Trop Anim Health Prod (2007) 39:237–254
DOI 10.1007/s11250-007-9001-9

ORIGINAL ARTICLE

Evaluation of biological and economic efficiency of smallholder pig production systems in North Vietnam

U. Lemke · B. Kaufmann · L. T. Thuy · K. Emrich · A. Valle Zárate

Accepted: 13 February 2007 / Published online: 12 April 2007

Abstract This study evaluates smallholder pig production systems in North Vietnam, comparing a semi-intensive system near a town with good market access, where a Vietnamese improved breed has replaced the indigenous pig breed, and an extensive system away from town, where the indigenous breed still prevails. Fieldwork was conducted in 64 households in four villages. Repeated farm visits yielded 234 structured interviews. Data were analysed by linear models and non-parametric tests. Production inputs and outputs were quantified, and feed use efficiency and economic efficiency were assessed. The gross margin was higher for semi-intensive production with the improved breed, while the benefit–cost ratio was higher under extensive conditions with the indigenous breed. The net benefit did not differ between systems. Twenty-four per cent of farmers yielded a negative net benefit. In one village under extensive conditions, live weight output from indigenous sows with crossbred offspring compared positively with the output from semi-intensive production with improved genotypes, but was associated with high inputs, making production inefficient. Results indicate that improved genotypes might not be an efficient production alternative for saving-oriented production with limited resource supply. Suitability of evaluation parameters, farmers' production aims, and factors impacting the production success in different systems are discussed.

Keywords Economic efficiency · Feed use efficiency · Local pig breed · Production system analysis · Smallholder pig production · Vietnam

U. Lemke (✉) · B. Kaufmann · A. Valle Zárate
Department of Animal Breeding and Husbandry 480a, University of Hohenheim, Institute of Animal Production in the Tropics and Subtropics, Garbenstr. 17, 70599 Stuttgart, Germany
e-mail: utelemke@uni-hohenheim.de

L. T. Thuy
National Institute of Animal Husbandry, Chem, Tu Liem, Hanoi, Vietnam

K. Emrich
Department of Bioinformatics, University of Hohenheim, Institute for Crop Production and Grassland Research, Stuttgart, Germany

Abbreviations

B	Ban (pig breed)
BCR	benefit–cost ratio
C	cash revenue
CW	Cornwall (pig breed)
DAAD	German Academic Exchange Service (Deutscher Akademischer Austauschdienst)
DFG	German Research Council (Deutsche Forschungsgemeinschaft)
DM	dry matter
FAO	Food and Agriculture Organization of the United Nations

FM	fresh matter
GJ	gigajoule
GM	gross margin
GSO	General Statistical Office Vietnam
hh	household
LSM	least-squares mean
lw	live weight
LW	Large White (pig breed)
MARD	Ministry of Agriculture and Rural Development Vietnam
MC	Mong Cai (pig breed)
ME	metabolizable energy
MJ	megajoule
mVND	million Vietnamese Dong
N	non-market value of production
NB	net benefit
NIAH	National Institute of Animal Husbandry Hanoi, Vietnam
O	opportunity feed costs
P_{25}, P_{75}	25th and 75th percentile
UNDP	United Nations Development Program
USD	US dollar
V	variable cash costs
VND	Vietnamese Dong (average exchange rate: 1 USD ~ 15 000 VND, year 2001/2)
$\bar{x}$	arithmetic mean

Introduction

Pig keeping is of great importance in Vietnam: 71% of farm households own pigs (MARD and UNDP, 2003) and pork accounts for 70% of all livestock products (Lich, 1999). Around 80% of pig production is small-scale (Lapar *et al.*, 2003). Pigs contribute up to 41% of the income of smallholder farmers in North Vietnam (Le Coq *et al.*, 2002). This paper focuses on smallholder pig keepers in the mountainous north-west of Vietnam, which in contrast to the lowland areas is a generally marginalized region (Jamieson *et al.*, 1998). The north-west has a low per-capita-income and income density from pig production, but it is one of the regions with the highest share of household income derived from pigs (Epprecht, 2005). Nevertheless, regional and local variations exist within the north-western part of the country. In densely populated mountain valleys, cropping is progressively limited by high land pressure, but farmers have increasing access to infrastructure and markets. Semi-intensive pig production is driven by the market demand for pork. Higher-yielding Vietnamese Mong Cai pigs and imported breeds have replaced the local Ban breed.

Hillsides and hilltops are less densely populated, land pressure is lower, and infrastructure and markets are less available and accessible. Low-input pig production has both income-generating and socio-cultural functions and is driven by the availability of farm resources. The local Ban breed still prevails but is increasingly being replaced by improved genotypes (Lemke *et al.*, 2002).

It has been argued that the replacement of local, lower-yielding pig breeds by higher-yielding breeds might offer an option for farmers to increase their income, owing to the higher biological performance of the improved genotypes and the resulting higher output. However, use of higher-yielding breeds might also imply an economic risk, especially for resource-poor farmers, owing to these breeds' higher input requirements. In this study, we evaluated pig production systems of different production intensity with a holistic approach, considering pig breeds as inherent system components. Efficiency of the use of monetary and feed resources at the production system level is used as an evaluation criterion. The study hypothesizes that semi-intensive pig production with improved breeds yields a higher revenue but demands a higher resource input, which farmers of the extensive system are not able or—because of their production objectives—are not willing to sustain.

Material and methods

Study area, households and animals

Fieldwork was conducted in Son La province, north-west Vietnam. The province comprises only 9% of agricultural land (GSO, 2001). The gross domestic product in Son La province is 126 USD per capita, while the Vietnamese average is 408 USD per capita (Statistical Department Son La, 2000; GSO, 2001). The population is dominated by ethnic minorities, mainly ethnic Thai, who account for 55% of the population (Van der Poel and Khiem, 1993). Four villages of Black Thai were selected based on differences in distance to market, altitude and pig production intensity. The villages of Ban Buon and Ban Bo are located in a mountain valley in the densely populated vicinity of the province capital Son La town. The villages have good market access but face increasing land pressure. Pig production is semi-intensive. The villages of Na Huong and Bo Duoi are located on a hillside relatively far from Hat Lot, the capital of Mai Son district. The distance between Son La town and Hat Lot is about 30 km. Communication from the villages to Hat Lot is hampered by the steep roads of poor quality. Markets in Hat Lot are available and accessible to a minor degree. Na Huong has slightly better market access than Bo Duoi as it lies at a slightly lower altitude and some sections of the connecting road have recently been paved. Land pressure in Na Huong and Bo Duoi is lower. Pig production is extensive. Apart from similarities specific to the pig production system, the villages of each system show differences in other, non-pig-production, aspects as well as development process/process of change in pig and agricultural production. Therefore, the results of this study are presented by village along with an indication of the system.

Stratified household selection included households with improved Mong Cai sows in the demand-driven villages and local Ban sows in the resource-driven villages. A total of 64 households were selected (Table 1). The study area and village and household selection have been described in detail by Lemke and colleagues (2006).

Selected farms were visited four times between March 2001 and July 2002. Two out of four visits were in a season of feed abundance (March to April) and two in a season of feed shortage (June to August). During each of four visits per farm, data were collected through structured household interviews. Open-ended interview questions focused on socio-economic household data, cropping, livestock husbandry, pig keeping management, pig production inputs and outputs, pig performances, and utilization of animal products, as information recalled by farmers for the previous 12 month.

Results were obtained by pig type, distinguishing sows (reproducing female), boars (reproducing male), piglets (birth to weaning) and fatteners (not reproducing male/female/castrated pig, weaning to offtake). Sows were classified as gilt (mature female before 1st farrowing), empty or in early gestation (days 1–60), in late gestation (days 61–114), or lactating.

Feed supply was assessed by recording feed components and their amounts supplied on test-day and percentages of the overall feed amount given to

Table 1 Overview on households, interviews, litters and offspring analysed

	Production system/village				Total
	Demand-driven, near town		Resource-driven, away from town		
	Ban Buon	Ban Bo	Na Huong	Bo Duoi	
Households (*n*)	17	16	16	15	64
Interviews (*n*)	60	60	57	57	234
Litters, Ban sows (*n*)	7	3	32	24	66
Litters, MC sows (*n*)	11	18	1	–	30
Litters, other sows (*n*)[#]	12	20	2	5	39
Total litters (*n*)	30	41	35	29	135
Ban fatteners (*n*)	–	–	68	139	207
LW×Ban fatteners (*n*)	13	–	45	7	65
Mong Cai fatteners (*n*)	57	28	–	–	85
LW×MC fatteners (*n*)	75	120	–	–	195
Other fatteners (*n*)[##]	66	42	74	21	203
Total fatteners (*n*)	211	190	187	167	755

B=Ban, CW=Cornwall, LW=Large White, MC =Mong Cai.

[#] B×MC, MC×B, MC×CW, LW×MC, CW×B, B×(CW×B), MC×(MC×B).

[##] B×MC, CW×B, CW×MC, CW×(MC×B), (LW×B)×B, LW×(B×MC), LW×(CW×B), LW×(LW×MC), LW×(MC×B), MC×(B×MC), MC×(CW×B), MC×(LW×MC), MC×(MC×B).

each batch of pigs. For homogeneous pig batches (i.e. including pigs of the same age and type), total feed supply was divided by the number of pigs per batch to approximate feed supply per pig. Mixed batches were excluded from calculations. Feed supply was assumed to equal pigs' daily feed intake. Accordingly, daily feed cash costs (VND/pig per day) were derived from feeding rations on test-day, using current feed market prices. Daily intakes of fresh matter (FM), dry matter (DM) and metabolizable energy (kg/pig per day, MJ ME/pig per day) were derived using nutritive values of local feedstuffs (NIAH, 2001).

Veterinary costs included vaccination, de-worming and curative treatment costs and were given directly by farmers or derived from the number and costs of cases per household (hh) per year. Dividing total costs (VND/hh per year) by the number of pigs (*n*/hh per year) yielded costs per pig (VND/pig per year).

The pig live weight offtake per household (kg/hh per year) was the sum of live weights of all pigs extracted from a household's pig herd during the previous 12 months. Division by the total number of pigs (*n*/hh per year) yielded the live weight offtake per pig (kg/pig).

The quotient of live weight offtake (kg/hh per year) and total metabolizable energy fed to pigs per year (GJ/hh per year) indicated feed use efficiency of pig production (kg/GJ). Total energy fed to pigs per year was approximated from energy intake on test-day in spring for fatteners and sows of different reproductive phases, number of pigs (n/hh per year) and the presence of each pig in the household in days. Sows were present 365 days, including empty periods, gestation (114 days) and lactation (60 days); the number of gestations per sow per year was considered. Fatteners were present until sale; they were assumed to consume feed from day 60 (weaning) to the day of offtake. Where individual household data were not available, village-specific arithmetic means for the spring season were used.

The following parameters indicated the economic success of pig producers:

$$\text{Gross margin (VND/hh per year)} = C - V$$

$$\text{Net benefit (VND/hh per year)} = (C+N)-(V+O)$$

$$\text{Benefit} - \text{cost ratio}_1\ (\text{BCR}_1) = C/V$$

$$\text{Benefit} - \text{cost ratio}_2\ (\text{BCR}_2) = (C+N)/(V+O)$$

The cash revenue (*C*) originated from the sale of pigs and manure. Variable cash costs (*V*) included costs for veterinary care, matings, purchase of pigs and purchase of feeds from market. The non-market value of production (*N*) comprised pigs that had been slaughtered or given away as gift and was based on the number and weight of the respective pigs and the village-specific average farm-gate price for a pig of this weight. Feed opportunity costs (*O*) were calculated from the amount of farm-produced maize/soya fed to pigs per household per year and respective average farm-gate prices. Maize and soya were both feedstuffs and major cash crops for almost all farmers. In comparison, other crops (vegetables, rice, rice bran, cassava) were only occasionally sold by some households in small amounts and were therefore neglected for calculation of feed opportunity costs. All monetary inputs and outputs are given in Vietnamese Dong with an exchange rate of 1 USD~15 000 VND (year 2001/2).

Data analysis was performed using SAS 8.02 (SAS Institute Inc., Cary, NC, USA). Continuous response variables were analysed using linear models with fixed effects. Normal distribution and variance homogeneity of residuals were tested for the applied models; if necessary, data were transformed prior to analysis. Least-squares means (LSM) were estimated and compared pairwise by Scheffé's method for multiple tests. LSM are given without standard errors if data had been transformed prior to analysis. A number of discrete quantitative variables were analysed by the non-parametric Kruskal–Wallis test. As this test evaluates the ordinal information of data, results are presented as medians and lower and upper percentile and not as arithmetic means and standard deviations.

Descriptive statistics of data are given if applied models do not explain variation at a significant level. In addition to the conventional levels of statistical significance, differences are considered at a lower significance level ($0.05<p\leq 0.1(*)$) for selected parameters analysed by the Kruskal–Wallis test. In the following, systematic components of statistical models applied are given, following the model notation suggested by Piepho and colleagues (2003), where the cross between two effects stands for the main effects and their interaction. For all models, *y* is the dependent variable, *V* is the village effect (four villages: Ban Buon, Ban Bo, Na Huong, Bo Duoi), *Y* is the year effect (two years: 2001, 2002), *S* is the

season effect (two seasons: spring, summer), and R is the effect of a sow's reproductive state (four states: gilt, empty/low gestation, late gestation, lactation). From the main model $y = V \times Y \times S$ (×R), the following reduced models were derived:

Model I (feed costs of sow rations on test-day):

$$y = V \times Y + V \times S + V \times R + Y \times S + Y \times R + S \times R$$

Model II (feed costs of fattener rations on test-day)

$$y = V \times Y + V \times S + Y \times S$$

Model III (fresh matter and dry matter intake of pigs on test-day)

$$y = V \times Y + V \times S + V \times T + Y \times S + Y \times T + S \times T$$

Model IV (animal costs, per-household veterinary costs, per-pig veterinary costs)

$$V \times Y$$

Model V (feed use efficiency, cash revenue, total output, variable cash costs, total variable costs)

$$y = V$$

Results and discussion

This section initially presents an overview of socio-economic characteristics of investigated farm households and of pig production management. Original research results on inputs, outputs, benefits and efficiency of pig production are presented and discussed in separate sections, and the final section discusses methodological restrictions of the study.

Socio-economic characteristics of pig keepers

Farms investigated represented integrated smallholder production systems. Households had on average six members, but were significantly larger away from town owing to higher numbers of children per family. The majority of households were not poor according to official Vietnamese poverty criteria, i.e. they had at the time of survey an income of more than 79,000 VND (or 5.3 USD) per capita per month. Farmers cultivated various crops, including paddy rice for consumption and maize as major cash crop. Main livestock species were pigs, cattle, buffaloes, chickens, ducks and fish. The median farm size was 1.0, 1.8, 3.0 and 1.7 ha in Ban Buon (near town), Ban Bo (near town), Na Huong (away from town) and Bo Duoi (away from town), respectively; village differences were significant. Major income sources were cropping, husbandry and off-farm jobs. The median cropping revenue was 3.3, 4.6, 22.3 and 12.6 mVND/hh per year in Ban Buon, Ban Bo, Na Huong and Bo Duoi, respectively; the figures were 2.5, 6.0, 0.7 and 0.2 mVND/hh per year for husbandry revenue and 0.0, 5.1, 0.0 and 0.0 mVND/hh per year for off-farm revenue. Differences in land holdings, major income sources and revenues indicated that households in the four villages followed different livelihood strategies and had different production objectives concerning pig production. Husbandry and especially pig keeping seemed to be of comparatively greater importance for farmers near town, while cropping seemed to be of greater importance away from town. Further details on characteristics of investigated households can be obtained from Lemke and colleagues (2005, 2006).

As household selection had purposely been stratified by village location, production pattern, production intensity and pig breed, results are representative only for smallholder pig keepers with similar characteristics in the northern uplands, but not for pig keepers or smallholder farmers in Vietnam in general.

Pig production management

Household pig herds were small, with 1.3 sows, 4.2 fatteners and 6.6 piglets. Only few households away from town kept boars, with few boars per herd. Herd size and composition did not differ statistically between villages. Near town, Mong Cai (MC) was the major sow line, but in Ban Buon, a few farmers also kept Ban sows. Large White (LW) was the major sire breed. Artificial insemination was common. All matings were charged in cash. Away from town, Ban sows were mated with exotic, crossbred or Ban boars. Mating was free of charge when boar and sow owners were relatives or for breeding within the own herd. Considerable inbreeding was reported for the Ban population.

Farmers fattened the offspring from their sows, but some farmers bought additional piglets for fattening. Pigs were permanently penned. Mixed pig batches (including pigs of different type and age) were observed in 19% of pens near town and in 37% of pens away from town, limiting the possibilities of performance-oriented feeding. Batches including intact boars were observed only away from town.

Diseased pigs were treated by 80% of farmers near town, but only by 7% and 29% of farmers in Na Huong and Bo Duoi, respectively; for vaccination coverage, the figures were 88%, 31%, 29% and 60%. Seventy-one per cent of farmers dewormed pigs. The overall disease prevalence, i.e. the number of diseased pigs among all pigs recorded in the study period, did not differ between villages. Given the extensive management away from town, this suggested considerable hardiness of Ban pigs.

Near town, pig keeping was mainly women's responsibility; away from town, household members tended to share the work. Farmers spent up to 5 hours per day on pigs. Collecting roughage and fuel for cooking pig feed was especially time-consuming, depending on season and herd size. Near town, a growing number of farmers bought fuel and feed from market, replacing labour-intensive by more costly management practices. Labour shortages resulted in temporary herd reduction or complete sale with later restocking.

Pig feed was usually cooked. The average feeding ration consisted of 4.6 kg roughage, 0.58 kg maize, 0.48 kg rice bran, 0.05 kg broken rice, 0.23 kg fresh and 0.26 kg dried cassava, 0.04 kg concentrate, 0.09 kg distiller's grains, 0.02 kg soybeans and 0.04 kg fish per pig per day (n=271). Composition of rations varied strongly between villages, seasons, years and pig types. Near town, farmers tended to feed higher amounts of energy-rich feeds per pig per day than away from town, where rations included higher amounts of roughage and fresh cassava. Farm-grown feed, i.e. maize, soybeans, cassava and rice bran, was abundant from the harvest in late summer until the next spring, with feed shortages in the months before the successive harvest. Near town, farmers bought all types of feed in considerable amounts from market to supplement farm-produced feed resources (Table 2). Away from town, only purchase of fish and concentrate was noteworthy.

Table 2 Percentage of households buying selected feed components, by village (percentages of raw data)

	Production system/village			
	Demand-driven, near town		Resource-driven, away from town	
	Ban Buon	Ban Bo	Na Huong	Bo Duoi
hh (n)	58	54	53	57
Maize (%)	31	20	0	2
Rice bran (%)	17	22	4	4
Cassava, dried (%)	9	11	0	0
Concentrate[#] (%)	53	59	11	39
Soybean (%)	43	22	0	0
Fish, dried (%)	79	46	60	49

Data pooled over years (2001, 2002) and seasons (spring, summer).
[#] Commercial energy-protein concentrate feed.

The daily energy intake was 31.9 MJ ME/pig per day for sows and 7.5 MJ ME/pig per day or 0.7 MJ ME/kg per day for fatteners. It was generally higher in the demand-driven and lower in the resource-driven villages, but gradations within systems were also observed. Sows of different reproductive stages had roughly the same energy intake. Hence, lactating sows with increased energy requirements were energy-deficient in all villages. In contrast, fatteners were oversupplied with energy, which was assumed to reflect their function as a "savings account" for surplus cash and feed resources. Energy intake also reflected seasonal and annual feed supply. In sum, feeding intensity was determined by resource availability rather than by performance-related requirements of pigs, but this dependence on available resources was more pronounced in resource-driven villages away from town. Within their respective systems, feeding of Ban and Mong Cai (MC) sows was adapted to their demands (except in lactation). Energy supply in resource-driven villages was lower than the estimated demand of MC sows.

Offtake reasons were sale (90% of households), slaughter (52%) and non-market transactions (35%). Slaughter in Na Huong away from town was significantly more frequent (93% of households) than in the other three villages (31–44%), owing partly to the fact that it was still common in Na Huong to pay hired fieldworkers with pork. Near town, farmers sold pigs in specified age/weight classes as weaners or fatteners. Away from town, pigs were sold at times of cash, feed or labour shortage, at any age and weight. Average sales prices per kg live weight were 17 800± 2000 VND for weaners (n=557), 11 400±2400 VND for fatteners (n=497) and 8760±1300 VND for sows (n=20).

Findings were in line with the argument that animals are only managed intensively when they make a significant contribution to production and income, as in the villages near town, but not if saving is their main function (Bennison *et al.*, 1997). Differences in market access and potential for cropping as an alternative income source might be major reasons for different pig production objectives in the two regions. Differences in wealth rank or spending power of households are also assumed to be of importance.

Under the observed management schemes, sows in Ban Buon farrowed 9.9 piglets per litter and had 1.4 litters per year, while the figures were 11.5 and 1.5 for Ban Bo. Away from town, sows farrowed 7.5 piglets per litter and had 1.1 litters per year. The productivity index (kg piglet weaned per year/(sow metabolic live weight)) was 2.0, 2.8, 1.2 and 0.8 kg/kg$^{0.75}$ for sows in the four villages, while the average daily gain of offspring between days 7 and 180 was 136, 177, 85 and 66 g/day, respectively. Different performance levels reflected the distribution of genotypes and differences in management intensity between villages and systems, but could not be separately quantified owing to the confounding of genetic and environmental effects, as higher yielding genotypes prevailed near town and lower-yielding genotypes prevailed away from town (Lemke *et al.*, 2006).

Inputs into pig production: variable cash costs

Overview over variable cash costs

Variable cash costs comprised feed, animal, veterinary and breeding costs. They were higher in the demand-driven and lower in the resource-driven villages (Fig. 1). Feed costs represented the major part of variable cash costs (Ban Buon 84% of variable cash costs; Ban Bo 58%; Na Huong 76%; Bo Duoi 37%). Breeding and veterinary costs in all villages were negligible.

Similarly, feed costs represented about 90% of the bulk of variable costs in other small-scale sow-weaner production systems (e.g. Van Eckert, 1993; Lan, 2000; Thuy, 2001). Thuy (2001) found for weaner-fattener systems without sow-keeping that total costs comprised 70% of feed costs but about 30% of animal costs. In the following, the components of variable cash costs are explored further.

Feed costs

Average feed costs were 1221±2151 VND/day for sows (n=169) and 285±693 VND/day for fatteners (n=272). However, only 66% of sow rations and 64% of fattener rations included purchased feeds, while the remaining rations consisted entirely of farm-grown feeds. For sows, the number of rations including

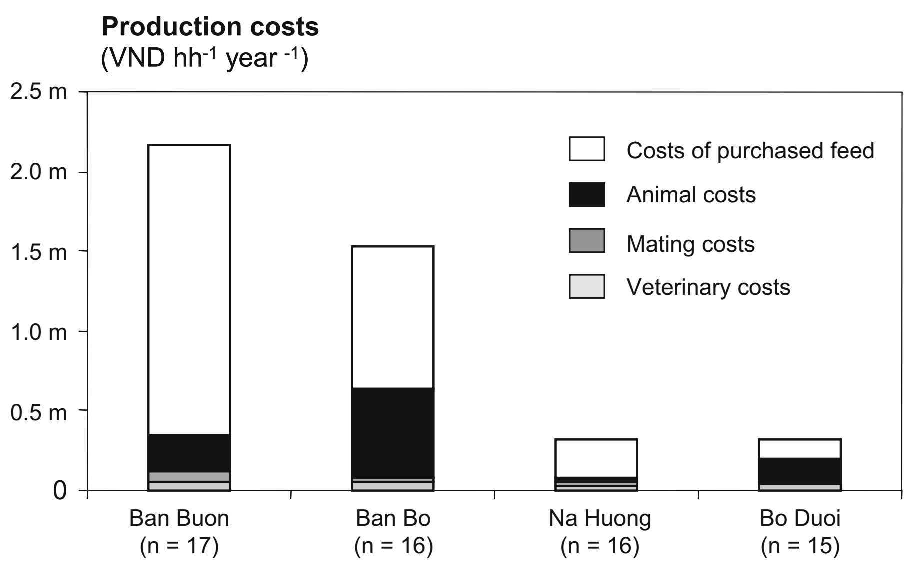

Fig. 1 Composition of variable cash costs in pig production, by village. Arithmetic means over all pig keepers, year 2002

purchased feeds differed significantly between seasons within years, while no village effect was found (analysed by logistic model). For fatteners, no significant effect was found of either year, season or village; however, in the case of fatteners the unbalanced data structure limited statistical analysis. For the sub-sample of rations including purchased feeds, cash costs were 1712±2243 VND/day for sows (n=81) and 446±824 VND/day for fatteners (n=174).

Feed costs were analysed by linear models. For concise presentation, we show results for sows and mention results for fatteners only where major differences in comparison with sows were found.

The village had the strongest effect on sows' daily feed costs ($p<0.001$); differences between reproductive states within seasons were slightly significant ($p<0.05$). For fatteners' feed costs, season and village both had strong effects ($p<0.001$; $p<0.001$), while the year×village effect was weak and slightly significant ($p<0.05$). Sows' daily feed costs were highest near town, intermediate in Na Huong and lowest in Bo Duoi (Fig. 2). All reproductive stages were fed at same daily costs, except for sows in late gestation, which received more costly rations in summer. Lactating sows were not prioritized in the allocation of feed and cash resources. Results for fatteners were in line with results for sows: in both years, costs were lower in resource-driven than in demand-driven villages and lower in spring than in summer.

In comparison with our findings, feed purchase in the densely populated Red River delta was less common but more costly: Thuy (2001) found only 48% of pig keepers to buy additional feed, but at costs of 5000 and 3400 VND/day for sows and fatteners, respectively, while Lan (2000) reported costs of 4000 and 3000 VND/day for sows and fatteners in 11% of households. In our study, many farmers mentioned that it was essential to buy dried fish as it stimulated pigs' appetite when rations consisted mainly of roughage. Purchase was also a strategy to cope with feed shortages, and thus might be more common in a region with less favourable cropping conditions like the mountainous area. Low feed costs might be due to smaller amounts purchased and lower prices of locally produced feeds.

Results confirmed that feeding was more intensive in the demand-driven and less intensive in the resource-driven villages. Within-system gradations were observed especially for the two villages away from town. We had assumed that feed purchase would be less frequent under extensive conditions, but this was not the case owing to the frequent purchase of small amounts of dried fish away from town.

Daily feed costs tended to increase from spring to summer, while the energy intake decreased (Lemke *et al.*, 2006). Before the harvest, stores were depleted and farmers lacked feed, but also crops for sale and thus cash. Empty stores could force farmers to buy feed from the market. Prices for local feeds (maize, rice bran, soybean) increased in shortage periods (Tra, 2003). As purchase of local feeds was more common near town, a stronger impact of seasonal price variations on daily feed costs is assumed.

Purchase of weaners for fattening

Sow-keeping farmers paid on average 0.9 mVND/hh per year for additional weaners. Annual costs differed

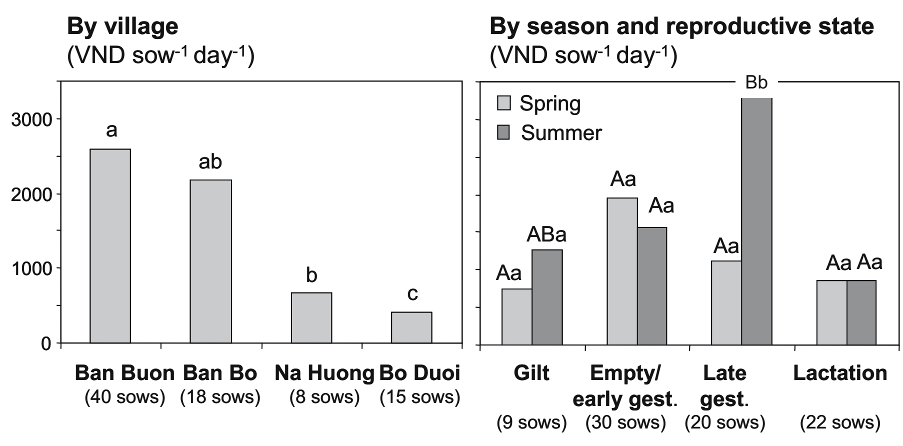

Fig. 2 Feed costs for sows on test-day. LSMs with the same letter do not differ significantly at $p<0.05$; decision is based on Scheffé's method for multiple tests. For season*reproductive state interactions, lower-case letters indicate differences between seasons within reproductive state, upper-case letters indicate differences between reproductive states within season

between villages ($p<0.01$, linear model) but not between years. Great and significant differences were notable between costs in Ban Bo near town (2.6 mVND/hh per year) and in the other three villages (0.6, 0.2 and 0.4 mVND/hh per year for Ban Buon, Na Huong and Bo Duoi, respectively).

Sow-keepers might buy additional weaners because they dispose of surplus cash or feed resources, to restock their herd after losses or to supply for upcoming festivities, owing to favourable market access, attempting to maximize their income from a higher number of pigs, or because of quality requirements or perceptions (Lemke *et al.*, 2006). The first two reasons might be relevant for all producers, while the remainder might be more decisive for the market-oriented producers in the villages near town.

Mating costs

The average mating fee was 19 352±14 896 VND (n=108). Away from town, numerous matings were conducted free of charge. If considering only charged matings, the median fees per mating were 25 000 VND (Ban Buon), 25 000 VND (Ban Bo), 40 000 VND (Na Huong) and 30 000 VND (Bo Duoi); village differences were significant ($p<0.01$, Kruskal–Wallis test). The higher mating fees away from town reflected higher transport costs. However, the total mating costs of 37 700±31 000 VND/hh per year did not differ between villages: near town, service was cheaper but was required more frequently owing to the higher farrowing frequency of sows (Lemke *et al.*, 2006). For smallholders in the Red River delta Thuy (2001) reported lower service fees (15 000 VND per pregnancy) but similar total costs (38 000 VND/sow per year) owing to a high farrowing frequency of 2.1 litters/year. Annual costs for mating dropped by 20% in herds affected by foot-and-mouth disease (Thuy, 2001).

Veterinary costs

Total veterinary costs per year were 2349±2965 VND per pig or 44 961±80 758 VND per household (n=61 hh). Annual deworming costs were 459±474 VND per pig or 8615±8123 VND per household (n=40 hh). For total and deworming costs, village differences were not significant.

Costs for curative treatment per year were 2418±2598 VND per pig or 57 036±96 934 VND per household (n=28 hh). Annual vaccination costs were 2487±2680 VND per pig or 34 826±42 253 VND per household (n=23 hh). Treatment and vaccination costs per pig tended to be higher in villages away from town, reflecting higher transport costs (Table 3). Per-household costs for curative treatment tended to be higher near town, where costs per pig were lower but farmers kept more pigs per year and treatments were more frequent. Per-household costs for vaccination reflected the fees per pig and tended to be higher away from town. Per-household vaccination costs did not correspond to the vaccination coverage, which was highest in Ban Buon and Bo Duoi. For veterinary costs the explanatory power of results is limited by the small number of observations.

Table 3 Annual costs for curative treatments and vaccinations, by village (least-squares means, LSM)

Cost component	Unit	Production system/village			
		Demand-driven, near town		Resource-driven, away from town	
		Ban Buon	Ban Bo	Na Huong	Bo Duoi
Treatment	hh (n)	13	10	1	4
	VND/pig per year	2 965[a]	1 361[b]	6 500[a]	2 265[a]
	VND/hh per year	61 769[a]	60 200[b]	39 000[ab]	38 250[ab]
Vaccination	hh (n)	14	4	4	9
	VND/pig per year	535[a]	794[a]	5 895[b]	3 025[b]
	VND/hh per year	6 250[a]	22 625[ac]	84 250[b]	37 333[bc]

Village differences significant for treatment costs per pig ($p<0.01$), treatment costs per household ($p<0.05$), vaccination costs per pig ($p<0.005$), vaccination costs per household ($p<0.01$) (linear models).

LSMs in the same row with the same superscript letter do not differ significantly at $p<0.05$.

Offtake from pig production

Offtake from pig production was evaluated in terms of live weight offtake and of the equivalent monetary value. The revenue from selling manure was included in the pig production cash revenue. Other benefits from pigs were not assessed in this study.

Households extracted on average 334 kg pig live weight per year (Table 4). The total offtake comprised offtake for sale, slaughter and gifts, with average amounts of 300, 82 and 28 kg/hh per year, respectively. Not all households extracted pigs for all purposes (see Pig production management above). Owing to different numbers of observations for each parameter, partial offtakes in Table 4 do not sum to the total offtake.

The total offtake was highest in villages near town, intermediate in Na Huong and lowest in Bo Duoi. The sold offtake was higher near town and lower away from town, and vice versa for slaughter. No significant village effect was found for the offtake for gifts.

Total live weight offtake in this study was comparable to findings of other authors on smallholder pig keeping in Vietnam, with 400–700 kg pork/hh per year (Donovan, 1997), 323–808 kg live weight/hh per year (IAE, 1997, cited by SVSV, 1998) and 60–580 kg live weight/hh per year (Tra, 2003).

The system and village differences in live weight offtake found in this study were associated with the distribution of genotypes and their respective performance realization. Near town, live weight offtake originated primarily from higher-yielding LW×MC fatteners in Ban Bo, but from LW×MC and additionally pure Mong Cai, LW×Ban and other fatteners in Ban Buon. Away from town, farmers kept mostly Ban fatteners in Bo Duoi but raised both pure Ban and LW×Ban in Na Huong. Inbreeding, associated with depression of performance, was found in Ban pigs in general but to a more pronounced degree among Ban pigs in Bo Duoi (Lemke *et al.*, 2006). It was also found that the number of pigs kept per household per year was highest in Ban Bo, intermediate in Ban Buon and Na Huong and lowest in Bo Duoi (Lemke *et al.*, 2006). Thus, an effect of pig turnover must be assumed, reflecting different pig performances but also different management strategies.

Feed use efficiency

This study aimed to evaluate the resource use efficiency of pig production at household level. Feed was a major resource, its availability limiting pig production. The feed conversion or feed efficiency of animals has been defined as the feed required per unit of product, e.g. kg feed required per kg weight gain. Instead, this study characterized the feed use efficiency at household level as live weight produced per household per year in relation to the feed required to produce this live weight, expressed in terms of metabolizable energy. To test the plausibility of results, fresh matter (FM) and dry matter (DM) intakes of pigs were assessed as auxiliary parameters.

Pigs had an average intake of 6.3±4.8 kg FM or 1.8±1.5 kg DM per pig per day (n=295). Sows of different reproductive stages had similar FM and DM intakes (analysed by linear models). Hence, we distinguished in analysis only between pig types

Table 4 Pig live weight offtake (kg/hh per year), by offtake purpose and village

Offtake	Production system/village								Total	
	Demand-driven, near town				Resource-driven, away from town					
	Ban Buon		Ban Bo		Na Huong		Bo Duoi			
	n	LSM	n	LSM	n	LSM	n	LSM	n	Mean
Total	14	389^{ab}	16	538^{a}	15	242^{bc}	15	157^{c}	60	334
Sale	14	371^{a}	16	510^{a}	13	123^{b}	13	143^{b}	56	300
Slaughter	5	24^{a}	7	40^{a}	14	134^{b}	6	61^{ab}	32	82
Gifts	5	26	3	59	8	19	6	24	22	28

Village differences significant for total offtake (p<0.001), sold offtake (p<0.001), offtake for slaughter (p<0.05) (linear models).
LSMs in the same row with the same superscript letter do not differ significantly at p<0.05.
Mean is arithmetic mean.

(sows, fatteners) but not between sows' reproductive stages. Both FM and DM intake were most strongly influenced by pig type ($p<0.001$). The FM intake differed also between years ($p<0.001$), while the DM intake differed between villages ($p<0.05$) and seasons ($p<0.05$), and between pig types within villages ($p<0.05$) and between seasons within years ($p<0.05$).

The FM intake was lower in fatteners than in sows (3.6 and 8.8 kg/pig per day, respectively) and was in 2001 lower than in 2002 (5.3 and 7.1 kg/pig per day, respectively).

The DM intake was lower in fatteners than in sows (1.1 and 2.3 kg/pig per day). This difference was found for fatteners and sows in general as well as for fatteners and sows in each village. The DM intake was higher in spring than in summer (1.9 and 1.5 kg/pig per day). However, seasonal differences were significant only in 2001 (2.0 and 1.4 kg/pig per day in spring and summer 2001). The DM intake was 1.9, 2.1, 1.5 and 1.3 kg/pig per day in Ban Buon, Ban Bo, Na Huong and Bo Duoi, respectively. The higher intake in Ban Bo differed significantly from the lower intake in Bo Duoi. Fatteners in all villages had the same DM intake, while sows tended to have a higher DM intake in demand-driven villages.

Kirchgeßner (1996) gave the feed intake of exotic pigs under intensive conditions as up to 3.1 and 5.9 kg FM/sow per day in gestation and lactation, respectively, and up to 3.4 kg FM/fattener per day. In line with our findings, high feed intakes have been reported for smallholder pig keeping in North Vietnam, with around 10 kg FM/pig per day (Peters *et al.*, 2005) and 0.7–3.0 kg basal diet (FM) plus 1.6–5.7 kg roughage (FM) per sow day, and 0.2–0.6 kg basal diet plus 0.4–0.7 kg roughage per fattener per day (Tra, 2003). Tra (2003) also found that the feed intake recorded through interviews tended to be overestimated. Pigs of Chinese descent are assumed to have a superior gut capacity for fibrous feeds, and unimproved breeds were reported to have a higher appetite than improved lean genotypes (Whittemore *et al.*, 2001, citing various authors). The feed intake depends on, among other things, the pig's gut capacity and nutrient requirements and the diet's nutrient density (Whittemore *et al.*, 2001), a low-energy diet causing higher feed intake. The low energy density of diets at smallholder farms in Vietnam, owing to high amounts of roughage, was confirmed by Peters and colleagues (2005), for example.

Results on the DM and FM intake confirmed that feeding strategies differed between pig types but also between years and seasons. Most farmers prepared one feed mixture and gave different shares of it to sows and fatteners; but some farmers prepared type-specific rations. In times of shortage, farmers tended to replace high-energy feeds, especially maize, with roughages, vegetables and fresh cassava with low DM content. In 2002, less feed was available owing to a poor harvest in the previous year. Thus, the FM intake increased in 2002. Similarly, feed replacements in the summer lean season were reflected in a decreasing DM intake (while the FM intake did not change). The DM intake also reflected system-specific feeding intensities as well as gradations within systems.

The intake of metabolizable energy of the household pig herd (GJ/hh per year) was related to the sold and total live weight offtakes (kg/hh per year), resulting in a feed use efficiency of 12.0 and 14.9 kg/GJ, respectively (Table 5). Feed use efficiency based on the sold offtake was higher in Ban Bo near town than in the other villages. Feed use efficiency based on the total offtake was highest in Ban Bo, intermediate in Na Huong away from town and lowest in the other two villages.

Various productivity indices have been used in literature, relating the output to the unit of resource use. Bosman and colleagues (1997) suggested expressing biological herd productivity by dividing the annual net weight change in a herd by the scarcest factor as denominator. As biomass was plentiful on farms in this study, and pigs were fed on bulky diets with low energy densities, the feed energy as limiting factor was preferred over the feed amount, also allowing us to deal with the very heterogeneous feed composition at farms. The offtake from the pig herd was used to approximate weight production in the herd.

For comparison, feed use efficiency was approximated from pigs' daily energy intake and daily gain reported by other authors. A low efficiency of 11.7–13.1 kg/GJ derived for LW×MC under smallholder conditions (Loc *et al.*, 1997) was in line with results for Ban Buon and Na Huong. A higher efficiency of 26–29 kg/GJ for LW×MC under improved conditions (Giang *et al.*, 2004) corresponded to results for Ban Bo. A still higher efficiency of 32.0 kg/GJ was derived for intensively kept Large Whites in Europe (Landesanstalt für Schweinezucht Forchheim, 2002).

Table 5 Feed use efficiency of household pig production (kg/GJ), expressed as the sold and total extracted live weight (lw) per household and year related to the total invested (inv.) metabolizable energy, by village (LSM)

	Production system/village				Total
	Demand-driven, near town		Resource-driven, away from town		
	Ban Buon	Ban Bo	Na Huong	Bo Duoi	
hh (*n*)	16	14	15	15	60
Sold lw/inv. energy	12.3[a]	23.0[b]	6.3[a]	6.9[a]	12.0
Total lw/inv. energy	12.7[a]	23.8[b]	15.0[ab]	9.0[a]	14.9

Village differences significant for sold live weight offtake over invested energy ($p<0.01$), total live weight offtake over invested energy ($p<0.05$) (linear models).

LSMs for villages in the same row with the same superscript letter do not differ significantly at $p<0.05$.

Factors accounting for low feed use efficiency included lower-yielding pig genotypes, which dominated away from town and were kept by few farmers in Ban Buon; long fattening periods with high feed 'investments' as observed away from town; and unbalanced feeding above pigs' requirements (Peters *et al.*, 2005), as reported for fatteners in this study (Lemke *et al.*, 2006).

Economic benefit and efficiency

The average cash revenue from the sale of pigs and manure was 3.4±3.1 mVND/hh per year. The total output comprised additionally the value of pigs consumed and given away as gifts and was slightly higher (3.9±3.0 mVND/hh per year). Variable cash costs were 1.1±1.4 mVND/hh per year. Total variable costs included additionally the opportunity feed costs and equalled 1.9±1.8 mVND/hh per year.

The total pig production output was highest near town, intermediate in Na Huong and lowest in Bo Duoi (Fig. 3), reflecting the differences in live weight output and the underlying differences in distribution of genotypes and production intensity between villages. In Na Huong, a higher output share than in the other villages was not sold but was used for subsistence purposes (village differences significant at $p<0.05$). The resulting cash revenue in Na Huong and Bo Duoi did not differ and was significantly lower than for demand-driven pig production near town.

Variable cash costs were significantly higher near town (Fig. 3), owing to the stronger use of external inputs. Total variable costs were highest near town, intermediate in Na Huong and lowest in Bo Duoi (Fig. 3), as the value of farm-grown feed given to pigs did not differ in Na Huong and the villages near town and was significantly higher than in Bo Duoi (village differences significant at $p<0.001$).

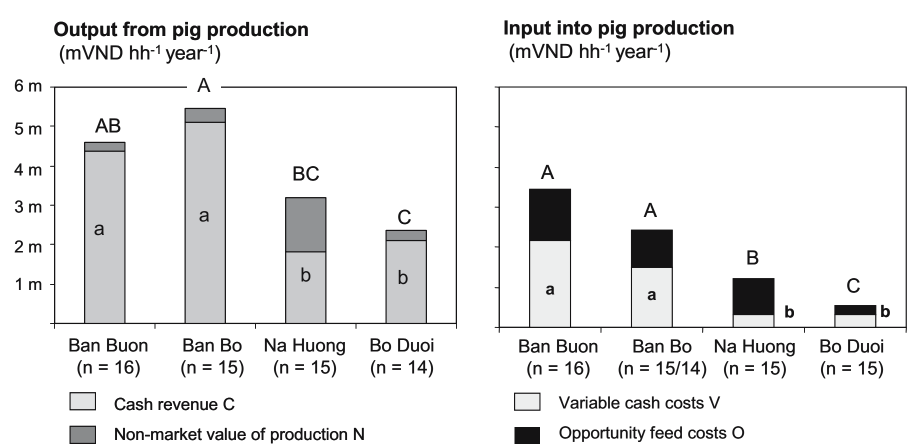

Fig. 3 Pig production outputs and input. Village differences significant for cash revenue *C* ($p<0.001$), total output *C*+*N* ($p<0.01$), variable cash costs *V* ($p<0.001$), and total variable costs *V*+*O* ($p<0.001$) (linear models). LSMs marked with the same letter do not differ significantly at $p<0.05$. Lower-case letters refer to *C* (left) and *V* (right); upper-case letters refer to *C*+*N* (left) and *V*+*O* (right)

Comparing market-related inputs and outputs, the two production systems could be contrasted as high-input–high-output and low-input–low-output systems. Additional consideration of (a part of) the non-market inputs and outputs changed the ranking order, and in particular pig production in Na Huong was redefined as a transitional stage between a low-input–low-output and high-input–high-output system.

The economic success of pig production was evaluated on the basis of gross margin (GM), net benefit (NB) and different benefit–cost ratio scenarios (BCR_1, BCR_2) (Table 6). To correct for the varying weight of end-products, GM and NB were also related to the live weight offtake per household per year.

Results were in the range of values reported by Tra (2003) for smallholder pig keepers in Son La (GM 0.5–3.8 mVND/hh per year, BCR_1 1.9–38.3). Other authors found GM values of 0.3–0.7 mVND/sow per year (sow-weaner production) and 0.02–0.05 mVND/fattener for Vietnamese smallholders (Lan, 2000; Thuy, 2001; Lapar *et al.*, 2003). Lan (2000) and Thuy (2001) reported higher daily feed costs than found in our study, which might partly explain their lower gross margins. Thuy (2001) found a negative GM for herds affected by epidemics. Peters and colleagues (2005) stated that smallholders in Vietnam frequently conduct pig production at a loss.

The GM was higher for demand-driven than for resource-driven pig production, but gradations within systems were found (Table 7). GM was highest in Ban Bo. In this village, the incidence of improved genotypes, live weight offtake and cash revenue tended to be higher, and cash costs, especially feed costs, tended to be lower than in the other village near town. In Bo Duoi away from town, farmers had a lower live weight offtake but sold a slightly, albeit not significantly, higher share of this offtake than did farmers in Na Huong. With similar cash costs, they thus yielded a slightly higher GM.

The NB did not differ between villages, as the higher total variable costs near town and in Na Huong outweighed the higher total output in those three villages. Significant village differences were found for BCR_2, but not for BCR_1 or for GM and NB related to the live weight offtake.

Van Eckert (1993) found that intensive pig keepers in Zimbabwe yielded higher pig performances but lower gross margins with improved breeds due to high production costs in comparison to traditional pig keepers with local pigs. Drucker and colleagues (1999) compared local, crossbred and exotic pigs kept by smallholders in Yucatan. They found higher growth and reproductive performances for exotic pigs. None the less, gross margin and net benefit measures were highest for local pigs, intermediate for crossbreds, and lowest for exotic pigs, owing to the higher production costs for the latter two genotypes. However, when additionally considering opportunity labour costs, the net benefit became negative for all genotypes, with an intermediate loss for local and the lowest loss for exotic pigs.

In our study, high outputs were associated with keeping of improved genotypes under improved management, i.e. keeping LW×MC under semi-intensive conditions, followed next by LW×B and other crossbreds in a semi-intensive to extensive/semi-intensive transitional system. High benefits were based on high outputs, but were further associated with the degree of market orientation as well as with the optimization of management at a given intensity

Table 6 Economic success of pig production: gross margin (GM), net benefit (NB) and benefit–cost ratios (BCR)

Parameter	hh (*n*)	Mean	Median	Minimum	Maximum
GM (mVND/hh per year)	59	2.0	1.2	−2.5	8.9
NB (mVND/hh per year)	58	1.6	1.4	−4.3	8.0
GM/lw offtake (VND/kg per year)	57	5797	6464	−13 560	38 244
NB/lw offtake (VND/kg per year)	56	4296	5730	−38 107	40 076
BCR_1	59	7.4	3.4	0.0	56.2
BCR_2	58	3.5	2.0	0.0	19.1

Mean is arithmetic mean ; lw, live weight.

$GM=C-V$; $NB=(C+N)-(V+O)$; $BCR_1=C/V$; $BCR_2=(C+N)/(V+O)$.

C=cash revenue, O=opportunity feed costs, N=non-market production value, V=variable cash costs.

Table 7 Gross margin (mVND/hh per year) and BCR_2, by village

Parameter	Production system/village							
	Demand-driven, near town				Resource-driven, away from town			
	Ban Buon		Ban Bo		Na Huong		Bo Duoi	
	Median	P_{25} to P_{75}	Median	P_{25} to P_{75}	Median	P_{25} to P_{75}	Median	P_{25} to P_{75}
hh (*n*)	16 (16)[#]		14 (13)		15 (15)		14 (14)	
GM	1.5	−0.9 to 3.1	3.1	1.8 to 6.0	0.5	0.0 to 1.1	1.0	0.7 to 2.4
BCR_2	1.2	0.4 to 1.9	2.1	1.0 to 4.5	2.7	1.8 to 4.3	3.0	1.6 to 8.3

[#] *n* refers to gross margin, (*n*) refers to BCR2.

P_{25}=25th percentile; P_{75}=75th percentile.

Village differences significant for GM ($p<0.05$) and BCR_2 ($p<0.05$) (Kruskal–Wallis test).

level, including, for example, more balanced feeding, shorter fattening periods, lower feed costs, and concordance between the performance level of the chosen pig genotype and the input intensity provided.

Farmers interviewed in the investigated villages indicated that high and timely cash revenue was most desirable, rather than high economic benefit or efficiency. This is in line with the findings of Teufel and colleagues (1998) for Punjabi goat keepers that liquidity might be a limiting factor for households, so that cash revenue is of higher relevance than cash income. In addition, the manifold non-market functions of pigs (e.g. saving, insurance and socio-cultural functions, manure supply) might even contradict the income-generating function of pigs. In our study, NB and BCR_2 considered the non-market costs and benefits to a stronger degree and were therefore found to better reflect smallholder production aims than GM and BCR_1. Nevertheless, it would be desirable to consider costs and benefits as comprehensively as possible, i.e. to additionally assess labour and other fixed costs as well as the non-market benefits of pigs. This would probably yield a different ranking order of breeds and systems, and further investigation is required to conduct a full cost analysis.

A high percentage of farmers conducted pig production at a loss (farmers with GM≤0: 20%; farmers with NB≤0: 24%), but this did not differ between villages (analysed by chi-squared test). The following traits were tested for their potential to distinguish between ineffective and successful producers: time since household foundation, total land area, paddy area, cropping/off-farm/total household revenue, schooling of head of household/his wife, wealth rank, number of family members/children/adults, pigs' feed use efficiency, maize amount harvested/sold/put aside for livestock, number of cattle/buffaloes/pigs/chickens per household, rate of subsistence production of pigs, overall pig mortality, and average reproductive performance of sows kept per household in the study year (litter size at birth, pre-weaning piglet mortality, farrowing frequency). The comparison was performed over all households, as analysis by village would have been based on extremely small sub-samples.

Pig producers with GM≤0 had lower total cash revenue, lower feed use efficiency, kept less maize for animals, had fewer chickens and used a greater share of the total offtake for non-market purposes (Table 8). Producers with NB≤0 disposed of less land, belonged to a higher wealth rank, had lower feed use efficiency, had a lower maize harvest, had a wife with more years of formal education, and kept fewer cattle.

The major trait associated with ineffective production was low feed use efficiency, impacted by keeping lower-yielding genotypes, less market-oriented offtake management and unbalanced feeding. According to Peters and colleagues (2005), improved growth efficiency through improved feeding is decisive in increasing the profitability of pig production in North Vietnam. Van Eckert (1993) found that successful pig keepers in Zimbabwe yielded higher pig performances owing to comparatively improved management.

Farmers with NB≤0 belonged to a higher wealth rank. They might find other income sources than husbandry more profitable, being less concerned about

Table 8 Traits of ineffective and successful pig producers

	Ineffective producers		Successful producers	
	Median	P_{25} to P_{75}	Median	P_{25} to P_{75}
Success of pig production defined in relation to gross margin (GM)				
Total revenue (mVND/hh per year)	13.1	6.5 to 17.2	19.0	14.2 to 25.6
Total lw/inv. energy (kg/GJ)	4.9	2.7 to 9.0	11.2	6.8 to 24.5
Sold lw/inv. energy (kg/GJ)	1.5	0.0 to 3.5	9.2	6.1 to 19.3
Maize for animals (t/hh per year)	0.6	0.5 to 1.0	1.0	0.5 to 1.5
Chickens (*n*/hh per year)	40	10 to 100	75	50 to 100
Subsistence production (%)	25	3 to 100	4	0 to 28
Success of pig production defined in relation to net benefit (NB)				
Total land (ha/hh)	1.1	0.5 to 2.2	2.0	1.2 to 3.0
Wealth rank	1.0	1.0 to 2.0	2.0	1.0 to 2.0
Total lw/inv. energy (kg/GJ)	4.4	2.2 to 6.3	14.4	7.6 to 25.5
Sold lw/inv. energy (kg/GJ)	2.3	0.4 to 5.6	10.6	6.0 to 21.9
Maize harvest (t/hh per year)	1.0	1.0 to 10.0	6.3	2.0 to 15.0
Wife's school years (years)	6	5 to 9	4	0 to 7
Cattle (*n*/hh per year)	0	0 to 0	0	0 to 1

Sample size: 17 farmers with GM≤0, 47 farmers with GM>0; 19 farmers with NB≤0, 44 farmers with NB>0.

Wealth rank: 0=rich, 1=better off, 2=medium, 3=poor, 4=hungry.

P_{25}=25th percentile; P_{75}=75th percentile; lw, live weight; inv. invested.

Difference between ineffective producers (GM≤0) and successful producers (GM>0) significant for total revenue ($p<0.05$), total lw offtake/inv. energy ($p<0.01$), sold lw offtake/inv. energy ($p<0.001$), maize for animals ($p<0.1$), chicken flock size ($p<0.1$), rate of subsistence production ($p<0.05$). Difference between ineffective producers (NB≤0) and successful producers (NB>0) significant for total land ($p<0.01$), wealth rank ($p<0.01$), total lw offtake/inv. energy ($p<0.001$), sold lw offtake/inv. energy ($p<0.01$), maize harvest ($p<0.05$), school years of wife ($p<0.1$) and number of cattle kept ($p<0.1$) (Kruskal–Wallis test).

efficient pig keeping. Teufel and colleagues (1998) and Huyen (2004) derived similar conclusions for Punjabi and Vietnamese smallholder livestock keepers. It had been assumed that better-educated women were more successful pig keepers, as women were mainly responsible for pigs and formal education was thought to make them more confident, e.g. in interacting with traders or adopting innovations. However, like farmers of a higher wealth rank, better-educated women might find other income sources more profitable or accessible, caring less about efficient pig keeping.

Farmers with GM≤0 did not belong to a higher wealth rank but had a lower total cash revenue than successful ones. This could possibly limit farmers' investment into pig production and hence pig performance. The lack of correspondence between total revenue and wealth rank was not necessarily a contradiction: Dufhues and colleagues. (2001) found that information from officially conducted wealth rankings reflected the well-being of households rather imprecisely. Producers with GM≤0 used a larger part of the total live weight offtake from pigs for non-market purposes, forgoing part of the cash revenue.

Farmers with NB≤0 disposed of less land and fewer cattle and harvested less maize, suggesting a lack of farm-grown feed and also income, owing to a lack of land and draught power. Farmers with GM≤0 kept less maize for animals and had fewer chickens, supporting the concept of scarcity of feed resources.

Methodological restrictions

Owing to the data structure on which this study relies, environmental and genetic effects on economic success and resource use efficiency of pig production were confounded. Under the prevailing distribution of genotypes in investigated villages, confounding of the main effects was inherent. The investigation of conditions in current pig production systems with a holistic approach was the objective of this study. A cross-factorial study design, including experimental redistribution of pigs, would be required to separately estimate main effects and their interactions on the economic success of pig production.

Data for this study were collected through structured household interviews. Interviews yielded information in a time- and cost-effective way, but the accuracy of data was assumed to be lower than that of measured or counted data. Deen and colleagues (1995) found that interview information on pig farm performance tended to overestimate actual values; less so for traits on which farmers received additional outsider information and more so for traits without outsider information provided. Hence, results in this study on cash costs, cash revenue and gross margin can be assumed to be more reliable, as they were based on farmers' interactions with traders and markets, while results on feeding, feed use efficiency, non-market production and opportunity costs were probably less reliable, being based on farmers' recalled information alone and moreover on complex approximation processes. None the less, comparison with other publications suggests that economic success and feed use efficiency of pig production in this study represent reasonable estimates.

Evaluation of pig production in this study was based on data for one year. However, smallholder production systems are characterized by strong annual variations, e.g. in input availability and prices (Lemke *et al.*, 2006) or annual outputs (Adams, 1996). Further investigations need to evaluate a larger number of pig producers over longer periods, allowing application of multifactorial models to test for factors affecting the success of household pig production, including the year effect.

This study found differences in the economic success and resource use efficiency of smallholder pig production in a demand-driven and a resource-driven production system. Differences were identified between villages within systems, reflecting transition processes towards increasing market orientation, production intensity and management optimization. Different evaluation parameters yielded different rankings of production systems and villages. The findings suggest that evaluation of smallholder pig production should be based on net benefit measures that consider both market and non-market benefits and variable and fixed costs, including cash costs and opportunity costs. Seasonal and annual variations of resource availability, prices and production patterns also need to be considered.

In confirmation of the initial hypothesis, demand-driven pig production with improved genotypes yielded a higher revenue but demanded a resource input that was higher than the input level sustained by farmers in resource-driven villages. In Na Huong (extensive/semi-intensive transitional system), the live weight output from Ban and LW × Ban pigs compared positively with the output from demand-driven production with Mong Cai pigs, but high production costs combined with a low market orientation made this form of production rather unsuccessful. However, resource-driven production yielded a comparatively high benefit–cost ratio. For these reasons, we would refrain from suggesting Mong Cai as a production alternative for the resource-driven system under the prevailing conditions of limited resource supply and market access, lower market orientation and stronger saving orientation. However, this study is limited in its ability to draw conclusions on the resource use efficiency of the investigated production systems and the pig breed as impact factor. To achieve this goal, a larger sample will be required as well as a cross-factorial design with different pig breeds tested under different keeping conditions. The present study supplies the foundation for such ongoing investigations.

Ineffective pig producers tended to focus on alternative income strategies and to practise a less market-oriented and more saving-oriented pig production. Development measures probably have a higher impact on farmers perceiving pig production as an income source rather than as a side activity supporting social commitments. Further, successful pig keeping seemed to require a certain resource endowment to support pig production by either cash resources in general or via household crop production.

Acknowledgements The financial support of the German Academic Exchange Service DAAD, the Federal State Baden-Wuerttemberg, and the German Research Council DFG is gratefully acknowledged.

References

Adams, R.H., 1996. *Livestock income, male/female animals, and inequality in rural Pakistan*, (Discussion Paper No. 21; International Food Policy Research Institute, Washington, DC).

Bennison, J.J., Barton, D. and Jaitner, J., 1997. The production objectives and feeding strategies for ruminant livestock owners in The Gambia: implications for policy makers. *Agricultural Systems*, **55**, 425–444.

Bosman, H.G., Moll, H.A.J. and Udo, H.M.J., 1997. Measuring and interpreting the benefits of goat keeping in tropical farm systems. *Agricultural Systems*, **53**, 349–372.

Deen, J., Martin, S.W. and Wilson, M.R., 1995. An evaluation of personal interviews as a method of estimating production indices on Ontario swine farms. *Preventive Veterinary Medicine*, **22**, 263–271.

Donovan, D., 1997. Development in the local context. case studies from selected hamlets in five Northern provinces. In: D. Donovan, A.T. Rambo, J. Fox, L.T. Cuc and T.D. Vien (eds), *Development Trends in Vietnam's Northern Mountain Region*, vol. 2. *Case studies and lessons from Asia*, (East-West Center, Hanoi, Vietnam), 1–93.

Drucker, A., Gómez, V., Ferraes-Ehuan, N., Rubio, O. and Anderson, S., 1999. Comparative economic analysis of Criollo, crossbred and imported pigs in backyard production systems of Yucatan, Mexico, (Wye College, University of London, unpublished report).

Dufhues, T., Dung, P.T. M., Hanh, H.T. and Buchenrieder, G., 2001. *Fuzzy information policy of the Vietnam Bank for the Poor in lending to and targeting of the poor in Northern Vietnam*, (Research in Development Economics and Policy Discussion Paper 3/2001; Verlag Ulrich E. Grauer. Beuren, Stuttgart).

Epprecht, M., 2005. *Geographic dimensions of livestock holdings in Vietnam. Spatial relationships among poverty, infrastructure and the environment*, (PPLPI Working Paper No. 24; FAO, Rome).

Giang, H.H., Ly, L.V. and Ogle, B., 2004. Digestibility of dried an ensiled sweet potato roots and vines and their effect on the performance and economic efficiency of F1 crossbred fattening pigs. *Livestock Research for Rural Development*, **16**, 1–9.

GSO (General Statistical Office), 2001. *Statistical Yearbook Vietnam 2000*, (Statistical Publishing House, Hanoi, Vietnam).

Huyen, N.T.T., 2004. *The impact of animal production in mountainous farming systems development in Northwest of Vietnam*, (Margraf Verlag, Weikersheim, Germany).

Jamieson, N.L., Cuc, L.T. and Rambo, A.T., 1998. The development crisis in Vietnam's mountains. *East- West Center Special Reports* **6**, 1–31.

Kirchgeßner, M., 1996. *Tierernährung. Leitfaden für Studium, Beratung und Praxis*, (DLG-Verlags-GmbH, Verlags Union Agrar, Frankfurt a. M., Germany)

Lan, L.T.K., 2000. *Epidemiology and economics of classical swine fever at smallholder level in Vietnam,* (MSc thesis, University of Reading, Department of Agriculture, Veterinary Epidemiology and Economics Research Unit).

Landesanstalt für Schweinezucht Forchheim, 2002. *Prüfung auf Mastleistung und Schlachtkörperwert*, (Landesanstalt für Schweinezucht Forchheim, Forchheim).

Lapar, L., Binh, V.T. and Ehui, S., 2003. *Identifying barriers to entry to livestock input and output markets in South-East Asia. The case of Vietnam*, (ILRI, Nairobi, Kenya).

Le Coq, J.F., Jésus, F., Nham, L.T. and Binh, V.T., 2002. Filière porc dans le Delta du Fleuve Rouge : identification des enjeux et recherche de solutions en concertation. *Colloque "Des approches innovantes au services du développement agricole"*, 23–27 September 2002, Hanoi, Vietnam.

Lemke, U., Thuy, L.T., Valle Zárate, A., Kaufmann, B.A., and Vang, N.D., 2002. Characterisation of smallholder pig production systems in mountainous areas of North Vietnam. *Deutscher Tropentag*, 9–11 October 2002. Witzenhausen, Germany.

Lemke, U., Kaufmann, B.A., Thuy, L.T. and Valle Zárate, A., 2005. Evaluation of smallholder pig production systems in North Vietnam. *56th Annual Meeting of the European Association for Animal Production*, 5–8 June 2005, Uppsala, Sweden.

Lemke, U., Emrich, K., Thuy, L.T., Kaufmann, B. and Valle Zárate, A., 2006. Evaluation of smallholder pig production systems in North Vietnam: pig production management and performances. *Livestock Science*, **105**, 229–243.

Lich, L.B., 1999. Livestock production development in the Northern provinces of Vietnam. *Policy Options for Using Livestock to Promote Rural Income Diversification and Growth in Vietnam*, (A research project funded by the Royal Embassy of Denmark, and the MARD. Planning workshop, Hanoi, 2 July 1999).

Loc, N.T., Ogle, B. and Preston, T.R., 1997. Protein supplementation of traditional diets for crossbred pigs under village conditions in Central Vietnam. *Livestock Research for Rural Development*, **9**, 1–5.

MARD and UNDP, 2003. *Farmer Needs Study*, (Project VIE/98/004/B/01/99; Statistical Publishing House, Hanoi, Vietnam)

NIAH, 2001. *Composition and Nutritive Value of Animal Feeds in Vietnam*, (Agricultural Publishing House, Hanoi, Vietnam).

Peters, D., Tinh, N.T., Hoan, M.T., Yen, N.T., Thach, P.N. and Fuglie, K., 2005. Rural income generation through improving crop-based pig production systems in Vietnam: diagnostics, interventions, and dissemination. *Agriculture and Human Values*, **22**, 73–85.

Piepho, H.P., Buechse, A. and Emrich, K., 2003. A hitchhiker's guide to mixed models for randomized experiments. *Journal of Agronomy and Crop Science*, **189**, 1–13.

Statistical Department Son La, 2000. *Statistical Yearbook Son La Province*, (Son La, Vietnam) (in Vietnamese).

SVSV (Strengthening of Veterinary Services in Vietnam), 1998. *Study on Livestock Economics: Processing and Marketing in Vietnam*, (ALA/96/20; MARD Vietnam, European Commission, Hanoi, Vietnam).

Teufel, N., Kuettner, K. and Gall, C., 1998. Contribution of goat husbandry to household income in the Punjab (Pakistan): a review. *Small Ruminant Research*, **28**, 101–107.

Thuy, N.T., 2001. *Epidemiology and economics of foot-and-mouth disease at smallholder level in Vietnam*, (MSc thesis, University of Reading, Department of Agriculture, Veterinary Epidemiology and Economics Research Unit).

Tra, H.T.H., 2003. *Assessing input in pig production with special focus on feed resources and feeding management in demand and resource driven production systems in Son La province, Vietnam*, (MSc thesis, Universität Hohenheim, Institut für Tierproduktion in den Tropen und Subtropen).

Van Eckert, M., 1993. *Kleinbäuerliche Schweinehaltung in Simbabwe. Eine sozioökonomische Analyse von Tierhaltungssystemen in den kommunalen Gebieten*, (Alano-Verlag, Aachen).

Van der Poel, P. and Khiem, N.D., 1993. *Land use in the Song Da watershed*, (SFDP Baseline study No. 2; Hanoi, Vietnam).

Whittemore, C., Green, D.M. and Knap, P.W., 2001. Technical review of the energy and protein requirements of growing pigs: food intake. *Animal Science*, **73**, 3–17.

Évaluation de l'efficacité biologique et économique des systèmes de production de porcs charcutiers par de petits propriétaires dans le Nord du Vietnam

Résumé – L'étude évalue les systèmes de production de porcs charcutiers par de petits propriétaires dans le Nord du Vietnam en comparant un système semi-intensif à proximité d'une ville ayant un accès à de bons marchés, où la race vietnamienne améliorée a remplacé la race de porcs indigènes ; et un système extensif à distance de la ville, où la race indigène prévaut encore. Un travail aux champs a été mené dans 64 ménages de quatre villages. Des visites répétées à la ferme ont produit 234 entretiens structurés. Les données ont été analysées par des modèles linéaires et par des tests non paramétriques. Il a été procédé à une quantification des apports et des sorties de la production et à une évaluation de l'efficacité de l'usage de l'alimentation et du rendement économique. La marge brute a été supérieure pour la production semi-intensive avec la race améliorée, tandis que le rapport coût/bénéfice a été plus élevé sous des conditions extensives avec la race indigène. Le bénéfice net n'a pas changé entre les systèmes. Vingt-quatre pour cent des fermiers ont généré un bénéfice net négatif. Dans un village où les porcs étaient élevés sous des conditions extensives, la production en poids vif des truies indigènes à progéniture croisée s'est comparée positivement au rendement d'une production semi-intensive avec des génotypes améliorés, mais a été associée à des apports élevés, rendant la production inefficace. Les résultats indiquent que des génotypes améliorés pourraient ne pas être une alternative de production efficace pour une production orientée vers la réalisation d'économies avec un apport de ressources limité. La discussion porte sur l'adéquation des paramètres d'évaluation, les objectifs de production des fermiers et les facteurs ayant une incidence sur le succès de la production dans les différents systèmes.

Evaluación de la eficacia biológica y económica de los sistemas de producción porcina en pequeñas granjas de Vietnam del Norte

Resumen – Este estudio evalúa los sistemas de producción porcina en pequeñas granjas de Vietnam del Norte, comparando un sistema semiintensivo cerca de la ciudad con buen acceso al mercado, en donde la raza vietnamita mejorada ha sustituido a la porcina indígena, y un sistema extensivo fuera de la ciudad, en donde aún prevalece la raza indígena. Se llevó a cabo un trabajo de campo en 64 viviendas de cuatro pueblos. Las visitas repetidas a las granjas dieron lugar a 234 entrevistas estructuradas. Los datos se analizaron mediante modelos lineales y pruebas no paramétricas. Se cuantificaron las inversiones o aportes productivos y sus resultados, y se evaluaron la eficacia de la utilización del alimento y la eficacia económica. El margen de beneficio bruto fue más alto para la producción semiintensiva con la raza mejorada, mientras que la relación beneficio-coste fue más alta en las condiciones extensivas con la raza indígena. El beneficio neto no difirió entre los dos sistemas. Un veinticuatro por ciento de los granjeros tuvieron un beneficio neto negativo. En un pueblo operando en condiciones extensivas, la producción del peso vivo de las cerdas indígenas con descendencia mestiza se comparó positivamente con la producción de un sistema semiintensivo con genotipos mejorados, aunque estaba asociado a unas altas inversiones, haciendo por tanto a la producción ineficaz. Los resultados indican que los genotipos mejorados podrían no ser una alternativa de producción eficaz para una producción orientada al ahorro con limitados recursos. También se discuten aquí la idoneidad de los parámetros de evaluación, los objetivos de producción de los granjeros, y los factores que impactan en el éxito de la producción de diferentes sistemas.