Estimating Crop-Specific Production Growth and Sources in China

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Abstract

This study uses aggregated provincial level data from 1979 to 2000 to estimate crop-specific production functions and identifies the sources of production growth for wheat, corn, soybean, rapeseeds, and cotton in China. The results show that fertilizer, pesticide, seeds, production specification, weather, and R&D are important determinants of crop yields. The land, fertilizer, and R&D are major contributors to production growth during the study period.

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Introduction

Since the introduction of rural reforms in China in the late 1970s, agricultural production for major crops has been increased significantly. Production for wheat, corn, soybean, rapeseeds, and cotton has been increased by 82 percent, 102 percent, 81 percent, 237 percent, and 62 percent, respectively, from 1979 to 2000 (Table 1).

China's increasing role in world trade calls for the need to understand its production growth and input utilization. Understanding crop-specific technology is a key to analyzing the comparative advantage of the individual crop and the potential for trade in the future. China is the largest producer as well as the largest consumer in the world for many major crops. A small change in production or in consumption will have a large impact on the world commodity market.

Most literatures on China's agricultural growth are conducted in the late 1980's and early 1990's, focusing on the period immediately following the introduction of rural reform. Moreover, most of these studies were based on the gross value of agricultural output (GVAO), with little information on crop specific information. In the absence of crop-specific input information, all of these studies had to make some strong assumptions about input use. The lack of crop-specific input information may have led to biased estimation for grain production functions in Chinese agriculture because crop production technologies may differ sharply among crops.

This study estimates China's crop specific production functions and analyzes the source of growth for each specific crop: wheat, corn, soybean, rapeseeds, and cotton by using provincial aggregated household survey data from 1978 to 2000.

Model and Data

Time-series cross-prefecture data from 1978 to 2000 from all major crop-producing provinces are used in this study. The data come from the Cost and Production Survey conducted by China's Price Bureau. The survey covers most of the major crops and includes 4067 households for wheat, 3843 households for corn, 1045 households for soybeans, 2042 households for rapeseeds, 1520 households for cotton in 2000's survey. Crop output, area, and yield data for each commodity was taken from China's Statistical Yearbook and China's Rural Statistical Yearbook published by National Statistical Bureau, and China' Agricultural Statistical Yearbook published by the Agricultural Publishing House of Ministry of Agriculture, Livestock Husbandry, and Fisheries.

We estimate the crop yield equation and then derive production by multiplying yield by the sawn area. The initial explanatory variables for the yield equations include inputs: land, labor, chemical fertilizer, seeds, pesticide, machinery, irrigation, other physical cost, regional production specialization, weather, and a set of regional dummy variables.

The weather has a large influence on agricultural performance, and consequently production estimates, but because of the difficulty of quantifying weather conditions for GVAO studies and data constraints, few studies have considered this influence on agricultural production with the exception of Carter and Zhang's study of the effect of the economic reforms on China's grain production. They found that good weather conditions were partly responsible for the rapid increase in grain output in the early 1980s. In this study, crop specific production estimates make it possible to include the weather as a dummy variable. It is classified as a bad weather (set to 1) when the yield less than 20 percent of normal yield.

The regional production specialization variable is represented by the share of specific crop area in total crop's areas. This variable is created to reflect the other factors such as soil quality and other regional government supports to the crop in specific year. It is expected that the regions with a higher share of the crop production have better suitable land and better environment for that crop's production and therefore higher yield for that crop.

Following Lin, multiple cropping index (MCI) is used to as an explanation variable. It is expected that the higher of the MCI, the lower of the yield in the region.

A set of regional dummy variables are used to represent time-persistent, regional differences in social, economic, and natural endowments not accounted for by the other variables and a time trend is used to represent the factor due to technological change during the research period.

Chemical fertilizer is measured in terms of pure nutrients (in kgs) rather than gross weight. The pure nutrients measure represents the effective contents of the fertilizer used. These effective contents are different for different types of fertilizer and they change over time.

In previous study, labor input is measured in stock terms. In this study, the labor input is measured by working days from the survey data. Since there is a huge labor surplus in agriculture in China, the negative sign has been from previous studies (Stavis). The negative sign for labor input means that rural China had an adequate labor pool, and the return on increasing labor input was negligible.

Following Fan and Pardey, the following quasi-translog specification was chose for yield equations:

$$\ln Y_{jt} = \alpha_0 + (\alpha_1 + \alpha_2 t)t + \sum_i (\beta_{1i} + \beta_{2i} t) \ln X_{ijt} + \gamma_1 MCI + \gamma_2 S + \sum_{I=2}^{7} \delta_I D_I + e_{jt} \qquad (1)$$

where Y is crop yield, t is time trend, X is physical inputs including land, fertilizer, pesticide, machinery, and seeds etc., MCI denotes the multiple cropping index, S represents the share of estimated crop in total sown area, and D is the dummy variables for different regions, j=1-n denotes the province which varies by crops, I=1-7 denotes 7 regions in China, and t is the years from 1979 to 2000.

The quasi-translog function represents a compromise between a Cobb-Douglas production function and translog specification. The Cobb-Douglas form implies constant elasticities for all time periods, which is unrealistic over 21 years from 1979 to 2000 in China. However, translog specifications have several multicollinearity problems due to the strong trending nature of many inputs. The Quasi-translog function form allows a reasonable flexible and allows production elasticities to vary over time. It can reduce the multicollinearity problem by imposing separability between all measured inputs but not between these inputs and time trend.

Model Estimation and Results

The models are estimated by SAS package. The different model specifications were tried. For comparative purposes, the Cobb-Douglas version of the yield equations are also estimated and reported. Since both the Cobb-Douglas function and quasi-translog estimates of ordinary least squares have autocorrelation problems, the AR1 procedure is used to estimate the same equation again to correct the problem.

As expected, labor and draft animals have a negative sign for all crops indicating the impact of these variables on yield were negligible. Thus these inputs are dropped from the models. Other variables are selected based on the sign and statistical significance and vary among different crop models.

The estimates for each crop are reported in Tables 2-6 for wheat, corn, soybean, rapeseeds, and cotton, respectively. Each table contains four estimates discussed in the above. The constant variance error (no heteroscedasticity) assumptions are examined by plots between the predicted values and residuals for equations of quasi-translog specifications with AR1 estimation. Four residual plots are reported in Figures 1, 3, 5, 7, and 9, respectively for wheat, corn, soybean, rapeseeds, and cotton. All plots show that the assumption for all crops' equations is reasonable hold.

The plots between predicted value and time trends are presented in Figures 2, 4, 6, 8, and 10 for wheat, corn, soybean, rapeseeds, and cotton, respectively. These plots suggest that there is a no autocorrelation problem for all yield equations.

The assumption of normal distribution for errors, outliners, and linearity were also diagnosed and no big problems were found.

The estimated results for wheat are reported in Table 2. The explanatory variables for the Cobb-Douglas function are fertilizer, pesticide, machinery, seeds, other physical input, the share of wheat area in the region, time trend, and regional dummy variables. All parameters for physical inputs are significant at below the 10 percent level. The share of wheat variable is significant at 1 percent with high t-value 5.29 indicating that provinces with high yields grow more wheat or that provinces with specialized wheat production have higher yields. It is not surprising that bad whether has a significant negative impact on yields. The time trend is positive and significant at 1 percent level. It suggests that technology change is another factor contributing to the increase in wheat yield during the study period. The results of the quasi-translog function corresponding to these variables show that some physical inputs in liner terms become not significant, but interaction terms with the time trend are significant for most of them. All these terms are kept in the final model that is used to separate the contributions of each factor to the yield in the following part of the section. The nonsignificance may be due to the multi-collinearity, but the parameters are not biased. The R^2 of 0.87 indicates that 87 percent of the variance in yield is explained by the explanatory variables and good for the yield equation estimation for this study.

The result for corn yield is reported in Table 3. Variables included in the equation are fertilizer, seeds, pesticide, other physical inputs, share of corn area in total sown area, weather dummy, and time trend. These variables are significant at 1-10 percent in linear term in Cobb-Douglas functions. These variables together with interaction terms with time are significant at 1-10 percent. The R^2, 0.84, indicates that the variables explain the yield well. Similar to the wheat equation, specialization variable and weather variables are highly significant.

The soybean yield estimates are reported in Table 4. The independent variables included in the model are fertilizer, seeds, pesticide, other physical input, specialization, whether, and time trend. The R^2 is 0.76.

The independent variables in the rapeseeds equation (Table 5) are fertilizer, manure, pesticide, other physical variables, specialization, MCI, weather, time trend, and regional dummy variables. Different from other models, specialization variable is not significant in Cobb-Douglas and Quasi-translog functions and suggest that there is not a big difference in major rapeseeds producing region and non major producing regions.

Cotton yield estimates are reported in Table 6. The selected variables in the final model are fertilizer, seeds, pesticide, other physical input, specification variable, weather variable, and time trend. All these variables are significant at 1 percent to 10 percent in Cobb-Douglas form and all linear terms and interactions are significant at 1 percent to 10 percent. The results show that weather and specialization variables are important factors in explaining the cotton yield.

The estimated yield equations are used to account for the separate contribution of each input to crop production. To avoid the variability of yield due to uncertainty in agricultural production, the three-year average from 1979 to 1981 and from 1998 to 2000 are compared. The total production growth for each crop is separate into area, fertilizer, specification, and other factors. The calculated results are reported in Table 7.

The results show that the land effects account for 31.1 percent, 19.95 percent, 19.95 percent increase in corn, soybean and rapeseeds production, respectively. The land effect on wheat production increase only account for about 0.41 percent, land reduction led to about 29 percent reduction in cotton production. Using the coefficients derived from the quasi-translog regression to account for the contributions from other factors, the results shat that chemical fertilizer is the large contributor except for the land for the production increase, especially for the soybean, wheat, and rapeseeds.

Specialization is significant factor in determining wheat, corn, and cotton yields. However, specialization did not contribute much to the output increase. In fact, wheat specialization factors led to a 3.78 percent decline of wheat production. This may be due to the government's grain responsibility policy and regional resource allocation did not based on their relative comparative advantages.

Weather is another factor to the variation of crop yield from the estimated equation. However, average weather condition between two periods did not have big difference. Therefore weather has no impact on wheat and corn yields and just has a slight influence on soybean yield (1.31 percent increase), rapeseeds (1.32 percent increase), and cotton (1.53 percent increase) during the two periods.

Soybean has the largest proportion of production growth explained by the total factor changes except time trend in the model, accounting for 72.81 percent. Followed by corn, there is 52.7 percent. Wheat and rapeseeds have almost the same proportions explained by all factors except time trend in the model, with 35 percent each. Different from other crops, cotton production growth in the two periods has almost nothing explained by the all factors except time trend in the model. This result is not surprising because China has started adopting Bt cotton since 1997 and Bt cotton area has been expended to 700 thousand hectares in 2000 (Huang et al. 2001). The adoption of Bt cotton increased yields and net returns significantly (Fernandez-Cornejo 2000, Pray et at. 2001).

The results of this study indicate that China's agricultural growth can be explained by R&D, especially for cotton, wheat, and rapeseeds.

Conclusions

Since the introduction of rural reforms in China in the late 1970s, agricultural production for major crops has been increased significantly. This paper estimated China's crop specific production functions and analyzed the sources of growth for each specific crop: wheat, corn, soybean, rapeseeds, and cotton by using provincial aggregated household survey data from 1979 to 2000. The results show that fertilizer, pesticide, machinery, seeds, regional specification, and weather are major factors in the determination of the crop yield in general. However, different crops have different determinants for the yield growth.

The increase in sawn area is the major factor contributing to production growth for corn (accounting for 31 percent), soybean (20 percent), and rapeseeds (20 percent) compared to the average of 1998-2000 with the average of 1979-1981. There was almost no production growth that was resulted from the area increase for wheat. There was a significant decline in cotton area that resulted in a 29 percent decrease in cotton production.

The growth in chemical fertilizer application is another major factor in production growth. The increase in chemical fertilizer application contributed to 45 percent of soybean growth, 25 percent of wheat growth, 24 percent of rapeseeds growth, 7 percent of corn growth, and 4 percent of cotton growth.

Production specialization has a significant impact on the crop yield. However, specialization did not contribute much to production increases during the study period due to the government’s strong intervention to the grain production.

The results indicate that research and development is the major contributor to the crop’s yields, especially for cotton, wheat, and rapeseeds production.

Table 1. Growth in Crop's Production and Yield in China, 1979-2000

	Production				Yield			
	1979-81 average (1'000 mt) (a)	1978-00 average (1'000 mt) (b)	Total Growth (%) (a-b)/a-1	Annual Growth Rate (%)	1979-81 average (mt/ha) (c)	1978-00 average (mt/ha) (d)	Total growth (%) (c-d)/c-1	Annual Growth Rate (%)
Wheat	59193	107748	82.03	3.04	2.047	3.790	85.18	3.13
Corn	60613	122347	101.85	3.57	3.037	4.937	52.56	2.46
Soybean	8242	14947	81.36	3.02	1.097	1.747	59.27	2.35
Rapeseeds	2950	9938	236.83	6.26	0.927	1.420	53.23	2.16
Cotton	2620	4253	62.32	2.45	0.537	1.050	95.65	3.41

Source: calculated based on USDA PSD data.

Table 2. Estimated Wheat Yield Function in China (1979-2000)
Dependent Variable: Log (Wheat Yield)

Explanatory Variable	Cobb-Douglas		Quasi-translog	
	OLS	AR1	OLS	AR1
Constant	6.37991 (39.79)*	5.8544(39.85)*	5.60601(19.28)*	4.9367(14.40)*
Log Fertilizer	0.0886 (5.20)*	0.0503(3.46)*	0.14408(4.58)*	0.1227(3.72)*
Log seeds	0.24808 (6.59)*	0.0721(2.26)**	0.16834(2.01)**	-0.0871(-0.96)
Log peste	0.06087 (4.81)*	0.0245(2.34)**	0.05769(2.45)**	0.0264(1.39)
Log mechex	0.0044 (0.33)	0.0161(1.68)***	-0.06304(-2.37)**	-0.0217(-0.91)
Log other exp	0.01216(1.13)	0.0215(2.72)*	0.00666(0.32)	-0.0002(-0.20)
Log share of wheat	1.43529(9.51)*	1.1073(5.29)*	1.56998(10.07)*	1.291(5.85)*
Bad Weather	-0.50263(-8.46)*	-0.4036(-11.47)*	-0.48742(-8.25)*	-0.3995(-11.30)*
Time	0.00817 (2.99)*	0.0189(7.51)*	0.07407(3.52)*	0.0909(3.78)*
Time* Log Fertilizer			-0.00605(-1.98)**	-0.0073(-2.43)**
Time* Log seeds			0.00416(0.76)	0.0102(1.78)***
Time* Log mechex			4.15E-05(0.02)	0.0029(1.76)***
Time* Log other exp			0.00667(3.49)*	-0.00021(-0.20)
Time* Time			-0.00066(-1.81)***	-0.00054(-1.09)
Dne	-0.13863(-2.46)**	-0.2102(-2.61)*	-0.10625(-1.91)	-0.1479(-1.81)***
Dnw	-0.38286(-12.92)*	-0.3283(-7.51)*	-0.35792(-11.97)*	-0.3063(-7.04)*
Dc	0.07054(1.42)	-0.0581(-0.73)	0.11441(2.29)**	-0.0224(-0.28)
Dse	0.13547(3.88)*	0.1206(2.26)**	0.1472(4.26)*	0.1239(2.35)**
Dsw	-0.05239(-1.17)	-0.2335(-3.85)*	-0.00945(-0.21)	-0.2008(-3.29)*
D.F.	440	425		419
R2	0.725	0.87		0.87
D.W.	0.692	1.89		1.90

Source: Estimated by Authors

Table 3. Estimated Corn Yield Function in China (1979-2000)
Dependent Variable: Log (corn yield)

Explanatory Variable	Cobb-Douglas		Quasi-translog	
	OLS	AR1	OLS	AR1
Constant	6.6450(44.89)*	6.1850(42.64)*	6.4877(24.96)*	6.1725(24.78)*
Log otherex	0.0386(2.98)*	0.0321(2.54)**		
Log seeds	0.2383(9.68)*	0.0998(4.30)*	0.2972(6.58)*	0.1579(3.50)*
Log Fertilizer	0.0830(4.95)*	0.0469(2.94)*	0.0995(3.05)*	0.0196(0.61)
Log peste	0.004687(0.49)	0.009726(1.21)	-0.0237(-1.32)	-0.0118(-0.84)
Time	0.009255(4.57)*	0.0167(8.25)*	0.0121(0.52)	0.0123(0.52)
Log share of corn	0.9773(8.12)*	0.9483(5.33)*	1.0635(8.55)*	1.0779(-1.97)**
Bad Weather	-0.3963(-8.82)*	-0.3493(-11.82)*	-0.4095(-9.05)*	-0.3543(-11.94)
*Time*Log Fertilizer			-0.001828(-0.54)	0.003157(1.02)
Time*Log pests			-0.001353(2.14)**	0.002948(2.18)
Time* Log seeds			-0.006758(-1.84)**	-0.007883(-2.06)**
Time* Time			-0.000178()-0.53	-0.000842(-1.97)**
Dne	0.0433(1.42)	0.0843(1.81)**	0.0556(1.83)***	0.0764(1.64)***
Dnw	0.1181(4.43)*	0.1723(4.22)*	0.1577(5.63)*	0.2026(4.90)*
Dc	-0.0456(-1.04)	-0.003234(-0.05)	-0.0221(-0.51)	0.0053(0.08)
Dse	0.2176(6.21)*	0.2194(3.94)*	0.2316(6.45)*	0.2363(4.20)*
Dsw	-0.0469(-1.88)**	-0.0424(-1.10)	-0.0546(-2.13)**	-0.0694(-1.76)***
D.F.	449	448	446	445
R^2	0.7144	0.8341	0.7140	0.8366
D.W.	0.8182	2.0185	0.8217	1.9793

Table 4. Estimated Soybean Yield Function in China (1979-2000)
Dependent Variable: Log (soybean yield)

Explanatory Variable	Cobb-Douglas		Quasi-translog	
	OLS	AR1	OLS	AR1
Constant	5.8301(33.53)*	5.2592(29.75)*	5.3741(21.65)*	5.2488(22.12)*
Log otherex			0.0908(4.48)*	0.0453(2.87)*
Log Fertilizer	0.0132(0.94)	-0.006412(-0.43)	0.0642(2.41)**	0.0133(0.49)
Log Seed	0.0986(2.33)**	0.0748(2.33)**	0.1172(1.74)***	0.0735(1.39)
Log pests	0.0328(2.81)*	-0.003388(-0.32)	-0.0436(-1.87)***	-0.0403(-1.81)***
Log depex	0.0442(2.14)**	0.001192(0.07)		
Time	0.0186(8.17)*	0.0227(9.22)*	0.0369(1.67)***	0.0456(1.91)***
Log share of soybean			0.1876(0.70)	-0.5676(-1.51)
Bad Weather	-0.4781(-8.14)*	-0.4999(-14.09)*	-0.4695(-8.15)*	-0.4978(-14.78)*
Time*Time			-0.000277(-0.72)	-0.000529(-0.97)
Time*Log otherex			-0.005174(-3.79)*	-0.002910(-2.94)*
Time*Log pests			0.005949(3.58)*	0.003166(1.89)***
Time* Log seeds			-0.002274(-0.44)	0.001341(0.29)
Time*Log Fertilizer			-0.00444(-1.99)**	-0.001871(-0.81)
Dn	-0.0912(-2.57)*	-0.1768(-3.18)*	-0.0971(-2.29)**	-0.2082(-3.40)*
Dnw	-0.1839(-3.38)*	-0.3131(-3.40)*	-0.0878(-1.59)	-0.2947(-3.28)*
Dc	0.1294(2.35)**	-0.0258(-0.29)	0.0651(1.35)	-0.0685(-0.88)
Dse	0.0811(1.81)***	0.0297(0.41)	0.0314(0.69)	-0.0209(-0.29)
Dsw	0.0120(-2.13)**	-0.2933(-3.86)*	-0.1640(-2.98)*	-0.3456(-4.35)*
D.F.	340	339	334	333
R^2	0.5366	0.7492	0.5624	0.7590

Source: Estimated by Authors

Table 5. Estimated Rapeseeds Yield Function in China (1979-2000)
Dependent Variable: Log (rapeseeds yield)

Explanatory Variable	Cobb-Douglas		Quasi-translog	
	OLS	AR1	OLS	AR1
Constant	4.7297(35.14)*	4.7297(35.81)*	4.5626(13.35)*	4.1235(13.46)*
Log otherex	0.0628(4.31)*	0.0464(3.52)*	0.0767(4.95)*	0.0470(3.38)*
Log seeds			-0.1268(-2.81)*	-0.1214(-2.77)*
Log menure	0.0578(3.35)*	0.0542(2.98)*	0.2307(5.65)*	0.1068(2.67)*
Log Fertilizer	0.1241(5.631)*	0.0643(2.65)*	0.0919(2.67)*	0.0969(2.59)*
Log pests	-0.0251(-1.51)	-0.0267(-2.11)**	-0.0402(-1.62)***	-0.0252(-1.17)
Time	0.0247(8.52)*	0.0295(9.95)*	0.0589(2.07)**	0.0959(3.65)*
Log share of rapesd			0.0413(0.14)	0.1121(0.29)
Time*Time			-0.000889(-1.85)***	-0.000708(-1.18)
Bad Weather	-0.5972(-9.11)*	-0.05674(-13.24)*	-0.5583(-8.68)*	-0.5559(-12.71)*
Time* Log Fertilizer			0.000174(0.05)	-0.005060(-1.52)
Time*Log pests			0.001315(0.59)	-0.000207(-0.10)
Time* Log seeds			0.009806(2.87)*	0.009979(3.22)*
Time*Log menure			-0.0130(-4.47)*	-0.004137(-1.49)
Dn	-0.0193(-0.38)	-0.0541(-0.75)	-0.0320(-0.63)	-0.0826(-1.18)
Dnw	0.0262(0.55)	0.0284(0.41)	0.0684(1.30)	0.0502(0.73)
Dc	-0.1859(-4.24)*	-0.2443(-3.43)*	-0.1903(-4.38)*	-0.2276(-3.38)*
Dse	0.2586(5.77)*	0.3503(5.03)*	0.2435(5.36)*	0.3404(5.30)*
D.F.	336	335	329	328
R^2	0.6317	0.777	0.6673	0.7879
D.W.	0.7854	2.2239	0.8751	2.0788

Source: Estimated by Authors

Table 6. Estimated Cotton Yield Function in China (1979-2000)
Dependent Variable: Log (cotton yield)

Explanatory Variable	Cobb-Douglas		Quasi-translog	
	OLS	AR1	OLS	AR1
Constant	4.2725(17.58)*	4.1662(17.69)*	4.8249(9.43)*	4.9151(9.40)*
Log otherex	0.0841(3.24)*	0.0360(1.55)	0.1516(2.83)*	0.0730(1.40)
Log seeds	0.0427(0.83)	0.0935(1.85)***	0.004517(0.04)	0.1663(1.64)***
Log Fertilizer	0.0452(1.49)	0.0290(1.24)	0.0133(0.26)	0.0714(1.44)
Log pests	0.008025(0.26)	-0.0528(-1.51)	0.1909(3.67)*	0.1427(2.43)**
Time	0.0242(6.19)*	0.0319(7.61)*	-0.0336(-0.83)	-0.0326(-0.73)
Log share of cotton	2.4008(5.87)*	2.2215(3.84)*	1.9080(4.59)*	1.7849(3.20)*
Bad Weather	-0.4856(-8.53)*	-0.4521(-10.61)*	-0.5252(-9.78)*	-0.4591(-10.95)*
Time*Time			-0.000764(-1.32)	-0.000305(0.43)
*Time*Log otherex			-0.009087(-2.20)**	-0.005329(-1.21)
Time*Log pests			-0.0200(-4.80)*	-0.0181(-4.26)*
Time* Log seeds			-0.002154(-0.32)	-0.0103(-1.44)
Time*Log Fertilizer			0.001485(0.30)	-0.005481(-1.18)
Dnw	-0.0925(-1.07)	-0.1496(-1.27)	-0.0622(-0.74)	-0.0420(-0.38)
Dc	0.3314(7.19)*	0.3412(5.21)*	0.2836(6.33)*	0.2944(4.78)*
Dse	0.1586(3.38)*	0.2145(3.11)*	0.1075(2.43)**	0.1657(2.63)*
Dsw	0.2881(4.78)*	0.2725(3.07)*	0.2228(3.82)*	0.1945(2.33)**
D.F.	252	251	247	246
R^2	0.6241	0.7572	0.6879	0.7837
D.W.	0.8709	1.9305	0.9580	1.9386

Source: Estimated by Authors

Table 7. Accounting for Growth in Crop Production by Region, 1979-2000 (%)

	Wheat	Corn	Soybean	Rapeseeds	Cotton
Land	0.41	31.10	19.95	19.95	-28.90
Chemical Fertilizer	24.92	6.95	44.86	24.25	4.03
Pesticide	7.77	10.91	0.81	-10.66	5.64
Machinery	3.83			0.90	
Seeds	1.82		4.93	-0.65	17.24
Specialization	-3.78	3.74	0.33	0.14	0.18
MCI					
Weather	0.00	0.00	1.31	1.32	1.53
Total explained	34.97	52.7	72.19	35.25	-0.28
R&D (Residuals)	65.03	47.3	27.81	64.75	100.28
Production	100.00	100.00	100.00	100.00	100.00

Source: Calculated by Authors

Fig 1. Wheat Yield Quasi–translog Resid/Pred Plot

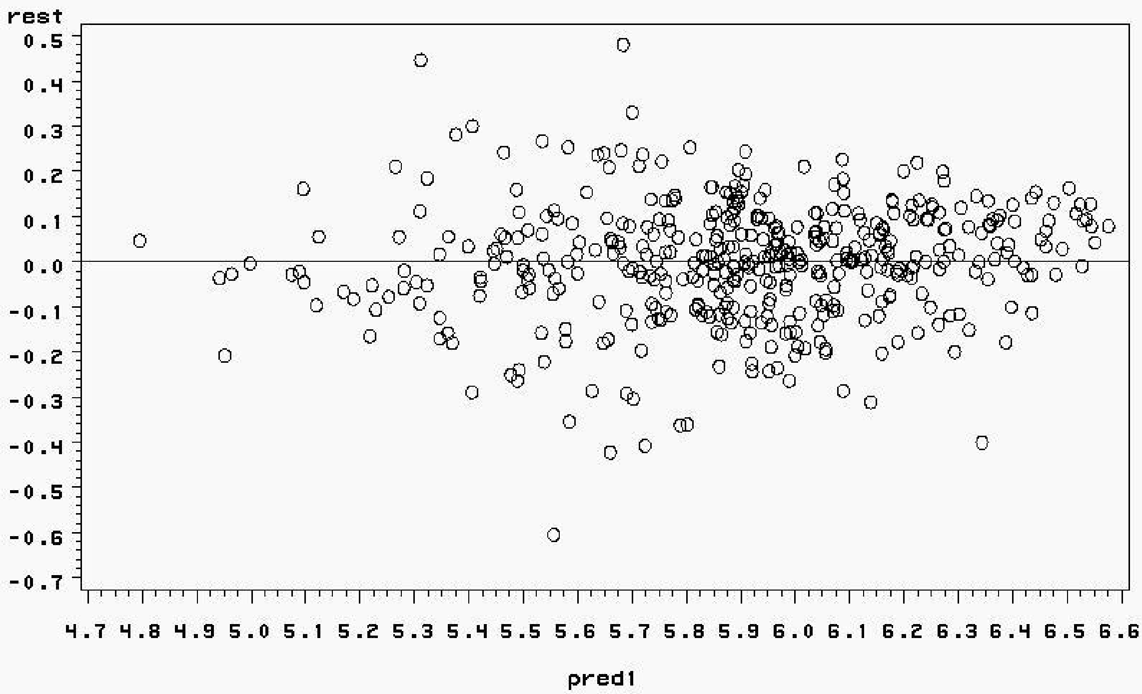


Fig 2. Wheat Yield Quasi–translog Resid/Time Plot

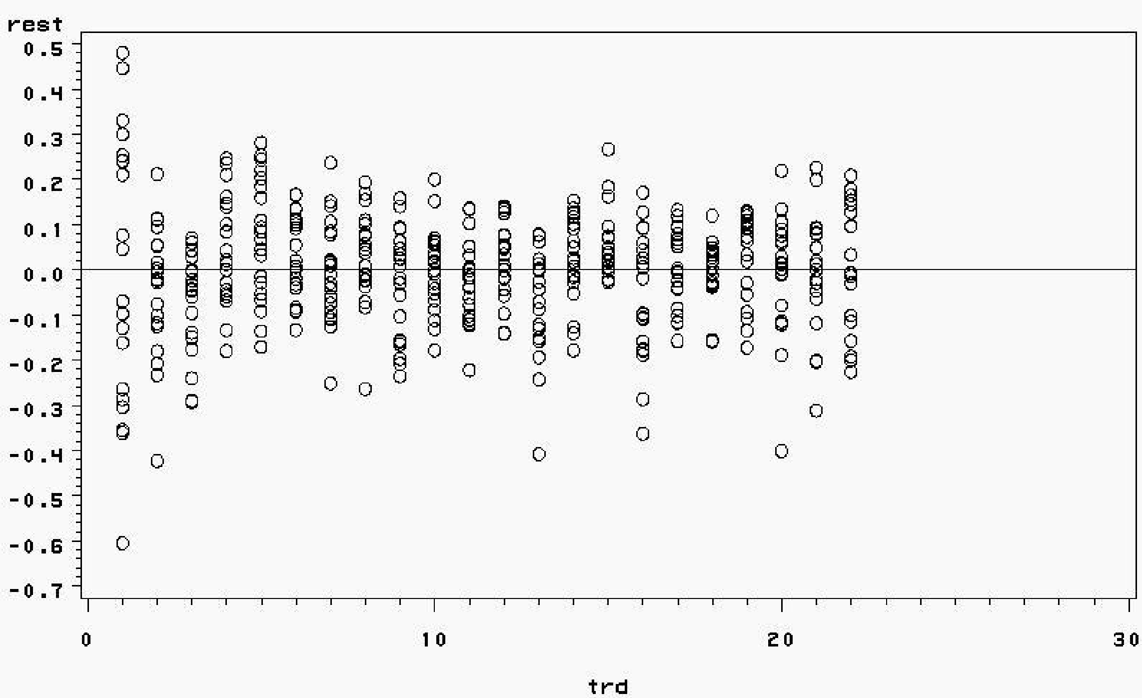


Fig 3. Corn Yield Quasi–Translog Resid/Pred Plot

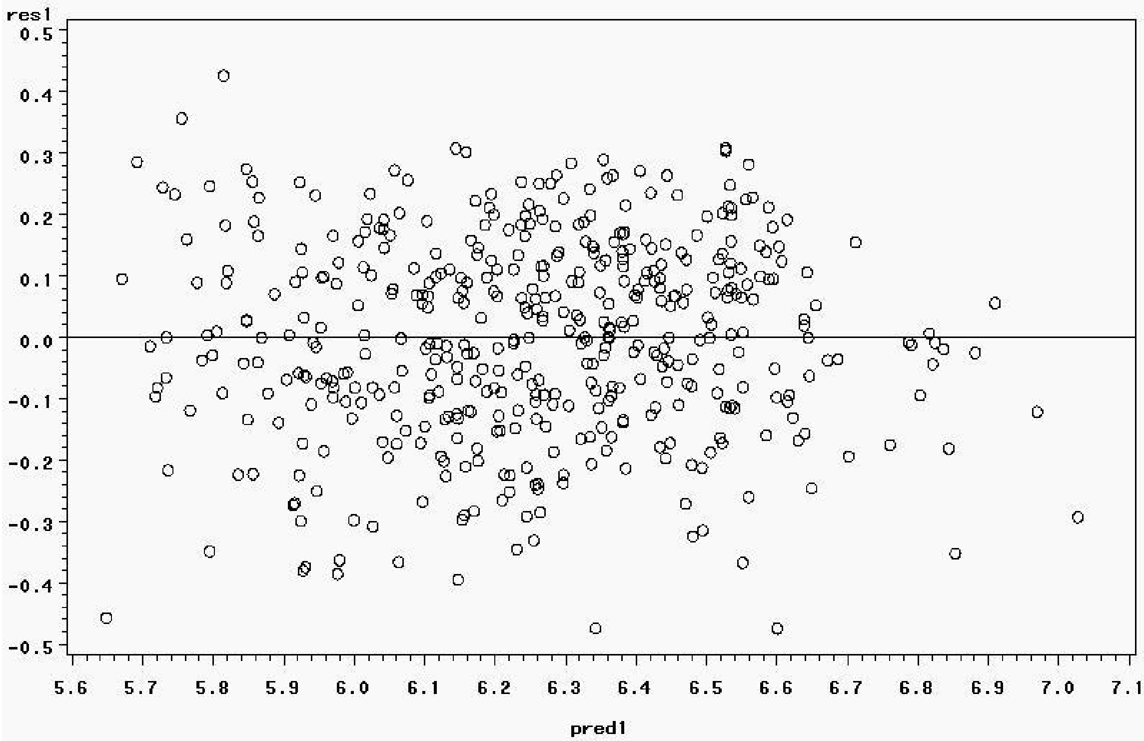


Fig 4. Corn Yield Quasi–Translog Resid/Time Plot

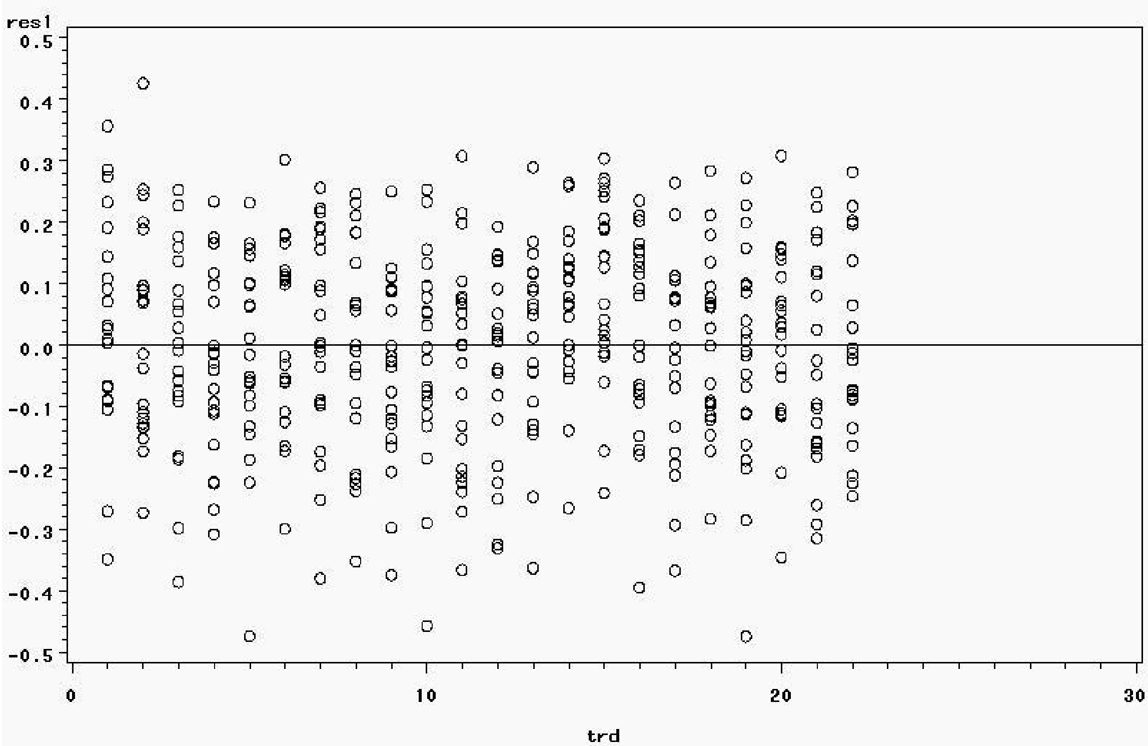


Fig 5. Soybesn yield Quasi−Translog Resid/Pred Plot

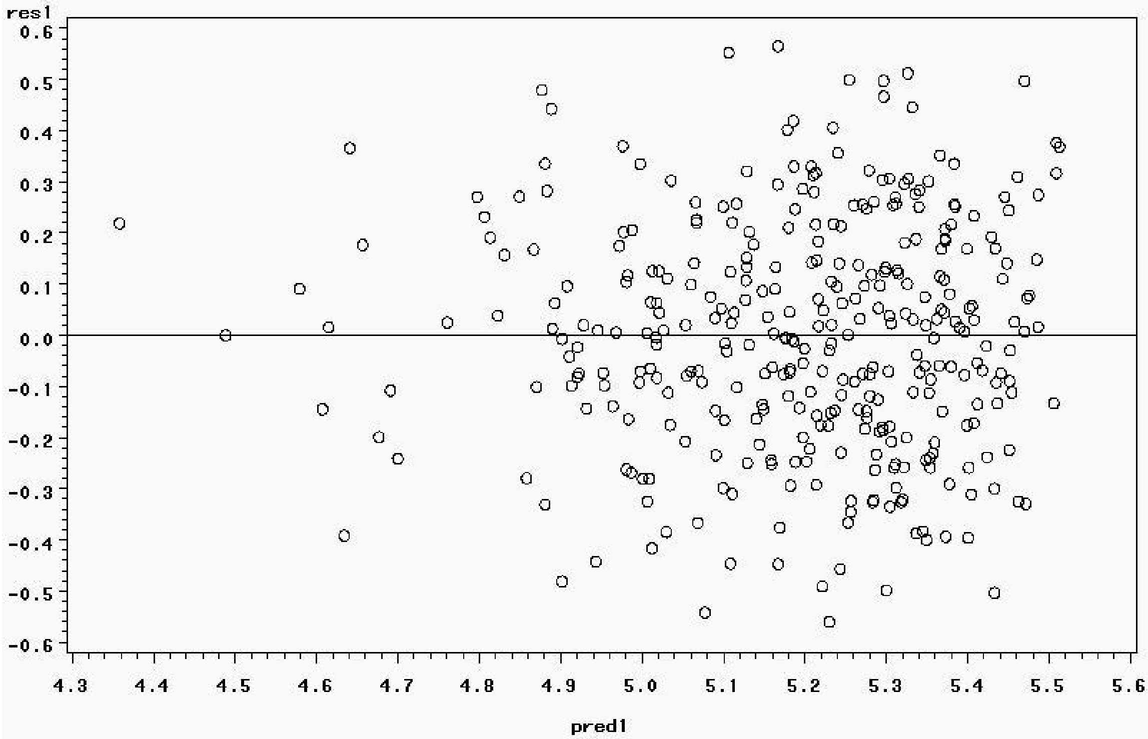


Fig 6. Soybesn yield Quasi−Translog Resid/Time Plot

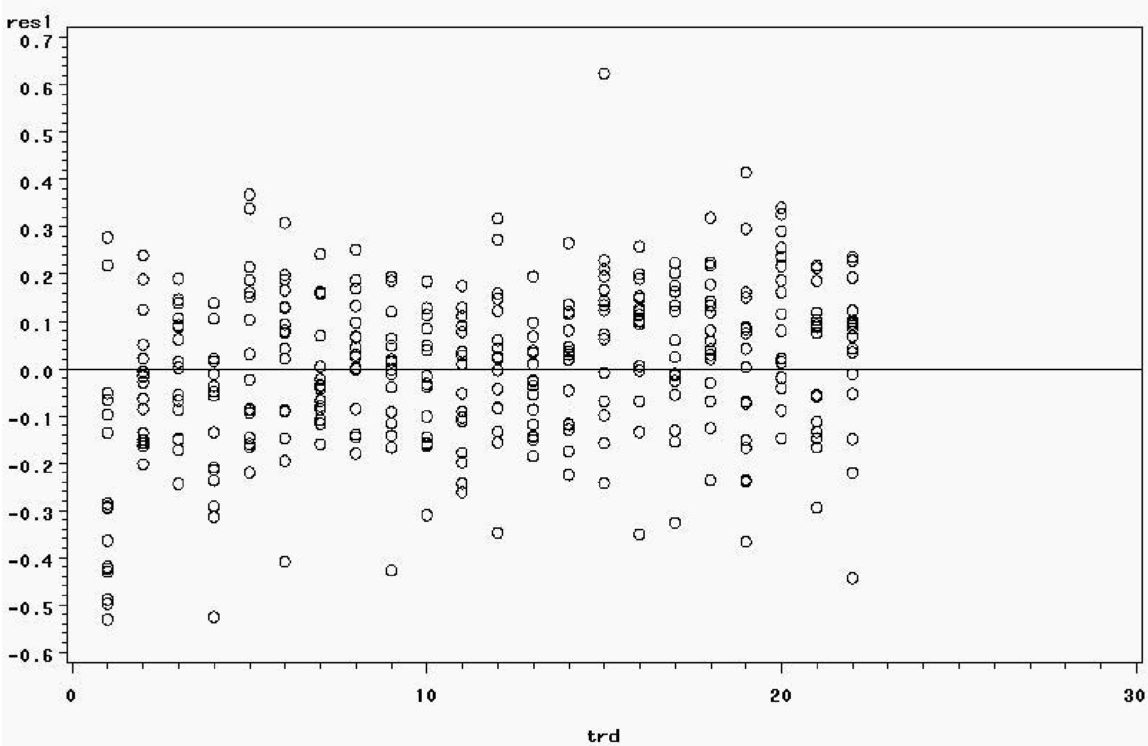


Fig 7. Rapesd Yield Quasi–translog Resid/Pred Plot

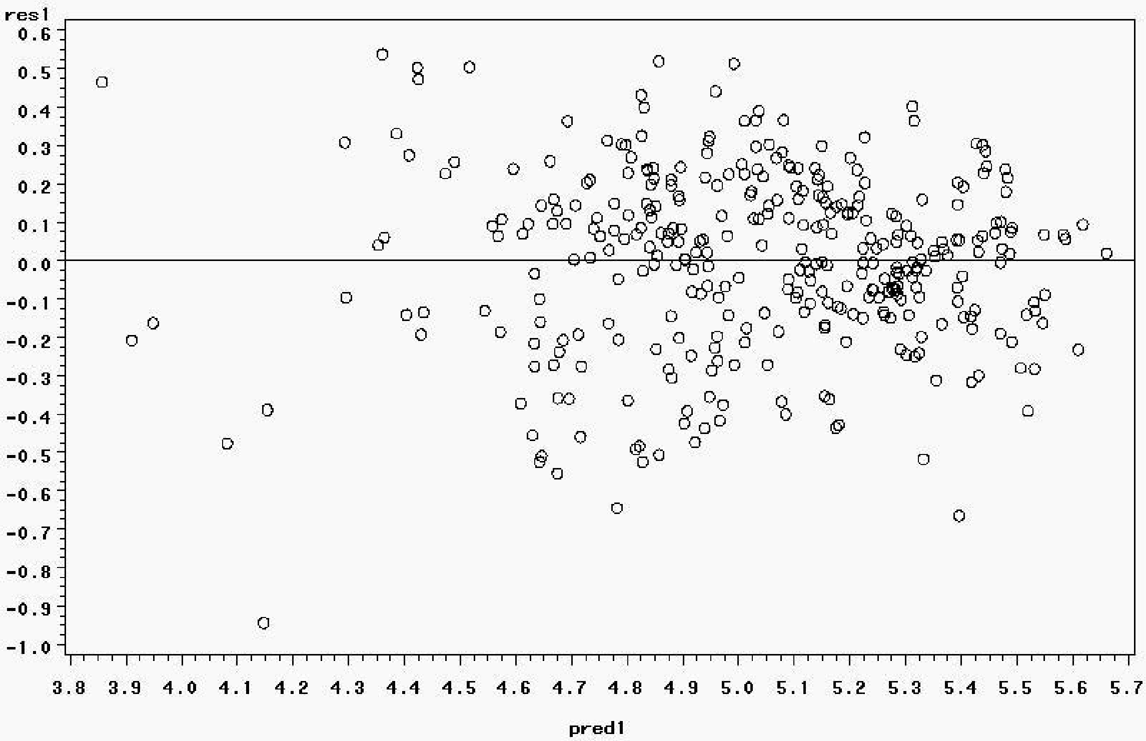
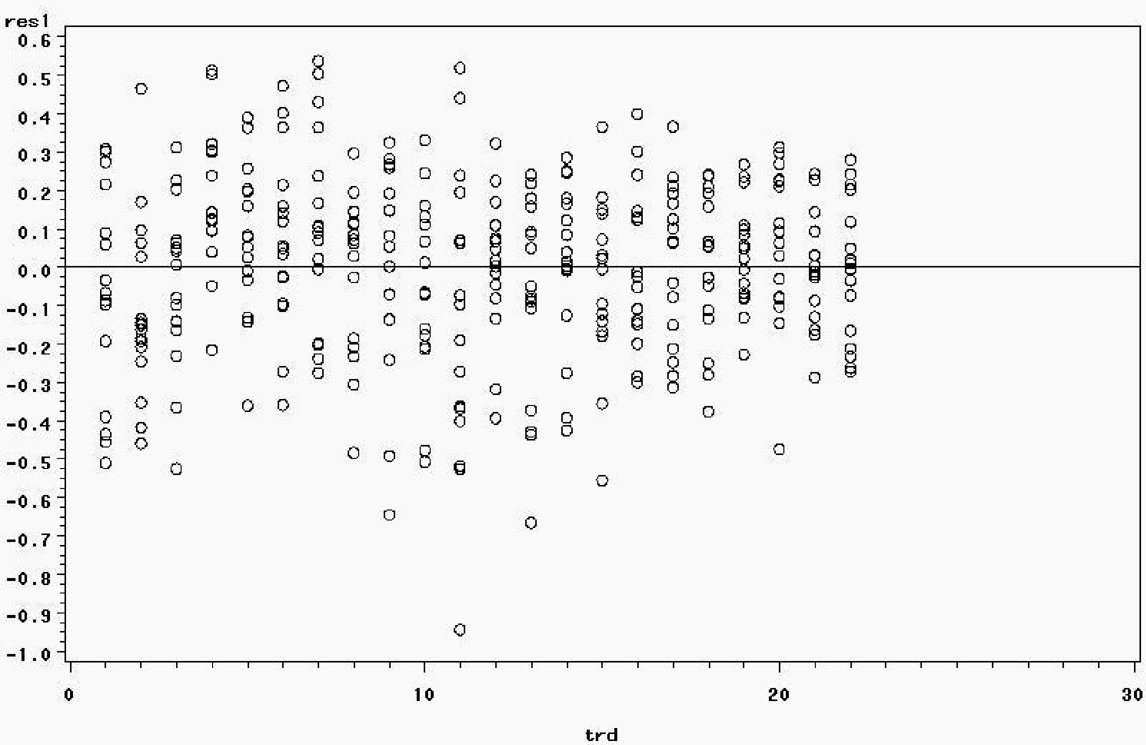


Fig 8. Rapesd Yield Quasi–translog Resid/Time Plot



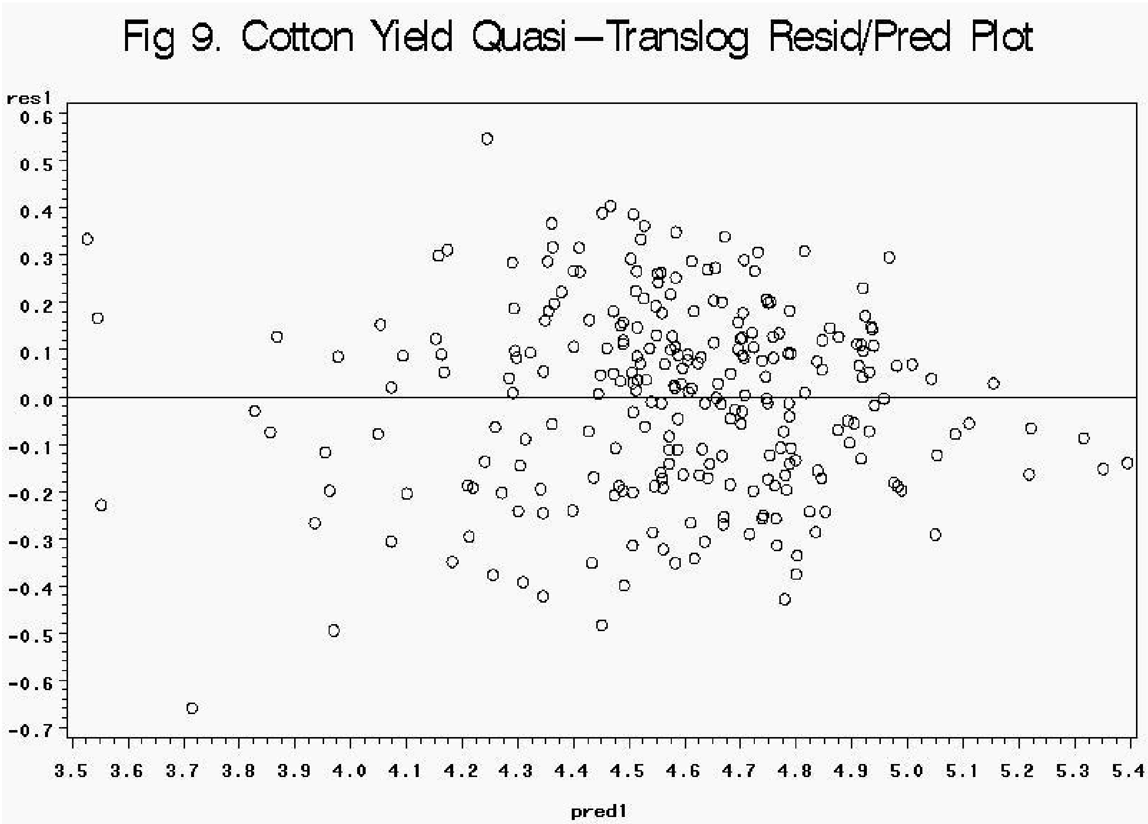


Fig 9. Cotton Yield Quasi–Translog Resid/Pred Plot
res1
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9 5.0 5.1 5.2 5.3 5.4
pred1

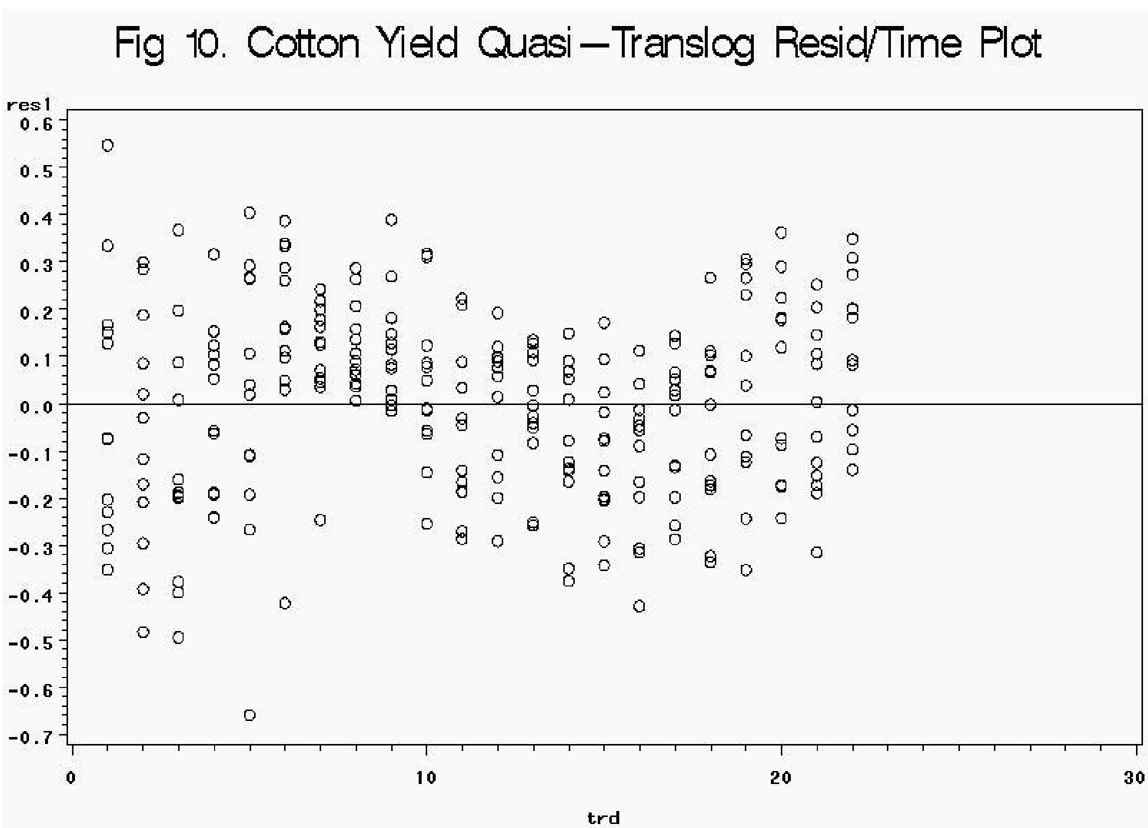


Fig 10. Cotton Yield Quasi–Translog Resid/Time Plot
res1
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
0
10
20
30
trd

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