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Agricultural Supply Response in Nepal during 1970-2000

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Abstract

The reliance on market-led approach to agricultural development is increasing. So, the study estimated the agricultural supply response functions for 15 commodities (paddy, maize, wheat, pulses, potato, vegetables, fruits, oilseeds, sugarcane, buffalo milk, buff meat, goats, chicken, hen-egg and fishery). It separates the agricultural supply decisions into crop area allocations/ livestock population and productivity levels. A dynamic response function of the Cobb Douglas form is employed with a combination of the partial adjustment and adaptive expectation principles by pooling the time-series and cross-section data.

The supply behavior of Nepalese agriculture has become more responsive to changes in the prices of outputs, inputs and development activities over the years. The output elasticity coefficients for food grains increased from around 0.10 in 1970s, to 0.30 in 1980s and further 0.50 in 1990s. The supply functions are more elastic for commercial crops than for subsistence foods, and are classified in four groups (i) elastic supply: cash crops, poultry and fishery, (ii) unit elastic supply: fine food grains, (iii) inelastic supply: coarse food grains, horticulture and large ruminants, and (iv) negative elasticity: traditional/ subsistence crops. Irrigation, agricultural research and development and market development indicators have larger impact to increase supply of preferred commodities than the traditional ones. In conjunctions with the food demand functions, the farm supply response functions can be used for agricultural market modeling.

Agricultural development policy has increasingly relied on the market-driven process to strengthen its contribution of nearly two-fifths to national income, increase welfare of nearly nine out of ten people who live in rural area, and eight out of 10 people who depend on farming.

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The Agriculture Perspective Plan 1995-2015 has assumed the growth of livestock and horticulture to be demand-driven and the growth of food grains, cash crops, fishery and forestry as supply-driven.

The Tenth Plan (2002-07) has further added emphasis to commercialize agriculture through the: (i) operation of market [supply, demand] forces for both the farm outputs and inputs, and (ii) provision of complementary rural infrastructures like irrigation, roads and research. So it is essential to know the agricultural commodity market models.

The present study sets a method for estimating the farm supply functions, traces the changes in the crop area and yield response functions over the years, and outlines issues further research.

Framework

Area and Yield Supply Functions

The agricultural supply models follow a dual approach by separating the output decisions into area and yield per hectare decisions. So the supply elasticity is sum of area elasticity and yield elasticity as follows:

$$\varepsilon qp = \varepsilon ap + \varepsilon yp \quad \ldots\ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad (1)$$

Where,

εqp = output elasticity with respect to price,

εap = area (hectare) elasticity with respect to price,

εyp = yield elasticity with respect to price,

The area harvested for crops and their yield depend on many factors like relative prices of crops, prices of inputs, government support programs and environmental factors. The area response and yield levels are dependent on a common set of factors, and are expressed as:

$$A_{idt} = f\,(P_{it}, P^{jt}, P_{xt}\, Z_{id}, W_{idt}) \quad (2)$$

$$Y_{idt} = g\,(P^{it}, P_{jt}, P_{xt}\, Z_{id}, W_{idt}) \quad (3)$$

Where,

A_i = crop area allocation (or livestock population) of commodity "i",

Y_i = yield per unit of resource of commodity "i",

f, g = functions referring to the area allocation and yield levels, respectively,

P_i = own -price of commodity (e.g., rice, mutton, etc),

P_j = price of competitive crop (e.g., sugarcane and jute for rice,),

P_x = price of inputs (like fertilizer, feed, labor, etc),

Z_i = quasi-fixed input (like irrigation, research, infrastructures, etc.),

W_i = environmental factors (e.g., rain fall, soil erosion, etc.),

d = districts 1,..., 73, and

t = years 1970, ..., 2000

Dynamic Supply Responses

Farmers' production decisions are generally analyzed under the frameworks of static equilibrium analysis or dynamic response patterns. The static equilibrium framework uses the production functions and may apply duality theory. The production function approach assumes perfect competition in all markets, sets profit maximizing goals, derive conditions for equilibrium, and estimate the elasticity of output with respect to inputs. The duality theory facilitates interfaces about the technology and producers' behavior indirectly from the cost and profit functions to derive input demand functions and the yield responses. The application of duality theory requires time-series and cross-section data on both the farm inputs-outputs and prices, which are very scarce and fragmented in Nepal.

The literature on farm supply responses extends the static profit-maximizing models in various ways. Many authors have used partial adjustment model to estimate the farm supply response. The basic model used by most researchers for analyzing acreage response is the Nerlovian partial adjustment model (Nerlove 1958 and 1979). Raj Krishna (1963) supposes that the elasticity of planned output with regard to price is at least equal to the elasticity of area planted, if the non-land inputs are varied at least in proportion to the area, and the returns to scale are not diminishing. Narayan and Parikh (1987) applied such models to estimate both the area and yield response functions. Kumar (1998) also used Nerlovian model to estimate the area response for wheat in India. Sometimes, the partial adjustment model and adaptive expectation models are combined as follows:

$$A_t^* = a_0 + a_1 P_t^* + a_2 z_t + u_t \qquad (4)$$

$$A_t - A_{t-1} = c\,(A_t^* - A_{t-1}) \qquad 0 < c \le 1 \qquad (5)$$

$$P_t^* - P_{t-1}^* = b\,(P_{t-1} - P_{t-1}^*) \qquad 0 < b \le 1 \qquad (6)$$

Where,

A_t = actual area under cultivation of a crop in time "t"

A_t^* = desired area for cultivation of a crop in time "t"

P_t^* = expected (normal) price of foods in time "t"

P_t = actual price of foods in time "t"

Z_t = other exogenous variables in time "t", and

U_t = unobserved random factor affecting the area under cultivation.

Equation (5) is as partial adjustment model and shows the relationship between the desired area and the actual area under a crop, where "c" is the coefficient of adjustment. Equation (6) is an adaptive expectations model and states how the expectations about prices are formed by adapting to the differences between actual and expected prices in the past. Substituting equations (4) and (6) in equation (5), the reduced form of equation for the actual area allocation under a crop becomes:

$$A_t = cba_0 + cba_1 P_{t-1} + ca_2 Z_t - ca_2 (1-b) Z_{t-1} +$$
$$(a-b-c) A_{t-1} - (1-c)(1-b) A_{t-2} + c\,\{U_{t-} (1-b) U_{t-1}\} \qquad (7)$$

In Equation (7), when b = 1, $P^*t = P_{t-1}$, it becomes a pure partial adjustment model, and variables A_{t-2}, Z_{t-1} and U_{t-1}dropout. For stability, the only restriction is $0 < c < 1$. We propose to apply the farm supply response functions of constant elasticity form. So with the variables specified in Equations (2) and (3) above, the Cobb-Douglas function is as follows:

$$A_{it}^* = c\, P_{it-1}^{\beta i},\, P_{jt-1}^{\beta j},\, P_{xt}^{\beta x},\, Z_t^{\beta z},\, W_t^{\beta w}\, e^{ut} \quad \ldots \quad \ldots \quad (8)$$

Following Johnston (1984), the partial adjustment process is specified conformably as

$$A_t/A_{t-1} = (A_t^*/A_{t-1})^{1-\lambda}\, e^{at} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

Combining these two relations, we have

$$A_t = c^{1-\lambda}\, A_{t-1}^{\lambda}\, P_{it-1}^{\beta i(1-\lambda)} P_{jt-1}^{\beta j(1-\lambda)}\, P_{at}^{\beta x(1-\lambda)}\, A_t^{\beta z(1-\lambda)}\, W_t^{\beta w(1-\lambda)}\, e^{ut} \quad (10)$$

Using lower case letters to denote natural logarithms, we have

$$at = c\,(1-\lambda) + \lambda_{at-1} + \beta i\,(1-\lambda)\, p_{it-1} + \beta j\,(1-\lambda)\, p_{jt-1} +$$

$$\beta x\,(1-\lambda)\, p_{at} + \beta z\,(1-\lambda)\, a_t + \beta w\,(1-\lambda)\, w_t + at \quad \ldots \quad (11)$$

Since the equation (11) is in double logarithmic form, it directly gives the elasticity coefficients. Assuming the estimated form of the equation (11) as denoted by:

$$\hat{Y}_t = c_0 + dy_{t-1} + e_1\, p_{it-1} + e_2\, p_{jt-1} + e_3\, p_{xt} + e_4 z_t + e_5\, w_t + u_t \quad \ldots \quad (12)$$

Then the estimated,

adjustment parameter = d

short-run (or impact) elasticity = e_i (i: 1, 2, ..., so on)

long-run (or full adjustment) elasticity = $e_i / (1-d)$

Johnston says that the same process will be repeated for a simple partial adjustment process when the dependent variable is a function of more than one explanatory variable. Even if the form of the adjustment process is similar, the speed of the adjustment process may be different [Johnston 1984, p. 351]. Also, the estimates of elasticity from the cross-section data usually give the long-run elasticity (Koutsoyannis 1984, P. 405).

Past Studies

APROSC (1981) approximated the crop supply response with area response using Nerlovian partial adjustment model on data for the 1965/66-77/78 period. It included explanatory variables like own-price or relative price (with respect to the completing crops), time trend and the lagged dependent variable, and found that the supply functions of cereals are steeply inelastic with own-price whereas the technical crops have around unity elasticity as follows:

Paddy	0.012	Jute	1.039
Wheat	0.125	Tobacco	0.997
Maize	0.095	Sugarcane	1.180

Thapa and Rosergant (1995) separated the farm output decisions into area and yield per hectare decisions. They estimated the Generalized Leontief profit function by using Zellner's generalized least squares for seemingly unrelated regressions on the regional cross-section time-series data for crop area, yield, technology, input use, and output and input price for the 1975-90 period. The crop area response elasticity with expected revenue per hectare was inelastic as follows:

Crops	Area elasticity	Yield elasticity	Total elasticity
Rice	0.06	0.22	0.28
Maize	0.15	0.14	0.29
Wheat	0.18	0.16	0.34

Note that the authors did not provide the crop supply elasticity for the country as a whole. So, we have reported the yield elasticity above as simple average of three ecological regions to get a first hand idea of the total crop supply elasticity with respect to own-prices. They also found that: (i) yield of all three crops are more sensitive to labour price (-0.08 to -0.20) than to fertilizer price (-0.04 to -0.08), (ii) elasticities of yield with respect to irrigation are fairly strong in the cases of rice and wheat (around 0.20), and (iii) impact of technology variable on rice and maize yield is comparable with that of irrigation but it is lower for wheat.

Bajracharya and Maskey (1998) studied the aggregate supply response for crop sector for the 1967/68-1994/95 period. They also split the index of aggregate agricultural production into index of gross cropped area and aggregate productivity index, both of which were expressed as function of lagged prices, irrigation, government budget expenditure and annual rainfall. The price variable was reinterpreted as regional Indo-Nepal variable. They applied Dickey Fuller test for stationary data, ran ordinary least squares for estimation of linear equations, and used Ramsey's RESET procedure for the possible omission of relevant explanatory variables. The study found that weather has consistently significant positive effect, changes in lagged-prices have an ambiguous effect, and the changes in both irrigation as well as government expenditure on agriculture has an insignificant effect. It did not report the agricultural supply elasticity coefficients nor did it differentiate the cash and cereal crops.

Data Base and Estimations

Attempts are made here to pool a database from variety of sources. Estimation of farm supply functions requires panel data sets on farm inputs and outputs, and farm prices from the farm management studies (FMS). So far two national FMS have been conducted in Nepal in 968/ 69 and 1983/ 85. These studies hardly provide necessary data for estimation of the production functions, profit functions or input demand functions. The studies on cost of cultivation are weak in survey design and estimation procedure. Data on government expenditure by commodity programs on research, manpower, infrastructures and extension are limited, unclassified, discontinues and unspecific. Data on environmental conditions are limited. Some data exist on the expenditure in irrigation sector.

The regression analysis uses the time-series data from 1970 - 2000 period. For the cross-section regressions, the dependant variables are three-year averages for 1997/ 98 - 1999/ 2000 periods by districts and the explanatory variables generally refer for the period 1991/ 92 - 2000/ 01. It considers 73 out of 75 districts in the country (Manang and Mustang districts are close to Tibet and are excluded as "out-liers").

Dependant variables

The food-grains and cash crops include area and yield of six crops, namely, paddy, wheat, maize, pulses, oilseeds and sugarcane. Time series data on the production of cereals and cash crops are available from mid-sixties onwards. Crop area and yield of pulses are available from 1991/ 92 onwards. Horticulture includes potato, vegetables and fruits. The data on the production and yield of potato are available from mid-sixties onwards. The data on area and yield of vegetables are available from the year 1991/ 92 onwards. The data on area and yield of fruits are available from the year 1993/ 94 onwards. The agricultural census data are used to extrapolate these series till the year 1976/77.

Livestock commodities consider the output and productivity of buffalo milk, buff meat, goat meat, and poultry meat and hen eggs. The data on outputs like milk meat, eggs and wool are available from 1988/ 89 onwards but time series data on their productivity are not available. Various sources are used to construct their series from 1974/75 onwards. The livestock productivity is imputed under some assumptions. For meat productivity, the culling rates assumed are buff 20 percent, goat 33 percent and chicken 50 percent of the population. The meat recovery ratio as percent of the body weight is based on standard norms. Only buffalo milk is considered (it covers about 70 percent of milk output). Data on area under fishery and its yield are available from the year 1987/ 88 onwards.

For regression analysis, the yield of crops and fishery by districts is weighted by the fraction of area under a crop in question in the district as compared to the national total. Similarly for livestock productivity, their populations by districts are used as weighted.

Cross-section explanatory variables

First, the market development indicator (MDI) is quantified as sum of motor road density (e.g. road in meter per sq km), telephone density (number of phone lines per sq km) and ratio of urban people to farm holdings (number of urban people per agri-holding). For a composite MDI, the weights for road, phone and urban population ratio turned out to be 95 percent, four percent and one percent, respectively. Temporally, MDI is equivalent to the cumulative increase in motor road length.

Second, data on irrigation are for the year 1999/ 2000 are expressed in percentages and weighted by the cultivated area in districts relative to the national total in year 1991/92. Third, agricultural research and development (R&D) is represented by the spread of improved farming practices among farmers, and are from the National Sample Census of Agriculture (NASC) 1991/ 92 and Crop Livestock Survey 1997-2000. Improved farming practices by districts are in percent, which are adjusted to crop area-weights relative to the national total. The data on improved practices for rice and vegetables are assumed to apply for fishery and fruits, respectively. Government's real expenditure on agricultural research for crops, horticulture, livestock and fishery groups are used in the time-series analysis.

Fourth, rented-land in 1991/92 is expressed as a percent of the total cultivated area by districts. Weights are proportional to cultivated area. Time-series data on land renting are extra/ interpolated from the NASC 1961/62, 71/72, 81/82 and 91/92. Fifth agricultural wages among the districts or adjoining districts are from the Nepal Living Standards Survey for year 1995/ 96. Time-series of agricultural wages are from the Farm Management Study 1968/69 and the Nepal Rastra Bank's working files from year 1976/77 onwards. Finally, soil erosion index is approximated by the percentage of cultivated areas with slopes of 4-30 degrees by districts (ICIMOD 1997). Temporally, soil erosion index is ratio of total cropped area to forest area.

Time-series explanatory variables

First, the price deflators for GDP, agri-GDP and non-agri-GDP are in 1984/ 85 prices. The current prices of fertilizer, farm outputs, wages and government expenditure on agriculture are converted into real quantities by dividing their prices with the agri-GDP deflator. Second for prices of farm outputs, the Central Bureau of Statistics defines the agricultural producer's prices as the post-harvest average retail prices for the first four months subsequent to harvesting but this series is too short. So, the national average annual retail prices of farm outputs are used to estimate the farm supply functions. Third, the fertilizer prices are weighted average of all fertilizers, and are common for all crops. Third, prices of animal feeds are approximated by the price of maize, oil-seed cakes, wheat-bran or rice-bran are assumed to represent animal feed prices. Finally, rainfall is in mille meter per year as arithmetic average of rainfall in 21 climatic stations throughout the country.

Computation Procedures

A five-step procedure is applied to 15 commodities, or 30 functions and 60 regressions. Agricultural area supply and yield level functions (Eq. 12) are estimated by following the procedures of weighted least square (WLS) and by pooling the time-series and cross-section data in stages. Step-I is about the cross section regressions: the crop area/ livestock population and their yields by districts are regressed against the explanatory variables like irrigation, research, MDI, soil erosion, land renting, wages (and forest area for ruminants). It directly gives the long-run elasticity of supply.

In step-II, the crop area/ livestock population and their yield are estimated over the years by using the coefficients from cross-section regressions and the time-series values of the explanatory variables in it. In step-III, the residues of the crop area/ livestock population and their yields are calculated by deducting their estimates from their actual values over the years. In step-IV, the residual dependent variables are regressed against its own-lagged values, prices of the farm outputs, fertilizers/ feeds and rainfall.

Finally, the long-term elasticity coefficients for the time-series variables are obtained by dividing the coefficients of independent variables (i.e., short-term impact multipliers) by the co-efficient of lagged dependent variable (i.e., the adjustment coefficient).

Results

Model evaluations

The weighted least square method preempts the heteroscedasticity problem. The values of coefficient of determination are larger than the zero-order correlation among the explanatory variables, and imply tolerable multi-co linearity. Autocorrelation test is not applicable in models with lagged dependant variables. In Table 1 and 2, the columns show equations and the rows show the variables entering into the equations. The model summary is provided at the bottom of Tables 3.6. For the area response model, the overall significance and coefficient of determination are satisfactory for both the cross-section and time-series regressions for all crops and fishery. For yield levels, the explanatory power of the model is little less but almost all models are again significant except the time-series regressions for maize and fruit. The model summary for the livestock sector is similar to the crop sector although there is some

Table 1. Total Elasticity of Supply of Crops and Fishes

Sr No	Explanatory variables	Commodity supply elasticity of									
		Paddy	Maize	Wheat	Pulses	Oilseeds	Potato	S' Cane	Veg	Fruits	Fish
1	Paddy price	0.99						0.13			-0.54
2	Maize "		0.90							0.32	0.04
3	Wheat "			1.21	1.84	1.98	0.26	1.40	0.94	-0.35	
4	Pulses "			-0.19	0.32	0.34	-0.18	-1.13	-1.26	0.28	
5	Oilseed "			-0.55	-1.24	-1.15	0.27	-1.05	-0.34	-0.27	
6	Potato "						0.56	0.00	0.55	0.15	
7	S' Cane "	-1.75	-0.77	-0.69	-1.19	-1.64	-0.40	0.60	0.00	-0.81	-0.39
8	Veg "							0.53	0.52		
9	Fruits "									0.13	
10	Fish "										1.18
11	Jute "	-0.22									
12	Fertilizer "	-0.40	-0.14	-0.16	-0.40	-0.51	-0.35	-0.45	-0.61	-0.24	0.18
13	Rainfall	1.15	0.21	-0.35	-1.12	-0.89	-0.08	-1.44	-0.57	0.16	
14	Market dev index	0.02	-0.02	0.10	-0.03	-0.01	-0.09	0.12	0.12	0.01	0.28
15	Agri wage rate	0.11	-1.14	0.72	-0.46	-0.03	-0.67	1.17	0.58	-0.67	-0.32
16	Erosion index	-0.03	0.06	-0.01	0.06	0.11	0.04	0.07	-0.01	0.00	
17	Irrigation stock	0.64	0.19	0.51	1.01	1.11	0.10	1.61	0.61	0.24	1.05
18	Land rent	0.29	0.01	0.08	0.07	0.30	0.20	0.30	0.15	0.05	0.18
19	Research stock	0.11	0.32	0.00	-0.03	-0.09	0.07	0.08	0.03	0.01	2.15
	Sum of elasticity	**0.93**	**-0.37**	**0.66**	**-1.17**	**-0.47**	**-0.28**	**1.41**	**0.73**	**-0.45**	**3.79**

Table 2. Total Elasticity of Supply of Livestock Products

Sr No	Explanatory variables	Dependant Variables				
		Buff Meat	Buff Milk	Goat	Chicken	Hen eggs
1	Buff meat prices	**0.55**	0.03	-0.15	0.62	
2	Buff milk "	-2.14	**0.11**			
3	Goat meat "	0.18		**-0.08**	-0.84	-0.97
4	Chicken "	0.67		0.16	**0.39**	0.07
5	Eggs "				-0.15	**0.91**
6	Maize "	0.23	-0.12	0.70	0.25	0.13
7	Wheat "			-0.61		0.33
8	Oilseed "	-0.04	-0.01			
9	Market Dev Index	0.12	0.14	0.07	0.07	0.09
10	Labor wage rate	0.26	0.08	-0.05	0.66	0.60
11	Erosion Index	0.02	0.00	-0.07	0.06	0.05
12	Irrigation Stock	0.12	0.11			
13	Land renting				0.24	0.25
14	Research Stock	0.02	0.03	0.03	0.02	0.02
15	Forest Area	0.04	0.20	0.31		
	Sum of elasticity	**0.03**	**0.55**	**0.31**	**1.32**	**1.49**

Note: Table 1 is derived from Table 3 and 4. Table 2 is derived from 5 and 6. The prices in crop supply equations are lagged by one year except for sugarcane where own-price lag is three years. For buff meat, goat, chicken and egg supply functions, the own-price lag is two years.

problem in the estimation of hen yield, goat population; buffalo milk yield and vegetable area because some of their values are extrapolated.

The Cobb Douglas (CD) function estimated by regression on the cross-section data directly give the long-run elasticity coefficients of area response or yield levels with respect to irrigation, R & D, MDI, sloppy cultivated area, land renting, wages and forest area. The CD function fitted on time series data has the lagged dependant variables as explanatory variable. Its coefficient gave the co-efficient for speed of adjustment that, for example, was 0.626 and 0.557 for paddy area and yield supply functions, respectively. That is, about 63 percent of adjustments of area under paddy and 56 percent of adjustment of its yield to the changes in prices are completed in the first year.

The coefficients of other explanatory variables gave the short-run supply elasticities. For paddy area and yield supply with respect to own-price, the short-run price elasticity was 0.20 and 0.38, respectively. The short-run elasticity coefficients are not presented here due to space limitations. The short-run paddy area and yield supply elasticity coefficients are divided by the coefficient of speed of adjustment to get the long-run area and yield supply elasticity coefficients as 0.32 and 0.68, respectively. And so on. Table 3-6 present the long-run elasticity coefficients for crop area/ livestock herd size and their productivity yield levels.

Table 3. Area Response Elasticity

Sr No	Explanatory Variables	Supply of Area Under									
		Paddy	Maize	Wheat	Pulses	Oilseeds	Potato	S' Cane	Veg	Fruits	Fish
1	Paddy price	**0.33***						0.22			-0.48#
2	Maize "		**0.38#**							0.38#	0.06
3	Wheat "			**0.80***	0.87#	0.74$	0.15	0.62	0.88#	-0.09	
4	Pulses "			-0.31	**0.17**	0.37	0.07	-0.56	-1.34#	-0.26&	
5	Oilseed "			-0.18	-0.66*	**-0.52#**	-0.07	-0.75#	-0.21	-0.11&	
6	Potato "						**0.29$**		0.59#	0.22#	
7	S Cane "	-0.60*	-0.32#	-0.41#	-0.47#	-0.72*	-0.35#	**0.37^**		-0.32*	-0.47&
8	Vegetable "								**0.46&**	0.26#	
9	Fruits "									**0.10&**	
10	Fish "										**0.96***
11	Jute "	-0.07									
12	Fertilizer "	-0.10	0.05	0.20	-0.21	-0.25^	0.16	-0.10	-0.54#	-0.16#	0.16
13	Rainfall	0.38$	0.08	-0.15	-0.69#	-0.47&	-0.02	-0.73&	-0.51$	-0.12	
14	Market DI	0.00	-0.01	0.04	-0.02	-0.01	-0.05	0.06	0.04$	0.00	0.23$
15	Wage rate	-0.05	-0.62#	0.33	-0.21	0.08	-0.40$	0.46	0.25	-0.31#	-0.31
16	Erosion I	-0.02	0.03	-0.01	0.03	0.06#	0.01	0.04	0.00	0.00	
17	Irrigation	0.31*	0.10	0.24*	0.52*	0.57*	0.03	0.72*	0.31*	0.11	0.96*
18	Land renting	0.14*	0.00	0.02	0.02	0.15	0.09	0.16	0.07	0.03*	0.22
19	Research	0.06*	0.16*	0.00	-0.01	-0.04*	0.04$	0.04	0.02#	0.00	1:76
	Sum of elasticity	**0.05**	**-0.17**	**0.57**	**-0.67**	**-0.03**	**-0.05**	**0.54**	**0.02**	**-0.26**	**3.09**

Model summary

CSE	N	73	73	73	73	73	73	57	73	73	49
	DF	66	66	66	66	66	66	50	66	66	43
	Vi	6	6	6	6	6	6	6	6	6	5
	R2	0.93	0.64	0.60	0.79	0.78	0.34	0.61	0.79	0.63	0.84
	F-value	132.6	19.4	16.2	41.8	39.0	5.6	12.9	43.4	18.8	45.0
TSE	N	28	28	28	28	28	28	26	24	24	25
	DF	21	22	21	20	20	19	16	16	12	18
	Vi	6	5	6	7	7	8	9	8	11	7
	R2	0.98	0.87	0.85	0.99	0.99	0.97	0.98	0.96	0.99	0.86
	F-value	138.4	28.2	54.0	228.2	188.9	80.8	106.2	54.1	184.9	18.7
	d-static	2.41	2.33	2.37	2.07	2.06	2.38	2.06	1.52	1.94	2.81

Notes:

1. *, #, $: t-values chosen for one, five and ten percent level of significance are 1.67, 2.00 and 2.66, respectively, at 60 degrees of freedom.

*, #, $: t-values chosen for one, five and ten percent level of significance are 1.73, 2.09 and 2.8, respectively, at 20 degrees of freedom.

@: The critical F-value at one percent level of significance and the degree of freedom as V1= 6 and V2 = 20 is 3.87 for time-series runs. F-value at V1 = 7 and V2 = 60 is 2.95 for cross-section runs. @ Indicates not significant.

&: Close to significant at 10 percent with t-values from 1.3 - 1.7 for degrees of freedom about 20 or more.

^: Significant at 15 percent with t-values above unity for 20 or more degrees of freedom, which is considered here only for own-price and fertilizer-price elasticity.

2. CSE: Refers to cross section equation, TSE: Refers to time series equation,

Table 4. Yield Response Elasticity

Sr No	Explanatory Variables	Supply of Area Under									
		Paddy	Maize	Wheat	Pulses	Oilseeds	Potato	S' Cane	Veg	Fruits	Fish
1	Paddy price	0.68*						-0.09			-0.07
2	Maize "		0.52#							-0.06	-0.03
3	Wheat "			0.41	0.98#	1.24#	0.11	0.78	0.06	-0.26	
4	Pulses "			0.12	0.16	-0.03	-0.25	-0.57	0.08	0.54	
5	Oilseed "			-0.37&	-0.58#	-0.63$	0.34	-0.30	-0.12&	-0.16	
6	Potato "						0.27		-0.05	-0.07	
7	S Cane "	-1.14*	-0.45#	-0.28	-0.72#	-0.93#	-0.05	0.24		-0.49&	0.09
8	Vegetable "								0.06	0.26	
9	Fruits "									0.03	
10	Fish "										0.22$
11	Jute "	-0.15									
12	Fertilizer "	-0.30	-0.19	-0.35&	-0.19^	-0.27	-0.52&	-0.36	-0.06	-0.09	0.02
13	Rainfall	0.77$	0.13	-0.20	-0.44&	-0.42	-0.06	-0.71	-0.07	0.28	
14	Market DI	0.03	0.00	0.06#	-0.01	0.00	-0.04	0.06	0.07#	0.01	0.05#
15	Wage rate	0.17	-0.52$	0.39$	-0.24	-0.11	-0.27	0.72	0.33$	-0.36*	-0.02
16	Erosion I	-0.01	0.02	0.00	0.03	0.05#	0.03	0.04	0.00	0.00	
17	Irrigation	0.33*	0.09	0.27*	0.49*	0.54*	0.06	0.89*	0.30*	0.13*	0.10#
18	Land renting	0.16*	0.02	0.06	0.05	0.16	0.11	0.14	0.08	0.03	-0.04
19	Research	0.05*	0.16*	0.00	-0.02	-0.04#	0.04$	0.04	0.02#	0.00	0.39
	Sum of elasticity	0.57	-0.20	0.09	-0.50	-0.44	-0.23	0.87	0.71	-0.19	0.70

Model summary

MS: CSE	N	73	73	73	73	73	73	57	73	73	49
	DF	66	66	66	66	66	66	50	66	66	43
	R2	0.92	0.64	0.69	0.79	0.77	0.36	0.64	0.80	0.65	0.42
	F-value	131.4	19.9	24.2	41.8	37.1	6.2	14.9	43.6	20.3	6.2
MS: TSE	N	28	28	28	28	28	28	26	24	24	25
	DF	21	22	21	20	20	19	16	16	12	18
	R2	0.96	0.32	0.95	0.97	0.98	0.90	0.98	0.85	0.76	0.98
	F-value	73.3	2.03@	56.7	93.2	123.8	20.3	109.0	9.1	2.84@	130.1
	d-static	2.77	1.94	2.09	1.98	2.03	1.85	1.59	2.17	2.75	1.92

The total supply elasticity with respect to the individual explanatory variables is obtained by adding the long-run area supply elasticity and the yield supply elasticity. For example the total supply elasticity of paddy with respect to own-price adds up to 0.99, which is nearly unit elasticity. Similarly in the long run, paddy supply with respect to the annual rainfall is elastic (e = 1.15). And so on. The last row "sum all" adds all the elasticity coefficients of the independent variables in the cross-section and time-series regressions.

Table 5. Livestock Population Elasticity

Sr No	Explanatory variables	Population of				
		Buff Meat	Buff Milk	Goat	Chicken	Hen eggs
1	Buff meat price	**0.62&**	-0.08	-0.07	0.59&	
2	Buff milk "	-2.04*	**0.10**			
3	Goat meat "	-0.11		**-0.21&**	-0.56&	-0.56$
4	Chicken "	0.78		0.16	**0.07**	-0.09
5	Eggs "				-0.30	**0.67 $**
6	Maize "	0.26	0.13^	0.51#	0.32	-0.27
7	Wheat "			-0.37#		0.65#
8	Oilseed "	-0.03	-0.13#			
9	Market DI	0.09*	0.13*	0.04#	0.07#	0.08#
10	Labor wage rate	0.01	-0.07	-0.42*	0.50#	0.57#
11	Erosion Index	0.01	0.00	-0.02	0.07*	0.06#
12	Irrigation stock	0.11#	0.05			
13	Land renting				0.24*	0.24*
14	Research stock	0.02#	0.03#	0.01	0.01	0.01
15	Forest Area	0.29*	0.23#	0.27*		
	Check Sum	**0.00**	**0.38**	**-0.09**	**0.99**	**1.38**

Model summary						
MS: CSE	N	73	73	73	73	73
	DF	66	66	67	67	67
	R2	0.56	0.52	0.34	0.47	0.53
	F-value	13.8	12.1	7.0	12.0	15.3
MS: TSE	N	25	25	25	25	25
	DF	17	19	19	18	19
	R2	0.89	0.96	0.99	0.93	0.91
	F-value	19.2	100.2	447.2	39.2	30.6
	d-static	1.93	2.20	1.49	1.61	2.55

Crop commodities

Changes in scale: The diagonal elements in Table 1 provide the crop supply elasticity with respect to own-price. The off-diagonal elements in the first 11 rows provide the cross-price elasticity. The remaining eight rows provide the supply elasticity with respect to the input prices, irrigation and research stock, land renting, sloppy cultivated area and rain fall. The last row provides sum of the total elasticity coefficients for a commodity, which is kin to the concept of the returns to scale. In nutshell, the overall agricultural supply function is quite inelastic because the pooled weighted average of the total elasticity coefficients for supply of all the 15 commodities in the last row of these tables comes to be 0.389. The weights applied are contribution of the commodity to agri-GDP. The sum of total elasticity coefficients shows that the supply response of commercial crops such as sugarcane is elastic with a coefficient of 1.41. The supply response of staple foods is inelastic with total elasticity below unity: rice

Table 6. Livestock Population Elasticity

Sr No	Explanatory variables	Population of				
		Buff Meat	Milk	Mutton	Chicken	Eggs
1	Buff meat price	**-0.07**	0.11	-0.09	0.03	
2	Buff milk "	-0.10	**0.01^**			
3	Goat meat "	0.29$		**0.12**	-0.28$	-0.41
4	Chicken "	-0.11		-0.01	**0.32$**	0.15#
5	Eggs "				0.16	**0.24^**
6	Maize "	-0.03	-0.25#	0.19^	-0.08	0.40#
7	Wheat "			-0.24#		-0.32#
8	Oilseed "	0.00	0.12#			
9	Market Dev Index	0.03	0.01	0.03	0.01	0.01#
10	Labor wage rate	0.25$	0.15*	0.37#	0.17*	0.02
11	Erosion index	0.01	0.00	-0.05*	-0.01$	-0.01$
12	Irrigation stock	0.01	0.06*			
13	Land rent				0.00	0.01
14	Research stock	-0.01	0.00	0.02#	0.01*	0.01*
15	Forest area	-0.25*	-0.03$	0.04		
	Sum of elasticity	**0.02**	**0.17**	**0.40**	**0.32**	**0.11**

Model summary

		Buff Meat	Milk	Mutton	Chicken	Eggs
MS: CSE	N					
	DF	17	19	19	18	19
	R2	0.32	0.70	0.35	0.36	0.52
	F-value	5.10	25.82	7.63	7.63	14.33
MS: TSE	N	25	25	25	25	25
	R2	0.86	0.92	0.95	0.95	0.99
	F-value	14.9	42.4	62.7	60.3	296.7
	d-static	2.29	1.55	1.65	2.16	1.00

0.93, wheat 0.66 and vegetables 0.73. For traditional/ subsistence foods, the total supply response turned negative: maize -0.37, pulses -1.17, mustard seeds -0.47 potato -0.28 and fruits -0.45. It may need reexamination.

Rice: Paddy supply elasticity with respect to its own-price is 0.99 and that with respect to rainfall is significantly elastic (e = 1.15). An increase in the prices of fertilizer, sugarcane and jute reduce both the area and yield elasticity coefficients of paddy. The role of sugarcane price is quite prominent (e = - 1.75). Paddy area elasticity with respect to the improved practices, land renting and irrigation are significantly positive. It is also true for its yield. Paddy yield elasticity with respect to irrigation is 0.33, which is highest. The area elasticity is significantly negative with respect to sloppy cultivated area, wage rates and MDI.

Maize: Maize supply with respect to own-price is inelastic (e = 0.90). Increase in the sugarcane prices significantly reduces the maize area and yield. Maize area rises with respect to the improved practices and, to some extent, with respect to sloppy cultivated area. It decreases with respect to wages and MDI. The pattern is similar for its yield.

Wheat: Wheat supply with respect to own-prices is quite elastic (e = 1.21): area elasticity is 0.80 and yield elasticity is 0.41. Fertilizer prices cut-down wheat yields (e = - 0.116). Sugarcane prices diminish wheat area and yield. Wheat area elasticity is high with respect to irrigation (e = 0.24), labor (e = 0.33) and MDI. Similar results are observed for yield.

Pulses: Pulses supply elasticity with respect to its own-prices is insignificant. But it turned elastic (e = 1.85) with respect to wheat prices. The reason may be that pulses are grown as subsidiary mixed with wheat crop. Pulses supplies are negative with respect to rainfall (e = - 1.12). Among the pulses, lentil area supply elasticity with respect to improved practice (e= 0.61) and its yield elasticity with it (e = 0.51) were significant when lentil alone was used as dependent variable (not shown in the tables). The picture would be more clear if a separate analysis is done for the supply for different pulses like lentil, chickpea, pigeon pea, black gram, grass pea, horse gram and soybeans. Pulses area elasticity is high with respect to irrigation (e = 0.52). So is its yield elasticity (e = 0.49).

Potato: Potato supply with respect to own-price is inelastic (e = 0.56). Increase in potato supply is also associated with wheat and oilseeds prices. Potato supplies decrease with sugarcane prices (e = - 0.41) and fertilizer prices (e = - 0.35). Potato area supply elasticity with respect to improved practices (e = 0.04) and land renting (e = 0.09) are positive. The pattern is similar for pulses yield. Land slopes are also important (e = 0.03). MDI and wages rates have negative effects.

Oilseeds: Oilseeds supply with respect to own-price turned negatively elastic (e = - 1.15)! The mustard prices alone could do not fully represent the prices of all oilseed crops? Oilseeds supply with respect to wheat prices turned elastic (e = 1.98). Prices of pulses also tend to increase oilseeds supply. It may be due to wheat-led cropping pattern in the winter. That is, the supply of oil seeds appears perverse and inelastic. It is difficult to explain. Oilseeds area elasticity with respect to irrigation is high (e = 0.57) so is its yield elasticity high (e = 0.54). Land renting and sloppy cultivated area also contributes positively.

Sugar: Sugarcane is an annual crop but its ratton is harvested in the second year. After trying lags of one to four years, the sugarcane prices with three years lag provided expected positive elasticity: its supply with respect to own-prices is inelastic (e = 0.60). Sugarcane area elasticity with respect to irrigation is high (e = 0.72) and so is its yield elasticity (e = 0.89).

Vegetables: Vegetable supply with respect to own-price is inelastic (e = 0.53); it is negative with respect to fertilizer prices (e = - 0.61) and prices of pulses (e = -1.26). Vegetable area elasticity with respect to irrigation (e = 0.31), MDI (e = 0.25) and improved practices (e = 0.02) are significant. Land renting also contributes positively (e= 0.07). Similar pattern holds true for vegetable yield elasticity. Vegetable yield elasticity turned positive with respect to agricultural wages (e = 0.33).

Fruits: Fruit supply with respect to own-price is inelastic (e= 0.13). Fruit area is increased by vegetable prices (e = 0.52), maize prices (e = 0.32) and potato prices (e = 0.15). In total, the fruit supply function might have turned irregular due to lumping together of different fruits. These are citrus fruits (orange, sweet orange, lime, lemon, other), deciduous fruits (apple, pear, walnut, peach, plum, apricot, persimmon, pomegranate and almond) and tropical fruits (mango, banana, guava, papaya, jackfruit, pineapple, litchi, areca nut and coconut). Fruit area and yield elasticity with respect to irrigation are inelastic (e = 0.12). It is negative with respect to wages (e = -0.31) and so is yield elasticity (e = -0.36).

Livestock commodities

Buff meat: Buff meat supply is very inelastic as the elasticity for total buffalo population and its bodyweight adds-up to 0.03 only. Buffalo population with two years lag is significant to explain its current population. Buff meat with respect to lagged own-price is inelastic (e = 0.55). But buff meat supply with respect to milk price is negative (e = -2.14). That is if milk prices go up, people reduce the buffalo slaughtering. Buffalo population elasticity with respect to forest area is 0.29. It is 0.11 with irrigated conditions. Buff weight is reduced by increase in the animal feed prices. The meat yield elasticity is low with respect to MDI (e=0.03) and high with respect to wages (e = 0.25). It turned negative with respect to forest area (e = -0.25).

Buffalo milk: Buffalo milk supply is inelastic with a coefficient of 0.55 for sum of its population and its milk yield. Milking buffalo population with one-year lag was significant to explain their current population. Buffalo milk supply elasticity with respect to own-price is low (e= 0.11). That is the changes in milk prices do not affect it much. It might reflect the fact that the milk prices fixed by the Dairy Development Corporation. Both the maize and oilseed-cake prices reduce the milk supply. Milking buffalo population elasticity is positive with respect to MDI (e = 0.13), improved practices (e = 0.03) and forest area (e = 0.23). Milk yield elasticity show similar pattern but it is negative with respect to forest area (e= -0.03).

Goat: Goat supply is inelastic (e=0.31) in total. Mutton supply turned totally inelastic (e = 0.01) with respect to own-prices, important (e=0.70) with respect to maize prices and also important (e = 0.27) with respect to forest area. It is negative with respect to wages (e = -0.41) and sloppy cultivated area (e = -0.02). Goat meat productivity elasticity is positive with respect to MDI (e= 0.03), improved practice (e=0.02) and wages (e=0.37).

Chicken meat: Chicken supply is elastic (e=1.32) in total. Chicken supply with respect to own-price two-year lag is significant and inelastic (e=0.39). Chicken population indicates positive relation with respect to maize price, MDI (0.07), wages (0.50), sloppy cultivated area (0.07) and rented area (0.02). Chicken yield elasticity with respect to improved practices (0.01) wages (0.17) and sloppy cultivated area (-0.01) are significant.

Eggs: Hen-egg supply is elastic (e=1.49) in total. Egg supply elasticity with respect to own-price of two years lag is little below unity (e=0.91). Laying hen population elasticity is significant with respect to MDI (e=0.01), wages (e=0.57), sloppy cultivated area (e=0.06) and land renting (e=0.24). As proxy to poultry feeds, hen population elasticity with wheat price (e= 0.65) and hen yield elasticity with maize price (e=0.40) are significant.

Fishery: Fish supply elastic (e= 1.71) in total. Fish supply is elastic (e=1.18) with respect to own-price. The area under fishery diminishes if area under paddy or sugarcane crops increases. Fishery area elasticity with respect to irrigation (e=0.96) and MDI (e=0.23) are significant. Fish yield elasticity is low with respect to MDI (e=0.05), irrigation (e=0.01) and even negative with land renting (e=-0.4).

Conclusions

A dynamic response function of the Cobb Douglas form is employed with a combination of the partial adjustment and adaptive expectation principles to estimate the supply functions for 15 commodities. The crop area allocations/ livestock population and productivity levels are estimated separately. The model provides a good fit for 13 out of 15 commodities considered based on the normal sign and significance of the own-price elasticity coefficients. The study shows that the supply behavior of Nepalese agriculture has become increasingly responsive to changes in the prices of outputs, inputs and development activities.

First, the supply elasticity of commodities has been increasing over the years. For example, the food grain supply elasticities were around 0.10 in 1970s, 0.30 in 1980s and around 0.50 in 1990s. Second, most of the commodity supply functions are responsive to own-prices and competing prices. The yield elasticity coefficients tend to emerge stronger than the area elasticity coefficients. Third, the supply functions are more elastic for commercial crops than for subsistence foods as follows:

Elastic supply:	cash crops, poultry and fishery,
Unit elastic supply:	fine food grains like rice,
Inelastic supply:	coarse food grains, horticulture and large ruminants, and
Negative elasticity:	traditional/ subsistence crops.

Fourth, the factors like irrigation, agricultural R & D and market development indicators have significant positive impact for the preferred commodities. The effect of rainfall and sloppy cultivated area are significant but these cut both ways depending on the commodities.

The proposed framework for database and analysis need to be further strengthened. The supply functions need to be separately estimated for more specific commodities within pulses, fruits and small ruminant categories. It is also necessary to improve the data set on farm inputs-outputs and their prices for facilitating better modeling of the agricultural supply functions. In conjunctions with the demand functions, the farm supply response functions can be used for agricultural market modeling.

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