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Institutional effects on changes in Chinese foodgrain production and its variability

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ABSTRACT

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By applying variance decomposition technique to the regional data from China, this paper discusses possible impact on Chinese foodgrain production and its variations created by institutional changes, including imposition of procurement quota and the introduction of the agricultural production responsibility system (APRS). Despite the imperfection of the analytical tool used, the results are quite useful and informative.

1. INTRODUCTION

While the importance and implications of changes in Chinese foodgrain production and its variabilities are well-known (Tang, 1982; Kueh, 1984; Bodin, 1985; Wan, 1989, chapter 1; Stone and Zhong, 1990), less is known about the root causes of the changes, particularly those in the variability of China's foodgrain output. However, identification of the root causes, though difficult as noted by Hazell (1984), is of particular significance for decision-makings at both farm level and various government levels.

For given crop varieties, foodgrain output and its variation are basically determined by changes in controllable inputs, climatic conditions and institutional factors. Some attempts have been made to estimate the effect of input changes on foodgrain output and its variability in China (Wan and

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Anderson, 1990; Wan et al., 1991). Conversely, shortage of sufficient weather data prevented detailed analysis of the relationship between climatic conditions and foodgrain production and its variation (Wan, 1989, chapter 2). To the author's best knowledge, no previous work has focused on institutional effects on China's foodgrain production and its variability although some relevant comments were made by Stone and Zhong (1990).

The purpose of this paper is twofold. First, changes in Chinese foodgrain production and its variability (indicated by variance) are decomposed into components associated with sown-area and yield changes over three time periods. This may also give some flavour of changing patterns in China's foodgrain production variability. Second, institutional or policy effects on the changes are discussed. An important step towards obtaining these objectives is to determine the break points in the time-series. This is addressed in Section 3, after briefly reviewing the variance decomposition technique in Section 2. The decomposition results can be found in Sections 4 to 6, together with discussions on the policy or institutional effects. Finally, a summary section is provided.

2. ANALYTICAL FRAMEWORK

Based on the work of Goodman (1960) and Bohrnstedt and Goldberger (1969), Hazell (1982) developed a variability (indicated by variance) decomposition technique, which decomposes the total output variability into sown-area and yield components of different crops and regions¹. A useful feature of this technique is that it enables calculation of the changes in the composition of total variability over time.

The basic formula to start with is:

$$Q_t = \sum_{k=1}^{n_r} \sum_{i=1}^{n_c} A_{t ki} Y_{t ki} \quad (1)$$

where Q denotes national foodgrain output, t time-period subscript, A sown-area, and Y yield. The subscripts k, i are for regions and crops and n_r and n_c represent number of regions and number of crops, respectively. Using h and j as the other subscripts for regions and crops, and letting

¹ Prior to 1988, there were 22 provinces, three municipalities and four autonomous regions in China (excluding Taiwan). For convenience, they are all referred to as regions.

crop subscripts (i, j) go from 1 to n_c and region subscripts (k, h) from 1 to n_r , it can be shown that:

$$\begin{aligned} \text{VAR}(Q_t) = & \sum_h \sum_j \text{VAR}(A_{thj}Y_{thj}) + \sum_h \sum_{i \neq j} \sum_j \text{Cov}(A_{thi}Y_{thi}, A_{thj}Y_{thj}) \\ & + \sum_j \sum_{h \neq k} \sum_k \text{Cov}(A_{thj}Y_{thj}, A_{tkj}Y_{tkj}) \\ & + \sum_{h \neq k} \sum_k \sum_{i \neq j} \sum_j \text{Cov}(A_{thi}Y_{thi}, A_{tkj}Y_{tkj}) \end{aligned} \quad (2)$$

$$\begin{aligned} \bar{Q}_t = & \sum_h \sum_j E(A_{thj}Y_{thj}) \\ = & \sum_h \sum_j [\bar{A}_{thj}\bar{Y}_{thj} + \text{Cov}(A_{thj}, Y_{thj})] \end{aligned} \quad (3)$$

The covariances in (2) can be decomposed further (see Bohrnstedt and Goldberg 1969, p. 1441). For an example,

$$\begin{aligned} \text{Cov}(A_{thi}Y_{thi}, A_{tkj}Y_{tkj}) = & \bar{A}_{thi}\bar{A}_{tkj} \text{Cov}(Y_{thi}, Y_{tkj}) \\ & + \bar{A}_{thi}\bar{Y}_{tkj} \text{Cov}(Y_{thi}, A_{tkj}) \\ & + \bar{A}_{tkj}\bar{Y}_{thi} \text{Cov}(A_{thi}, Y_{tkj}) \\ & + \bar{Y}_{thi}\bar{Y}_{tkj} \text{Cov}(A_{thi}, A_{tkj}) \\ & - \text{Cov}(A_{thi}, Y_{thi}) \text{Cov}(A_{tkj}, Y_{tkj}) + R \end{aligned} \quad (4)$$

where \bar{A} and \bar{Y} denote means of sown-area and mean yield, respectively. R is a residual component containing terms with third or higher moments.

Let $t = 1, 2$ and defining each variable in the second period as its counterpart in the first period plus the change in the variable between the two periods, as indicated by δ , e.g., $\bar{A}_{2hi} = \bar{A}_{1hi} + \delta\bar{A}_{hi}$ and $\text{Cov}(A_{2hi}, A_{2ki}) = \text{Cov}(A_{1hi}, Y_{1kj}) + \delta \text{Cov}(A_{hi}, Y_{kj})$, then:

$$\begin{aligned} \bar{Q}_2 = & \sum_h \sum_j (\bar{A}_{1hj} + \delta\bar{A}_{hj})(\bar{Y}_{1hj} + \delta\bar{Y}_{hj}) \\ & + \sum_h \sum_j \text{Cov}(A_{1hj}, Y_{1hj}) + \sum_h \sum_j \delta \text{Cov}(A_{hj}, Y_{hj}) \\ = & \sum_h \sum_j \bar{A}_{1hj}\bar{Y}_{1hj} + \sum_h \sum_j \text{Cov}(A_{1hj}, Y_{1hj}) \\ & + \sum_h \sum_j \bar{A}_{1hj} \delta\bar{Y}_{hj} + \sum_h \sum_j \bar{Y}_{1hj} \delta\bar{A}_{hj} \\ & + \sum_h \sum_j \delta\bar{A}_{hj} \delta\bar{Y}_{hj} + \sum_h \sum_j \delta\text{Cov}(A_{hj}, Y_{hj}) \end{aligned} \quad (5)$$

can be obtained. As the first two terms in the RHS of the above equation are equivalent to \bar{Q}_1 , the change in the mean production is thus:

$$\begin{aligned}\delta\bar{Q} &= \bar{Q}_2 - \bar{Q}_1 \\ &= \sum_h \sum_j \bar{A}_{1hj} \delta\bar{Y}_{hj} + \sum_h \sum_j \bar{Y}_{1hj} \delta\bar{A}_{hj} \\ &\quad + \sum_h \sum_j \delta\bar{A}_{hj} \delta\bar{Y}_{hj} + \sum_h \sum_j \delta\text{Cov}(A_{hj}, Y_{hj})\end{aligned}\quad (6)$$

Equation (6) indicates that change in mean production can be attributed to four sources, as described in Table A1². When both sides of (6) are divided by $\delta\bar{Q} \times 100\%$, a percentage contribution by each source can be obtained.

A similar procedure can be applied to derive the components of change in the variance of production. Without duplicating the derivation as given in Hazell (1982, pp. 46–47), Table A2 is used to list the sources of change in total production variance.

The third source in Table A2 is composed of two parts, one due to changes in intra-crop yield variances and the other due to changes in various yield covariances. The second part can be further disaggregated into three components (Hazell 1982, p. 31), as summarised in Table A3. The sixth term in Table A2 is also composed of two parts, one due to changes in intra-crop covariances between sown-area and yield, and the other due to changes in inter-crop and inter-region covariances between sown-area and yield. The second part can be further disaggregated as well into three components (Hazell 1982, p. 22), as defined in Table A4.

It is feasible to express a variable in the first period as its counterpart in the second period less the change, and then to find sources of changes in total mean output and output variance. However, as this approach confounds pure and interaction effects (Hazell, 1982), it is thus not adopted in this study.

3. DATA AND SPLIT OF TIME PERIODS

The data used in this study comprise 1949–1985 time series on yield, area sown and output for eight crops (cf. row headings of Table 2) and 12 to 21 individual regions (cf. row headings of Table 1). Following Hazell (1984), each time series was detrended by a quadratic function in order to remove some of the effects generated by changes in inputs, technology and perhaps weather patterns. The incompleteness of data raises the necessity

² Table with ‘A’ preceeding its number is presented in the Appendix of the paper.

to define Other-region (Other-region is defined as sum of the following eight regions: Menggu, Jilin, Beijing, Hebei, Jiangxi, Fujian, Yunnan and Xizang (Tibet)), Other-grain (Other-grain is equivalent to foodgrain excluding rice, wheat, maize, soybeans, tubers, sorghum and millet), a Residual Region (Residual Region is defined as sum of all regions whose data are not available) and a Residual Grain (Residual Grain is defined as sum of all crops whose data are not available). It also causes difficulties when quadratic functions are used to detrend these data (for a necessarily lengthy discussion, see Wan, 1989; section 4.3). It is, however, noted that (a) the data used cover 70–80 per cent of national output and total area sown for foodgrain; and (b) the decomposition results were not distorted by the data deficiency (Wan, 1989, p. 104).

The split of time periods is important for this kind of analysis because different splits may well lead to different conclusions (Tisdell and Alaudin, 1988). Although selection of time periods is inevitably arbitrary, it largely depends on the objectives of the study. To attempt to identify the effects of major institutional changes on Chinese foodgrain production and its variability, the whole period under study (1949–85) is divided into three sub-periods: 1949–58, 1962–77 and 1978–85.

The first subperiod (1949–58) was dominated by a non-socialist farming system, which includes the first land reform (1949–52) and the cooperative transformation of agriculture (1952–57). The socialist commune system, built on the advanced agricultural production cooperatives, was initiated in August of 1958 and implemented by the end of 1958 (Ma, 1982). As far as crop production is concerned, 1958 can be classified into the period with nonsocialist farming. Although socialist elements kept increasing in the agricultural sector from 1952 onwards and the foodgrain procurement policy was initiated in 1953, strict government control over agricultural production and marketing was not politically overwhelming in this period. The inclusion of 1958 in the first sub-period is also due to the fact that 1959–61 was an unusual period in China and thus excluded from the analysis. The impact of the ‘great leap forward’ on production in 1958 is probably insignificant. It is noted that 1952–57 is the first five-year plan period.

The second sub-period (1962–77) is characterised by a fully socialist farming system. During this period, the three-tier system of collective farming³ was established and consolidated. It is the collective farming structure that made it possible for political intervention, e.g., procurement

³ The three-tier system is equivalent to the well-known commune system where the three tiers represent commune, production brigade and production team.

policy, and a highly centralised command system to be effective. This period includes the infamous 'cultural revolution' (1966–76) when radical politics prevailed. It also includes the 'green revolution' in which modern cereal varieties were widely adopted.

The third sub-period (1978–85) can be characterised as having a family-farming system. In many aspects, it is similar to the system before 1958. However, it differs from the non-socialist farming system because the three-tier production structure still remains. In particular, the procurement policy was fully in operation during 1978–85. This policy was aimed at ensuring the basic needs of national food consumption and restricting large fluctuations in foodgrain production. Since this policy was implemented through a strict control over sown-areas by political force, it could only be really effective after the socialist administrative structure, i.e., commune system, was well-established in early 1960s. It is expected that procurement policy would produce a stabilising effect on foodgrain production. The third sub-period also differs from the second sub-period as the agriculture production responsibility system (APRS) was introduced in 1978. From 1978 onwards, individual farmers gained certain decision powers and families were directly facing and bearing risks in their crop production and marketing.

Therefore, analysis of the changes in the foodgrain production and its variability from the first sub-period to the second sub-period can reveal the impact of collective farming on the changes. In essence, the impact is from the introduction of the central planning and army-style command system. Conversely, changes in the foodgrain output and its variability between the second and the third sub-periods may show the effect of recent economic reform and APRS on the changes. If the first and the third sub-periods are considered, the effect of procurement policy can be examined. It is worth emphasising that the effect of the procurement policy on the changes in the mean and variance of China's foodgrain production may not be significant in the first sub-period as the quotas were not very tight and no restrictions on sown-areas could be directly imposed by the central government. It is in this sense that we can discuss the effect of procurement policy by analysing the decomposition results between the first and third sub-periods.

4. EFFECT OF COLLECTIVE FARMING: 1949–58 vs. 1962–77

The transition from private to collective farming was accompanied by a progressive introduction of economic plans. These plans were basically for maintaining and stabilising foodgrain production, largely through control over sown-areas. The transition also coincided with the progressive adoption of modern cultivars, which certainly contributed much to the increased

foodgrain output, but may also bring about higher variability of foodgrain production (Hazell 1984). The effect of modern cultivars, however, should mainly be on means and variances of crop yields rather than sown-areas. Thus, change in the variability of foodgrain production in China between 1949–58 and 1962–77 is expected to be inversely related to changes in sown-areas, but positively related to changes in yields. The change in mean production is expected to be dominated by those components associated with yield. As shown in the following subsections, the decomposition results are largely consistent with the above comments.

4.1 Changes in mean production

Total average output of China's foodgrain increased by 1271.90 billion jin (1 jin = 0.5 kg) from 3344.60 billion jin in 1949–58 to 4616.50 billion jin in 1962–77. Reduction in the mean of total sown-area led to a reduction of 43.25 billion jin, or a negative 3.4% contribution to the total change in mean output (cf. the bottom row of Table 1). This reduction is matched by the increase in the mean production due to changes in the covariances between sown-area and yield. The effect of change in the interaction of mean sown-area and mean yield is relatively negligible. Thus, about 100% of the increase in the total mean output is from the increases in mean yield.

Referring to the far-right column of Table 1, all but the artificially-defined residual region contributed positively to the changed national output. The major foodgrain producers (Jiangsu, Shandong, Sichuan, Hubei, Henan and Hunan) contributed nearly half of the total increase in China's foodgrain output from 1949–58 to 1962–77.

At the regional level, except Xinjiang whose changed output was consisted of 46.5% from increase in mean sown-area but only 33.6% from increase in mean yield, growth of output for all the other regions were largely attributed to mean yield changes. Notably, twelve out of the 22 individual regions recorded more than 100% contribution from increase in mean yield. It is interesting to note that apart from the Other-region the above-mentioned twelve regions all had a negative contribution from mean sown-area changes. In other words, those who did experience decreases in sown-areas lifted mean yields far more than those who did not. For instance, yield increase contributed from 34% (Xinjiang) to 148% (Anhui) to regional increase in mean production. Conversely, changes in mean sown-area decreased the mean of Anhui's foodgrain production by more

billion (U.S.) = 10^9 .

TABLE 1

Components of change in mean production of total foodgrain, by region, from 1949–58 to 1962–77

Region	Component ^a				Contribution to total change
	$\delta \bar{Y}$	$\delta \bar{A}$	$\delta \bar{Y}, \delta \bar{A}$	$\delta \text{Cov}(A, Y)$	
	(%)				
Anhui	148.4	-34.3	-17.3	3.2	5.3
Hubei	52.8	35.1	8.0	4.1	7.2
Hunan	76.2	13.5	3.1	7.2	7.0
Guangdong	131.9	-24.5	-8.9	1.5	5.0
Gansu	115.2	-15.6	-3.2	3.5	1.1
Guangxi	92.0	-3.0	-0.3	11.4	3.8
Guizhou	102.4	-3.8	-0.7	2.1	0.9
Heilongjiang	66.1	17.1	7.5	9.3	4.0
Henan	136.2	-25.3	-7.8	-3.1	7.1
Jiangsu	103.0	5.6	-4.7	-3.8	10.1
Liaoning	128.6	-23.7	-8.1	3.3	3.1
Ningxia	53.1	33.9	9.3	3.6	0.4
Qinghai	48.0	30.0	10.1	12.0	0.3
Shaanxi	107.5	-2.9	-1.6	-3.1	2.6
Sichuan	118.4	-19.6	-2.9	4.2	7.3
Shandong	128.5	-25.8	-4.0	1.2	7.8
Shanghai	51.1	44.5	2.7	1.8	1.1
Shanxi	106.9	-6.4	-0.9	0.4	2.7
Tianjin	99.8	-15.5	0.5	15.2	0.5
Xinjiang	33.6	46.5	11.7	8.2	2.0
Zhejiang	88.9	4.1	0.7	6.3	4.4
Other-region	108.2	-5.0	-0.8	-2.3	16.4
Residual Region	5113.3	-945.6	-1538.0	-2529.6	-0.1
All China	100.8	-3.4	-1.0	3.5	100.0

^a See Table A1 for definitions of the symbols.

than 34%, but lifted Xinjiang's output by 47% (Table 1). Regions such as Ningxia, Qinghai, Heilongjiang and Xinjiang increased their sown-areas possibly by reclamation, while other regions that increased their sown-areas most likely did so through intensification of cropping, e.g., Jiangsu, Zhejiang.

By crop, nearly 46% of the increase in the overall mean production is from rice. Some 48.9% (24.0 + 24.9) is from wheat and maize (Table 2). Crops such as millet, soybeans and sorghum decreased their mean production. The decreases are entirely due to decreases in their mean yields, reflecting the fact that the Chinese governments neglected production of

TABLE 2

Components of change in mean production of total foodgrain, by crop, from 1949–58 to 1962–77

Crop	Component ^a				Contribution to total change
	$\delta \bar{Y}$	$\delta \bar{A}$	$\delta \bar{Y}, \delta \bar{A}$	$\delta \text{Cov}(A, Y)$	
	(%)				
Rice	77.3	10.8	2.8	9.1	45.5
Wheat	90.0	7.3	0.3	2.4	24.1
Maize	69.3	13.3	6.6	10.7	24.9
Tubers	110.2	-7.8	2.8	-5.2	5.9
Soybeans	-312.5	263.5	64.5	84.5	-0.8
Sorghum	-3264.1	1955.5	698.3	710.3	-0.2
Millet	-134.6	164.2	38.4	32.0	-2.3
Other-grain	362.6	-155.8	-69.0	-37.7	2.6
Residual Grain	-21.0	67.4	86.4	-32.8	0.2
All China	100.8	-3.4	-1.0	3.5	100.0

^a See Table A1 for definitions of the symbols.

coarse grains. However, these decreases are basically cancelled out by the increases in the mean production of the other-grain.

4.2 Changes in production variability

As shown in Table 3 (far-right column), the total increase in variance between 1949–58 and 1962–77 consists of some 83.1% due to increase in yield variance and covariances [$\delta \text{VAR}(Y)$], 3.2% due to increase in mean yield, and 14.0% due to increase in the covariance between sown-area and yield. The ‘pure’ yield effect ($\delta \bar{Y} + \delta \text{VAR}(Y)$) accounted for 86.3%, while the ‘pure’ sown-area effect ($\delta \bar{A} + \delta \text{VAR}(A)$) accounts for a tiny -0.8%. In other words, the increased variability is largely from changes in yield, particularly in yield variance. The contribution by sown-area is probably negative. From the bottom row of Table 3, the contribution by sums of regional intra-crop variances is negligible (4.6%). The dominant source of the increased variability is output covariance between crops and regions (61.9%), which is mostly attributable to increase in yield covariances between crops and regions. In fact, the increase in the yield covariances between crops and regions alone contributed more than 62% to the total change in the variance of China’s foodgrain production over the two periods under consideration.

Further decomposition of the 79.9% (3.3 + 14.2 + 62.4) contribution due to yield covariances indicates that 17.0% of the contribution is due to

TABLE 3

Components of change in the variance of total foodgrain production, All China, from 1949–58 to 1962–77

Component ^a	Sums of intra-crop variance	Inter-crop covariances within regions	Inter-region covariances within crops	Covariances between crops and regions	All China
	(%) ^b				
$\delta \bar{Y}$	0.2	0.1	0.6	2.3	3.2
$\delta \bar{A}$	-0.1	0.0	0.1	0.1	0.1
$\delta \text{VAR}(Y)$	3.2	3.3	14.2	62.4	83.1
$\delta \text{VAR}(A)$	0.4	-0.5	2.2	-3.0	-0.9
$\delta \bar{Y}, \delta \bar{A}$	0.0	0.0	0.0	0.0	0.0
$\delta \text{Cov}(A, Y)$	0.3	-0.5	9.7	4.6	14.0
$\delta \bar{A}, \delta \text{VAR}(Y)$	-0.1	-0.4	1.0	-3.2	-2.7
$\delta \bar{Y}, \delta \text{VAR}(A)$	0.4	-0.5	1.6	-2.0	-0.5
$\delta \bar{Y}, \delta \bar{A}$	0.3	-0.1	4.0	1.3	5.5
$\delta \text{Cov}(A, Y)$					
δR	0.0	0.0	-1.4	-0.5	-2.0
Sum	4.6	1.4	32.0	61.9	100.0

^a See Table A2 for definitions of the symbols.

^b The percentages are obtained by using the absolute value of change in total variability as denominator. Thus, a negative figure in the table means a stabilising contribution and vice versa.

changes in standard deviations of yields, 5.1% due to changes in yield correlation coefficients, and the remaining 57.8% due to changes in the interaction of changes in standard deviations and correlation coefficients (Table A5). This suggests that concurrent changes in both the standard deviations of and correlation coefficients between yields are the main source of the overall increase in the variance of China's foodgrain production.

Increase in the covariances between sown-area and yield contributed 13.7% ($-0.5 + 9.7 + 4.6$) to the total variability change (Table 3). This is composed of 9.5% due to increase in inter-region covariances within crops (Table A6). Increases in standard deviations of sown-area and yield contributed about 5.3%, which is cancelled out by the component due to decreased correlation coefficients between sown-area and yield, thus leaving almost all of the increase covariance between yield and sown-area being attributable to increase interaction among variance of sown-area, yield variance and the correlation coefficients between yield and sown-area.

The 4.6% contribution of the sums of intra-crop variances within regions is composed of 3.2% due to change in yield variance, 0.2% due to change

in mean yield and 0.4% due to change in the variance of sown-area (Table 3).

The composition of the 4.6% contribution by regions is tabulated in Table 4. Since the Residual Region is artificially defined to allow for successful variance decomposition (Wan, 1989) and thus should be ignored when interpreting the results, the largest contributor is Hunan (12.5%), followed by the Other-region (11.0%). Three regions (Ningxia, Qinghai and Tianjin) contributed nil when rounding to one decimal point.

The composition of the 4.6% contribution is also presented by crops in Table 5. Rice accounts for 52.2% of the 4.6% contribution. Three crops (tubers, soybeans and millet) had reductions in their variances from 1949–58 to 1962–77. However, their combined effect is only -0.6% ($-0.2 - 0.1 - 0.3$), which can hardly be seen as significant.

5. EFFECT OF THE APRS AND ECONOMIC REFORM: 1962–77 vs. 1978–85

The major feature of the APRS and economic reform in general is the gain of decision power of local organisations and individuals. From 1978 onwards, there has also been the gradual removal of direct political intervention by the central and provincial governments. Resource allocation, particularly of land, has become more rational or more in accordance with local conditions than hitherto. Therefore, any concurrent changes across regions in either crop yield or sown-area should be less in 1978–85. In addition, as farmers have taken on full responsibility in their farming, care is given to every phase of the production process and every means is used to secure the yield. As individual farmers, rather than the community (production team, brigade or commune) have become the decision-makers, they may have tended to be risk-averse, rather than risk-neutral or even risk-preferring. These changes have probably helped to reduce yield variability. On the other hand, as average yield increases, perhaps resulting from continued expansion of modern cultivars, it may still contribute positively to production variability (Anderson et al., 1990). These assertions are broadly supported by the decomposition results.

5.1 *Changes in mean production*

As for the previous case, sources of change in mean production are dominated by yield increment (Table 6). On average, China's foodgrain production increased by 2421.40 billion jin from 4616.50 billion jin in 1962–77 to 7037.90 billion jin in 1978–85. About 97% of this increase is from mean yield increase, and 5.3% from increase in the mean of sown-area (bottom row of Table 6). Also, every region raised its mean yield and

TABLE 4

Components of changes in the sums of intra-crop variances, by region, from 1949–58 to 1962–77

Region	Component ^a										Sum ^c
	$\delta \bar{Y}$	$\delta \bar{A}$	$\delta \text{VAR}(Y)$	$\delta \text{VAR}(A)$	$\delta \bar{Y}$ $\delta \bar{A}$	$\delta \text{Cov}(A, Y)$	$\delta \bar{A}$ $\delta \text{VAR}(Y)$	$\delta \bar{Y}$ $\delta \text{VAR}(A)$	$\delta \text{Cov}(A, Y)$ $\delta \bar{Y}, \delta \bar{A}$	δR	
(%) ^b											
Anhui	9.5	−1.6	55.6	3.0	0.1	28.9	−8.6	1.4	11.4	0.2	4.6
Hubei	1.1	1.0	14.4	22.3	0.1	30.1	7.2	11.0	16.7	−3.8	6.1
Hunan	1.3	0.4	26.9	13.0	0.0	36.8	3.2	8.5	13.9	−4.1	12.5
Guangdong	1.5	−0.1	99.1	−0.8	0.0	11.6	−12.9	−0.7	3.7	−1.4	4.7
Gansu	0.9	0.4	63.5	6.1	0.0	12.0	4.3	3.2	10.1	−0.5	0.4
Guangxi	0.4	0.0	44.8	5.6	0.0	34.0	0.6	5.3	13.4	−4.1	3.7
Guizhou	1.7	−1.0	85.3	6.5	0.0	17.2	−5.1	0.9	0.0	−5.4	0.2
Heilongjiang	5.1	0.6	40.0	2.5	0.0	21.8	11.3	4.0	16.1	−1.3	1.6
Henan	10.7	−0.6	112.7	0.2	−0.2	−9.7	−10.4	−2.5	−2.0	1.7	6.2
Jiangsu	3.1	0.3	40.2	18.0	0.0	16.0	−0.6	14.2	12.8	−3.9	8.9

Liaoning	21.6	0.1	91.8	-4.0	0.0	-2.9	-15.0	-6.4	14.2	0.5	1.5
Ningxia	6.9	5.4	44.8	0.5	-0.3	17.7	16.1	-4.1	13.9	-0.8	0.0
Qinghai	0.2	2.2	27.9	9.9	0.1	19.5	13.6	8.0	19.2	-0.4	0.0
Shaanxi	1.5	-0.1	105.6	4.7	0.0	-11.4	-2.7	3.4	-2.5	1.3	0.6
Sichuan	6.7	-3.2	84.2	4.2	-0.1	8.7	-4.8	3.6	7.6	-7.0	4.3
Shandong	4.8	-0.8	75.5	3.6	-0.1	3.1	-1.0	4.3	12.1	-1.4	6.7
Shanghai	1.2	1.7	10.5	36.9	-0.1	24.7	2.5	11.7	13.8	-2.9	0.1
Shanxi	4.8	-1.1	76.0	3.4	-0.1	3.1	-0.8	3.7	9.7	1.4	0.5
Tianjin	7.5	1.8	24.8	12.6	0.6	20.4	4.1	13.3	11.5	3.5	0.0
Xinjiang	0.4	9.0	7.6	6.8	-1.7	40.1	4.4	3.4	33.4	-3.4	0.2
Zhejiang	0.3	0.5	40.0	6.4	0.0	33.3	4.7	4.7	13.6	-3.5	3.6
Other-region	5.3	-2.4	115.5	-1.9	0.3	-21.1	-3.1	7.6	-5.4	5.2	11.0
Residual Region	6.5	-3.8	87.6	13.4	-0.2	-20.1	-6.4	16.1	0.8	6.2	22.8
China	4.8	-1.2	69.3	8.5	-0.0	5.7	-2.7	8.2	7.3	0.3	100.0

^a See Table A2 for definitions of the symbols.

^b The percentages are obtained by using the absolute value of change in the sum of intra-crop variances of each region as denominator. Thus, components in each row sum to 100.0 or -100.0. A negative figure in the table means a stabilising contribution and vice versa.

^c The sum indicates the regional contribution to the sums of intra-crop variances.

TABLE 5

Components of changes in the sums of intra-crop variances, by crop, from 1949–58 to 1962–77

Component ^a	Rice	Wheat	Maize	Tubers	Soy-beans	Sorghum	Millet	Other-grain	Residual Grain	All China
	(%) ^b									
$\delta \bar{Y}$	1.9	8.9	1.9	-185.7	125.0	64.7	26.7	5.3	18.6	4.8
$\delta \bar{A}$	0.5	0.2	2.7	-228.6	-75.0	-23.5	-60.0	-28.0	-4.9	-1.2
$\delta \text{VAR}(Y)$	37.4	95.4	27.9	1528.57	325.0	500.0	113.3	24.0	255.5	69.3
$\delta \text{VAR}(A)$	11.7	1.3	6.7	-871.4	-100.0	23.5	60.0	39.3	6.3	8.5
$\delta \bar{Y}, \delta \bar{A}$	0.0	-0.2	-0.1	14.3	0.0	0.0	0.0	0.7	-0.2	-0.0
$\delta \text{Cov}(A, Y)$	30.7	1.2	23.3	-828.6	-475.0	-311.8	-266.7	16.7	-120.5	5.7
$\delta \bar{A}, \delta \text{VAR}(Y)$	1.7	-6.4	8.2	114.3	-100.0	-194.1	-53.3	-17.3	-31.6	-2.7
$\delta \bar{Y}, \delta \text{VAR}(A)$	7.6	-1.3	10.5	42.9	0.0	5.9	40.0	35.3	8.4	8.2
$\delta \bar{Y}, \delta \bar{A}, \delta \text{Cov}(A, Y)$	12.9	0.8	21.2	242.9	50.0	-11.8	20.0	8.0	-51.9	7.3
δR	-4.4	0.2	-2.4	71.4	150.0	47.1	20.0	16.0	20.3	0.3
Sum ^c	52.2	13.1	21.5	-0.2	-0.1	0.4	-0.3	3.2	10.2	100.0

^a See Table A2 for definitions of the symbols.^b The percentages are obtained by using the absolute value of change in the sum of intra-crop variances of each crop as denominator. Thus, components in each column sum to 100.0 or -100.0. A negative figure in the table means a stabilising contribution and vice versa.^c The sum indicates the contribution of the crop to the sums of intra-crop variances.

TABLE 6

Components of change in mean production of total foodgrain, by region, from 1962–77 to 1978–85

Region	Component ^a				Contribution to total change
	$\delta \bar{Y}$	$\delta \bar{A}$	$\delta \bar{Y}, \delta \bar{A}$	$\delta \text{Cov}(\bar{A}, Y)$	
	(%)				
Anhui	101.7	0.2	-0.3	-1.5	4.7
Hubei	123.4	-12.1	-2.5	-8.8	4.9
Hunan	59.5	37.4	8.9	-5.8	7.8
Guangdong	108.3	-4.3	-1.0	-3.0	5.0
Gansu	96.1	6.1	0.2	-2.4	1.2
Guangxi	80.5	23.7	5.5	-9.7	3.6
Guizhou	81.9	18.6	2.2	-2.6	1.9
Heilongjiang	68.6	31.8	4.7	-5.1	3.9
Henan	117.0	-17.8	-2.5	3.3	6.4
Jiangsu	140.0	-31.0	-12.0	3.0	7.4
Liaoning	88.9	4.8	7.9	-1.7	3.9
Ningxia	74.0	23.3	3.7	-0.9	0.4
Qinghai	84.1	21.4	7.8	-13.3	0.2
Shaanxi	100.2	-3.8	0.4	3.2	2.2
Sichuan	90.4	10.5	2.9	-3.8	11.6
Shandong	109.3	-9.7	1.7	-1.3	8.5
Shanghai	197.0	-92.2	-1.8	-3.1	0.2
Shanxi	128.7	-23.8	-5.2	0.3	1.8
Tianjin	105.5	13.0	-2.8	-15.8	0.4
Xinjiang	64.8	35.6	7.2	-7.6	1.4
Zhejiang	80.3	19.8	5.0	-5.1	5.6
Other-region	95.2	4.0	3.8	-3.0	17.3
Residual Region	281.0	-355.4	-166.7	341.1	-0.3
All China	96.7	5.3	2.5	-4.5	100.0

^a See Table A1 for definitions of the symbols.

output in the second period. As shown in the far right column of Table 6, the largest contributor besides the Other-region is Sichuan (11.6%), followed by Shandong (8.5%). It is seen again that (i) a majority of those who registered more than 100% contribution from $\delta \bar{Y}$ had deductions in their average sown-areas; (ii) the major producers (Jiangsu, Shandong, Sichuan, Hubei, Henan and Hunan) contributed about 47% to the country's increase in average output.

From Table 7, it is apparent that important crops continued to surge in outputs and unimportant crops continued to decrease. The main factor lies in the mean yields. The first four crops in the table gained their increases mainly through increase in yields, supplemented by increases in sown-areas.

TABLE 7

Components of change in mean production of total foodgrain, by crop, from 1962–77 to 1978–85

Crop	Component ^a				Contribution to total change
	$\delta \bar{Y}$	$\delta \bar{A}$	$\delta \bar{Y}, \delta \bar{A}$	$\delta \text{Cov}(A, Y)$	
	(%)				
Rice	88.2	17.7	3.9	–9.9	47.0
Wheat	89.3	11.4	2.8	–3.5	26.4
Maize	69.8	32.0	9.5	–11.3	23.4
Tubers	86.7	13.9	2.6	–3.2	6.3
Soybeans	342.7	–315.0	–45.7	118.0	0.5
Sorghum	–257.4	373.2	76.0	–91.8	–1.3
Millet	–449.8	564.8	123.6	–138.6	–0.5
Other-grain	–137.8	262.8	36.8	–61.8	–2.0
Residual Grain	–19.8	52.6	24.1	43.1	0.4
All China	96.7	5.3	2.5	–4.5	100.0

^a See Table A1 for definitions of the symbols.

Conversely, the rest of the crops would have lost more ground through reductions in mean yields if their sown-areas had not been considerably increased. The increases in the sown-areas for less important crops in 1978–85 were likely due to the reduction in procurement quotas for fine grains and due to relaxation of macro-control over sown-areas, which enabled farmers to cultivate according to local conditions. The decreases in mean yields of coarse grains were possibly due to the lack of government supports in terms of input supply and relatively low purchasing price.

5.2 Changes in production variability

As shown in Table 8, total variance of China's foodgrain production had decreased from 1962–77 to 1978–85, 75.0% of which came from reduced variability of yield. The changes in yield and sown-area covariance contributed some 25.7% of this reduction. The interaction of changes in mean yield, mean sown-area and covariances between sown-area and yield contributed 10.3% of the reduction. Conversely, increase in average yield continued to be the main source of enhancing the production variability (+11.5%) and the second most important positive contribution is from the changes in the mean of sown-area (+3.4%). The change in the covariances between crops and regions is the dominant source in the reduction of the yield variability (–55.5%).

TABLE 8

Components of change in the variance of total foodgrain production, All China, from 1962–77 to 1978–85

Component ^a	Sums of intra-crop variance	Inter-crop covariances within regions	Inter-region covariances within crops	Covariances between crops and regions	All China
(%) ^b					
$\delta \bar{Y}$	0.8	-0.1	6.0	4.8	11.5
$\delta \bar{A}$	0.4	-0.2	3.0	0.3	3.4
$\delta \text{VAR}(Y)$	-3.2	-2.9	-13.4	-55.5	-75.0
$\delta \text{VAR}(A)$	-1.1	0.8	-4.6	2.9	-2.0
$\delta \bar{Y}, \delta \bar{A}$	0.1	0.0	0.2	-0.1	0.2
$\delta \text{COV}(A, Y)$	-0.8	-0.1	-14.2	-10.6	-25.7
$\delta \bar{A}, \delta \text{VAR}(Y)$	-0.1	0.0	-1.9	-0.9	-2.8
$\delta \bar{Y}, \delta \text{CAR}(A)$	-0.5	0.3	-2.4	0.9	-1.7
$\delta \bar{Y}, \delta \bar{A}$	-0.6	0.0	-4.9	-4.8	-10.3
$\delta \text{COV}(A, Y)$					
δR	0.0	0.1	1.4	0.9	2.4
Sum	-5.0	-2.2	-30.7	-62.1	-100.0 ^c

^a See Table A2 for definitions of the symbols.

^b The percentages are obtained by using the absolute value of change in total variability as denominator. Thus, a negative figure in the table means a stabilising contribution and vice versa.

^c The negative value indicates decrease in the total variability over the two periods; cf. note b to this table.

Overall, change in the inter-region covariances within and not within crops contributed -92.8% (-30.7 - 62.1) to the change in the total variability. Changes in the inter-crop covariances within regions contributed a small -2.2%. The sums of intra-crop variance of all regions shared only -5.0% (Table 8).

Further decomposition of the -71.8% (-2.9 - 13.4 - 55.5) contribution due to changes in yield covariances shows that changes in standard deviations of yields shared -60.0% and changes in the correlation coefficients of yields shared another -55.2%. The remaining 43.4% is due to change in the interaction between yield standard deviations and correlation coefficients of yields (Table A7). These results consistently suggest the importance of reducing central planning in the context of stabilising China's foodgrain production.

Table A8 presents the results from the disaggregation by covariances between yield and sown-area, which is the second most important component in reducing the overall variability (Table 8). It indicates that reduction

TABLE 9

Components of changes in the sums of intra-crop variances, by crop, from 1962–77 to 1978–85

Component ^a	Rice	Wheat	Maize	Tubers	Soy-beans	Sorghum	Millet	Other-grain	Residual Grain	All China
	(%) ^b									
$\delta \bar{Y}$	23.0	10.8	27.6	2.6	33.3	–0.0	60.0	–1.2	–10.8	16.5
$\delta \bar{A}$	8.1	5.4	29.9	2.6	16.7	–44.4	–0.0	–13.9	–17.8	7.1
$\delta \text{VAR}(Y)$	–36.0	–88.6	–40.0	–69.1	–133.3	–177.8	–240.0	–57.4	–208.9	–64.3
$\delta \text{VAR}(A)$	–21.0	–6.8	–18.1	–8.9	–150.0	–92.6	–380.0	–39.1	–31.0	–21.8
$\delta \bar{Y}, \delta \bar{A}$	0.6	1.4	2.8	0.0	0.0	14.8	20.0	1.2	1.5	1.3
$\delta \text{Cov}(A, Y)$	–47.7	–10.0	–47.8	–13.1	183.3	207.4	640.0	–2.3	151.6	–15.9
$\delta \bar{A}, \delta \text{VAR}(Y)$	–4.8	0.8	–16.6	–2.1	33.3	88.9	60.0	14.8	24.6	–1.2
$\delta \bar{Y}, \delta \text{VA}(A)$	–11.4	–5.2	–11.5	–0.5	–50.0	–40.7	–160.0	–3.2	–11.5	–10.2
$\delta \bar{Y}, \delta \bar{A}, \delta \text{Cov}(A, Y)$	–15.0	–8.2	–28.0	–0.5	–33.3	–25.9	–80.0	2.0	14.9	–12.0
δR	4.3	0.4	1.6	–11.0	0.0	–29.6	–20.0	–0.9	–12.7	0.40
Sum ^c	–49.2	–10.0	–18.6	–3.8	–0.1	–0.6	–0.1	–6.9	–10.6	–100.0 ^d

^a See Table A2 for definitions of the symbols.^b The percentages are obtained by using the absolute value of change in the sum of intra-crop variances of each crop as denominator. Thus, components in each column sum to 100.0 or –100.0. A negative figure in the table means a stabilising contribution and vice versa.^c The sum indicates the contribution of the crop to the sums of intra-crop variances.^d The negative value means that the sums of intra-crop variances decreased over the two periods under consideration.

in the correlation coefficients between yield and sown-areas is the most influential factor in contributing to change in this covariance (-23.5%), followed by standard deviation of yield and sown-area (-18.8%). The remaining influence is from the interaction effect ($+17.4\%$).

Turning to change in the sum of intra-crop variance of individual crops (Table 9), it is found that all crops had a lower variability in the second period. This is primarily due to reductions in variances of yield and sown-area and possible reductions in the interactions of mean yield and variance of sown-area, and/or in the covariance between sown-area and yield. A similar pattern emerges for change in the sum of intra-crop variance of individual regions as shown in Table 10.

To sum up, the introduction of APRS and economic reform have had a significant effect on raising crop yields, presumably through motivating farmers' initiatives. Further expansion of modern cultivars in the second period may also have helped to lift yields. The increases in crop yields are largely responsible for the jump in total mean production. Surprisingly, this jump is accompanied by a rather substantial decrease in total variability. It is quite clear that relaxation of macro-control over both the agricultural sector and the whole economy eliminated, to some extent, the concurrent shifts in sown-areas and/or input applications across regions. This is the major source of reduction in variability. The reduction in simultaneous changes across regions is evidenced by the decreases in the correlation coefficients of yields and correlation coefficients between yield and sown-area. It is noted that intra-crop variance of sown-area decreased for all regions except Guangdong over the two periods (Table 10). The major reason behind this may lie in the fact that the procurement policy was still in force in the third sub-period, which may have prevented large swings of sown-areas among different crops, and that farmers were able to follow a rational rotational farming system, which normally cannot be easily changed unless by political force, as happened in 1962–77.

6. EFFECT OF PROCUREMENT POLICY: 1949–58 vs. 1978–85

As argued previously, the procurement policy was not effective prior to 1960s as its implementation requires a powerful political setting-up which was not available until then. Thus, the policy should be useful in stabilising foodgrain production during 1962–77, particularly in terms of sown-areas, although the basic aim of the policy was to obtain sufficient foodgrain for urban residents and non-grain producing regions. However, the results in section 4.2 indicate that the stabilising effect of procurement policy seems very small. This is possibly because procurement policy was implemented without due regard to its impact on production covariabilities. Frequent

TABLE 10

Components of changes in the sums of intra-crop variances, by region, from 1962–77 to 1978–85

Region	Component ^a										Sum ^c
	$\delta \bar{Y}$	$\delta \bar{A}$	$\delta \text{VAR}(Y)$	$\delta \text{VAR}(A)$	$\delta \bar{Y}$ $\delta \bar{A}$	$\delta \text{Cov}(A, Y)$	$\delta \bar{A}$ $\delta \text{VAR}(Y)$	$\delta \bar{Y}$ $\delta \text{VAR}(A)$	$\delta \text{Cov}(A, Y)$ $\delta \bar{Y}, \delta \bar{A}$	δR	
	(%) ^b										
Anhui	16.8	10.1	-43.3	-21.4	1.1	-38.3	-3.7	-9.9	-13.4	2.0	-4.2
Hubei	34.9	0.4	-6.4	-35.6	0.1	-61.4	0.1	-20.0	-16.2	4.1	-5.1
Hunan	21.6	16.6	-30.8	-24.0	1.4	-50.4	-8.5	-10.6	-19.6	4.3	-11.4
Guangdong	5.3	-0.9	-79.5	0.2	-0.0	-22.6	0.7	0.1	-5.2	1.9	-3.7
Gansu	10.9	10.4	-70.3	-10.1	0.5	-22.9	-7.6	-3.5	-8.4	0.9	-0.3
Guangxi	18.2	11.9	-45.3	-12.9	0.8	-48.3	-6.9	-6.3	-15.4	4.2	-3.1
Guizhou	11.6	6.0	-66.3	-16.9	0.2	-26.0	-1.9	-5.5	-5.3	4.0	-0.1
Heilongjiang	29.1	30.7	-60.6	-22.9	2.6	-37.7	-10.6	-11.1	-21.7	2.1	-0.7
Henan	2.9	0.1	-99.4	-8.8	1.2	7.6	4.4	-4.5	-2.6	-1.0	-5.4
Jiangsu	34.0	-5.9	-23.5	-34.3	0.1	-44.2	2.7	-23.2	-10.0	4.2	-7.6

Liaoning	35.1	34.1	-70.9	-34.3	6.8	-4.0	-0.3	-20.1	-33.5	-12.9	-1.0
Ningxia	23.1	21.8	-68.4	-11.4	1.6	-32.0	-10.5	-9.5	-16.1	1.4	-0.0
Qinghai	21.9	22.8	-46.5	-18.8	2.3	-36.5	-13.1	-9.8	-23.1	0.8	-0.0
Shaanxi	1.6	6.1	-110.5	-10.0	-0.2	18.4	-4.3	-2.7	4.6	-3.0	-0.3
Sichuan	20.3	12.1	-77.9	-12.7	1.2	-22.0	-7.1	-8.3	-12.8	7.3	-3.8
Shandong	20.9	15.6	-73.4	-14.8	2.5	-17.0	-7.0	-9.1	-19.4	1.8	-5.1
Shanghai	23.9	-5.0	7.6	-61.7	-0.5	-52.2	-1.4	-13.1	-3.7	6.1	-0.1
Shanxi	21.0	2.4	-72.4	-14.1	1.6	-17.3	-0.6	-7.0	-13.7	0.2	-0.2
Tianjin	45.4	-1.7	-18.9	-51.6	0.6	-47.1	7.9	-20.7	-17.7	3.7	-0.0
Xinjiang	20.6	18.6	-33.3	-22.4	1.3	-51.7	-8.6	-9.4	-18.0	2.9	-0.1
Zhejiang	20.1	13.7	-43.4	-13.0	1.1	-49.4	-7.5	-7.4	-17.9	3.8	-3.0
Other-region	12.9	5.2	-83.0	-17.0	1.1	1.0	-0.3	-8.0	-8.5	-3.4	-17.5
Residual Region	9.8	6.1	-83.3	-27.9	1.9	12.7	2.5	-9.6	-9.9	-2.3	-27.0
China	16.5	7.1	-64.3	-21.8	1.3	-15.9	-1.2	-10.2	-12.0	0.4	-100.0 ^d

^a See Table A2 for definitions of the symbols.

^b The percentages are obtained by using the absolute value of change in the sum of intra-crop variances of each region as denominator. Thus, components in each row sum to 100.0 or -100.0. A negative figure in the table means a stabilising contribution and vice versa.

^c The sum indicates the regional contribution to the sums of intra-crop variances.

^d The negative value means that the sums of intra-crop variances decreased over the two periods under consideration.

changes in procurement quotas often meant a proportional increase or decrease of sown-area for a crop of most, if not all, regions. This may well enhance inter-region covariability of sown-area within crops, as seen in Table 3. Worse still, quotas were normally tied to input allocations and this could, in turn, lead to strong yield covariabilities. Further, the absolute decrease in total variance of China's foodgrain production due to change in sown-area variability is 1.49×10^{12} jin² from 1949–58 to 1962–77. This value is quite large. But, the overwhelming increases in other components outweighed the variability-reducing effect of procurement policy. Thus, the relative or percentage contribution from decreased sown-area variability turned out to be very small (–0.9%). It was previously argued that most of the increase in foodgrain production variability from 1949–58 to 1962–77 was due to the highly centralised command system in China in the latter period. A secondary factor may be the narrower genetic base of modern cultivars, in comparison with traditional varieties. These assertions were supported, at least partially, by the result in Section 5.

To see the effect of procurement policy on production and its variability, the comparison of changes in the components between 1949–58 and 1978–85 may be more informative. This is because the centralised system was gradually removed after the economic reform of 1978 and blind commands were no longer accepted. Also, the quotas were reduced and imposed more in line with regional production capacities in 1978–85. As far as institutional form is concerned, these two periods are somewhat similar. As production technology has improved substantially over the two periods, its effects are presumed to be mainly on mean yields rather than on variability. The strict implementation of procurement policy in the second period is perhaps the most important institutional factor in distinguishing the two periods. It is hypothesised that the comparison will indicate both a 'green revolution' effect on yield variability and a procurement effect on sown-area variability.

6.1 Changes in mean production

According to Table 11, every region (excluding Residual Region) raised its mean output. About half of the regions experienced a decrease in sown-area. Increase in mean yield dominated the sources of the increased mean output. For nearly half of the regions, more than 100% increase in output was from increase in mean yields. Taking China as a whole, the mean production increased by some 3693.30 billion jin, 99% of which came from yield changes, with less than 2% from interaction between changes in mean yields and mean of sown-area. The other components contributed almost nothing.

TABLE 11

Components of change in mean production of total foodgrain, by region, from 1949–58 to 1978–85

Region	Component ^a				Contribution to total change
	$\delta\bar{Y}$	$\delta\bar{A}$	$\delta\bar{Y}, \delta\bar{A}$	$\delta\text{Cov}(A, Y)$	
	(%)				
Anhui	133.7	-18.4	-16.3	1.0	5.0
Hubei	73.6	17.6	9.7	-1.0	6.0
Hunan	65.3	21.9	12.3	0.5	7.4
Guangdong	124.3	-14.1	-9.5	-0.7	5.0
Gansu	107.1	-4.7	-2.9	0.6	1.1
Guangxi	86.5	6.4	5.7	1.3	3.7
Guizhou	89.2	10.7	1.2	-1.1	1.4
Heilongjiang	65.4	20.7	11.6	2.3	3.9
Henan	130.5	-20.7	-9.6	-0.2	6.7
Jiangsu	120.5	-4.9	-14.6	-1.0	8.8
Liaoning	106.8	-8.6	1.2	0.6	3.5
Ningxia	57.3	28.3	13.0	1.3	0.4
Qinghai	58.7	22.2	18.5	0.6	0.3
Shaanxi	104.1	-3.0	-0.9	-0.2	2.4
Sichuan	103.7	-3.9	0.8	-0.6	9.4
Shandong	120.5	-18.2	-2.2	-0.1	8.1
Shanghai	72.5	24.5	2.1	0.9	0.7
Shanxi	116.1	-9.9	-6.6	0.4	2.2
Tianjin	98.6	-2.8	1.2	3.0	0.4
Xinjiang	39.4	39.0	19.7	1.9	1.7
Zhejiang	84.1	10.1	5.7	0.1	5.0
Other-region	100.9	-0.6	2.4	-2.7	16.9
Residual Region	964.3	-229.5	-642.6	7.7	-0.1
All China	98.8	0.0	1.6	-0.4	100.0

^a See Table A1 for definitions of the symbols.

From Table 12, it is clear that most of the increase in mean production is from major or important crops. As in Table 11, contributions from change in covariance between sown-area and yield are negligible. Decreases in coarse grain outputs were the result of decreases in their mean yields, just as the increase in mean yield is responsible for increase in outputs for the important crops.

6.2 Changes in production variability

The increase in mean production is accompanied by a decrease in total variance (Table 13), thus the relative variability (often measured by CV)

TABLE 12

Components of changes in mean production of total foodgrain, by crop, from 1949–58 to 1978–85

Crop	Component ^a				Contribution to total change
	$\delta \bar{Y}$	$\delta \bar{A}$	$\delta \bar{Y}, \delta \bar{A}$	$\delta \text{Cov}(A, Y)$	
	(%)				
Rice	81.0	12.2	7.2	–0.4	46.2
Wheat	89.4	8.0	3.1	–0.6	25.2
Maize	66.5	16.9	16.4	0.3	24.2
Tubers	98.0	0.4	5.8	–4.2	6.1
Soybeans	–1204.8	875.2	385.9	43.7	–0.2
Sorghum	–648.0	459.3	291.8	–3.1	–0.7
Millet	–227.4	217.2	109.1	1.0	–1.4
Other-grain	1869.9	1081.6	–715.7	27.5	0.4
Residual Grain	–21.3	43.7	58.2	19.4	0.3
All China	98.8	0.0	1.6	–0.4	100.0

^a See Table A1 for definitions of the symbols.

had decreased materially from 1949–58 to 1978–85. Table 13 shows that, from 1949–58 to 1978–85, variability of yield increased drastically, while variability of sown-area decreased substantially. The effect of the ‘green revolution’ on variability seems strong, as indicated by the large contribution due to mean yield and variance of yield. The ‘pure’ yield effect contributed 324.3% ($222.9 + 101.4$) to the total change in the variability of China’s foodgrain production. However, the risk-inducing effect of the ‘green revolution’ is seemingly outweighed by the risk-reducing effect of procurement policy, which is reflected by the negative contributions associated with sown-area, e.g., $\delta \text{VAR}(A)$, $\delta \text{Cov}(A, Y)$, $\delta \bar{Y}$ and $\delta \text{VAR}(A)$. Therefore, the procurement policy was successful in reducing the variance of sown-area, which led to a decrease in total variability by 66.4 per cent. The policy was also useful in reducing the contribution made by the components of changes in the covariance between sown-area and yield (-165.6%), in the interaction of mean yield and variance of sown-area (-101.8%), and in the interaction of mean yield, mean sown-area and covariance between yield and sown-area (-134.5%). More importantly, 68.7% of the decrease in total variability is due to changes in covariances between crops and regions. Assuming that the ‘green revolution’ enhanced the covariance between crops and regions, and that weather patterns did not change significantly over the two periods, the importance of procurement policy in reducing production variability is clear.

TABLE 13

Components of change in the variance of total foodgrain production, All China, from 1949–58 to 1978–85

Component ^a	Sums of intra-crop variance	Inter-crop covariances within regions	Inter-region covariances within crop	Covariances between crops and regions	All China
	(%) ^b				
$\delta \bar{Y}$	16.4	10.0	46.7	149.8	222.9
$\delta \bar{A}$	-2.0	2.4	5.8	10.7	16.8
$\delta \text{VAR}(y)$	-8.3	1.4	38.2	70.2	101.4
$\delta \text{VAR}(A)$	-7.0	-4.4	-18.2	-36.8	-66.4
$\delta \bar{Y}, \delta \bar{A}$	-0.2	0.2	1.0	5.2	6.2
$\delta \text{Cov}(A, Y)$	2.9	-3.7	4.3	-0.4	3.2
$\delta \bar{Y}, \delta \text{VAR}(A)$	-9.0	-7.0	-26.8	-59.0	-101.8
$\delta \bar{Y}, \delta \bar{A}$					
$\delta \text{Cov}(A, Y)$	-3.4	-6.1	-18.7	-106.2	-134.5
δR	1.1	2.8	0.5	13.3	17.8
Sum	-16.3	-27.5	12.5	-68.7	-100.0 ^c

^a See Table A2 for definitions of the symbols.

^b The percentages are obtained by using the absolute value of change in total variability as denominator. Thus, a negative figure in the table means a stabilising contribution and vice versa.

^c The negative value indicates decrease in the total variability over the two periods; cf. note b to this table.

If the 'green revolution' did lead to a increase in cereal production variability due to a narrowing of the genetic base of crop varieties, the correlation coefficients between yields within crops should have gone up. This is indeed the case. The increase in inter-region yield correlation coefficients contributed a positive 7.4% to the change in total variability of China's foodgrain production (Table A9). The inter-crop correlation coefficients of yields and yield correlation coefficients between crops and regions were marginally lower in the second period. Therefore, overall change in the correlation coefficients of yields, if significant, is not destabilising total foodgrain production. Thus, one may doubt if the impact of the 'green revolution' on foodgrain variability is of real concern in China. The contribution of yield covariances (93.1%) is mainly from increases in standard deviation of yields (57.9%) and the interaction between changes in yield standard deviations and correlation coefficients among yields (35.8%) (Table A9).

The large negative contribution due to change in covariance between yield and sown-area (-158.9%) is made up of -88.4% from changes in

TABLE 14

Components of changes in the sums of intra-crop variances, by crop, from 1949–58 to 1978–85

Component ^a	Rice	Wheat	Maize	Tubers	Soy-beans	Sorghum	Millet	Other-grain	Residual Grain	All China
	(%) ^b									
$\delta \bar{Y}$	117.9	139.9	99.7	-1.2	73.7	172.1	39.7	6.8	202.5	100.5
$\delta \bar{A}$	46.3	6.9	163.3	-13.6	-37.4	-61.8	-74.1	-42.2	-62.6	-12.4
$\delta \text{VAR}(Y)$	16.6	94.0	-278.3	-14.9	-4.5	43.7	9.2	-113.1	-120.7	-51.2
$\delta \text{VAR}(A)$	-40.8	-9.8	-2.2	-39.3	-77.6	-76.2	-14.5	-6.8	-59.0	-43.2
$\delta \bar{Y}, \delta \bar{A}$	2.0	-1.8	-10.0	0.8	-4.5	0.2	-7.8	1.5	-4.4	-1.0
$\delta \text{COV}(A, Y)$	-107.7	-24.9	-7.4	-42.1	-52.8	14.2	-21.1	11.3	7.3	-41.1
$\delta \bar{A}, \delta \text{VAR}(Y)$	2.8	3.8	-57.0	7.3	9.5	-32.3	-26.0	40.4	24.0	18.0
$\delta \bar{Y}, \delta \text{VAR}(A)$	-53.5	-73.4	-0.5	-1.4	-53.5	-159.8	-17.9	-9.0	-132.8	-55.4
$\delta \bar{Y}, \delta \bar{A}, \delta \text{COV}(A, Y)$	-83.9	-37.2	-39.7	12.5	2.7	2.6	2.1	0.9	7.4	-21.0
δR	0.3	2.6	-17.7	-8.2	44.4	-2.6	10.6	10.3	38.2	6.9
Sum ^c	-20.3	19.4	9.3	-42.0	-2.7	-2.8	-4.0	-42.3	-14.5	-100.0 ^a

^a See Table A2 for definitions of the symbols.^b The percentages are obtained by using the absolute value of change in the sum of intra-crop variances of each crop as denominator. Thus, components in each column sum to 100.0 or -100.0. A negative figure in the table means a stabilising contribution and vice versa.^c The sum indicates the contribution of the crop to the sums of intra-crop variances.^d The negative value means that the sums of intra-crop variances decreased over the two periods under consideration.

yield and/or sown-area standard deviations, -118.2% from changes in the correlation coefficients between yield and sown-area, and the remaining $+47.7\%$ from the interaction (Table A10). All the correlation coefficients decreased from 1949–58 to 1978–85, as shown in the third column of Table A10.

The components of change in the sum of intra-crop variances within regions are presented by crops in Table 14. It is found that output variances of most crops decreased from 1949–58 to 1978–85 except for wheat and maize. These two crops are presumed to be influenced more by seed-fertiliser technology than other crops are. In particular, all crops experienced a large decrease in sown-area variance. This, again, implies the stabilising effect of procurement policy. Scanning Table 14, change in mean yield is generally the major factor. Other-crop (or other-grain) reduced variability to a larger extent than any of the explicitly considered crops. This is consistent with the result that the Other-region, which is mainly engaged in other-grain production, had a large decrease in its variability (-338%), as shown in Table 15. From Table 15, a majority of the regions increased their sum of intra-crop variances. It is obvious that 18 out of 22 regions (excluding Residual Region) decreased their sown-area variances, while 17 regions increased their yield variances. Increase in mean yields led to increase in regional variability for all regions. This pattern is consistent with the earlier assertion that the ‘green revolution’ may have brought about higher yield variance, but procurement policy possibly had a stabilising effect on sown-area.

7. SUMMARY

To examine the effect of institutional changes on variability, a variance decomposition technique was applied to the Chinese foodgrain production data for the period from 1949 to 1985 with 1959–61 excluded. It is found that the total variability, as indicated by variance, of Chinese foodgrain production increased from 1949–58 to 1962–77 by $1.67 \times 10^{14} \text{ jin}^2$, and then decreased from 1962–77 to 1978–85 by $1.72 \times 10^{14} \text{ jin}^2$. Therefore total variability decreased by some $4.96 \times 10^{12} \text{ jin}^2$ between 1949–58 and 1978–85. Meanwhile, average production kept increasing from 1949–58 to 1962–77 and from 1962–77 to 1978–85. It can thus be concluded that relative variability in 1978–85 was lower than that in the earlier periods.

Changes in the mean values of yield and sown-area have always destabilised Chinese foodgrain production. This was particularly so between 1949–48 and 1978–85. Changes in yield variance and covariances were the major determinants of the changed (increased or decreased) total variability. Changes in the variance and covariances of sown-area created a

TABLE 15

Components of changes in the sums of intra-crop variances, by region, 1949–58 to 1962–77

Region	Component ^a										Sum ^c
	$\delta \bar{Y}$	$\delta \bar{A}$	$\delta \text{VAR}(Y)$	$\delta \text{VAR}(A)$	$\delta \bar{Y}$	$\delta \text{Cov}(A, Y)$	$\delta \bar{A}$	$\delta \bar{Y}$	$\delta \text{Cov}(A, Y)$	δR	
					$\delta \bar{A}$		$\delta \text{VAR}(Y)$	$\delta \text{VAR}(A)$	$\delta \bar{Y}, \delta \bar{A}$		
	(%) ^b										
Anhui	991.5	-34.4	139.9	-372.7	3.3	73.3	4.1	-982.9	-31.6	109.5	-0.9
Hubei	36.1	12.4	132.1	5.0	1.5	-83.3	69.9	1.3	-74.3	-0.8	4.5
Hunan	385.9	227.4	-119.1	-259.0	13.1	10.1	-55.1	-331.1	-13.5	41.1	-0.7
Guangdong	25.4	-1.1	150.3	-5.9	0.3	-25.9	-20.1	-9.3	-15.4	1.7	5.8
Gansu	17.2	7.9	56.9	1.9	0.4	11.2	-10.1	3.7	9.0	1.9	0.4
Guangxi	11.4	3.6	46.3	-8.0	-0.7	27.5	7.9	-6.7	21.0	-2.3	3.1
Guizhou	30.3	5.3	151.3	-27.0	-0.4	-20.3	-10.7	-13.6	-3.4	-11.4	0.3
Heilongjiang	21.1	2.8	33.8	-7.1	-0.1	26.4	13.3	-9.2	19.5	-0.4	7.1
Henan	505.1	-22.2	179.4	-91.0	-13.2	-55.1	-17.4	-328.1	-74.4	16.8	2.7
Jiangsu	134.7	2.5	253.3	13.4	-1.1	-119.9	-12.6	-41.6	-129.7	1.2	5.4
Liaoning	176.6	5.0	91.8	-55.4	-0.5	18.1	20.5	-150.9	25.2	-30.2	4.0

Ningxia	45.9	25.2	47.6	-5.9	-2.2	21.3	0.6	-53.0	20.3	0.2	0.0
Qinghai	177.5	733.1	-789.1	-268.0	87.9	580.9	-339.4	133.6	-289.8	73.3	0.0
Shaanxi	8.9	0.4	89.8	2.3	0.1	-4.5	1.5	4.5	-1.0	-2.0	1.8
Sichuan	578.1	-129.7	-67.8	-137.8	-7.0	-160.9	92.6	-140.4	-146.9	19.8	1.1
Shandong	69.3	-6.3	87.4	-15.4	-0.7	4.2	-3.5	-33.4	-2.3	0.8	9.6
Shanghai	5.9	3.8	33.8	17.8	-0.2	6.6	14.7	9.5	4.4	3.8	0.3
Shanxi	23.0	-4.1	95.6	-2.4	-0.7	3.1	-22.9	-0.4	5.2	3.6	1.8
Tianjin	34.6	-0.4	32.3	-12.6	-1.1	22.2	16.3	-4.9	-2.6	16.1	0.1
Xinjiang	12.6	114.4	-55.3	-47.3	-38.3	123.1	-122.3	-61.0	180.9	-6.8	0.2
Zhejiang	11.2	17.0	54.7	-7.9	-1.3	11.1	17.8	-13.8	10.3	0.9	2.5
Other-region	22.5	-1.0	-46.5	-28.1	1.5	-35.3	1.9	-10.7	-3.2	-1.1	-79.8
Other-region	22.5	-1.0	-46.5	-28.1	1.5	-35.3	1.9	-10.7	-3.2	-1.1	-79.8
Residual Region	35.1	-18.1	-101.5	-10.9	-2.5	-4.6	20.0	-17.8	-10.1	10.3	-67.3
China	100.5	-12.4	-51.2	-43.2	-1.0	-41.1	18.0	-55.4	-21.0	6.9	-100.0 ^d

^a See Table A2 for definitions of the symbols.

^b The percentages are obtained by using the absolute value of change in the sum of intra-crop variances of each region as denominator. This, components in each row sum to 100.0 or -100.0. A negative figure in the table means a stabilising contribution and vice versa.

^c The sum indicates the regional contribution to the sums of intra-crop variances.

^d The negative value means that the sums of intra-crop variances decreased over the two periods under consideration.

stabilising effect on Chinese foodgrain production. In general, changes in yield mean, yield variance and covariances, covariance between sown-area and yield, and interaction among mean yield, mean sown-area and covariance between yield and sown-area were the most influential components of the changes in the total variability. Conversely, changes in mean production were dominated by the source of changes in mean yield, either at the national level or at the regional level.

It seems that the highly centralised planning system when coupled with the commune structure led to a very unstable period of China's foodgrain production in 1962–77. The centralised system might be useful in stabilising regional intra-crop sown-areas, but it probably increased inter-region covariabilities of both sown-area and yield. These covariabilities were most important in contributing to the changes that have occurred in the variability of Chinese foodgrain production since 1949.

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APPENDIX: SUPPLEMENTARY TABLES

TABLE A1

Components of changes in mean production

Description	Symbol
Change in mean yield	δY
Change in mean area	$\delta \bar{A}$
Interaction between changes in Mean yield and mean sown-area	$\delta \bar{Y}, \delta \bar{A}$
Change in covariance between sown-area and yield	$\delta \text{Cov}(A, Y)$

TABLE A2

Components of change in variance of production

Term	Description	Symbol
1	Change in mean yield	$\delta \bar{Y}$
2	Change in mean sown-area	$\delta \bar{A}$
3	Change in yield variance	$\delta \text{VAR}(Y)$
4	Change in sown-area variance	$\delta \text{VAR}(A)$
5	Interaction between changes in mean yield and mean sown-area	$\delta \bar{Y}, \delta \bar{A}$
6	Change in covariance between sown-area and yield	$\delta \text{Cov}(A, Y)$
7	Interaction between changes in mean yield and sown-area variance	$\delta \bar{Y}, \delta \text{VAR}(A)$
8	Interaction between changes in mean sown-area and yield variance	$\delta \bar{A}, \delta \text{VAR}(Y)$
9	Interactions between changes in mean sown-area and yield, and changes in covariance between yield and sown-area	$\delta \bar{Y}, \delta \bar{A}$ $\delta \text{Cov}(A, Y)$
10	Change in residual	δR

TABLE A3

Components of change in the inter-crop and inter-region yield covariances

Description	Symbol
Change in standard deviation of yield	$\delta \sigma_Y$
Change in correlation coefficient between yields	$\delta \rho_{(Y,Y)}$
Change in the interaction among standard deviation of yield and correlation coefficient between yields	$\delta \sigma_Y, \delta \rho_{(Y,Y)}$

TABLE A4

Components of change in the inter-crop and inter-region covariances between sown-area and yield

Description	Symbol
Changes in standard deviations of sown-area and yield	$\delta\sigma_Y, \delta\sigma_A$
Change in correlation coefficient between yield and sown-area	$\delta\rho_{(Y,A)}$
Change in the interactions among standard deviations of sown-area and yield, and correlation coefficient between yield and sown-area	$\delta\sigma_Y, \delta\sigma_A, \delta\rho_{(Y,A)}$

TABLE A5

Disaggregation of the contribution due to changes in yield covariances from 1949–58 to 1962–77

	Component ^a			Sum
	$\delta\sigma_Y$	$\delta\rho_{(Y,Y)}$	$\delta\sigma_Y$	
			$\delta\rho_{(Y,Y)}$	
			(%)	
Crops within regions	3.11	0.00	0.00	3.11
Inter-crop within regions	1.74	−0.02	1.45	3.16
Inter-region within crops	2.75	0.89	10.04	13.66
Between crops and regions	9.36	4.27	46.32	59.97
Sum	16.96	5.14	57.80	79.90

^a See Table A3 for definitions of the symbols.

TABLE A6

Disaggregation of the contribution due to change in covariance between sown-area and yield from 1949–58 to 1962–77

	Component ^a			Sum
	$\delta\sigma_A$	$\delta\rho_{(Y,A)}$	$\delta\sigma_Y, \delta\sigma_A$	
	$\delta\sigma_Y$		$\delta\rho_{(Y,A)}$	
	(%)			
Crops within Regions	0.09	−0.12	0.28	0.26
Inter-crop within regions	0.56	−1.00	−0.08	−0.52
Inter-region within crops	−0.59	0.87	9.25	9.53
Between crops and regions	5.24	−5.08	4.26	4.43
Sum	5.32	−5.33	13.72	13.70

^a See Table A4 for definitions of the symbols.

TABLE A7

Disaggregation of the contribution due to changes in yield covariances from 1962–77 to 1978–85

	Component ^a			Sum
	$\delta\sigma_Y$	$\delta\rho_{(Y,Y)}$	$\delta\sigma_Y$	
			$\delta\rho_{(Y,Y)}$	
	(%)			
Crops within regions	–3.06	0.00	0.00	–3.06
Inter-crop within regions	–2.25	–2.25	1.77	–2.73
Inter-region within crops	–11.19	–8.59	6.83	–12.96
Between crops and regions	–43.52	–44.37	34.83	–53.05
Sum	–60.02	–55.21	43.43	–71.80

^a See Table A3 for definitions of the symbols.

TABLE A8

Disaggregation of the contribution due to change in covariance between sown-area and yield from 1962–77 to 1978–85

	Component ^a			Sum
	$\delta\sigma_A$	$\delta\rho_{(Y,A)}$	$\delta\sigma_Y, \delta\sigma_A$	
	$\delta\sigma_Y$		$\delta\rho_{(Y,A)}$	
	(%)			
Crops within regions	–0.52	–0.82	0.39	–0.95
Inter-crop within regions	–0.08	0.04	–0.07	–0.11
Inter-region within crops	–11.37	–15.57	13.05	13.88
Between crops and regions	–6.83	–7.16	4.03	–9.96
Sum	–18.79	–23.51	17.40	24.90

^a See Table A4 for definitions of the symbols.

TABLE A9

Disaggregation of the contribution due to changes in yield covariances from 1949–58 to 1978–85

	Component ^a			Sum
	$\delta\sigma_Y$	$\delta\rho_{(Y,Y)}$	$\delta\sigma_Y$	
			$\delta\rho_{(Y,Y)}$	
	(%)			
Crops within regions	–7.66	0.00	0.00	–7.66
Inter-crop within regions	6.08	–6.50	1.24	1.34
Inter-region within crops	14.28	7.35	13.42	35.06
Between crops and regions	45.23	–1.50	20.72	64.45
Sum	57.93	–0.64	35.82	93.10

^a See Table A3 for definitions of the symbols.

TABLE A10

Disaggregation of the contribution due to change in covariance between sown-area and yield from 1949–58 to 1978–85

	Component ^a			Sum
	$\delta\sigma_A$	$\delta\rho_{(Y,A)}$	$\delta\sigma_Y, \delta\sigma_A$	
	$\delta\sigma_Y$		$\delta\rho_{(Y,A)}$	
	(%)			
Crops within regions	–4.39	–8.60	5.72	–7.26
Inter-crop within regions	–15.33	–17.29	10.49	–22.13
Inter-region within crops	–9.30	–18.29	8.36	–19.24
Between crops and regions	–59.40	–73.98	23.10	–110.28
Sum	–88.43	–118.16	47.67	–158.90

^a See Table A4 for definitions of the symbols.

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