tobit regression to estimate the possible effects of off-farm employment on investment (Equation 2). The results indicate a negative relationship between off-farm employment and investment in agricultural machinery. Noticeably, the coefficient between the two variables maintains the negative sign even with the inclusion of extra covariates. However, the results show that there is no statistical significance between the two variables in any of the four scenarios. In each scenario, migration is statistically significant and positively related to farm machinery investment, implying that households with more migrant members tend to invest more in agricultural machinery. As discussed in the methodology in Section 4, this result could be biased due to omitted variables (e.g. access to information). Therefore, to avoid this bias and to deal with potential endogeneity problems, we use the farm wage as the instrumental variable for estimating the off-farm wage.

Table 5 provides the results of Equation 4. Regardless of the choice of covariates, the coefficient of the farm wage is negative and statistically significant. Thus, as expected, wage increases in agriculture attract more labourers to farm work and reduce off-farm employment.

6 Ploughing (animal traction), rice transplanting, caring for crops, harvesting, unskilled construction work, weaving, rattan furniture making, grill worker, tailoring and sewing.

7 For this study, off-farm activities refer to non-agricultural activities carried out by rural households.

Table 3: Definition and descriptive statistics of the variables

	Description	Mean
fm	1= household has at least one farm machine	0.26
investment	investment in agricultural machinery (million riels; current value), full sample	0.81
Investment	investment in agricultural machinery (million riels; current value), if investment >0	3.02
off_farmworkday	total number of days doing off-farm work last month by household	39.50
hhsize	household size	4.54
migrat_n	number of migrant household members	1.03
v_farmwage	daily farm wage at village level (riels/day)	14269
hhhead_age	average age of household head	46.81
hh15_64m	number of household members age 15-64 (male)	1.36
hh15_64f	number of household members age 15-64 (female)	1.53
hh_land	agricultural land owned by household (ha)	1.47
irrigted_land	irrigated agricultural land (ha)	0.68
hhhead_sex	sex of household head (1=male)	0.80
hhhead_mar1	marital status (1=married)	0.80
hhhead_mar2	marital status (1=widow)	0.15
hhhead_school_year	years of schooling of household head	4.34
hhhead_occ	main occupation of household head (1=agriculture)	0.70
region1	region (1=plains)	0.46
region2	region (1=Tonle Sap)	0.32
region3	region (1=coastal)	0.08
farm_income	net annual farm income (riels)	3000000
v_extension_worker	1=agricultural extension worker in the village	0.02
v_govent_support	1=village received technical support from government	0.48
v_ngo_support	1=village received technical support from NGO	0.48
wealth_index	asset wealth index	0.65

Table 4: Tobit regression results

Variables	(1)	(2)	(3)	(4)
	tobit	tobit	tobit	tobit
	investment	investment	investment	investment
off_farmworkday	-0.007	-0.0017	-0.0016	-0.0015
migrat_n	0.5680***	0.5625***	0.5458***	0.5440***
hhhead_age	0.0317*	0.0354**	0.0303*	0.0305*
hh15_64m	1.4055***	1.2813***	1.0874***	1.0896***
hh15_64f	0.1522	0.1236	-0.0484	-0.0478
hh_land	0.8212***	0.8802***	0.7367***	0.7358***
irrigted_land	0.8536***	0.8021***	0.7625***	0.7626***
hhhead_sex	0.5769	0.7473	1.0316	1.018
hhhead_mar1	2.5156	2.2731	2.1248	2.164
hhhead_mar2	0.5551	0.6913	0.8964	0.9263
hhhead_school_year	0.2596***	0.2831***	0.1955***	0.1962***
hhhead_occ		1.7881***	2.2225***	2.2074***
region1		1.9866***	1.7535**	1.8318**
region2		1.2499	1.1028	1.1534
region3		-0.3887	-0.7114	-0.6403
farm_income			0.00002	0.00002
wealth_index			0.5755***	0.5798***
v_extension_worker				-0.4131
v_govent_support				-0.1014
v_ngo_support				0.1711
constant	-14.3865***	-17.3176***	-16.6397***	-16.7632***
N	1862	1862	1862	1862
Pseudo R2	0.0658	0.0712	0.0774	0.0775

Note: Significant at ***1 percent, **5 percent and *10 percent; explanatory variables listed in Table 4.

Table 5: First stage of ivtobit regression results

Variables	(1)	(2)	(3)	(4)
	first stage	first stage	first stage	first stage
	off_farmworkday	off_farmworkday	off_farmworkday	off_farmworkday
v_farmwage	-0.0004**	-0.0004**	-0.0004**	-0.0004**
migrat_n	-0.1453	-0.1599	-0.179	-0.1727
hhhead_age	0.0582	-0.0178	-0.0211	-0.0259
hh15_64m	11.8616***	12.2332***	12.1366***	12.0657***
hh15_64f	12.6101***	12.4698***	12.3388***	12.2949***
hh_land	-1.2082**	-0.9520*	-0.7275	-0.6731
irrigted_land	-1.2658*	-1.3315*	-1.3868*	-1.4093**
hhhead_sex	4.2194	2.9299	3.2985	3.4597
hhhead_mar1	-4.3454	-2.3255	-2.4284	-2.4655
hhhead_mar2	0.3779	-0.9735	-0.8397	-0.6656
hhhead_school_year	-0.0217	-0.4043	-0.4765*	-0.4683*
hhhead_occ		-18.1486***	-17.6753***	-17.5857***
region1		3.9815	3.9626	2.7645
region2		4.0095	3.6971	2.6648
region3		2.4531	2.3121	0.6099
farm_income			-0.0002**	-0.0002**
wealth_index			0.5061	0.4705
v_extension_worker				-1.4252
v_govent_support				2.8514*
v_ngo_support				-1.4871
Constant	9.6588*	23.2094***	23.6850***	24.0100***

Note: Significant at ***1 percent, **5 percent and *10 percent. Explanatory variables listed in Table 4

Table 6 displays the results of ivtobit modelling using the farm wage as the instrumental variable for off-farm employment estimation. An increase in off-farm employment induces an increase in the level of household investment in agricultural machinery. This does mean that households substitute machines for household labour that is used off-farm. The result is sensitive to the choice of covariates. Off-farm employment (off_farmworkday) shows no statistical significance in models 1 and 2; however, when we include more variables such as farm income, wealth index, support from government and NGOs, the ivtobit regression confirms a statistically significant positive relationship between off-farm employment and agricultural machinery investment at the 10 percent level.

Also, farm incomes and wealth index variables exert a strong positive influence on investment in machinery and equipment, especially household assets. We can say that households that own more assets tend to invest more in agricultural machinery when off-farm employment

increases. Other variables such as household agricultural landholdings (hh_land and irrigted_land) and household head schooling (hhhead_school_year) also have a significantly positive association with agricultural machinery investment. Households that are more educated and have more land tend to invest more in agricultural machinery. The number of household migrant members (migrat_n) was positive and significant at the 99 percent level. This result indicates that the more migrant members the household has, the more likely it is to invest in agricultural machinery.

Table 6: ivtobit regression results of household investment in farm machinery

Variables	(1)	(2)	(3)	(4)
	ivtobit	ivtobit	ivtobit	ivtobit
	investment	investment	investment	investment
off_farmworkday	0.1559	0.2198	0.2570*	0.2683*
hhhead_age	0.023	0.0401*	0.0364	0.0382
migrat_n	0.5947***	0.5988***	0.5923***	0.5906***
hh15_64m	-0.5327	-1.4392	-2.0692	-2.1844
hh15_64f	-1.8949	-2.6258	-3.2273*	-3.3537*
hh_land	0.9965***	1.0706***	0.8993***	0.8920***
irrigted_land	1.0732***	1.1102***	1.1356***	1.1577***
hhhead_sex	-0.0912	0.139	0.2347	0.1397
hhhead_mar1	3.2288*	2.7957	2.7658	2.8457
hhhead_mar2	0.512	0.9443	1.1673	1.1643
hhhead_school_year	0.2671***	0.3760***	0.3196***	0.3232**
hhhead_occ		5.8389**	6.8540**	7.0143**
region1		1.2781	0.934	1.3032
region2		0.4201	0.2102	0.5025
region3		-0.8179	-1.1811	-0.6642
farm_income			0.0001*	0.0001*
wealth_index			0.4644***	0.4732***
v_extension_worker				-0.0111
v_govent_support				-0.8837
v_ngo_support				0.6026
constant	-15.1816***	-21.5207***	-21.6274***	-22.1197***
model Wald chi-squared	189.5***	171.6***	163.3***	157.4***
N	1862	1862	1862	1862
N_uncensored	496	496	496	496
N_left-censored	1366	1366	1366	1366
Wald test of exogeneity	0.230	0.134	0.090	0.095

Note: Significant at ***1 percent, **5 percent and *10 percent. Explanatory variables listed in Table 4

6. Discussion

In Cambodia, the rapid emergence of farm machinery in the late 2000s evoked questions regarding cost, loan payments and degree of utilisation, especially given famers' reliance on informal loans at very high interest rates to buy farm machinery and equipment. Moreover, there was concern that due to lack of information and limited knowledge, some farmers were buying machinery without knowing or looking into what they needed and without a proper cost-benefit analysis. Machinery is expensive to own and operate and depreciation costs can be high. Farmers were therefore vulnerable to "walking blindly" into a poverty trap situation of high interest payments for inappropriate and underused machines.

Even so, purchases of agricultural equipment increased as newer models were introduced, especially low-cost and user-friendly machines such as power tillers imported from Thailand. Thus factors beyond the questions of cost and utilisation, such as reduction of difficult tasks, desire for individual ownership and most importantly, as this paper finds, the scarcity of labour, are most likely to influence farmers' purchase decisions.[8] The influence of these factors needs to be examined rather carefully because of the impact they have had on poor farmers.

One of the problems facing small farm mechanisation in Cambodia is mechanical poverty. Because small-scale farmers' access to bank loans remains limited, they often have little choice but to resort to high interest rate loans from informal lenders. The issue of mechanical poverty is perceived to lie in farmers' reliance on off-farm incomes to repay loans because their farm incomes are not sufficient to cover both the cost of buying farm machinery and daily living expenses.

That said, there is no doubt that when more investment is made in mechanisation, agriculture is transformed towards modern farming. Farm labour scarcity, mainly due to the garment industry where workers are in high demand and migration to other countries, accelerated the spread of farm mechanisation. The demand for additional labour for transplanting and harvesting occurs during relatively short periods of time. In the past, the need for labour during these critical periods was met by members of the extended family or neighbouring farm households. These labour exchange systems have deteriorated over the last decade because of the outflow of labour to off-farm work in urban areas, mainly in the garment and construction sectors, as well as the outflow to other countries.

Agricultural mechanisation was initially introduced to help overcome labour shortages in agriculture, as this paper finds. The subsequent spread of mechanisation may not only have replaced out-going labour, but also increased labour efficiency, possibly resulting in shorter times to complete farming tasks.

The results of this study can make a significant contribution to transform agriculture from a traditional sector to a modern one. However, further study into the impact of agricultural mechanisation on total output (or social welfare) is required. If machine-based farming produces higher yields and, ultimately, makes poor farmers better off, then concomitant development of the non-agriculture sector will pave the way for further expansion of agricultural mechanisation, which in turn may hasten the modernisation of farming and improvements in social welfare.

8 Insight into the roles these factors play in investment decisions to buy farm machinery is essential to understanding the full context of household decision-making in rural areas.

7. Conclusion and policy implications

This paper studies the effect of labour movement on the level of farm mechanisation in Cambodia. Statistics show that there has been a vast movement of labour out of rural areas in the last decade. The majority of rural migrants moved to Phnom Penh or overseas, mainly for work. This phenomenon has affected local rural labour markets, drastically reducing the number of agricultural workers. At the same time, the numbers of agricultural machines such as tractors, power tillers, threshers and water pumps increased year after year.

Using off-farm employment and investment in agricultural machinery as proxies for labour movement and farm mechanisation, respectively, ivtobit regression analysis of the relationship between labour movement and agricultural farm mechanisation reveals that an increase in off-farm employment significantly raises farmers' investment in agricultural machinery. In other words, the movement of labour in Cambodia induces farmers to purchase or invest in more agricultural machinery, which in turn leads to further mechanisation of agriculture. Interestingly, the study also confirms a positive association between the number of migrant household members and the level of investment in agricultural machinery (see Table 6): the more migrant members a household has, the greater the investment in agricultural machinery. While studies in some countries found an association between agricultural mechanisation and an increase in labour productivity, which triggers movement into off-farm activities (labour out-migration), our empirical findings confirm that the opposite is true for Cambodia. Consistent with the study of Oshiro (1985), we find that the mechanisation of Cambodia's agriculture sector is largely the result of a scarcity of agricultural labour.

Migration out of rural areas, either to urban areas or overseas, attracted by higher wage rates for off-farm work, is an emerging phenomenon in Cambodia. Improving and maintaining agricultural productivity and production therefore necessitates further expansion of mechanisation. Thus investing in farm machinery and equipment is a must for many farmers.

To smooth the transition to increase farm mechanisation and to cope with the rate of rural out migration, there would be merit in incorporating the following considerations into policy assessments:

- Farm mechanisation expansion requires that greater attention be paid to marketing, especially the prices of tractors, tillers, water pumps and other farm equipment.
- The cost of inputs such as gasoline, spare parts and servicing should also be closely monitored.
- Machinery hire services should be expanded, whether through public or private enterprises, so that farmers who cannot afford to buy their own are able to hire the machines and equipment they need.
- Low-interest-rate credit should be made widely available to enable farmers to buy farm machinery and equipment, thus avoiding plunging farmers into a potential risk-induced poverty trap.
- Finally, Land Leasing Law and its implementation should be reformed to give farmers more and better options for improving production and make it easier for them to obtain loans and manage loan payments.

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