Modelling agricultural supply response in Vietnam using a GIS and positive mathematical programming

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The potential for supplementing sparse economic data and aggregate production data with a detailed specification of land quality constraints obtained from a Geographical Information System, in order to parameterise a regional model of rice acreage response in Vietnam, is investigated in this paper. It is asserted that such an approach has advantages in terms of improved credibility amongst agricultural scientists cum policy makers because of the detailed attention to land capability, compared to conventional elasticity based approaches that are commonly used for agricultural policy analysis when data is scarce. The approach relies on the use of Positive Mathematical Programming to calibrate the acreage response for land classes where more than one farming system is observed in the baseline data. Sensitivity of the model to the nature of the calibration assumptions are presented, and results regarding acreage response with respect to rice prices, in different seasons and regions are presented and discussed.

It is concluded that while the current model relies on some heroic assumptions regarding interpretation of the available information, it could be improved considerably, and at low cost, if taken up and developed within the Ministry. There remains, however, a research agenda regarding farm household decision making in rice based production systems of Vietnam that could provide for improved calibration in the future.

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Introduction

Whilst there is enormous potential for quantitative policy analysis of the Vietnamese agricultural sector, the successful development and implementation of models for this purpose is limited by a number of constraints: these include poor existing data sets in Vietnam and limited budget for further collection of data; a low level of skills in quantitative economics within the Ministry; and a high level of scrutiny placed on "black box" economic models by senior advisers, who largely have agricultural science backgrounds. These constraints undoubtedly apply more universally to agricultural policy analysis in developing countries. This paper reports on a study that was undertaken to investigate the potential for developing a programming approach to specifying rice acreage response in Vietnam, which aims to make use of all available data and to reduce the concerns of the agricultural scientists cum policy makers regarding the representativeness of the modelled supply responses[1].

Agricultural scientists are not the only ones who are sceptical of the representativeness of supply response in market models, calibrating the supply function is one of the most significant limitations to developing a representative equilibrium model of an agricultural sector. Whilst demand elasticities are well grounded in theory of utility and consumer choice, and the income constraint that binds decisions is easy to measure; supply response is constrained by a myriad of location specific characteristics that are much more difficult to measure, including resource, climatic, market and infrastructure characteristics, which are accounted for in simple supply elasticity measures. For these reasons, adoption of elasticities from the literature – from studies in another time or place - which is the common practice, is much more problematic for supply than it is for demand.

One of the issues that is regularly raised in discussions in Vietnam regarding the representativeness of supply response is the inflexibility of rice based cropping systems. Unlike the broadacre conditions of Australian wheatbelt, the rice production systems of Vietnam are much more inflexible, with growing conditions favouring rice almost universally in the wet season. Moreover, there are up to three crops grown per year, and opportunities for diversifying away from rice outside the traditional rice growing season depend, in part, on the availability of irrigation; and on the economics of alternative crops; as well as policy and infrastructure constraints that have the potential to impose common property characteristics on farming system choices at the village level[2], at least within irrigation schemes. At the more aggregate level, the degree of flexibility between rice and upland crops will depend largely on the resource characteristics of the particular location, such as the productivity of the land; its suitability of rice growing and the returns from other crops; and climatic conditions affecting the number of crops that can be grown per year. As an example of climatic factors, there are some regions in Vietnam where saline intrusion in the dry season limits cropping period to a single wet season crop, there are other areas where flooding affects opportunities for production in the wet season.

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[1] It is part of an Australian Centre for International Agricultural Research (ACIAR) project aimed at building capacity in market analysis within the Ministry of Agriculture and Rural Development (MARD) Vietnam. Funding from ACIAR to support this study is gratefully acknowledged.

[2] For example, an individual wishing to grow vegetables in a plot that is surrounded by rice growers will be unable to because the soil will be water logged; and decisions regarding how such infrastructure will be used will be partly political.

One alternative means of specifying supply in market models is to use a mathematical programming framework, which allows more emphasis to be placed on the resource characteristics limiting cropping choices. The basis of this approach is to develop supply response from a range of representative farm models, as outlined for example by Hazell and Norton (1986). The main problem with this approach is that it is difficult to replicate the baseline solution, because gross margins represented in linear models will put all acreage into the activity with the highest gross margin, unless the model is constrained, often unrealistically, to restrict the area of the highest returning activity.

More recently, a method of calibrating linear programming models of agricultural supply, known as positive mathematical programming, has been developed. This method involves developing a quadratic cost function for the 'favourable' activities such that the marginal return on all activities in the baseline solution are equated with the opportunity cost of resources. The approach has been applied in the US (eg. Preckel et al 2002) and widely in European Union policy studies (eg. Paris and Howitt 1998, Heckelei et al 2000, Rohn et al 2003), and methods of calibrating the model have become more sophisticated over time, with recent applications using maximum entropy techniques which use cross sectional cost data and prior information to fit the quadratic cost function (eg. Heckelei 2003).

The PMP approach taken in this study was dictated by pragmatism regarding the availability of data in Vietnam, and the specification at this stage is simpler than those applications in developed countries, but it does captures the two basic features of the rice area planting decision problem. These are the resource conditions at the regional level, and the economics of alternative cropping choices. One of the points of departure from the developed country studies taken here is that the (annual) choice variable is a sequence of seasonal crops, whereas most PMP studies focus on decisions regarding individual crops. The choice of annual acreage allocation is adopted here because of the overlapping of cropping options on the seasonal calendar, which make it difficult to define land constraints on a seasonal basis. A list of the data that was available to do the study is given in Table 1.

Table 1. Description of the data available to the study

Item	*Available data*	*Source*
Production data	Time series on rice areas planted, by season, and major upland crops; and corresponding yields; at the province level.	Government Statistical Office (GSO)
	GIS of agricultural land resources, including land use category (annual cropping, perennial etc); soil type; irrigation status; severity of seasonal flooding and salinity intrusion; slope; plus simulated rice yield potential by season. Data on a 1,600 ha grid	Hoanh et al's (International Rice Research Institute) Rice Model for Vietnam
Farming systems	Qualitative description of the major farming systems by agro-ecological region	MARD
Economic data	Gross margin budgets for rice and upland crops in the north and south.	ACIAR project
	Recent commodity prices by region	MARD

Methodology

The choice variables in the math programming model are the areas of annual cropping land allocated to each farming system, defined as a sequence of seasonal crops, in each land class, in each region. There are three crops defined in the model namely: rice, irrigated upland and upland. Upland crops grown in rotation on rice land include groundnut, maize, root crops and vegetables, and it would be preferable if these commodities were distinguished in the model for the purposes of policy analysis, but at this stage there was insufficient data on upland crops either to delineate farming systems by individual upland crop or to represent the economics of these different crops. Details on how the base period activities and constraints were determined from the available data are described in a subsequent section.

The basis for the economic component of a math programming supply model is the gross margin, but in the manner of PMP it is necessary to further define a quadratic cost function to ensure that the model solution is consistent with the activity levels chosen in the base period. To demonstrate the problem of overspecialisation that can arise in a linear model, the gross margins and base period activities for one land class in the Red River Delta is illustrated in Table 2. Based on the available information, it would appear the only rational farming systems choice would the cropping combination "spring rice – summer rice – upland". The fact that other crops choices are observed in the base period can be attributed to "unexplained costs" associated with the apparently superior options. These "costs" could be driven by a number of factors, including resource conditions affecting the ability to plant a winter crop; market conditions affecting the ability to market the winter crop; resource conditions affecting the relative productivity of maize versus rice in the spring season, differences in the type of rice varieties grown in the double and triple cropping alternatives; differences in the cost or availability of labour or capital in farms within the land class; and perceptions regarding risk to name a few.

Table 2: Estimated returns to cropping combinations in the Red River Delta

Number of crops	*Rotation*	*Gross Margin '000 dong per ha*	*Base Area '000 ha*
2	Spring Rice – Summer Rice	10,572	166.16
2	Spring (irrigated) Upland – Summer Rice	7,605	23.29
3	Spring Rice – Summer Rice-Upland	13,164	219.12
3	Spring (irrigated) Upland – Upland – Upland	8,212	30.71

Clearly, if these gross margins were inserted into a math programming model the result would be a much more specialised selection of farming systems than is observed in the baseline. The term "positive mathematical programming" has been used to refer to a method of solving this so-called "calibration problem", which is assumed to arise because of insufficient information regarding the economics of the represented choices, which are largely attributed to heterogeneity (hence divergence returns) within the resource class that is not captured in the model. The process of calibrating the model can be summarized as follows[3]:

Suppose there is a set of N potential choices A_i that can be selected on a total area $\overline{L}$ of a (deemed to be) homogenous land class, each choice having different gross margins, ranked in descending order for the purposes of notation (A_1 is the area allocated to the highest ranking gross margin). The Lagrangian for the allocation problem is:

$$\text{Maximize: } \sum_N (P_i - c_i).A_i + \lambda(\overline{L} - \sum_N A_i) \qquad (1)$$

Where P_i, c_i are revenue earned and (observed) cost incurred per hectare for the i^{th} activity.

The solution to the linear problem is:

$A_1 = \overline{L}$; $A_2,\ldots,A_n=0$

$\lambda = P_1 - c_1$;

However, it is observed that there are *m* activities chosen in the baseline, such that:

$A_1 < \overline{L}$; and $A_2,\ldots,A_m>0$; $A_{m+1},..,A_n = 0$

Which implies:

$P_1-c_1 > \lambda$; $P_2-c_2 > \lambda$; $\ldots P_{m-1}-c_{m-1} > \lambda$; $P_m-c_m = \lambda$

[3] Exposition based on the PMP literature (eg. Howitt 1995, Heckelei 2002) although terminology used here is simpler because of the single resource constraint.

Thus the solution appears not to equate marginal returns with the opportunity cost of resources for m -1 activities in the baseline solution. The phenomenon is explained by the existence of a hidden or unknown increasing marginal cost, such that the true marginal returns for all activities are in fact, equated at the margin. The calibration problem, then, is one of finding the hidden values that result in all baseline activities being equated to the opportunity cost of land (or whatever resource constraint applies) at the margin.

In general the solution to the calibration problem has been to define a quadratic cost function for each activity as:

$$C_i(A_i) = a_i A_i + \frac{1}{2} b_i A_i^2 \qquad (2)$$

So that the marginal cost is:

$$\frac{\partial}{\partial A_i} C_i = a_i + b_i A_i \qquad (3)$$

And in fact, for all non – marginal activities in the basis (i<m),

$$P_i - a_i - b_i A_i = \lambda \qquad (4)$$

A value ρ_i, which is the premium of the i^{th} gross margin over the marginal (m^{th}) gross margin, is the "hidden cost[4]". That is:

$$a_i + b_i A_i = c_i + \rho_i \qquad (5)$$

where:

$$\rho_i = GM_i - \lambda; \qquad (6)$$

which can also be written $\rho_i = GM_i - GM_m$

The problem is that while the total value $c_i + \rho_i$ can be determined, there are an infinite number of combinations of a_i and b_i that can be chosen to calibrate this function. Various justifications have been proposed for selecting the value of the quadratic term b_i, for example Howitt (1995) suggested setting $a_i = c_i$ and $b_i = \frac{\rho_i}{A_i}$; whereas Heckelei (2003) suggests that b_i could be determined by assuming that the observed cost is the average cost (thus $c_i = a_i + \frac{1}{2} b_i$) which implies that $b_i = \frac{2\rho_i}{A_i}$.

Heckelei (2003) also suggests that a price elasticity of supply could be used to calibrate the curvature of the cost function. This doesn't help to overcome the problem that we don't really know what the elasticity is, but it at least allows for an analysis of the impact of various elasticity assumptions on aggregate price responsiveness in the presence of resource constraints.

[4] Authors terminology. Howitt (1995) calls it the shadow value on the calibration constraint.

Since the approach taken in this model is to examine substitution between farming systems rather than individual crops, the most appropriate "elasticity" on which to calibrate the quadratic function is the elasticity of area response with respect to the "hidden cost" ρ_i. In much of the discussion that follows this is referred to as the marginal cost elasticity, and is defined as follows:

The first order conditions can be used to derive a relationship between area and rho.

$$P_i - a_i - b_i A_i = \lambda = P - c - \rho \tag{7}$$

Gives

$$A_i = \frac{1}{b_i}(\rho_i + c_i - a_i) \tag{8}$$

Taking the derivative with respect to rho we have:

$$\frac{\partial A_i}{\partial \rho_i} = \frac{1}{b_i} \tag{9}$$

And if we define an elasticity which is the responsiveness of area change relative to the premium (or hidden cost) rho:

$$\varepsilon_i = \frac{\partial A_i}{\partial \rho_i} . \frac{\rho_i}{A_i} \tag{10}$$

Then we can write a general definition for b_i as:

$$b_i = \frac{1}{\varepsilon_i} . \frac{\rho_i}{A_i} \tag{11}$$

and a_i is:

$$a_i = c + \rho - b_i A_i \tag{12}$$

Note that this formulation is identical to Howitt (1995) where the marginal cost elasticity is 1, and Heckelei's (2003) average cost interpretation where the elasticity is 0.5.

Clearly, more analysis on the economics of farm household decision making, and on cross sectional level differences in returns to alternative farming systems, would provide a better basis for determining the curvature of the cost function, which might include risk preferences, resource productivity and access to markets, but for the time being our calibration problem is solved, provided that we are able to specify an elasticity that defines how steep the substitution rate is between the "apparently better" rotations and the marginal one. The steeper the slope is, the more the calibration parameters behave like a calibration constraint, that is the more inflexible is the substitution between the "apparently better" rotations and the marginal one.

Building the model

Physical data

The farming systems description provided by MARD gave information on the major cropping combinations in the annual cropping lands of Vietnam, for different classes of resource quality in each agro-ecological region level. For example, in the Red River Delta region, the categories described included the alluvial soils along the major rivers; the acid sulphate and saline soils of the coastal regions; and the irrigated lowlands, with separate systems described for those areas that were affected by seasonal flooding. GIS data on land resources in Vietnam, assembled by IRRI to populate a process based model of national rice production (Hoanh et al 2004), provided the basic data used in this study to characterize the resources of each province in Vietnam. As summarised in Table 1, the GIS contained details for each 1,600 square hectares of land in Vietnam, including land use classification, slope, soil type, seasonal extent of flooding and salinity intrusion, and irrigation status.

This GIS data was used to quantify the area of land in each category by province (as shown in Table 3), and then this land was allocated to each the farming systems described for that land type in a spreadsheet, so that the total area sown to each of the seasonal rice crops, and upland crops, could be calculated. A heuristic procedure was used to determine the combination of farming systems that matched the province level data on area sown to rice by season, and annual upland crops. The seasonal level rice data was particularly useful in determining the likely areas of each cropping pattern, as illustrated in Figure 1 using an aggregate example of the Northern Mountainous Region. The process was quite straightforward for regions where relatively few land types or farming systems were defined; in regions where more cropping options or more land use categories were described, the use of province level (rather than regional) data helped to simplify the process in many cases; although further field investigation could be done to verify the final assumptions regarding base level areas of the different cropping systems.

Total Land Area		Irrigated Options		Rainfed Options		Totals		
		Spr Rice - Sum Rice	Spr Upland - Sum Rice	Spr Upland - Sum Rice	Upland - Upland	Spring Rice	Summer Rice	Upland Crop
GIS data*		Area planted to Spring Rice GSO	Balance of irrigated area					Balance of upland crop
Irrigated Land	317.7	306.4	11.2	Balance of area planted to summer rice	Balance of rainfed area	306.4	317.7	159.4
Balance							Sum over farming systems	
Rainfed Land	362.9			217.1	147.7	0.0	217.1	512.6
Annual cropping land from GSO data								
Regional Total	680.5				Totals	306.4	534.8	672.0
				GSO Statistics on Area sown		**306.4**	**534.8**	**672.0**

* Rapid expansion of irrigated area means statistics may be out of date. Where GIS data on irrigation was less than area of (irrigated) spring rice, irrigated area was adjusted upwards.

Figure 1: Example of allocation of areas to farming systems from GIS GSO data, Northern Mountainous Region

Table 3: Resource categories by agro-ecological zone, for land described as annual cropping land, in thousands hectares

Region and resource group	***Area***	***Farming systems described by MARD****
Northern Mountains	**680.53**	
Dry	362.85	Summer Rice - Upland; 2 Upland crops
Irrigated	317.67	Spring Rice - Summer Rice; Spring Rice - Summer Rice - Winter upland; Spring Maize - Summer Rice; Spring Maize - Summer Rice - winter upland;
Red River Delta	**557.02**	
Alluvial soil along river bands	44.80	Spring Rice - Summer Rice - Winter upland; Spring Maize - Summer Rice - winter upland;
Saline or acid sulphate coastal soils	37.60	Spring Rice - Summer Rice
Flooded lowlands	35.34	Rice- Fish
Non Flooded lowlands	439.27	Spring Rice - Summer Rice; Spring Rice - Summer Rice - Winter upland; Spring Maize - Summer Rice; Spring Maize- 2 upland crops
North Central Coast	**479.49**	
Alluvial soil along river bands	6.54	Spring Maize - summer rice
Saline or acid sulphate coastal soils	8.52	Spring Rice - Summer Rice
Flat coastal	117.97	Spring Rice - Summer Rice; Spring upland - Summer rice; 3 upland crops
Rainfed upland	38.22	3 upland crops
Rainfed lowland	111.48	Summer Rice - upland; 2 upland crops
Irrigated lowland	196.76	Spring Rice - Summer Rice; Spring Upland - Summer Rice
South Central Coast	**315.26**	
Irrigated lowland	161.49	Spring Rice - Summer Rice; Spring upland - summer rice
Rainfed lowland	107.53	Summer Rice - Upland
Irrigated upland	8.21	Spring Rice - Summer Rice
Rainfed upland	38.03	Summer Rice- upland; 2 upland crops; Summer rice only
Central Highlands	**275.40**	
Irrigated valleys	103.00	Spring Rice - Summer Rice; Spring upland- summer rice
Rainfed uplands	172.40	Upland only
North East South	**668.61**	
Saline or acid sulphate coastal soils	85.61	Summer rice only
Alluvial soil along river bands	61.42	Spring rice- summer rice
Rainfed grey soils, upland	22.19	Upland only
Rainfed grey soils, lowland	373.04	Summer Rice- Autumn rice; Summer Rice - Upland; Upland only
Irrigated grey soils, lowland	95.31	Spring Rice- Early Autumn Rice - Late Autumn Rice; Spring upland - upland
Rainfed redsoils	31.03	Upland only
Mekong River Delta	**2036.36**	
Irrigated cropping land	883.99	Spring Rice- Early Autumn Rice - Late Autumn Rice; Spring Rice - Autumn Rice – upland; Spring Rice- Autumn Rice; Summer Rice - Autumn Rice
Irrigated, severely flood affected	658.90	Spring Rice- Autumn Rice
Rainfed, severely flood affected	72.38	Rice - 2 upland; Rice – upland
Single cropping land in saline intrusion zone	421.09	Summer rice only
National Total	**5012.65**	

** In general, these descriptions were provided by general resource category as identified in the table, and the allocation of areas to each farming system used in the model was based on the exercise illustrated in Figure 1.*

At the end of this process, the resource constraints and cropping activities for the model were complete. The potential area of rice production is illustrated in Table 4, which shows the minimum area that would be sown if all the upland intensive rotations were chosen, and the maximum area that could be sown if all the available rice growing land were used for rice intensive rotations. The minimum and maximum intensity shows the associated seasonal cropping intensity at the aggregate level (potential sown area divided by land area). The relatively high intensity of the

Mekong Delta reflects the existence of triple cropping in this region, which is possible in irrigated lands with the use of modern varieties.

Table 4: Potential rice cropping intensity of different regions

Region	Land Area	Minimum rice area	Maximum rice area	Minimum Intensity	Maximum Intensity
Northern mountains	680.53	317.67	844.07	47%	124%
Red River Delta	557.02	72.94	1041.09	13%	187%
North Central Coast	479.49	8.52	809.27	2%	169%
South Central Coast	315.26	169.70	484.95	54%	154%
Central highlands	275.40	103.00	206.00	37%	75%
North East South	668.61	61.42	1154.87	9%	173%
Mekong River Delta	2036.36	2879.95	4075.55	141%	200%

Note: Area refers to total area of annual crop land by region, not all of which might be able to grow rice. Minimum and maximum rice areas are the amount that would be chosen if all the "low rice" or "rice intensive" cropping combinations were chosen in each resource category. Intensity more than 100% reflects double and triple cropping combinations.

Gross margin assumptions

In order to derive gross margin assumptions across all regions and land types, with the limited data available, the following simple representation[5] was used:

$$GM_{jkr} = P_{jk}.y_{jkr}.(1 - c_{jk}) \qquad (13)$$

Where the subscripts j,k,r refer to season, land class, and region respectively, c is cost of production as a percentage of gross revenue, y is yield per hectare.

Regional rice (paddy) prices[6] P_j were multiplied by a seasonal price index (Hai 2003) reflecting the harvest month, cost of production was determined as a ratio of gross revenue based on gross margins obtained from a recent survey of households in the Red River and Mekong Deltas, from a recent ACIAR project (Sally Marsh, personal communication), which were used to represent costs in the north and south of Vietnam. Marsh's gross margin data are summarised in Table 5.

[5] This formula was used to calculate baseline costs of production per hectare which were later assumed to be fixed when price shocks were introduced to the model simulations.
[6] Average of three seasons 1999-2001

Table 5: Gross margin data for seasonal rice crops in the Red River and Mekong Deltas, '000 dong per hectare.

	RRD Ha Tay Spring Rice	*RRD* Ha Tay Summer Rice	*MRD* Cantho Spring Rice	*MRD* Cantho Summer Autumn	*MRD* Cantho Summer
Yield tonnes per ha	6.03	5.3	4.5	3.2	3.2
Cash Costs	2,674	2,608	1,971	1,749	1,484
Labour days	209	204	53	54	43
Gross Revenue	10,816	9,499	5,446	3,791	3,903
Gross Margin	4,999	3832	2,680	1,232	1,774
Costs as % Revenue	54%	60%	51%	67%	55%

Note: Costs include labour, valued at 15,000 dong per day. Data obtained from Sally Marsh, personal communication, based on a household survey conducted in 2000.

To obtain representative yields by region and resource group, a calibration exercise fitting aggregate yields for each region and season to the area in each resource group, where yield penalties were applied to differentiate between relatively high yielding land classes. These yield penalties were based on a simple regression analysis of yield data generated by IRRI's rice production model (Hoanh et al 2004), against slope, irrigation status, soil type, flood proneness as the explanatory variables for potential rice yield in each region and season, and representing the resulting values in proportion to the maximum values obtainable in that region & land class. In general, indices obtained from that analysis ranged between 81% for severely flood prone, 85% for steep rainfed lands; around 90% for rainfed rice relative to 100% for irrigated lowlands.

Yields were derived as follows:

$$\hat{y}_{jr} = y'_{jr} \sum_k (\varphi_{jkr} \cdot \frac{A_{jkr}}{\sum_k A_{jkr}})$$

where $\hat{y}_{ij}$ is the aggregate yield observed for region r, season *j*;

y'_{ij} is the maximum yield (obtained where the yield penalty is 1)

φ_{jkr} is the yield penalty that applies to resource group *k* in region r, season *j*

$$(\varphi_{jkr} = \frac{y_{jkr}}{y'_{jr}})$$

A_{jkr} is the area of land used in season *j*, resource group *k* and region r;

Economics of upland production

Upland crops grown in rotation on rice land include groundnut, maize, root crops and vegetables, and the yields, areas sown, and prices of these products vary significantly between regions. To obtain an estimate of gross margin for the general category "upland crop", gross revenue per hectare for each region was calculated on the basis of prices, yields, and share of total upland cropping area, in each region. Using the same formula (Equation 13 above), costs of production as a percentage of revenue was based on Marsh et al's data for winter maize. The seasonal yield penalties calculated for rice were used to adjust these regional gross margins for individual land classes. Marsh's data on spring maize was used to determine the gross margin for the irrigated upland crop. This figure was obtained for the Red River Delta and the gross margin for irrigated upland cropping in other regions was adjusted according to the regional maize price differential. Summary statistics on upland cropping are shown in Table 6.

Table 6: Importance and type of upland cropping in the paddy lands and gross margins used to represent the "upland crop", '000 per ha.

	Upland area relative to total annual cropped area[1]	Maize	Groundnut	Cassava	Sweet Potato
		Share of total upland crop area			
Northern Mountains	68%	39%	3%	20%	39%
Red River Delta	42%	29%	6%	58%	7%
North Central Coast	61%	22%	9%	48%	21%
South Central Coast	55%	13%	7%	19%	62%
Central Highlands	81%	40%	3%	8%	49%
North East South	62%	40%	8%	5%	47%
Mekong River Delta	7%	23%	6%	47%	24%

	Gross Revenue '000 dong per hectare	Gross Margin '000 dong per hectare
Northern Mountains	4,952.73	1,556.98
Red River Delta	8,245.60	2,592.15
North Central Coast	5,720.04	1,798.19
South Central Coast	5,470.11	1,719.63
Central Highlands	6,171.30	1,940.06
North East South	7,561.90	2,377.22
Mekong River Delta	8,445.60	2,655.02

1. *Upland area / (rice area + upland area)*

Source: Calculated as discussed in the text from GSO and Marsh et al's data.

The calibration exercise

The calculated annual return for a particular farming system is the sum of the gross margins from the seasonal cropping activities of that system, and this annual return was calculated for each of the farming systems described in Table 7, plus additional farming systems that represent other feasible combinations of seasonal crops given the resource constraints that apply to a particular land class. Thus in addition to the 48 choices indicated in Table 7, 20 more farming system alternatives were included in the model.

The gross margins for each of the defined choices were compared to the baseline activity levels, and results are summarised in Table 7, which divides the choices into three categories. The column classed as "economic" refers to the land groups where only one activity was chosen in that land class, even though others are physically possible, and the choice reflects a superior gross margin. The group "physical" refers to the allocations where the choice of farming activity is constrained by resource characteristics and only one reported *or feasible* farming combination is practiced there. Around 58% of all possible choices present a *calibration problem* for which it is necessary to determine a quadratic cost function, as outlined in the previous section.

For the activities where calibration was required, quadratic cost functions were estimated using the formula in equations 11 and 12.

Table 7: Status of gross margin and baseline area allocations

	Baseline area choices explained by:		
	Economic	Physical	Unexplained*
Northern Mountains	0%	0%	100%
Red River Delta	15%	6%	79%
North Central Coast	52%	4%	44%
South Central Coast	37%	0%	63%
Central Highlands	0%	63%	37%
North East South	19%	21%	61%
Mekong Delta	0%	57%	43%
National	11%	30%	58%

* Calibration problem, multiple activities chosen although one activity has the highest gross margin.

Results

The model was calibrated using a range of assumptions about the elasticity of the marginal cost curve, and the impact of a 10% change in the price of rice on areas allocated to each rotation and hence total rice acreage were estimated. Results are reported in Table 8, which show the elasticity of rice acreage with respect to rice price. Two different sets of figures are shown which illustrate the inflexibility of acreage response to increasing prices compared to decreasing prices.

For any given assumption regarding the elasticity of the underlying cost curve, calculated rice acreage elasticities vary widely between regions. The response to an increase in the rice price is driven by the opportunities for increasing rice acreage (which depends on the share of total land already in rice intensive rotations) and the relative economics of the alternative farming systems. The response to a decrease in rice price is less constrained hence the elasticity is generally higher.

The impact of the assumed elasticity of the marginal cost curve on the calculated rice acreage elasticity varies substantially between regions, and this is driven by a number of factors, including the degree to which to which the calibration technique was required to complete the model specification; the relative economics of the activity choices; and intensity of rice cropping currently practiced relative to the maximum and minimum potential intensity. The impact of changing the underlying curvature of the marginal cost curve is, as would be expected, very significant. A relatively flat marginal cost curve causes greater substitution between rotations and therefore a greater rice acreage response with respect to rice prices.

The lower values for the marginal cost elasticity appear to produce aggregate acreage elasticities that are more consistent with a priori expectations regarding aggregate supply response[7]. However, that does not necessarily imply that the steeper cost elasticity assumption is correct for Vietnam, as it has been shown that conventional

[7] For example, the FAO/UNCTAD elasticity database used in Agricultural Trade Policy Simulation Model assumes a rice price elasticity of supply of 0.21; Golleti and Rich (1998) use a value of 0.38 in the North and 0.311 in the South.

time series analysis of supply response (and hence conventional wisdom on supply elasticities) may significantly underestimate elasticity because of poor specification of price expectations (Williams and Wright, 1991) in time series analysis of supply response. It would perhaps be more instructive to focus the analysis of supply response on the shape of the "marginal cost curve" or the substitutability of farming system options, rather than to use a priori expectations about national supply response to determine what the correct marginal cost assumption is. If we were to use Heckelei interpretation of b_i (based on the assertion that observed cost is average cost, which implies the marginal cost elasticity is 0.5), then the predicted acreage response for Vietnamese rice is 0.36 in the upwards direction and 0.6 in the downwards direction.

Table 8: Impact of marginal cost curve elasticity on the calculated rice acreage response, by region.

Assumed elasticity of "marginal cost curve"	1	0.5	0.2	0.1
	Calculated rice acreage elasticity			
	At 10 % increase in the price of rice			
Northern Mountains	1.30	0.72	0.37	0.25
Red River Delta	0.85	0.85	0.36	0.18
North Central Coast	0.28	0.16	0.09	0.06
South Central Coast	1.17	0.64	0.26	0.13
Central Highlands	1.26	0.63	0.25	0.13
North East South	1.64	0.82	0.33	0.16
Mekong River Delta	0.16	0.08	0.04	0.02
National	0.58	0.36	0.16	0.09
	At 10% fall in the price of rice			
Northern Mountains	4.16	2.08	0.83	0.42
Red River Delta	1.82	0.91	0.36	0.18
North Central Coast	1.94	1.00	0.42	0.23
South Central Coast	1.28	0.64	0.26	0.13
Central Highlands	1.26	0.63	0.25	0.13
North East South	1.13	0.56	0.23	0.11
Mekong River Delta	0.30	0.15	0.06	0.03
National	1.20	0.60	0.24	0.12

The effect on rice acreage in the different seasons is illustrated in Table 9 (using the marginal cost elasticity assumption of 0.2). These differences can be explained by the nature of choices and constraints in each region, for example, in the Northern Mountainous regions, the response in the rainy season comes from substitution of (ample) double upland cropping into rice – upland cropping in the rainfed areas, and because the land constraint is not binding on the price rise, the calculated elasticity is the same in both directions. In contrast, in the spring the substitution is from irrigated upland to irrigated rice, and this is limited by the constraint on irrigated land available, so responsiveness to the price increase is much lower than to the price fall.

In the Red River Delta, the substitution occurs between double cropping and two alternatives, summer rice – upland, and upland only. This means that the responsiveness of the spring rice crop is more elastic than the summer rice crop. The response is symmetrical to price changes because the land constraint is not binding on increasing rice intensity when price increases. The South Central Coast is insensitive to spring rice price changes because the gross margin on spring rice is always higher than for irrigated upland even when the rice price falls by 10%; and there is no scope for increasing spring rice production when the price rises. Of all the regions, the North East South has a high responsiveness to rice price in the rainy season, and this is because of the potential for substituting between upland and summer rice in that region. The Mekong River Delta exhibits a negative acreage elasticity with respect to the rice price in the rainy season, and this is because of the switching into triple cropping (which is a spring – double autumn[8] rice) rotation, away from double cropping pattern that involves a rainy season crop.

Table 9: Variation in the calculated rice acreage response, by region and season.

		Spring	*Summer (Rainy)*	*Autumn*	*Annual*
Northern Mountains	Rise	0.37	0.37		0.37
	Fall	1.60	0.37		0.83
Red River Delta	Rise	0.49	0.23		0.36
	Fall	0.49	0.23		0.36
North Central Coast	Rise	0.08	0.09		0.09
	Fall	0.35	0.48		0.42
South Central Coast	Rise	0.00	0.15	0.77	0.26
	Fall	0.00	0.15	0.77	0.26
Central Highlands	Rise	0.95	0.00		0.25
	Fall	0.95	0.00		0.25
North East South	Rise	0.00	0.62	0.21	0.33
	Fall	0.00	0.36	0.21	0.23
Mekong River Delta	Rise	0.27	-0.76	0.08	0.04
	Fall	0.96	-2.69	0.12	0.06
National	Rise	0.28	0.04	0.13	0.16
	Fall	0.78	-0.36	0.17	0.24

The effect of the assumed marginal cost elasticity on the calculated impact of a price change on the regional gross margin is illustrated in Table 10. The relatively greater acreage response associated with the higher marginal cost elasticity means that the calculated impact of the price change on gross margin is larger, but the difference is not as pronounced as the difference in the underlying acreage response. Those regions having a relatively large impact on gross margin (irrespective of the underlying marginal cost elasticity) are those that have a higher rice cropping intensity.

It should be noted that these results only show the impact on producers' gross margins, associated with price shocks. The welfare impacts that would be calculated in a model that included market equilibrium impacts would include the effect on consumers of final equilibrium prices associated with the implied price elasticities of supply.

[8] In fact, the classification of autumn rice in the MRD covers the entire summer (rainy)-autumn period but the hybrid short duration varieties used in the triple cropping pattern are referred to as autumn rice.

Table 10: Effect of marginal cost curve elasticity on the calculated impact on rice price changes on the regional gross margin.

	Change in the regional gross margin	
Assumed elasticity of the marginal cost curve	**1**	**0.1**
	Rice price increases 10%	
Northern Mountains	23%	18%
Red River Delta	24%	21%
North Central Coast	19%	18%
South Central Coast	24%	18%
Central Highlands	16%	10%
North East South	19%	14%
Mekong River Delta	22%	20%
National	22%	19%
	Rice price decreases 10%	
Northern Mountains	-20%	-17%
Red River Delta	-23%	-20%
North Central Coast	-20%	-18%
South Central Coast	-20%	-18%
Central Highlands	-12%	-10%
North East South	-17%	-14%
Mekong River Delta	-23%	-21%
National	-21%	-19%

Discussion

The structure of the model presented here offer some advantages over the traditional approach of relying on a aggregate elasticity assumption[9] in that it takes account of the resource constraints by region, and hence provides a more realistic depiction of the feasible responses at the regional level, and generates results that indicate a greater elasticity to price falls than to price increases that are explained by land capability. Because the explanations of acreage response come down to discussions of land capability and the gross margins of farming systems within those land classes, the approach offers some promise for improving credibility of the modelled responses amongst the agricultural science trained policy makers in the Ministry.

The methods used to calibrate the model could be improved on all fronts, but the advantage of the approach is that the data requirements are relatively low and much of the knowledge required to improve the model could be obtained from the expertise already in the Ministry. Some of the improvements that could be made at relatively low cost are:

- Improved representation of the options within each land class, and quantification of the area allocated to each farming system. This could be done by consultation with experts in the regional offices of the Ministry.

[9] This approach is used in both Equilibrium Displacement Models (eg Piggot et al 1993) and in mathematical programming models of market equilibrium where supply functions are calibrated to some assumed functional form (eg. Goletti and Rich 1998).

- Improved data on gross margins at the regional level. While this would incur some field cost the ongoing maintenance costs associated with this type of model are minor compared with, for example, the large data collection exercise needed to maintain Huang et al's (2002) econometric based EDM model of the Chinese agricultural sector

- Incorporation of yield response in the model

- Delineation of 'upland cropping' into the major upland crops

There remains, however, the problem of determining the elasticity of the marginal cost curve, and this is an area that would benefit from more detailed analysis of farm household decision making within the rice-based farming systems currently practiced in Vietnam.

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