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The economics of land fragmentation in the north of Vietnam*

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Land fragmentation, where a single farm has a number of parcels of land, is a common feature of agriculture in many countries, especially in developing countries. In Vietnam, land fragmentation is common, especially in the north. For the whole country, there are about 75 million parcels of land, an average of seven to eight plots per farm household. Such fragmentation can be seen to have negative and positive benefits for farm households and the community generally. Comparative statics analysis and analysis of survey data have led to the conclusion that small-sized farms are likely to be more fragmented, and that fragmentation had a negative impact on crop productivity and increased family labour use and other money expenses. Policies which allow the appropriate opportunity cost of labour to be reflected at the farm level may provide appropriate incentives to trigger farm size change and land consolidation. Policies which tip the benefits in favour of fewer and larger plots, such as strong and effective research and development, an active extension system and strong administrative management, may also lead to land consolidation.

Key words: development economics, land fragmentation, land use and tenure, production economics.

1. Introduction

Land fragmentation, where a single farm has a number of parcels of land, is a common feature of agriculture in many countries, especially in developing countries. Land fragmentation is considered an impediment to efficient crop production and many countries have implemented policies encouraging land consolidation. Such policies have been implemented in Kenya, Tanzania, Rwanda (Blarel *et al*. 1992), Albania, Bulgaria (Sabates-Wheeler 2002) and are now being considered in Vietnam. In the larger context, if land fragmentation means that more labour and other resources are used than is necessary

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and that these resources can be used more effectively elsewhere in the economy, then there is likely to be an overall economic gain from reduced fragmentation. However, even though land fragmentation may have negative impacts on farms and the overall economy, there are reasons why there may be benefits to farmers from some degree of fragmentation. Land fragmentation can mean that farmers have land plots of different quality, allowing them to diversify their crops, spread labour requirements, and reduce production and price risks.

The aim of the paper is to investigate the current situation of land fragmentation in the north of Vietnam, and its effects on and relationship to crop productivity. Comparative statics analysis is used to examine the relationship between land fragmentation and farm size, agricultural production ability, off-farm jobs, and the amount of land rented-in and -out. A key hypothesis investigated is that consolidation of agricultural land in Vietnam is desirable in the long run.

The paper is organised as follows. In sections 1 and 2 some background to Vietnamese agriculture and the issue of land fragmentation is presented. Causes, advantages and disadvantages of land fragmentation are discussed in section 3. Evidence of land fragmentation in the north of Vietnam and its relationship to crop productivity, farm size and other factors are the subject of section 4. The comparative statics analysis is presented in section 5. In section 6 an empirical model is proposed which allows the examination of effects of land fragmentation on crop productivity. Conclusions and policy implications are drawn in the last section.

2. Background

Vietnam started economic reforms with the introduction of the *Doi Moi* (renovation) policy in 1986. The *Doi Moi* policy aimed to shift the Vietnamese economy from a central planning model to one largely based on market principles. In the agricultural sector, Resolution 10 in 1988 recognised the farm household as an autonomous economic unit, freed-up markets for inputs and outputs, recognised private ownership of the means of production (except land) and provided longer terms for land use (Pingali and Xuan 1992; Hung and Murata 2001). The new land policies contributed to the demise of collectivised agriculture, although less so in the south where collectivisation had been limited (Kerkvliet 1995).

The 1993 Land Law formalised the allocation of land use rights to farmers begun after Resolution 10. Farmers were allocated land for long-term use and granted five rights of land use including the rights of transfer, exchange, lease, inheritance and mortgage. By virtue of providing increased security of tenure over land, facilitating access to credit and making land use rights tradeable, the 1993 Land Law is seen as providing the foundations for a formal market for land (Do and Iyer 2003). In the north, the land allocation process varied between districts, although equity between households was a

primary consideration, as was land quality and the number of labour equivalents (*Dinh Suat*) in a household. Other considerations influencing land allocations were social policies, the irrigation system, distance to plots and capacity for crop rotation. In order to maintain the principle of equality, each household was allocated plots with different locations and land quality. As a result, households have a number of plots, often scattered over a wide area. For the whole country, there are about 75 million parcels of land, an average of seven to eight plots per farm household (Vy 2002). *Ex-post* analysis has shown the land allocation process to have been remarkably equitable (Ravallion and van de Walle 2001).

There are different degrees of land fragmentation throughout Vietnam, with some regions and locations being more seriously fragmented than others. In the south of Vietnam, the degree of land fragmentation is not so pronounced. There was less concern with equitable distribution in the south, and land allocation to households was also more likely to be based on land held prior to re-unification in 1975 (Luong and Unger 1999; Ravallion and van de Walle 2001; Do and Iyer 2003). However, in the north of Vietnam in 1998, farms in the Red River Delta (RRD) and the Northern Mountainous region had, on average, 7 and 10–20 plots, respectively (Lan 2001).

Concern about land fragmentation resulting from this 'equitable' allocation of agricultural land has emerged in recent years with some authors asserting that fragmentation seems to be a serious problem for agricultural production in Vietnam (Lan 2001; Ministry of Agriculture and Rural Development 2002; Research Institute of Agricultural Planning 2004). In 1998, the government issued a policy to promote the exchange of land plots to encourage larger plot areas. Since then, provinces in the north, especially in the RRD, have established steering committees to conduct pilot studies on plot exchange. Throughout the whole country, there are 700 communes in 20 provinces where plot exchanges were and are being implemented. In these areas land was effectively re-allocated to farmers with the aim of reducing the number of plots. In Thanh Hoa province, for example, plot numbers decreased by 51 per cent after three years of implementation of the policy (1998–2001). On average, the number of plots per farm household decreased from 7.8 to 3.8 plots (Ministry of Agriculture and Rural Development 2002).

Reports to the central and local governments have argued that plot exchange should be implemented where farmers realise there is a problem caused by fragmentation and plot exchange is unlikely to lead to new conflicts over land allocation. However, promoting voluntary exchange of plots between farmers to overcome land fragmentation is a narrow policy approach compared to policies favouring the development of the market for land use rights, such as effective land titling and reducing restrictions on the transfer of land use rights. In many provinces the land re-allocation process has occurred without much input from farmers. Often farmers have only been involved in the assessment of land quality in order to determine the exchange coefficients between different classes of land.

2.1 Reasons for land fragmentation

In the literature, researchers have classified causes of land fragmentation into two broad categories: supply-side and demand-side causes (Bentley 1987; Blarel *et al*. 1992). The supply-side causes refer to an exogenous imposition on farmers of a pattern of land areas, while the second reflects varying degrees of fragmentation chosen by farmers (Blarel *et al*. 1992).

A supply-side explanation of land fragmentation puts the view that it may happen involuntarily as a result of historical and geographical issues, population pressure and patterns of inheritance (Bentley 1987). Historical issues may be more significant where land is scarce. In most developing countries in Africa and Asia where labour is cheap, crop production is mainly carried out by hand cultivation and animal traction. This is suited to small-scale and self-sufficient production. In such cases fragmentation results, and can also be a result of geographical conditions where the terrain is hilly and upland areas exist. Historical and geographical causes of land fragmentation are hard to overcome and it may take a long time to consolidate such land areas.

Land fragmentation can also be explained by pressure of population growth (Bentley 1987; Blarel *et al*. 1992). Farms in regions where population growth is high and farmers have less off-farm opportunities may be more fragmented. Another cause of land fragmentation can be inheritance, where farmers want to give their children land of similar quality. Also land fragmentation can arise from the failure of land markets to operate effectively because of government regulations on land transactions (Bentley 1987; Blarel *et al*. 1992). The above mentioned explanations are observed in many developing countries, such as China (Nguyen *et al*. 1996), Ghana and Rwanda (Blarel *et al*. 1992).

In Vietnam, land fragmentation has mainly been caused by the land allocation process (Hung and MacAulay 2002; Research Institute of Agricultural Planning 2004). Furthermore, an inadequate regulatory framework and high transactions costs restrict participation in land market transactions (AusAID 2001; World Bank 2003; Asian Development Bank 2004).

'Demand-side' causes of land fragmentation arise when farmers consider that land fragmentation may have some benefits. In this case it is possible for the private benefits of land fragmentation to exceed its private costs (Blarel *et al*. 1992; Hung and MacAulay 2002). By cultivating plots in different areas (such as lowland and upland), variation in output may be less because the risks caused by drought, flood and diseases are spread. Another reason farmers want to keep fragmented farms is that they may be able to use their seasonal labour more effectively. Although labour is generally in surplus in Vietnam, especially in the RRD, in peak times (transplanting and harvesting periods) and during the winter crop growing period, more labour is demanded. Therefore, farmers may reduce peak time labour periods by diversifying crops in different plots. It is also possible that the transaction costs are sufficiently

high that farmers are unwilling to undertake the set of land transactions that would be needed to reduce the degree of fragmentation.

The above demand-side reasons for fragmentation explain the choice of farmers to retain certain levels of fragmentation that they perceive are beneficial to them. These positive benefits are the impacts of fragmentation on risk-spreading, seasonal labour spreading and crop diversification. Another potential benefit is that the land user can mortgage or sell just a portion of their land. They may also give land to their children as an inheritance more easily when the children want to live separately.

However, land fragmentation causes many negative effects including higher costs, increased negative externalities, loss of land due to boundaries and a greater potential for disputes between neighbouring farmers (Blarel *et al*. 1992; Lan 2001; Hung and MacAulay 2002; Research Institute of Agricultural Planning 2004). Production costs may also be higher due to higher costs for labour, as it takes more time to travel between plots and to operate an activity such as irrigation for many small units of land. A major source of higher production costs is higher transport costs for inputs and outputs. Other problems caused by fragmentation may be higher negative externalities which can happen when farmers cultivate different crops or varieties (Bentley 1987). This leads to greater potential for disputes between neighbours. Land fragmentation also causes land loss due to plot boundaries or bunds and access routes. This land loss is directly related to the number of plots. In addition, it is hard to apply some new technologies when farms are small and fragmented. This is likely to be a main disadvantage of land fragmentation in Vietnam. These advantages and disadvantages of land fragmentation are summarised in Table 1.

Although there are disadvantages of land fragmentation, farmers in many provinces, especially in the north and north central regions of Vietnam, still retain their many parcels of land. Historical and institutional constraints discussed previously are likely to be key reasons for this. However, it is possible that farmers could benefit from some degree of land fragmentation, by reducing risks from flood, drought and diseases, making more efficient use of seasonal labour and enabling crop diversification.

3. Land fragmentation in the north of Vietnam: evidence from survey data

3.1 Measuring land fragmentation

There is no standard measurement of land fragmentation. This leads to difficulties in determining when farm households are ‘very fragmented’ or ‘less fragmented’. Bentley (1987) reports that most authors have used two simple measures together to assess land fragmentation: the average number (either regional or national) of plots per farm and the average farm size. However, some authors have considered that land fragmentation should be measured by six parameters: farm size, the number of plots, plot size, plot

Table 1 Costs and benefits associated with land fragmentation

Benefits of many plots		Costs of many plots	
Private benefits	Public benefits	Private costs	Public costs
Immediate and ongoing benefits/costs			
Risk spreading – Flooding – Diseases and pests – Output variation Crop rotation flexibility/diversity Seasonal labour spreading	Equality of treatment Implicit insurance	Cost increases More labour used Access difficult Border land loss	Less labour released Higher transaction costs when used as collateral
Longer term benefits/costs			
Inheritance flexibility Small parcels to transfer/sell/mortgage	Increased biodiversity Reduced spread of diseases	Disputes increased Irrigation difficult Mechanisation difficult Application of new technology difficult	Mechanisation delayed Application of new technology delayed Planning of commercial production zones difficult Land use planning difficult

shape, spatial distribution and the size distribution of the fields (King and Burton 1982; Bentley 1987). In this paper, two main measures of fragmentation are used: the number of plots per farm household alone and a measure, based on Simpson's diversification index, which considers the number of plots, plot size and farm size. Blarel *et al*. (1992) have also used these two indicators to measure land fragmentation in Ghana and Rwanda. Simpson's index of land fragmentation is defined as $(1 - (\Sigma_j a_j^2/A^2))$ where a_j is the area of the j-th plot, A is the farm size and $A = \Sigma a_j$. This index has a value between zero and one. A value of zero means that the farm household has only one parcel or plot of land, which indicates complete land consolidation, while a value close to one means the household has numerous plots and the farm is 'very fragmented'.

3.2 Evidence of fragmentation from survey data

Two provinces in the north, Ha Tay and Yen Bai, were chosen as research sites. In each province, two districts, one where farm sizes were smaller than average and the other where farm sizes were larger than average, were chosen. This same procedure was followed in selecting two communes in each district. Dai Dong and Thach Hoa communes in Thach That district, and Song Phuong and Tho Xuan communes in Dan Phuong district were selected in Ha Tay province. In Yen Bai province, the four communes were Dai Dong and Bao Ai in Yen Binh district, and Mau Dong and Dong Cuong in

Table 2 Land fragmentation in Ha Tay and Yen Bai provinces, 2000

Provinces	Yen Bai	Ha Tay	Total
Number of households	91	97	188
Farm size (m^2)			
Mean	24 327	5232	14 475
Median	11 890	3702	4176
Areas of plot (m^2)			
Mean	3222	847	2116
Average area of smallest plots	211	303	258
Average area of largest plots	17 751	2741	10 007
Simpson's index		Percentage of households	
0–0.2	19.8	4.1	11.7
0.2–0.4	17.6	3.1	10.1
0.4–0.6	16.5	18.6	17.6
0.6–0.8	30.8	42.3	36.7
0.8–1.0	15.4	32.0	23.9
Mean†	0.51	0.68	0.59
Median†	0.58	0.72	0.68
Number of plots		Percentage of households	
≤ 2	8.8	3.1	5.9
3–5	25.3	48.5	37.2
6–8	28.6	27.8	28.2
9–11	13.2	11.3	12.2
> 11	24.2	9.3	16.5
Mean†	7.55	6.18	6.84
Median†	7	5	6
Distance from house to plot (m)		Percentage of plots	
0–300	23.3	18.5	21.1
300–700	43.7	32.2	38.4
700–1000	11.5	11.9	11.7
1000–3000	18.3	34.7	25.8
> 3000	3.2	2.7	3.0
Mean (m)†	653.1	805.4	722.9
Median†	500	600	500

Note: †Expressed in relevant units, not percentages.

Van Yen district. Data for two years (2000 and 2001) were collected from approximately 200 households using prepared questionnaires.

Ha Tay province located in the RRD is characterised by low-lying land and a small farm size, while Yen Bai province is located in an upland region and has a larger farm size. The distribution of land types is different in the two regions, with farms in Yen Bai having a higher percentage of forestry land than Ha Tay. This is one reason for the larger farm size. Part of Ha Tay province has some upland area, and therefore the average farm size is likely to be larger than that of other provinces in the RRD. Average farm sizes including settlement land, agricultural land, ponds, and forestry land in Ha Tay and Yen Bai were 5232 and 24 337 m^2 in the year 2000, respectively (Table 2). More than 40 per cent of the surveyed farms in Ha Tay had a farm

size less than 3000 m^2, while in Yen Bai this figure was 31 per cent. Only 3 per cent of the surveyed farms in Ha Tay had a farm size larger than two hectares, while in Yen Bai this figure was 37 per cent, and even higher in some communes such as Dai Dong (55 per cent).

Farm size is closely related to plot size, as when farm size is small, individual plot areas on average cannot be very large. In Ha Tay, the average farm size and plot size in a commune with smaller average farm size (Dai Dong) were in turn 3182 and 384 m^2, while these figures for a commune with larger average farm size (Thach Hoa) were 9412 and 1263 m^2, respectively. The same situation was observed in Yen Bai province. Of the total number of plots in Ha Tay and Yen Bai, 53 per cent and 54 per cent respectively, had areas of less than 400 m^2, although the average areas of plots in the two provinces were different (1126 m^2 in Ha Tay and 3084 m^2 in Yen Bai). These average plot area differences are explained by larger forestry land plots in Yen Bai.

Households in the surveyed areas had an average of 6.8 plots of land, with the figures for Ha Tay and Yen Bai being 6.2 and 7.6 plots, respectively (Table 2). The average number of plots also varied from region to region and commune to commune. Only 9 per cent of farms in Ha Tay had more than 11 plots, while this figure for Yen Bai was more than 24 per cent. If the degree of fragmentation is measured by the number of plots, Yen Bai's farms were 'more fragmented' than those in Ha Tay, while if the degree of fragmentation is measured by Simpson's index the conclusion is the reverse. On average, Simpson's index was 0.68 for farms in Ha Tay and 0.51 for those in Yen Bai. More than 74 per cent of farms in Ha Tay had a value of the index higher than 0.6 while for Yen Bai it was only 46 per cent. This means that in Yen Bai there were larger plots and/or smaller plots because this index is sensitive to the area of the largest or smallest plots.

Land fragmentation can be more serious if plots are scattered over wider areas. To measure this, farmers were asked to estimate the distances from their farm houses to each of their plots. According to data in Table 2, about 37 per cent and 22 per cent of the total number of plots in Ha Tay and Yen Bai, respectively, were located further than 1 km from the farmer's house.

4. Comparative statics farm model

In this paper, a household model related to the crop production of the household is used. It is assumed that a labour market exists in which households can hire labour and be employed. There is also assumed to be a market for land use rights; that is, farmers can rent-out or rent-in land. Credit is constrained. A household must pay some transaction costs for their entry into the land transaction and credit markets. Land fragmentation (the number of plots) is given and assumed to affect production costs. Let household i be endowed with a fixed amount of labour ($\bar{L}_i$), capital ($\bar{K}_i$), land ($\bar{A}_i$), a number of plots ($\bar{N}_i$) and a given level of agricultural ability (α_i). This variable was introduced by Deininger and Jin (2003), and although agricultural

ability is unobservable it varies among producers and can be estimated from production functions derived from the household panel data which will have household fixed effects. A detailed estimation of this variable is given in Hung (2006).

Assuming that household i has j plots, y_{ij} is output obtained in plot j ($j = 1, \ldots, N$) of household i ($i = 1, \ldots, M$). The production function for plot j of household i therefore is

$$y_{ij} = \alpha_i F_{ij}(l_{fij}, l_{hij}, x_{ij}, a_{ij}) \tag{1}$$

where α_i is the farm-specific parameter that captures the agricultural production ability of farm household i; l_{fij} is the family labour used in plot j, household i; l_{hij} is the hired-in labour used in plot j of household i; x_{ij} is a vector of inputs used in plot j of household i, and $\Sigma_j x_{ij} = X_i$; a_{ij} is the area of plot j of household i, and $\Sigma_j a_{ij} = A_i$ (A_i is operating area of household i).

A householder is assumed to maximise his/her income from three sources: agricultural production outputs from all plots, off-farm work and renting-out (or -in) land. Thus for household i:

$$\begin{aligned}\pi = {} & \sum\nolimits_j P_i \alpha_i F_{ij}(l_{fij}, l_{hij}, x_{ij}, a_{ij}) + w_1 L_{oi} - w_2 L_{hi} + G^{out}(\bar{A}_i - A_i)(r_2 - T_2) \\ & - G^{in}(A_i - \bar{A}_i)(r_2 + T_2) - \sum\nolimits_j (P_{xi} + T_3)x_{ij} - G^{bor}\Big[\sum\nolimits_j (P_{xi} + T_3)x_{ij} \\ & + G^{in}(A_i - \bar{A}_i)(r_2 + T_2) + w_2 L_{hi} - \bar{K}_i\Big](r_1 + T_1)\end{aligned} \tag{2}$$

where P_i is the price of output; $\bar{L}_i = L_{fi} + L_{oi}$ is the total household labour; $L_{fi} = \Sigma_j l_{fij}$ is the total labour working on farm; $L_{oi} = \bar{L}_i - L_{fi} = \bar{L}_i - \Sigma_j l_{fij}$ is the total labour working off-farm; $L_{hi} = \Sigma_j l_{hij}$ is the total hired-in labour; w_1 and w_2 are wages of off-farm jobs and hired-in labour, respectively.

$$\begin{aligned}K_i &= \sum\nolimits_j (P_{xi} + T_3)x_{ij} + G^{in}(A_i - \bar{A}_i)(r_2 + T_2) + w_2 L_{hi} \\ &= (P_{xi} + T_3)X_i + G^{in}(A_i - \bar{A}_i)(r_2 + T_2) + w_2 L_{hi} \\ &= \text{total operating capital}\end{aligned}$$

$G^{bor} = 1$, if the household borrows money, and 0 otherwise;
$G^{out} = 1$, if the household rents out land, and 0 otherwise;
$G^{in} = 1$, if the household rents in land, and 0 otherwise.
If $G^{out} = 1$, then $G^{in} = 0$ and $G^{in} = 1$, then $G^{out} = 0$;
$G^{out} = G^{in} = 0$, if the household has no land transaction (no renting-in or -out);
r_1 and T_1 are interest rate and credit transaction costs, respectively;
r_2 and T_2 are the land rental rate and transaction costs, respectively.

T_3 is the transaction cost associated with fragmentation. It is assumed that an increase in the number of plots may increase some costs of transportation, labour use and other costs so that the effect is to increase the direct costs.

Assume that the production function, $F(\cdot)$, satisfies the standard assumptions:

$$\frac{\partial F}{\partial z} = F_z > 0 \text{ (where } z = l_{fij}, l_{hij}, x_{ij} \text{ and } a_{ij})$$

$$\frac{\partial^2 F}{\partial z^2} = F_{zz} < 0; \text{ and } F_{zz^*} > 0 \text{ (where } z^* = l_{fij}, l_{hij}, x_{ij}, a_{ij} \text{ and } z \neq z^*)$$

This means that positive marginal products and diminishing marginal returns are required. In solving the maximisation problem (2) a household will choose optimal levels of l_{fij}^*, l_{hij}^*, x_{ij}^* and a_{ij}^*. It is assumed that the production function, $F(\cdot)$, is identical for households but not for plots. There are different marginal value products for different plots (even if a major part of the land area is a cultivated rice crop) because of land quality. In the later section, dummy variables are included to capture land quality in the empirical model. The first-order conditions of the problem (2) for each household are (where the conditions relating to plots are summed for the household and dropping the subscript i for households):

$$\sum_j \frac{\partial \pi}{\partial l_{fj}} = \sum_j P\alpha \frac{\partial F}{\partial l_{fj}} - Nw_1 = 0 \tag{3}$$

$$\sum_j \frac{\partial \pi}{\partial l_{hj}} = \sum_j P\alpha \frac{\partial F}{\partial l_{hj}} - Nw_2 = 0 \tag{4}$$

$$\sum_j \frac{\partial \pi}{\partial l_{hj}} = \sum_j P\alpha \frac{\partial F}{\partial l_{hj}} - Nw_2(1 + r_1 + T_1) = 0\,, \tag{4'}$$

for households who borrow money

$$\sum_j \frac{\partial \pi}{\partial x_j} = \sum_j P\alpha \frac{\partial F}{\partial x_j} - N(P_x + T_3) = 0 \tag{5}$$

$$\sum_j \frac{\partial \pi}{\partial x_j} = \sum_j P\alpha \frac{\partial F}{\partial x_j} - N(P_x + T_3)(1 + r_1 + T_1) = 0\,, \tag{5'}$$

for households who borrow money

$$\sum_j \frac{\partial \pi}{\partial a_j} = \sum_j P\alpha \frac{\partial F}{\partial a_j} - N(r_2 - T_2) = 0\,, \tag{6}$$

for households who rent-out land

$$\sum_j \frac{\partial \pi}{\partial a_j} = \sum_j P\alpha \frac{\partial F}{\partial a_j} - N(r_2 + T_2) = 0\,, \tag{6'}$$

for households who rent-out land

$$\sum_j \frac{\partial \pi}{\partial a_j} = \sum_j P\alpha \frac{\partial F}{\partial a_j} - N(r_2 + T_2)(1 + r_1 + T_1) = 0\,, \tag{6''}$$

for households who rent-in land and borrow money.

Thus, for households who do not rent land in or out (no land transactions):

$$N(r_2 - T_2) < \sum_j P\alpha \frac{\partial F}{\partial a_j} < N(r_2 + T_2) \tag{7}$$

$$N(r_2 - T_2) < \sum_j P\alpha \frac{\partial F}{\partial a_j} < N(r_2 + T_2)(1 + r_1 + T_1) \tag{7'}$$

for households who borrow money.

The first order conditions allow the derivation of a set of comparative statics conclusions and a full derivation of these is given in Hung (2006).

Equation (3) implies that the total value of the marginal product of family labour from all plots of a household should be equal to the off-farm wage multiplied by the number of plots. If the total returns to family labour are maintained at some level, an increase in the off-farm wage will reduce the number of plots. Thus, the opportunity for off-farm labour is one of the key factors that will encourage land consolidation.

Conclusions drawn from the full comparative statics derivations detailed in Hung (2006), include the following points. These conclusions relate to the new optimal equilibrium situation that results when specific variables, such as agricultural ability, number of plots and transaction costs, are marginally changed.

- The optimal level of farm land operated by the household increases with increasing agricultural production ability of the household, α. The amount of land rented-in also increases with increasing agricultural production ability of the household and decreases for households with a higher land endowment, $\bar{A}$. Therefore, rental markets will tend to lead to 'small/poor but efficient' crop producers (Deininger and Jin 2003). Currently, most of the rural population in Vietnam is still involved in agricultural production because the opportunity for off-farm jobs is limited. However, in the future when the opportunity for off-farm employment is greater, land may tend to be transferred to small-sized farms with high agricultural ability.
- An increase in the number of plots will lead to a reduction in the total farm area that is optimal. Thus, small-sized farms are likely to be 'more fragmented' than large-sized farms. This seems to be for the case in North Vietnam where small-sized farms are often located in areas of more fertile land and tend to be fragmented. Farmers with land in the fertile RRD in North Vietnam tend to keep all their plots even when plot size is small. Bentley (1987) also reported that land fragmentation is present for small, subsistence-orientated production.
- Households who rent-out land will rent-out more land if the land is more fragmented. However, households who rent-in land will rent-in less land in the case where land is more fragmented. Thus, if farm land is fragmented, the farming sector has insufficient incentives to attract farmers to be involved in agricultural production and farmers tend to leave farming. In addition, land fragmentation, as measured by the number of plots, decreases with

increasing agricultural production ability of the household. Therefore, an effective system of extension and training to increase agricultural ability is needed to facilitate land consolidation.

- The farm area operated by a household decreases with an increase in transaction costs associated with the credit market, the land rental market and land fragmentation. A decrease in transaction costs will increase the optimal farm size. Therefore, reducing transaction costs or a strong administrative system may assist the process of land accumulation to be more active and give farmers greater incentives to increase farm production.
- A reasonable assumption is that households with high agricultural ability that specialise in agricultural production will continue to rent-in land and their off-farm opportunities will remain the same as before. Those households with low agricultural ability who join the off-farm labour force will take advantage of an increase in off-farm wages, w_1. The amount of land rented-out increases as off-farm wages increase. Thus, an increase in the wage rate for off-farm employment may increase land transacted in the rental market. This may lead to a decrease in the equilibrium rental rate which will make everybody better off (Deininger and Jin 2003). An increase in the opportunity for off-farm jobs may be a key policy to encourage not only an active market for land use rights but also agricultural production and an increase in farmers' incomes.

5. An empirical model and results

If the production function in Equation (2) follows constant returns to size, then the output function is equivalent to the yield function. When returns to size are unclear, instead of the output function, the yield function can be estimated with the adjusted land areas.

The yield function can be written as:

$$\begin{aligned} y &= \alpha F(l_f(N), l_h(N), x(N)) \cdot h(A) \\ h(A) &= A^{\mu 1} e^{\mu 2 A} \end{aligned} \tag{8}$$

where y is the yield, l_f and l_h are family and hired labour, respectively, x is a vector of other variable production inputs (fertilisers, seed, pesticides, etc.), N is the number of plots and α is the agricultural production ability of farm households. It is assumed that land fragmentation affects the level of production inputs used.

The yield function, y is assumed to be separable into functions F and h. Function F is the yield per unit of land area while function h incorporates economies of farm size (MacAulay and Hertzler 2000). If there are no economies or diseconomies of size, μ_1 will be one, μ_2 will be zero and function h will equal the area A. Function F can be designed with the variables in different forms. In order to examine the relationship between not only fragmentation and productivity but also between fragmentation and production inputs, the translog form is used. However, the problem of collinearity occurs for the full

Table 3 Results from frontier regression analysis of annual crop yield function for Ha Tay and Yen Bai provinces

Estimates†	Coefficients	*t* value
Intercept	6.751	23.65***
Seed application	0.106	2.14**
Nitrogen input	–0.141	–2.08**
Potassium input	–0.034	–0.80
Phosphorus input	–0.001	–0.10
Family labour	–0.212	–3.85***
Hired labour	0.021	1.70*
Other money expenses	–0.111	–3.13***
Number of plots	–1.081	–5.13***
Farm area	0.074	2.25**
Farm areas (exp)	–0.001	–1.65*
Seed application × Nitrogen	0.013	1.67*
Seed application × Potassium	–0.003	–1.67*
Seed application × Family labour	–0.040	–2.85***
Seed application × Other money expenses	0.011	1.64*
Seed application × Number of plots	–0.016	–1.12
Nitrogen × Potassium	0.021	2.59***
Nitrogen × Phosphorus	–0.001	–0.27
Nitrogen × Family labour	0.016	0.53
Nitrogen × Other money expenses	0.023	1.57
Nitrogen × Number of plots	0.062	1.19
Potassium × Phosphorus	–0.002	–1.36
Potassium × Family labour	0.003	0.26
Potassium × Other money expenses	–0.008	–0.94
Potassium × Number of plots	0.019	1.20
Family labour × Other money expenses	0.022	1.58
Family labour × Number of plots	0.211	3.52***
Other money expenses × Number of plots	0.064	1.56
Dummy for the number of crops (soil quality)	0.195	3.81***
Dummy for paddy crops	–0.126	–2.62***
Dummy for cash crops	0.407	6.66***
Dummy for land use change	0.452	6.58***
Sample size, *n*	508	
Log likelihood function	–265.39	
Lambda squared ($\lambda^2 = \sigma_u^2/\sigma_v^2$)	0.464	2.85***
Sigma-squared (σ_v^2)	0.098	11.38***

Notes: ***, ** and * are significant at 1%, 5% and 10% level, respectively. †The dependent variable is the equivalent rice yield of a crop rotation (kg/sao/year).

translog form. Therefore, the squared terms and interactive terms of variables with few observations are excluded from the model. For example, there are only 81 observations for hired labour in the total 508 observations.

In the model, it was expected that fragmentation, represented by the number of plots, would have a negative sign while dummies for the number of crops (representing soil quality), cash crops and land use change would have positive signs. Land use change means that farm households change land use from 'traditional crops' (e.g. rice, corn, vegetables) to fruits, fish or flowers. Results are given in Table 3.

The production function was estimated using frontier regression methods with panel data (508 plot-based observations over two years from agricultural land on 188 farm households in the north of Vietnam). The software used was LIMDEP version 7.0 (Greene 1998). From the results it would seem that a reasonable response function has been estimated (transcendental form in land area and translog form in other variable inputs except hired labour). The λ^2 which is equal to σ_u^2/σ_v^2 (where σ_u^2 is the variance of the one-side error term, U and σ_v^2 is the variance of two-side disturbances, V) were reasonable and significantly different from zero at 1 per cent indicating that the model disturbances capture technical inefficiency.

For the estimated model, the coefficient of farm area and its exponential term were statistically different from zero. This means that, statistically, farm area has been shown to have an effect on productivity as reflected in the equivalent rice yield. As a result, an increase in farm area may increase crop yield but with decreasing rates. Thus, in terms of farm area, economies of farm size are likely to be present in the north of Vietnam. If farm size is measured by output, returns to size do not seem to be present in the research area, that is, the production function follows constant returns to size in relation to output (Hung 2006).

The coefficient of the number of plots was statistically different from zero and negative. In addition, the partial elasticity of the number of plots was negative.[1] This result suggests that there is a negative effect of plot number on farm performance. Wan and Cheng (2001) also found that there was a negative relationship between the number of plots and individual crop productivity in China. The coefficients of interaction terms between the number of plots and family labour and other money expenses were also statistically different from zero and positive, supporting the idea that the number of plots has increased family labour costs and other money expenses. Therefore, fragmentation has shown an effect on not only crop productivity but also on labour and other money expenses.

The coefficient of family labour was also statistically different from zero at 1 per cent and negative. The direct effect of family labour on the equivalent rice yield may be negative. Agricultural labour in Vietnam is in surplus supply; therefore, farmers use more family labour than needed on their fields. However, on average the elasticity of family labour was positive but small. If the level of seed application remains at some level, a reduction in the number of plots may cause the elasticity of family labour to be negative.[2] This result suggests that the number of plots also increases the level of family labour used, therefore land consolidation or a reduction in the number of plots of the farm household may release more labour for other sectors of the economy.

[1] The elasticity of the number of plots is equal to –0.32 which is estimated with other variables at average levels.

[2] The elasticity of family labour is equal to 0.036 which is estimated with other variables at average levels.

Farmers in the north of Vietnam, especially in the RRD, apply intensive farming techniques for annual crops and rice. In the range of data being considered, farmers had high technical efficiency and the production function 'operated' in the 'flat' areas around the maximum point of the function. Thus, an increase in inputs may not increase productivity (Hung 2006).[3] For the estimated model, the coefficients of nitrogen input and other money expenses were significant but negative. This result suggests that the direct effects of these inputs on crop productivity are negative. On average, the elasticity of nitrogen was negative while it was positive for other money expenses. This is the case because in the research sites 71 per cent of cultivated land was for rice which is a major crop in the north and the RRD.[4]

The coefficients of the dummies for cash crops and land use change were statistically different from zero and had positive signs while the coefficient of the dummy for paddy crops (rice, corn, cassava and sweet potato) was negative. This means that paddy crops have lower equivalent yields than other crops and farmers may increase their crop outputs as well as income by producing cash crops (vegetables, soybean, peanuts, flowers and fruit). Farmers' crop outputs and their incomes increase as crop patterns change from producing 'traditional crops' to other crops such as fruit, flowers and fish. This result suggests that retaining a 'quota' policy on the area of rice land may not help farmers to increase their outputs and incomes. Under current government policy, land required to grow rice remains at about four million hectares.

Another model (not reported here) showed that land fragmentation was positively and significantly related to crop diversity (Hung 2006). In the context of subsistence-orientated agricultural production, this may lead to security of farmers' incomes. The trade-off between the level of crop diversity and land fragmentation and commercial production is an area for further study.

6. Conclusion

From a theoretical point of view, fragmentation of plots on farms has benefits and costs as listed in Table 1. These benefits and costs will be different for different farm households and thereby affect the economics of land fragmentation for individual households and society.

In this paper, various methods have been used to investigate the economics of land fragmentation, including both theoretical comparative statics analysis and empirical analysis of survey data from farm households in the north of Vietnam. Using survey data from 508 plot-based observations from 188 farm households in the north of Vietnam it was found that fragmentation had a negative impact on crop productivity (measured in equivalent rice yield) and increased family labour use and other money expenses.

[3] The elasticity of seed application is equal to 0.07, nitrogen –0.04, potassium 0.05, and other money expenses 0.19 which are estimated at the average levels of other inputs.

[4] There are 359 observations for rice and corn in the total 508 observations.

As Vietnam appears to have surplus agricultural labour, at least for much of the production year, the real benefits to farm households from land consolidation may not be apparent until the real opportunity cost of farm labour begins to rise. This opportunity cost will clearly be affected by a number of factors such as the availability of employment opportunities for the farm family members and the wage rate associated with these opportunities, the level of education and age of the rural workforce, the time of year and season. The transaction costs involved in job search will be an issue as will the reliability of the employment. Therefore, creation of new off-farm jobs and movement of the agricultural labour force to other sectors of the economy will be a key policy for agricultural and rural development in the future.

Administration reforms are being considered in Vietnam. This may lead to a reduction in the transaction costs associated with the credit market, the market for land-use rights and land fragmentation. Comparative statics analysis suggests that if this were the case then land consolidation would be encouraged and the market for land-use rights would likely be more active.

In the future, agricultural land may be concentrated in the hands of households who have a high agricultural ability. Comparative statics analysis also shows that land fragmentation is likely to decrease with increasing agricultural production ability. Therefore, expansion and improvement of the extension and training systems in rural areas should facilitate land consolidation.

These results have a wider applicability beyond Vietnam. Across many developing countries land fragmentation is a significant policy issue. There are tradeoffs involved but it is apparent that as the opportunity cost of labour rises there will be incentives for land consolidation. In a similar way, if the transactions costs associated with land transactions can be reduced, and productivity raised then land consolidation will be more likely to occur. These are general findings resulting from basic economic decision-making processes of farm households.

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