Supply Response and Risk in Chinese Agriculture: A New Look

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Abstract

The main objective of this paper is to model the production and supply response in Chinese agriculture, which includes not only the standard arguments like expected prices but also risk. We extend Lin's work [1991, 1992] by modelling supply response as a three-equation model. We fit our model to data for 28 Chinese provinces from 1970 to 1997 to determine whether national Chinese agricultural supply is price and price risk responsive. Further, we fit our model to data for North, Northeast, South and Southeast regions. Results from the three systems equations are compared to single equation estimations. At the national level, Chinese agriculture is found to be price and price risk responsive. The regional analyses suggest that significant regional differences exist. Unlike Lin, we do not find the household responsibility system (HRS) to be the dominant factor in increased yields in different regions of China.

Keywords: Supply Response; **Chinese Agriculture**; **Risk; HRS**

JEL Classifications: **O13**, **O53**, **Q11**, **Q18**

Introduction

It is now well acknowledged that in terms of overall economic growth, the Chinese economy in the last 16 years has grown at over 9% per annum in real terms. Such a growth rate of real GDP is impressive. A careful analysis of Chinese reform and growth shows that it has been influenced by two important features which China has in common with many less developed countries (LDC's): (i) a large ratio of agricultural output to real gross national product; and (ii) a substantial proportion of rural labour to total supply of labour [Hussein and Stern 1994]. The agricultural sector grew at a respectable rate since 1978 – 79 particularly after the introduction of price reforms and the household responsibility system (HRS) [Lin 1992]. By 1993, government controlled prices of goods, which have been traditionally low, eg. grain and cooking oil had increased to almost the market level. It is also reported that many regions of China have abolished low-price rations of food grains [see eg. Kueh and Ash 1993; see also Hussain and Stern; Lin 1992].

Although Chinese agriculture has progressed well after 1978, there are some important issues, which could be of concern in the future. First, since China is mainly a labour-abundant, land-scarce economy, the acreage under cultivation did not grow along with the growth of population. In fact in some regions/provinces, sown acreage has actually decreased [see, e.g. Walker,1993]. Hence, a substantial increase in production must have occurred through a rise in yields via more intensive use of technology on land (eg. a rise in multiple cropping due to greater use of fertiliser, new seeds and irrigated water). Second, there has been some evidence to suggest that the initial spurt in food grain production after 1978 has petered out [Kueh and Ash, 1993] as the momentum to reform agricultural prices has run out of steam. Indeed, while the agricultural prices were liberalised after 1978, and the early eighties saw an improvement in the agricultural terms of trade, in the late 1990's the terms of trade may have turned against the agrarian sector vis-à-vis industry, reducing the incentive to produce and market the product in the open economy. Government interventions in the middle 1980's stabilised the terms of trade only temporarily. Third, the exact role of the HRS in providing incentives has come under close scrutiny. It is claimed with some empirical support that the HRS has been a major instrument in raising production and supply, possibly by providing greater security to farmers

[Lin 1991, 1992]. However, a clearer definition of property rights in land will be needed to overcome problems of uncertainty in the future. Thus, the nature of non-market as well as market incentives in the future will probably add to risk and uncertainty in farm production decisions. While empirical works on recent advances in Chinese agriculture have been quite thorough and clear, little attention has been paid to capturing the impact of risk and uncertainty on agricultural production and supply response in Chinese agriculture.

The major aim of this paper is to model the production and supply response in Chinese agriculture, which includes not only the standard arguments (eg. expected prices, yield etc.), but also risk. In particular, we will pay special attention to the hypothesis advanced by Traill [1977], Seale and Shonkwiler [1987], and Ghatak and Seale [1993] that under certain conditions inclusion of risk variables in a model of agricultural production could reduce predicted farm output and supply. In this way, we extend the works of Lin [1991, 1992] and shed some light over the problem of farm production decisions under risk and uncertainty. We also extend Lin's [1991, 1992] work by modelling supply response as a three-equation system instead of a single-equation model. We fit our model to data for 28 Chinese provinces from 1970 to 1997 to determine whether national Chinese agricultural supply is price and price risk responsive. Further, we fit our model to North and Northeast regions and South and Southeast regions. Results from the three systems equations are compared to single equation estimations. The final section draws conclusions.

Theory: Lin's Model

In a recent paper, Lin [1992] specifies a Cobb-Douglas type production function for Chinese agriculture with four traditional inputs as arguments – land, labour capital and fertiliser – plus a number of other variables like the ratio of production team, converted to the household responsibility system (HRS), a multiple cropping index (MCI), market price relative to manufactured input prices (GP), the percentage of total sown area in non-grain crops (NGCA) and a time trend (T). To allow for regional specific factors like soil quality, weather, etc. he includes a regional dummy for each of 28 provinces in the production function.

First, Lin actually estimates an agricultural yield function. Then, he estimates a "supply-responsive" function with the same dependent variable (i.e., the value of total yield (Y_{it})) as follows:

$$\ln(Y_{it}) = ß_1 + ß_2\, HRS_{it} + b_3 \ln MP_{t-1} + b_4 \ln GP_1 + ß_5 T_1 + \sum^{n} ß_6 D_i + U_{ut}$$

t=1

Lin then uses a feasible generalised least squares (FGLS) method to a stochastic frontier regression to obtain (consistent) estimates of parameters[1]. Lin concludes that decollectivisation (i.e., the introduction of HRS) improves total factor productivity particularly during 1978 –84. The adjustment in state procurement prices has also contributed positively to output growth. The current relative stagnation is mainly explained by a significant fall in state procurement prices, leading to a sharp drop in the use of fertiliser and an 'exodus' of farm labourers from the rural sector.

Clearly Lin's analysis of production and supply response boils down to the testing of a yield equation with both price and non-price variables as arguments. In this sense, it is a hybrid function, which does not really conform to the conventional analysis of supply response function, which uses acreage or output as the dependent variable. Nor does it include risk analysis.

Empirical Model

In what follows, we specify a three-equation, supply response model consisting of a sown acreage equation, a yield per sown acre equation, and a price dependent, inverse demand equation. The acreage equation includes price risk explicitly as a factor which accounts for changes in acreage (A_1) under cultivation:

(1) $$A_{it} = \alpha_0 + \alpha_1 P^e{}_1 + \alpha_2 V_{pt} + \alpha_4 F_{it} + \alpha_5 DHRS_1 + \varepsilon_{it}$$

(2) $$Y_{it} = ß_0 + ß_1 L_{it} + ß_2 K_{it} + ß_3 F_{it} + ß_4 DHRS_1 + \varepsilon_{t2}$$

(3) $$P_1 = C_0 + C_1(A_{it} + Y_{it}) + C_2 I_{it} + \varepsilon_3$$

Where A_{it} is the natural log of sown acres planted in province i (=1,….,28) at time t; $P^e{}_1$ is the natural log of expected market price at time t; V_{pt} is the expected market price risk at time t; DHRS is a dummy for the household responsibility system (for 1970 – 1979, DHRS = 0; for 1980 – 1987, DHRS = 1); F_{it} is the natural log of fertiliser per sown acre in i at t; Y_{it} is the natural log of the value of yield per sown acre in i at t; L_{it} is the natural log of labour per sown acre in i at t; K_{it} is the natural log of capital per sown acre in i at t; I_{it} is the natural log of real per capita income in i at t; ε_3 is the error term of equation j (=1,2,3) in province i; and α_0 , $ß_0$ and C_0 are intercepts. It has to be conceded that in addition to the HRS, there were several other policy changes in Chinese agriculture after 1979 [see, Lin,1992]. Those changes have different implications for the acreage and output responses. Hence, the use of dummy variables may not appropriately capture all the effects of HRS.

A major advantage of a supply response system over a single-equation yield or acreage supply model is that simultaneous and cross-equation relationships can be incorporated into the estimation procedures to obtain consistent parameter estimates. Our model explicitly allows for market price being simultaneously determined by the quantity supplied and to changes in provincial per capita income [collected by us independent of Lin's work as Lin's data set only includes gross value of agricultural output].

We first fit pooled data from 28 Chinese provinces to estimate national supply response[2]. We do this to compare the results from our model with those of Lin [1992] who only reported national results. Next we disaggregate our pooled data into regions and fit our model to pooled data of North and Northeast provinces and then to data of three Southwest and three Southern provinces. The data were those used by Lin [1992] and were kindly provided to us by him. The original sources of the data include State Statistical Bureau [1980a, 1980b, 1984a, 1984b, 1987, 1988a, 1988b, 1997], Chinese Agricultural Yearbook [1981 – 88]: China Statistical Yearbook [1981 – 97], Ministry of Agriculture [1989, 1997] and Ministry of Agricultural Planning Bureau [1984, 1989, 1997]. For a more complete description of the data, see Lin [1992].

National Results

The three-equation supply response model was estimated by pooling data of the 28 provinces allowing for different provincial intercepts but constraining the slope parameters to be the same across provinces. We used full information maximum likelihood (FIML) form the statistical package Time Series Processor (TSP). The results are reported in table 1, column (2).

We followed Lin [1992] by modelling expected market price by its one time-period lagged price and the expected price risk variable as the square of the deviation of the market price in each time period from its mean divided by the number of observations.

Our results differ from those of Lin [1992] in several important ways. The acreage response is significantly (α = .05) and positively responsive to changes in expected price although the response is inelastic. It should be noted that where agricultural activity is the main activity in a region, output might not be very price responsive. The parameter estimate on expected price is .3977 (.096) [3]. Further the parameter on the household system variable (DHRS) is positive (.0250) but insignificant (α = .05). Lin attributed HRS as the dominant factor in the increase of output but found no evidence of price responsiveness in his "production function" and some evidence in his "supply response" model. It should be pointed out that Lin was modelling total yield so that we also need to look at the parameter estimate of DHRS in the yield equation to see whether the HRS was dominant in significantly increasing yield per sown acre. We do that below.

Table 1. Parameter estimates from a three-equation supply response model for pooled Chinese provincial data, 1970 –97[a]

	National[b]			North and North-east[c]			South and South-west[d]		
Variables	System	Single-equation	Single equation ARI)[e]	System	Single-equation	Single equation ARI)[e]	System	Single-equation	Single equation ARI)[e]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
P_{t-1}	.397 (.096)[f]	.174 (.056)	.254 (.051)	1.512 (.047)	1.562 (.045)	1.53 (.049)	.078 (.091)	.089 (.05)	.167 (.037)
VP_{t-1}	-.010 (.02)	-.005 (.002)	-.003 (.001)	-.015 (.005)	-.015 (.002)	-.012 (.042)	-.002 (.002)	-.002 (.002)	-.001 (.001)
F_t	-.081 (.023)	-.067 (.017)	-.058 (.021)	-.482 (.041)	-.437 (.042)	-.450 (.042)	.007 (.047)	-.003 (.029)	-.010 (.010)

DHRS	.025 (.026)	.017 (.016)	.036 (.017)	.228 (.059)	.175 (.050)	.110 (.041)	-.067 (.039)	-.060 (.024)	-.029 (.011)
Yield per acre equation									
L_t	.140 (.034)			-.351 (.053)			.083 (.075)		
K_t	.276 (.041)			.176 (.087)			.077 (.057)		
F_t	.131 (.031)			.103 (.08)			.198 (.054)		
DHRS	.042 (.028)			.210 (.060)			.137 (.031)		
Table 3 (Continued)									
Inverse Demand Equation									
Constant	2.77 (.135)			2.98 (.17)			2.807 (.291)		
$(A_t + Y_t)$	.001 (.004)			.004 (.007)			-.004 (.014)		
I_t	.45 (.03)			.45 (.05)			.50 (.05)		
DHRS	-.164 (.023)			-.13 (.038)			-.161 (.05)		

[a] Parameter estimates of he provincial dummies are not reported in order to save space. These parameters and standard errors can be requested from the authors.

[b] Data from 28 Chinese provinces were pooled to obtain national results and are (by region): Heilongjiang, Jilin, and Liaoning (North-east); Beijing, Hebei, Henan, Shaanxi, Shandong, Shanxi, and Tianjin (North); Gansu, Neimanggu, Nigxia, Qinghai, and Xinjiang (North-west); Anhui, Hubei, Hunan, Jiangsu, Jiangai, Shanghai, and Zhejiang (Centre); Fijian, Guangdong, and Guangxi (South); and Guizhou, Sichuan, and Yunnan (South-west).

[c] For provinces in the North and Northeast regions, see footnote b.

[d] For provinces in the South and Southeast regions see footnote b.

[e] Maximum likelihood was used to estimate that AR1 specified acreage equations.

[f] Standard errors are reported in parentheses.

Note: P represents the loge of market price, F the $\log_e$ of fertiliser per sown acre, L the $\log_e$ of labour per sown acre, K_t the log of power used per sown acre, I_t the $\log_e$ of per capita provincial income, DHRS represents a dummy variable for years with and without the household responsibility system and V_p represents the market price risk measured by:

$(P_t - P)^2 ln$ where $P = \sum_t P_t ln$ and n is the number of observations.

The parameter on expected risk is negative (-.010) as expected and significantly different form zero (α = .05). This indicates that an increase in expected risk (an expected increase in price variability) has a negative impact on acreage response. Finally, the parameter on the fertiliser per sown acreage variable is negative (-.081) and significant (α = .05). This indicates perhaps that as more fertiliser became available in the latter years of the sample, Chinese farmers substituted fertiliser for land.

The yield equation results indicated that yield per sown acre is positively and significantly affected by the amount of labour, capital, and fertiliser utilised per sown acre. These responses, however, are inelastic in that a one percent increase in labour, capital, or fertiliser would increase yield per sown acre by .14%, .27% and .13% respectively.

The DHRS parameter estimate (.042) with its associated asymptotic standard error (.028) indicates that the HRS did not significantly impact yield per sown acre at the national level. This evidence combined with the insignificant result of the DHRS parameter in the acreage equation certainly differs from Lin's [1992] result and would that Lin inappropriately modelled supply response.

The inverse demand equation indicated that the total value of yield did not have a significant impact on market price but provincial income per capita did. The provincial income per capita parameter estimate (.49) with asymptotic standard error (.030) represents an inelastic price flexibility. The DHRS parameter estimate (-.161) with its associated asymptotic standard error (.023) indicates that the household responsibility system had a negative affect on market price.

The sown acreage equation could be considered singly as is often done in more traditional supply response modelling. For comparative purposes, the acreage equation was estimated with least squares (LS) and with maximum likelihood (ML) for an ARI error specification. These results are reported in columns (3) and (4) of table1. The main difference in results from the system estimation is that the parameter of DHRS is positive and significant for the single equation ARI specification. The ARI ML expected price coefficient is positive, significant, and similar to the FML estimate while that of LS is lower.

Regional Results

The previous results and those of Lin [1992] did not allow for regional differences except via regional intercepts (dummies). Provincial differences existed particularly for output growth and yield growth per sown acre. For example, output growth increased in the North, remained constant in the Northeast and decreased in the South and Southeast during the period 1978 - 88 when compared to the shorter period 1978 – 86. The North and Northeast percent contribution to national grain output increased over 1978 – 88 when compared to 1952 – 65 [Walker,1993]. The opposite is found for the South and Southeast regions. Given these differences even in direction between northern and southern regions, it seems appropriate to fit our model to pooled provincial data at the regional level.

North and North-east

The data of the seven North and three Northeast provinces are pooled in a similar manner to the national pooling, and the three-equation supply response model is used to fit these data. Results are reported in column 5 of table 1. We obtained enormous differences in the parameter estimates of the variables in different regions of China (see table 1).

The expected price responsiveness (positive and significant ($\alpha = .05$)) is much greater that that estimated using the nationally pooled data. In fact, the elasticity is approximately 1.5 percent. The parameter on price risk is negative and significant as found in the national analysis but almost three times its size (-.004 for the national versus -.011 for the Northern regions). The other two variables, $\log_e$ of fertiliser per sown acre and DHRS, also have larger (in absolute terms) parameter estimates than those of the national analysis. Unlike the national level result, the DHRS has a positive and significant effect on acreage response.

All three of the inputs in the yield equation as well as DHRS have significant parameter estimates. Again, unlike at the national level, DHRS has a positive and significant impact on yield per sown acre. One perhaps surprising result is that the parameter estimate on the natural log of labour per sown acre is negative. Results for the inverse demand equation were essentially the same as those of the national analysis.

LS and ML with an ARI specification were also used to estimate the acreage response equation without consideration of the other two equations. Parameter estimates and significance levels were essentially unchanged from those of the three-equation results.

<u>South and South-east</u>

The South and Southeast regions consisted in this analysis as three provinces each. It should be noted that differences in crops and techniques differ more between the South and Southeast that between North and Northeast.

Unlike the results from the two northern regions, the acreage equation results of the two southern regions differ significantly from those at the national level when utilising the three-equation model. The signs of the expected price and expected price risk parameters have the same signs as before (positive and negative, respectively) but both are statistically the same as zero ($\alpha = .05$). The other two variables also have insignificant parameter estimates.

Differences continue when inspecting the yield equation. The three input parameter estimates are all positive but only that of fertiliser per sown acreage is different from zero ($\alpha = .05$). The parameter estimate on DHRS is positive and significant as in the case of the two northern regions but not at the national level.

The LS estimates of the acreage equation were similar except the case of DHRS to those of the three-equation system. None of the acreage equation parameters except that of DHRS differed statistically from zero. The HRS had a significant impact on acreage response, but it was negative instead of positive as one might expect based on Lin [1992]. The ML estimation with ARI specification results were different from those obtained from the other two estimators. The expected price parameter was positive (.15) with an asymptotic standard error (.04) less that half the parameter's size and thus indicates significant and positive acreage response to expected changes in market price. Again, the parameter on DHRS was negative and statistically different from zero.

Conclusions

A three-equation supply response model was used to fit provincial annual data (1970 – 1997) of 28 Chinese provinces and then to the data of 10 northern and six southern provinces. A single-equation acreage response model was also estimated with and without a serial correlation specification for comparison with the supply system results.

Our results suggest that Chinese agriculture was price and price risk responsive at the national level. Increases in price tended to increase acreage sown while increased price risk tended to decrease acreage sown. The regional analyses strongly suggest that significant regional differences exist. The ten North and Northeast regions were more price and price risk responsive than found at the national level. Results based on the six south and Southeast provinces are less clear. The system analysis indicated positive and negative responses to price and price risk, respectively, but the parameter estimates were insignificant. However, the parameter on expected price for the single equation, ARI corrected estimation was positive and significant.

Unlike Lin [1992], we do not find the household response system to be the dominant factor in increased yields in China during the sample period. Concerning acreage response, the HRS parameter estimates were positive but insignificant at the national level and opposite results were found from the northern and southern analyses; HRS had a positive and significant impact in the north but negative and significant in the south. HRS was found to have an insignificant effect on yield per acre sown at the national level, but positive and significant in the two regional analyses.

Our results are more optimistic than Lin's [1992] that a market price system or a rational pricing policy can have a positive affect on agricultural output in China. The conversion to the household responsibility system did have positive impacts at least in certain provinces and regions but, unless the system has many positive and continuing dynamic effects, one would not expect the increases to continue at high levels into the future based just on this institutional change.

Endnotes

[1] FGLS will only be consistent if the dummy variables are uncorrelated with the regressors of the model. If correlation exists the estimates will be inconsistent and biased (Seale 1990).

[2] Data from 28 Chinese provinces were pooled to obtain national results and are (by region): Heilongjiang, Jilin, and Liaoning (North-east); Beijing, Hebei, Henan, Shaanxi, Shandong, Shanxi, and Tianjin (North); Gansu, Neimanggu, Nigxia, Qinghai, and Xinjiang (North-west); Anhui, Hubei, Hunan, Jiangsu, Jiangai, Shanghai, and Zhejiang (Centre); Fijian, Guangdong, and Guangxi (South); and Guizhou, Sichuan, and Yunnan (South-west).

3 The asymptotic standard error is in parenthesis.

References

China Agriculture Yearbook, Beijing: Agriculture Press, 1981– (annual).

China Statistical Yearbook, Beijing: China Statistical Press, 1981-1989 (annual).

Ghatak, **S**. **and Seale**, **J**.**L**.**(Jr)**, (1993) "Rice, Risk and Rationality; Explorations in Supply Response in West Bengal (India). University of Leicester, Economics Department Discussion Paper, No. 93/8.

Gujarati, D. (1988), *Basic Econometrics*, McGraw Hill

Hussain, A. and Stern, N. (1994) "Economic Transition on the Other Side of the Wall: China", CP no. 29, LSE STICERD, *The Development Economics Research Programme Discussion Papers*, No 29.

Kueh, **Y**.**Y**. **and Ash**, **R**.**F**. (1993), "*Economic Trends in Chinese Agriculture: The Impact of Post-Mao Reform*", Clarendon Press, Oxford.

Lin, **J**.**F**. (1992), "Rural Reforms and Agricultural Growth in China", *American Economic Review* 82, pp. 34 – 51

Lin, **J**.**F**. (1991), "The Household Responsibility System Reform and the Adoption of Hybrid Rice in China", *Journal of Development Economics*, 30 (pp. 353 – 72).

Maddala, **G**.**S**. (1989), *Introduction to Econometrics,* Macmillan Publishing Company, New York, Chapter 10.

Seale, **James L**., **Jr**. (1990), "Estimating Stochastic Frontier Systems with Unbalanced Panel Data: The Case of Floor Tile Manufactories in Egypt". *Journal of Applied Econometrics* 5, pp. 59 – 74.

Seale, **J**.**L**. **(Jr)** and **J**.**S**. **Shonkwiler** (1987), Rationality, Price Risk and Response". *Southern Journal of Agricultural Economics,* pp. (111 – 17).

State Statistical Bureau (1980a), *National Agricultural Statistics for the 30 Years Since the Founding of the People's Republic of China, 1974 – 1979* [in Chinese: *Jianquo 30 Nian Quanguo Nongye Tongji Ziliao, 1949 – 1979*]

(1984a), *National Agricultural Statistics (Continuation)*, 1978 – 1983 [in Chinese: *Quanguo Nongye Tongji Ziliao (Xubain), 1978 – 1983*], Beijing: State Statistical Bureau, 1984.

(1984b), *China Trade and Price Statistics*, *1952 -1983* [in Chinese: *Zhong-guo Maoyi Wujia Tongji Ziliao*, *1952 – 1983*], Beijing: China Statistical Press, 1984.

(1987), *A Compilation of National Income Statistics, 1949 – 1985* [in Chinese: *Guominshouru Tongji Ziliao Huiban, 1949 – 1985*] Beijing: China Statistical Press.

(1988a), *A Compilation of Price Statistics Documents* [in Chinese: *Wujia Tongji Wenjian Huibian*]. Beijing: China Statistical Press.

(1988b), *China Price Statistics Yearbook*, 1988 [in Chinese: Zhongguo Wujia Tongji Nianjian, 1988], Beijing: China Statistical Press.

Traill, **B**. (1977), "Incorporation of Risk Variables in Econometric Supply Response Analysis", unpublished PhD Thesis, Cornell University.

Walker, **K**. (1993), "Trends in Crop production", In *Economic Trends in Chinese Agriculture: The Impact of Post-Mao Reforms*, Kueh, Y.Y. and Robert Ash (eds.), Clarendon Press, Oxford.