Chapter 3

PRIMARY ANALYSIS OF FOODGRAIN PRODUCTION VARIABILITY

3.1 Introduction

In this chapter a set of selected single-variable measures will be used to provide a descriptive picture of the intra-region and intra-crop variability of foodgrain production in China. By doing so, instabilities of yield, sown area and output can be ranked by crops and/or regions, and the consistency of different measures of instability can be tested. The next section is concerned with choice of single-variable measures of instability, followed by tests of consistency. In the remaining sections, variabilities of area sown, yield and output are analysed separately. The relationship between variabilities of production, yield and sown area is discussed in the last second section. The chapter is concluded with a summary.

3.2 Single-variable Measures of Instability

Single-variable measures of instability are those indicating the relative magnitude of variability for a single set of observations. While they do not account for any covariability among the variables under consideration, this does not prevent them from being useful intra-series indicators of variability. As the single-variable measures are normally unit-free, they can be of particular use in ranking instabilities of different variables or of different samples of the same variable.

Many single-variable measures have been applied to the study of commodity instability, especially in the context of international trade (Murray 1978, Amran 1982, Newbery and Stiglitz 1985). These include percentage range (PR), average percentage change (APC), Coppock index (CI), moving average (MA), coefficient of variation (CV) and its variants (Table 3.1).

The percentage range is possibly the simplest measure of instability. However, its value is determined by only two points of the transformed data set. This implies its limitation in representing the overall year-to-year variability.

The coefficient of variation is perhaps the most commonly-used measure of instability. The weakness of CV lies in that it ignores the presence of trend in the data. To overcome this weakness, CV is often calculated from a detrended series. The author shares the view that the use of CV on a detrended data set is probably suitable for most purposes (Offutt and Blandford 1983). Clearly, as defined in Table 3.1, CV2 is less affected by outliers than is CV1.

A characteristic of average percentage change is its flexibility in weighting downward and upward fluctuations. If upward fluctuations deserve more weight, APC1 (cf. Table 3.1) should be used. In the contrary situations, APC2 should be used. The use of $Max(X_t, X_{t-1})$ in APC3 and APC6 corrects asymmetry in the other APCs. Put another way, APC3 and APC6 measure downward and upward fluctuations with the same weight. Therefore, choices of APCs are dependent on the different consequences caused by downward and upward fluctuations. A pitfall of APC is that a steady increase or decrease of the variable would be

Table 3.1: Single-variable Measures of Instability

Measure	Formula	Reference
Percentage Range (PR)	(1) $PR = Z_{max} - Z_{min}$ $Z_t = \left\lvert \frac{X_t - X_{t-1}}{X_{t-1}} \right\rvert$.	B
Coefficient of Variation (CV)	(2) $CV1 = \sqrt{\frac{\sum (X_t - \overline{X})^2}{N-1}} / \overline{X}$	B
	(3) $CV2 = \frac{\sum \lvert X_t - \overline{X} \rvert}{N-1} / \overline{X}$	B
Average Percentage Change (APC)	(4) $APC1 = \sum \left\lvert \frac{X_t - X_{t-1}}{X_{t-1}} \right\rvert / (N-1)$	B
	(5) $APC2 = \sum \left\lvert \frac{X_t - X_{t-1}}{X_t} \right\rvert / (N-1)$	A
	(6) $APC3 = \sum \left\lvert \frac{X_t - X_{t-1}}{Max(X_t, X_{t-1})} \right\rvert / (N-1)$	A
	(7) $APC4 = \sum \left(\frac{X_t - X_{t-1}}{X_{t-1}} \right)^2 / (N-1)$	B
	(8) $APC5 = \sum \left(\frac{X_t - X_{t-1}}{X_t} \right)^2 / (N-1)$	A
	(9) $APC6 = \sum \left(\frac{X_t - X_{t-1}}{Max(X_t, X_{t-1})} \right)^2 / (N-1)$	B
Coppock Index (CI)	(10) $CI = antilog \sqrt{\frac{\sum (W_t - K)^2}{N-1}}$ $W_t = \log X_{t-1} - \log X_t$; $K = \frac{1}{N-1} \sum W_t = \frac{1}{N-1} (\log X_N - \log X_1)$.	C
Moving Average (MA)	(11) $MA(I) = \frac{1}{N+1-I} \sum_{t=r+1}^{N-r} \left\lvert \frac{X_t - M_t(I)}{M_t(I)} \right\rvert$ I = length of moving average; $r = (I - 1) \div 2$; $M_t(I) = \frac{1}{I} \sum_{k=t-r}^{t+r} X_k$.	B
Cuddy Index	(12) $I_x = CV1 \sqrt{1 - \overline{R}^2}$ $\overline{R}^2$: adjusted R^2 from detrending equation.	D

A: Author.

B: Offutt and Blandford (1983).

C: Coppock (1962).

D: Cuddy and Della Valle (1979).

considered unstable movement, which is incorrect. A solution to this problem is to detrend the data before the APCs are calculated.

The Coppock index gives a good approximation of average year-to-year percentage variation net of trend. By taking logarithms of the original observations, the effect of large outliers is somewhat moderated. Two drawbacks of CI limit its use in measuring variability: (a) the assumption of constant percentage rate of increase as the long-run trend; (b) the mean of growth rate depends only on the first and the last observations in the data. CI is also referred to as logarithmic variance.

As far as MA is concerned, the length of moving trend is normally chosen without convincing rationale. Also, an I-period centered moving deviation causes $(I-1)\div 2$ observations to be dropped from each end of the series.

It can be proved that the final measure of variation in Table 3.1, proposed by Cuddy and Della Valle (1979), is identical to CV1 if CV1 is calculated from a comparably detrended time series. I_x is thus discarded from further consideration here.

The obvious point should be made that different measures measure different things, e.g., PR denotes the most extreme changes over the whole period and the other measures indicate year-to-year variability. In addition, different measures assume different natures of the data, e.g., a CV based on the original series does not assume any trend in the data, while CI and MA do. Thus it is unrealistic to expect that different measures would offer consistent descriptions of instability unless the measures under consideration contain the same implication and impose the same assumptions on the distribution of the data.

Although the choices of instability measures are arbitrary in most cases (Offutt and Blandford 1983), two factors appear to be important when making the choice, namely, the purpose of the research and the perception of the analyst of the properties of the data series. Since this study is basically focused on year-to-year variability, PR is irrelevant and is thus excluded from further discussion. In order to offer information for different users and to conduct consistent tests, measures (2) to (11) listed in Table 3.1 will be calculated.

As discussed in the previous paragraphs, the calculations of CV and APC require data-detrending. The purpose of detrending is to remove systematic changes in the series. Unfortunately, no unambiguous line can be drawn between systematic and random components of a series, although statistical tests are available to test the randomness (Mendenhall, Scheaffer and Wackerly 1981, p. 596). Very often, a plot of the data will reveal what kind of trend is dominating, and thus what appropriate technique may be employed to remove the trend In the process, attention should be directed to detect cycle component and long-term movement. There is no reason to suspect the existence of cycle changes in the Chinese foodgrain production data, as yields are generally increasing and sown areas decreasing. The plots of some of the data sets when estimating the missing values in Chapter 2 support this argument. Consequently, a quadratic function $Y_t = \alpha + \beta t + \gamma t^2 + \mu_t$ is fitted to the original data set, where Y is the variable in question, t is time subscript, α, β, γ are parameters and μ_t is the disturbance. The detrended series (Z) will be centered on the mean of Y, $(\overline{Y})$, i.e., $Z_t = \overline{Y} + e_t$, where e is the estimated residual.

The choice of the length of moving trend for MA calculation is rather arbitrary. Five is chosen since it is the length of the medium-term economic plan in China. The plan might have bearings on the structural changes of the Chinese economy. It is noted that the choice should reflect the structural cycle length.

3.3 Consistency Test of Single-variable Measures

Since variabilities of area sown, yield and output measured by the middle 10 single-variable indicators i.e., measures (2) to (11) of Table 3.1, are calculated for 9 crops (including the other-grains and total foodgrain) and 23 regions (including the other-regions and China), the necessity to present only part of the computing results, say, variability measured by 3 indicators is clear. If all indicators calculated give consistent results, employing one variability measure will suffice; otherwise, more results should be reported. That is why the consistency tests are conducted before presenting the outputs of calculation.

Two kinds of correlation coefficients are adopted here to assess the consistency of different measures of instability. These are Pearson's correlation coefficient (R_p) and Spearman's rank correlation coefficient (R_s).

To facilitate the consistency test, the calculated values of the instability indicators are arranged in two ways: on a cross-crop basis and on a cross-region basis. On a cross-crop basis, a matrix of 10 columns, representing 10 single-variable measures of instability, and 9 rows, representing 9 crops, is formed for each of the 23 regions. On a cross-region basis, a matrix of the same 10 columns and 23 rows representing 23 regions is formed for each of the 9 crops. Therefore, 32 matrices are formed.

For every matrix, R_p and R_s are computed among the columns, and there are 45 distinct values for each of the correlation coefficients. In other words, 90 coefficients are obtained from each of the 32 matrices.

The above procedure is repeated three times for sown areas, yields and outputs, respectively.

In brief, 8640 correlation coefficients are calculated. To make the presentation as clear as possible, only the numbers of insignificant correlation coefficients between different measures are presented in Tables 3.2 to 3.7. The tests are conducted under the null hypothesis that the correlation coefficient is nonpositive and the alternative hypothesis that the correlation coefficient is positive. It is noted that many of the 8640 tests are with different degrees of freedom, which makes the testing somewhat involved. All the tests are undertaken at the 5 per cent significance level.

Treating each table as a square matrix, the asymmetry of Tables 3.2 to 3.7 indicates the difference between R_p and R_s in assessing agreement of the different instability measures. This is most obvious in Tables 3.2 and 3.3, which are obtained based on area-sown data. Combining these two tables, there are 5 insignificant R_ss only, but 64 R_ps are insignificant. The total numbers of insignificant R_p and R_s are quite close when yield data are used (272 vs 285). If Tables 3.6 and 3.7 are considered (based on output data), the order of the numbers is reversed (266 vs 248).

Tables 3.4 to 3.7 look reasonably similar in terms of the distribution pattern. The

Table 3.2: Number of Insignificant R_p and R_s Among Different Instability Measures Based on Area-sown Data and Cross-region Matrix
(out of 23 regions)

	APC1	APC2	APC3	APC4	APC5	APC6	MA	CI	CV1	CV2
APC1										
APC2										
APC3										
APC4		1	1							1
APC5				1						
APC6				1						1
MA				1						
CI	3	3	1	8	8	7	2			2
CV1				3	1			2		
CV2	1			5	3	2		4		

Note: (1) Lower-left triangle for R_p and upper-right for R_s;
(2) Blank indicates that all the correlation potentially overviewed in each cell were tested as being significantly positive at the 5 per cent level.

Table 3.3: Number of Insignificant R_p and R_s Among Different Instability Measures Based on Area-sown Data and Cross-crop Matrix
(out of 9 crops)

	APC1	APC2	APC3	APC4	APC5	APC6	MA	CI	CV1	CV2
APC1										
APC2										
APC3										
APC4										
APC5				1						
APC6										
MA										1
CI					3					
CV1				2						
CV2				2						

Note: (1) Lower-left triangle for R_p and upper-right for R_s;
(2) Blank indicates that all the correlation potentially overviewed in each cell were tested as being significantly positive at the 5 per cent level.

Table 3.4: Number of Insignificant R_p and R_s Among Different Instability Measures Based on Yield Data and Cross-region Matrix
(out of 23 regions)

	APC1	APC2	APC3	APC4	APC5	APC6	MA	CI	CV1	CV2
APC1				1					11	17
APC2				2					13	17
APC3				2					12	17
APC4	1	1	1		1	1	2	2	10	13
APC5	1	1	2	1					13	17
APC6					1				12	17
MA				3	2				16	18
CI				5	3	2			16	18
CV1	11	11	11	13	17	14	14	16		
CV2	17	16	15	13	19	15	14	16		

Note: (1) Lower-left triangle for R_p and upper-right for R_s;
(2) Blank indicates that all the correlation potentially overviewed in each cell were tested as being significantly positive at the 5 per cent level.

Table 3.5: Number of Insignificant R_p and R_s Among Different Instability Measures Based on Yield Data and Cross-crop Matrix
(out of 9 crops)

	APC1	APC2	APC3	APC4	APC5	APC6	MA	CI	CV1	CV2
APC1										1
APC2									1	2
APC3									1	3
APC4										
APC5									1	1
APC6										2
MA									2	5
CI	1			1					1	4
CV1	1	1	1		3	1	1	2		
CV2	1	2	2		4	1	4	3		

Note: (1) Lower-left triangle for R_p and upper-right for R_s;
(2) Blank indicates that all the correlation potentially overviewed in each cell were tested as being significantly positive at the 5 per cent level.

Table 3.6: Number of Insignificant R_p and R_s Among Different Instability Measures Based on Output Data and Cross-region Matrix
(out of 23 regions)

	APC1	APC2	APC3	APC4	APC5	APC6	MA	CI	CV1	CV2
APC1									13	15
APC2				1					15	16
APC3				1					15	16
APC4	1	2	5		2		2	2	13	13
APC5	1		2	4					14	16
APC6				1					13	14
MA				4	2				14	15
CI	1	1		7	4	1			14	15
CV1	9	9	9	14	14	10	11	10		
CV2	10	13	11	16	16	16	14	11		

Note: (1) Lower-left triangle for R_p and upper-right for R_s;
(2) Blank indicates that all the correlation potentially overviewed in each cell were tested as being significantly positive at the 5 per cent level.

Table 3.7: Number of Insignificant R_p and R_s Among Different Instability Measures Based on Output Data and Cross-crop Matrix
(out of 9 crops)

	APC1	APC2	APC3	APC4	APC5	APC6	MA	CI	CV1	CV2
APC1									1	2
APC2									2	2
APC3									2	2
APC4										
APC5			1						2	2
APC6									2	2
MA									2	2
CI					1				2	2
CV1		1	1		1		1	1		
CV2	1	1	1	2	2	1	2	2		

Note: (1) Lower-left triangle for R_p and upper-right for R_s;
(2) Blank indicates that all the correlation potentially overviewed in each cell were tested as being significantly positive at the 5 per cent level.

Table 3.8: Number of Insignificant R_p and R_s Among Different Instability Measures: Aggregation of Tables 3.2 to 3.7

	APC1	APC2	APC3	APC4	APC5	APC6	MA	CI	CV1	CV2
APC1				1					25	35
APC2				3					31	37
APC3				3					30	38
APC4	2	4	7		3	1	4	4	23	27
APC5	2	1	5	5					30	36
APC6				2	1				27	36
MA				8	4				34	41
CI	5	5	1	21	19	10	2		33	42
CV1	21	22	25	29	35	25	29	29		
CV2	30	32	29	38	44	35	34	36		

Note: (1) Lower-left triangle for R_p and upper-right for R_s;

(2) Blank indicates that all the correlation potentially overviewed in each cell were tested as being significantly positive at the 5 per cent level.

remarkable difference between the numbers of insignificant correlation coefficients based on area sown data (69) and those based on other data (557 based on yield data and 514 based on output data) may have a bearing on the extent of instability of the data themselves. When a variable is fairly stable, more consistent results would be obtained by different instability measures (e.g., area sown in China) than otherwise.

Since the patterns of frequencies reported in Tables 3.2 to 3.7 are so similar, an aggregation seems justified for condensing the results and is undertaken in Table 3.8. This derived table suggests that the single-variable measures can be classified into three groups. Group one consists of CV1 and CV2. Although they are highly correlated and none of the R_p or R_s between them is insignificant, they are not highly correlated with the other eight measures. The first three APCs, APC6 and MA form the second group because they are highly correlated with all the correlation coefficients significant. Among the remaining measures, namely, APC4, APC5 and CI, there are few insignificant correlation coefficients, especially as indicated by R_p. They compose the last group. It is noted that, within each group, the measures provide quite consistent information according to both R_p and R_s.

Thus, it is a matter of selecting one indicator from each group. Consequently, CV2, MA and APC5 are chosen for indicating variabilities. Because CV1 exaggerates the effect of outliers, CV2 is chosen from group 1. In examining group 3, CI is rejected largely because of the two drawbacks discussed in relation to Table 3.1. APC4 is also discarded since it weights upward fluctuations more heavily than downward movements, which is inconsistent with farmers' and government's expectations. With a reluctance on the grounds of analytical economy to use two APC measures, MA is the choice from group 2. Among the three indicators, CV2 measures instability from long-term trend, MA from short-run trend, and APC5 from long-term trend but measuring year-to-year variations. APC5 is the only one among the chosen measures whose value is strongly influenced by outliers.

3.4 Variability of Area Sown

Until recently, research on variations in area sown had been ignored in China (Wan 1987). This is possibly because area sown in China used to be planned by politicians and the scarcity of land left no space for manipulation of sown areas in China. With the introduction of the agricultural production responsibility system, variability of area sown will inevitably attract more attention.

As displayed in Figures 3.1 and 3.2, sown area for each crop did not exhibit much variation, although sown areas for coarse grains were generally more volatile than that for fine grains. This came as no surprise because China has been utilising as much land as possible to produce foodgrain and rapid changes in the sown areas are restricted by the limited land resource. The relatively stable sown areas owe much to the highly centralized economic system in China. It is noted that Chinese governments have been trying to achieve stable production since the early 1950s, mainly through area control by over-detailed plans.

The instabilities of sown areas as indicated by CV2, MA and APC5 are presented in Tables 3.9 to 3.11. Results by other measures can be found in Appendix A.

It is found that area-sown instabilities measured by CV2 are generally greater in magnitude than those measured by MA, which, in turn, are generally greater than those measured

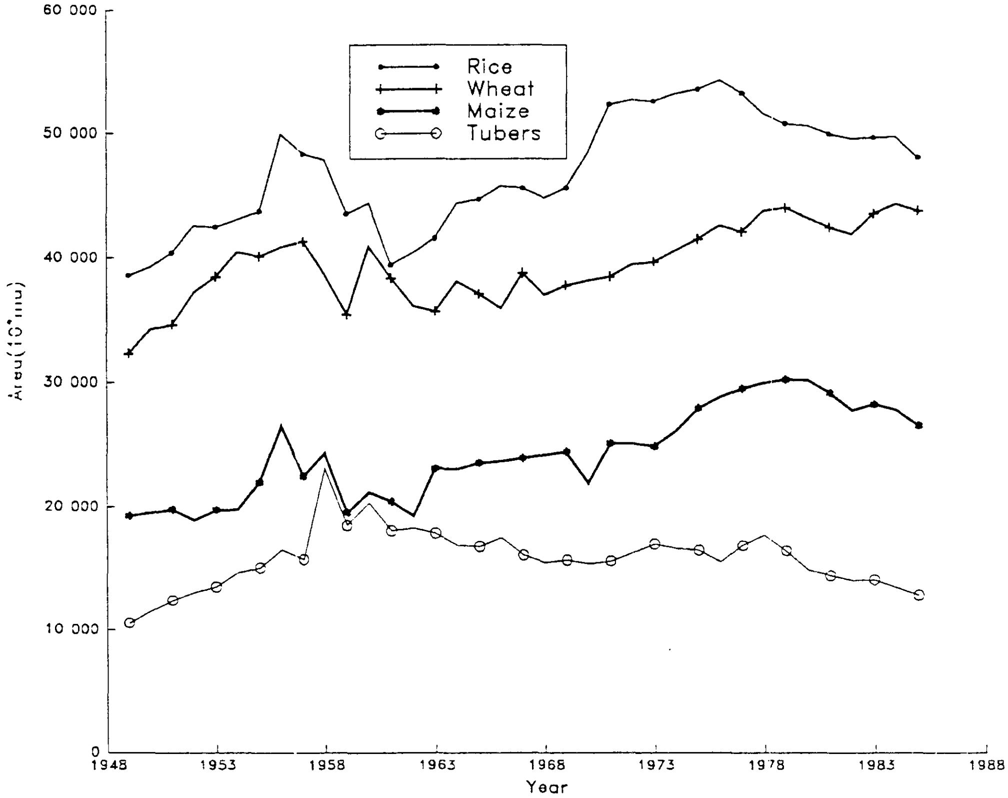

Figure 3.1: China's Sown Areas for Rice, Wheat, Maize and Tubers.

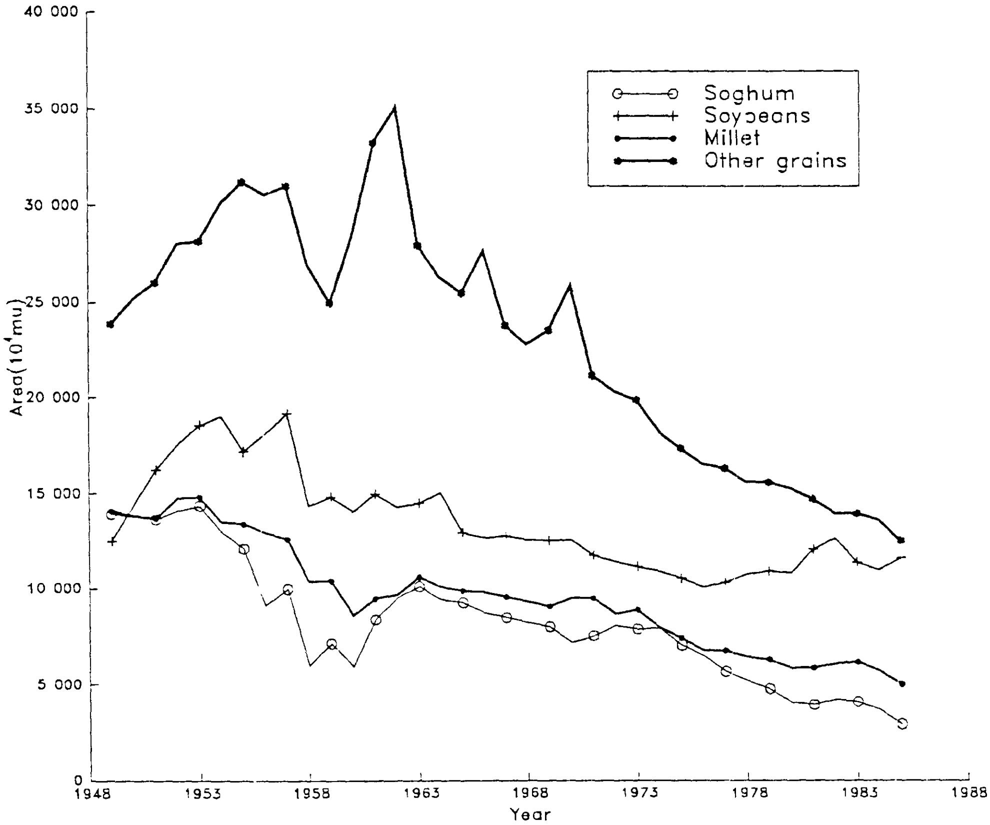

Figure 3.2: China's Sown Areas for Soybeans, Sorghum, Millet and Other-grains.

Table 3.9: Area Sown Variability Measured by CV2

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.12	0.12	0.25	0.10	0.16	0.60	0.59	0.61	0.12
Hubei	0.17	0.09	0.10	0.15	0.19	0.47	0.67	0.40	0.04
Hunan	0.13	0.20	0.18	0.17	0.20	0.28	–[1]	–	0.08
Guangdong	0.05	0.58	–	0.14	0.17	–	–	–	0.06
Gansu	0.21	0.09	0.15	0.13	0.13	0.20	0.23	0.13	0.02
Guangxi	0.09	0.56	0.11	0.33	0.23	–	–	–	0.08
Guizhou	0.05	0.31	0.04	0.32	0.07	–	–	–	0.06
Heilongjiang	0.25	0.34	0.12	0.11	0.08	0.25	0.09	0.23	0.08
Henan	0.16	0.08	0.20	0.08	0.22	0.49	0.35	0.48	0.11
Jiangsu	0.17	0.12	0.14	0.10	0.38	0.75	0.81	0.25	0.08
Liaoning	0.41	0.38	0.18	0.34	0.14	0.26	0.32	0.31	0.09
Ningxia	0.13	0.18	–	0.25	0.21	–	–	–	0.07
Qinghai	0.00	0.20	–	0.14	–	–	–	–	0.07
Shaanxi	0.05	0.02	0.06	0.28	0.19	0.24	0.19	0.21	0.05
Sichuan	0.07	0.20	0.10	0.10	0.12	0.18	–	–	0.05
Shandong	0.51	0.05	0.25	0.08	0.41	0.47	0.50	0.50	0.10
Shanghai	0.21	0.18	0.37	0.91	0.79	–	–	–	0.12
Shanxi	0.30	0.06	0.17	0.08	0.39	0.19	0.15	0.19	0.07
Tianjin	0.41	0.20	0.28	0.29	0.26	0.31	0.25	0.15	0.08
Xinjiang	0.16	0.22	0.14	0.31	0.32	0.19	0.26	0.24	0.16
Zhejiang	0.09	0.12	0.25	0.12	0.30	–	–	–	0.04
Other-regions	0.08	0.14	–	0.21	0.22	–	–	–	0.03
China	0.09	0.06	0.13	0.07	0.18	0.31	0.24	0.24	0.03

[1] Data not available.

Table 3.10: Area Sown Variability Measured by MA

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.05	0.03	0.14	0.05	0.08	0.13	0.10	0.10	0.01
Hubei	0.04	0.03	0.03	0.05	0.07	0.15	0.12	0.06	0.02
Hunan	0.03	0.10	0.07	0.07	0.07	0.13	–[1]	–	0.02
Guangdong	0.01	0.18	–	0.04	0.07	–	–	–	0.02
Gansu	0.07	0.02	0.08	0.04	0.07	0.07	0.04	0.05	0.01
Guangxi	0.02	0.23	0.05	0.11	0.07	–	–	–	0.02
Guizhou	0.02	0.12	0.02	0.07	0.04	–	–	–	0.03
Heilongjiang	0.09	0.07	0.07	0.07	0.04	0.06	0.04	0.06	0.01
Henan	0.07	0.02	0.04	0.05	0.07	0.10	0.07	0.05	0.01
Jiangsu	0.03	0.03	0.06	0.06	0.09	0.15	0.16	0.05	0.02
Liaoning	0.09	0.17	0.08	0.15	0.03	0.07	0.06	0.14	0.01
Ningxia	0.04	0.03	–	0.10	0.09	–	–	–	0.03
Qinghai	0.00	0.03	–	0.06	–	–	–	–	0.03
Shaanxi	0.02	0.02	0.04	0.07	0.04	0.07	0.04	0.05	0.02
Sichuan	0.03	0.04	0.03	0.05	0.04	0.06	–	–	0.02
Shandong	0.25	0.03	0.05	0.04	0.07	0.09	0.09	0.05	0.01
Shanghai	0.03	0.09	0.14	0.22	0.13	–	–	–	0.03
Shanxi	0.10	0.02	0.06	0.06	0.06	0.08	0.04	0.06	0.02
Tianjin	0.25	0.07	0.07	0.16	0.08	0.12	0.08	0.11	0.03
Xinjiang	0.07	0.03	0.03	0.12	0.17	0.09	0.19	0.07	0.03
Zhejiang	0.02	0.05	0.08	0.04	0.05	–	–	–	0.01
Other-regions	0.02	0.05	–	0.08	0.05	–	–	–	0.02
China	0.02	0.02	0.03	0.03	0.04	0.05	0.03	0.04	0.01

[1] Data not available.

by APC5. The influence of outliers on APC5 is seen by some extremely small or large values in Table 3.11. An interesting finding is that all the three measures under discussion indicate an increasing intra-crop variability from important crops to less important ones (roughly from the left to the right of the tables). This implies that the Chinese government had possibly made more efforts to control the areas sown for major crops (mainly fine grains).

According to Table 3.9, area sown for foodgrain production in Xinjiang was the most unstable among the regions, followed by Anhui and Shanghai. Among crops, wheat is of the least instability, followed by tubers and rice for China. Turning to short run variability as measured by MA, rice had the least instability, followed by wheat and millet for China.

Table 3.11: Area Sown Variability Measured by APC5

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.01	0.01	0.10	0.01	0.04	0.26	0.15	0.20	0.00
Hubei	0.01	0.01	0.00	0.01	0.02	0.18	0.22	0.05	0.00
Hunan	0.00	0.10	0.04	0.02	0.03	0.10	–[3]	–	0.00
Guangdong	0.00	0.58	–	0.01	0.01	–	–	–	0.00
Gansu	0.03	0.00	0.04	0.01	0.02	0.02	0.01	0.01	0.00
Guangxi	0.00	0.39	0.01	0.06	0.03	–	–	–	0.00
Guizhou	0.00	0.05	0.00	0.03	0.01	–	–	–	0.00
Heilongjiang	0.04	0.03	0.02	0.02	0.01	0.03	0.01	0.02	0.00
Henan	0.03	0.00	0.01	0.02	0.03	0.09	0.05	0.07	0.00
Jiangsu	0.00	0.01	0.01	0.02	0.05	0.95	1.62	0.02	0.00
Liaoning	0.08	0.18	0.05	0.24	0.01	0.11	0.03	0.50	0.00
Ningxia	0.01	0.01	–	0.05	0.03	–	–	–	0.00
Qinghai	0.00	0.01	–	0.03	–	–	–	–	0.01
Shaanxi	0.00	0.00	0.01	0.02	0.01	0.02	0.02	0.01	0.00
Sichuan	0.00	0.01	0.00	0.01	0.01	0.01	–	–	0.00
Shandong	1.39	0.01	0.01	0.01	0.07	0.12	0.14	0.11	0.00
Shanghai	0.01	0.05	0.09	14.73[1]	0.44	–	–	–	0.00
Shanxi	0.06	0.00	0.02	0.03	0.03	0.02	0.01	0.01	0.00
Tianjin	40.73[2]	0.02	0.02	0.46	0.04	0.09	0.03	0.05	0.00
Xinjiang	0.03	0.01	0.00	0.08	0.20	0.03	0.20	0.03	0.01
Zhejiang	0.00	0.01	0.04	0.01	0.02	–	–	–	0.00
Other-regions	0.00	0.01	–	0.04	0.03	–	–	–	0.00
China	0.00	0.00	0.01	0.01	0.01	0.04	0.02	0.02	0.00

[1,2] These values seems suspiciously large. However, the calculations are correct.

[3] Data not available.

Xinjiang still had the least stable sown area for foodgrain in the short-run. In terms of APC5, Qinghai and Xinjiang had the largest values for foodgrain production, though these might be affected by outliers in the data. Table 3.11 also shows that, for China as a whole, rice and wheat are the most stable crops, followed by maize and tubers. The relatively unstable rice sown area according to CV2 can be explained by the unusual expansions of rice planting in the middle 1950s and early 1970s. The expansion probably shifted the mean area sown, and CVs are, in the author's opinion, less able than measures based on moving differences to take this into account.

In summary, area-sown variability was effectively controlled by the government. This is seen by the inverse relationship between the measured instability and the importance of the crops. The regions with larger variations of area sown are either least important in terms of national foodgrain production (e.g., Tianjin, Shanghai and Xinjiang) or mainly engaged in coarse grain production (e.g., Qinghai, Liaoning, Heilongjiang and Henan) which attracted less government attention.

3.5 Yield Variability

Yield variability, variability of area sown and their interactions completely determine production instability. While sown areas at the regional level could be controlled in the short run by political means in China, crop yields are mainly subject to environmental conditions. However, environmental effects on yield can be influenced, though not fully controlled, by capital construction and farm management. This justifies the research on yield instability.

The most important factor that causes crop yield variation is weather, particularly rainfall and temperature. The weather factors are strongly associated with geographical location. For example, both temperature and precipitation increase from the north to the south and from the west to the east in China.

To visualize any relationship between yield variability and locations, Figures 3.3 is presented below. In this map, values of CV2, APC5 and MA are marked for those regions with available data. As measured by MA, variability of regional foodgrain yield increased from the south to the north and from the east to the west. The same conclusion can be drawn in terms of APC5. However, when CV2 is considered, the highest variability seems centered at the middle-east This is probably due to the fact that mean yields in the middle-east of China had possibly changed more or more frequently than in the other parts, and that CV2 is less capable of taking this into account in comparison with APC5 or MA.

The above arguments also hold in the case of rice and, less clearly, in the case of wheat (Figures 3.4 and 3.5). Maps were not drawn for other crops because of insufficient data for these crops.

It is necessary to point out that the weak trend in location-oriented variability may be attributable to the absence of consideration of regional differences in the production volumes and degrees of production concentration. As diversification normally reduces risk, a region with larger area sown for a crop may be presumed to have smaller yield variability of the crop. Put another way, the larger the area sown of a region is, the more probable the production activities of sub-regions in the region could offset each other. Supposing this argument holds, removal of the influence of the size of area sown might result in a stronger geographical trend of yield variability. However, the argument in not valid unless two conditions are satisfied. First, the crop in question must be planted across a large area, not concentrated in one part of a region. Second, the covariabilities of crop yields of sub-regions must be significantly negative. Unfortunately, the absence of sub-regional data prevents any attempt to test these assertions.

Tables 3.12 to 3.14 show the variability of yield by crops and regions as measured by CV2, MA and APC5. The results by other single variable measures are tabulated in Appendix A. Comparing corresponding values in these three tables, they become smaller from Table 3.12 to Table 3.13 to Table 3.14. This is similar to the case of area sown. However, when the relationship between variability and importance of a crop is considered, the picture is not as clear as in the case of area sown. After scanning and comparing values in different columns within each table, it appears that yields of wheat, sorghum and soybeans are generally less stable than other crops. For example, out of 23 regions (including China as a whole), wheat was associated with the largest CV2 among crops for 11 regions.

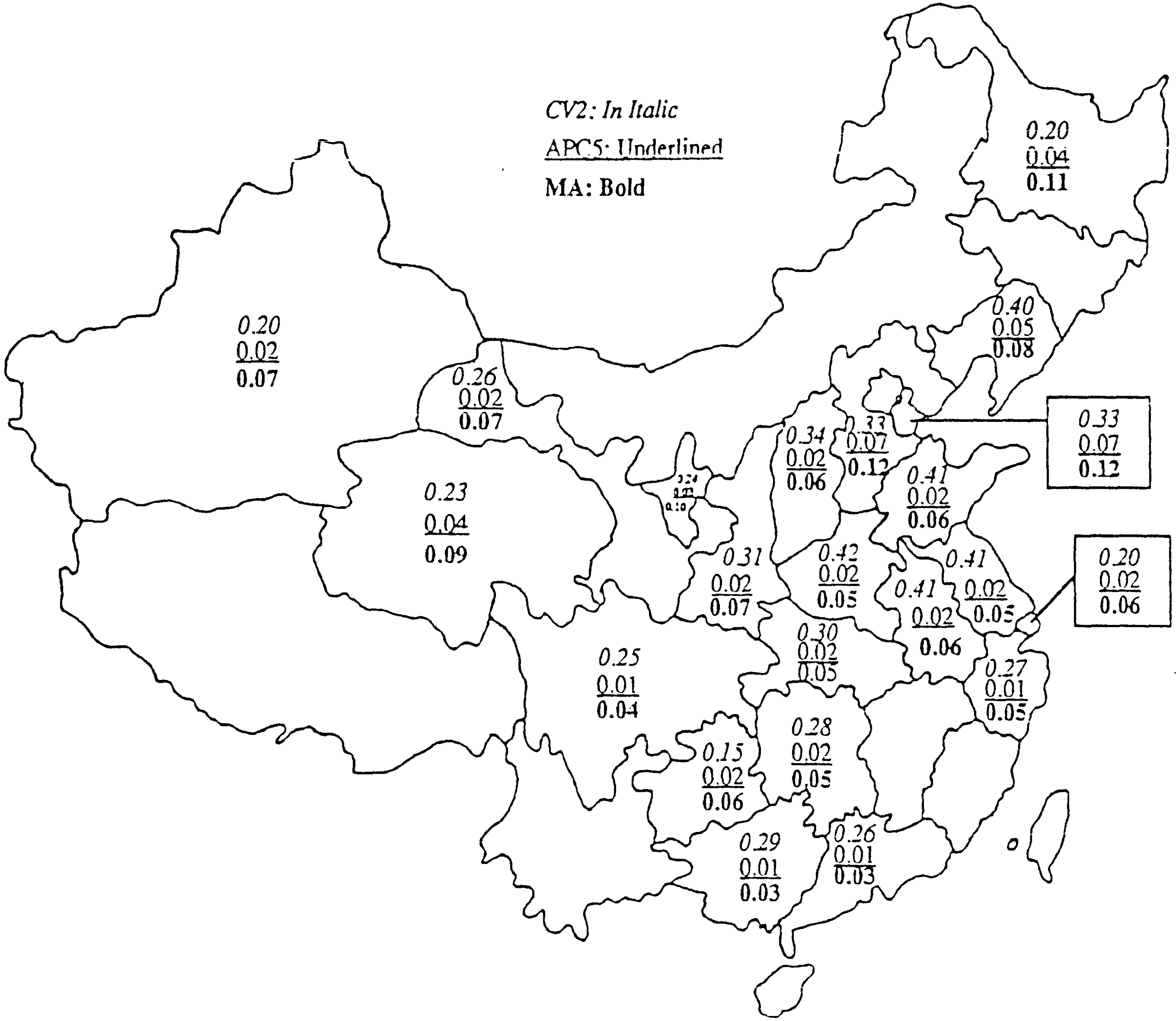

Figure 3.3: Variability of Regional Foodgrain Yield: All Crops

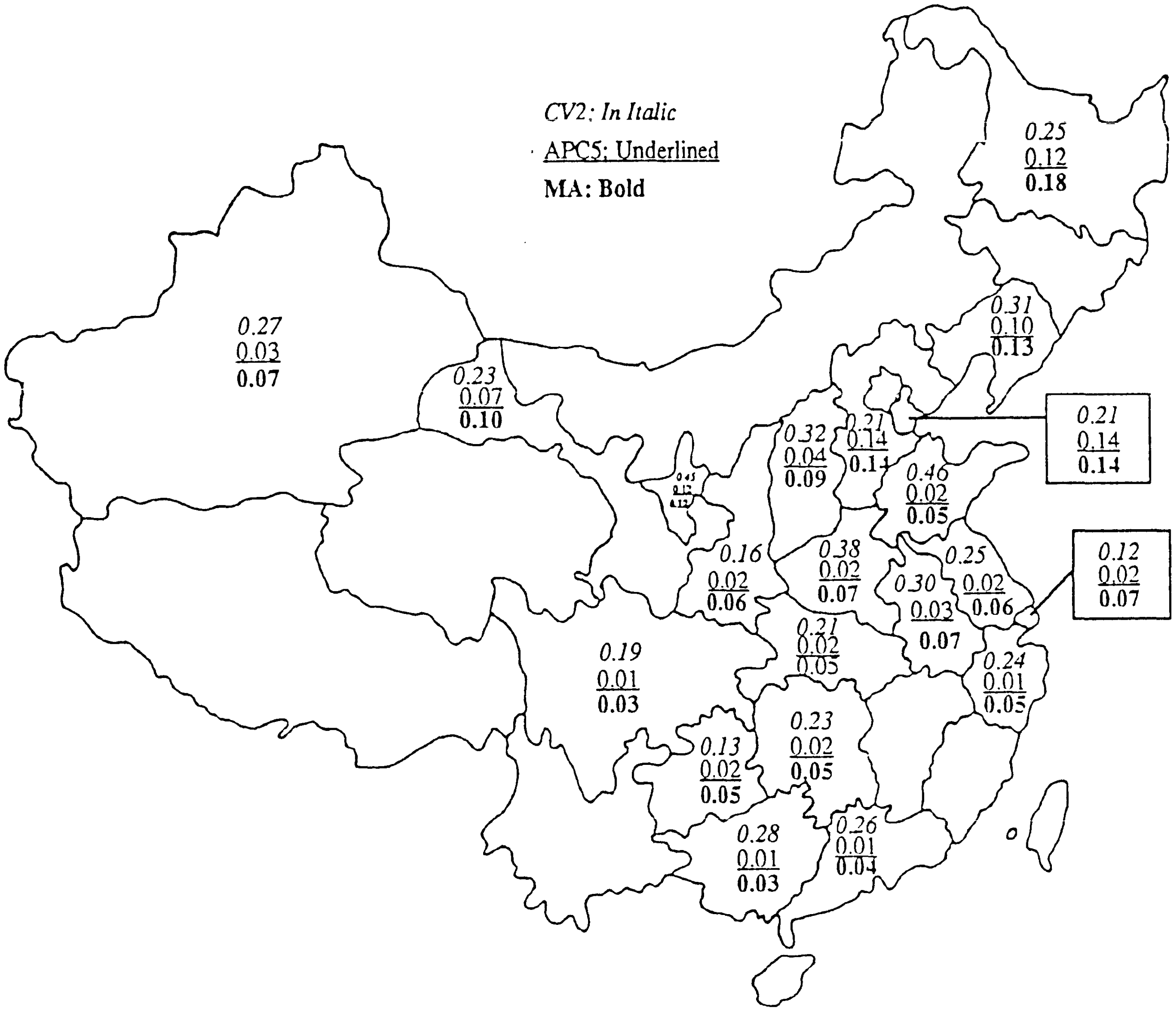

Figure 3.4: Variability of Regional Rice Yield

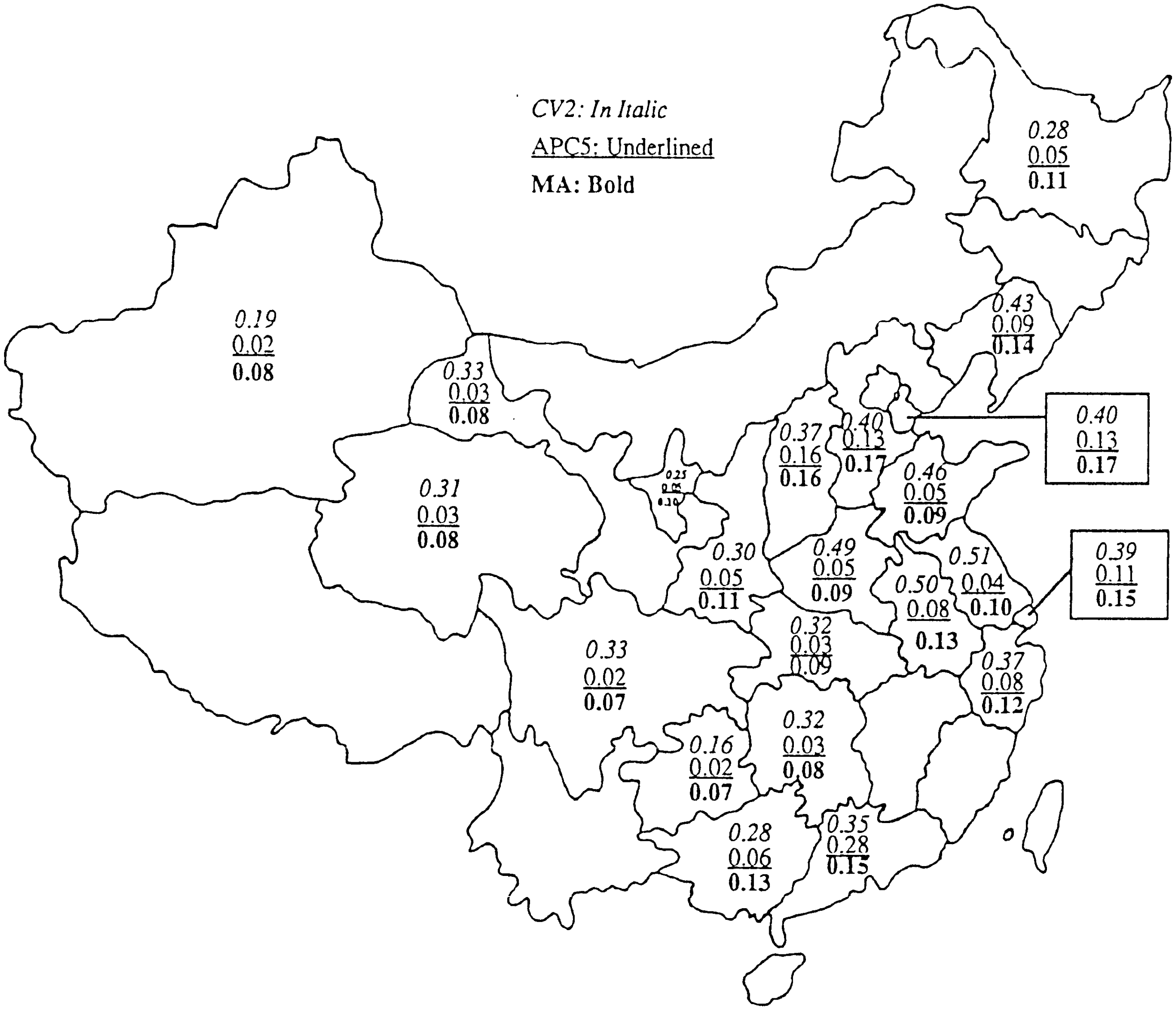

Figure 3.5: Variability of Regional Wheat Yield

Table 3.12: Yield Variability Measured by CV2

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.30	0.50	0.41	0.36	0.27	0.27	0.33	0.37	0.41
Hubei	0.21	0.32	0.33	0.18	0.19	0.32	0.20	0.24	0.30
Hunan	0.23	0.32	0.27	0.29	0.33	0.25	–[1]	–	0.28
Guangdong	0.26	0.35	–	0.24	0.22	–	–	–	0.26
Gansu	0.23	0.33	0.36	0.13	0.26	0.26	0.17	0.19	0.26
Guangxi	0.27	0.28	0.28	0.13	0.15	–	–	–	0.29
Guizhou	0.13	0.16	0.28	0.11	0.17	–	–	–	0.15
Heilongjiang	0.25	0.28	0.27	0.14	0.14	0.24	0.17	0.26	0.20
Henan	0.38	0.49	0.41	0.30	0.24	0.19	0.21	0.30	0.42
Jiangsu	0.25	0.51	0.42	0.34	0.27	0.40	0.20	0.49	0.41
Liaoning	0.31	0.43	0.37	0.11	0.14	0.40	0.17	0.33	0.40
Ningxia	0.45	0.25	–	0.32	0.16	–	–	–	0.24
Qinghai	0.00	0.31	–	0.17	–	–	–	–	0.23
Shaanxi	0.16	0.30	0.38	0.17	0.16	0.32	0.23	0.20	0.31
Sichuan	0.19	0.33	0.37	0.25	0.28	0.28	–	–	0.25
Shandong	0.46	0.46	0.42	0.33	0.23	0.23	0.24	0.28	0.41
Shanghai	0.12	0.39	0.18	0.26	0.64	–	–	–	0.20
Shanxi	0.32	0.37	0.28	0.22	0.18	0.43	0.23	0.31	0.34
Tianjin	0.21	0.40	0.40	0.22	0.36	0.46	0.32	0.30	0.33
Xinjiang	0.27	0.19	0.22	0.22	0.27	0.14	0.19	0.19	0.20
Zhejiang	0.24	0.37	0.21	0.19	0.32	–	–	–	0.27
Other-regions	0.19	0.33	–	0.17	0.18	–	–	–	0.20
China	0.23	0.39	0.35	0.18	0.16	0.35	0.20	0.24	0.30

[1] Data not available.

Table 3.13: Yield Variability Measured by MA

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.07	0.13	0.11	0.14	0.18	0.17	0.14	0.10	0.06
Hubei	0.05	0.09	0.07	0.07	0.10	0.10	0.09	0.12	0.05
Hunan	0.05	0.08	0.12	0.14	0.10	0.10	–[1]	–	0.05
Guangdong	0.04	0.15	–	0.08	0.06	–	–	–	0.03
Gansu	0.10	0.08	0.09	0.09	0.13	0.14	0.10	0.11	0.07
Guangxi	0.03	0.13	0.05	0.09	0.12	–	–	–	0.03
Guizhou	0.05	0.07	0.06	0.08	0.09	–	–	–	0.06
Heilongjiang	0.18	0.11	0.11	0.15	0.11	0.16	0.13	0.13	0.11
Henan	0.07	0.09	0.07	0.08	0.15	0.10	0.08	0.10	0.05
Jiangsu	0.06	0.10	0.08	0.09	0.09	0.13	0.08	0.09	0.05
Liaoning	0.13	0.14	0.08	0.07	0.11	0.09	0.09	0.17	0.08
Ningxia	0.12	0.10	–	0.15	0.11	–	–	–	0.10
Qinghai	0.00	0.08	–	0.10	–	–	–	–	0.09
Shaanxi	0.06	0.11	0.07	0.08	0.10	0.10	0.10	0.09	0.07
Sichuan	0.03	0.07	0.06	0.08	0.06	0.09	–	–	0.04
Shandong	0.05	0.09	0.06	0.07	0.10	0.10	0.07	0.07	0.06
Shanghai	0.07	0.15	0.11	0.14	0.13	–	–	–	0.06
Shanxi	0.09	0.16	0.06	0.08	0.15	0.09	0.07	0.15	0.06
Tianjin	0.14	0.17	0.18	0.11	0.17	0.22	0.16	0.18	0.12
Xinjiang	0.07	0.08	0.06	0.14	0.13	0.09	0.14	0.11	0.07
Zhejiang	0.05	0.12	0.08	0.08	0.07	–	–	–	0.05
Other-regions	0.06	0.08	–	0.11	0.11	–	–	–	0.06
China	0.03	0.06	0.04	0.04	0.06	0.06	0.06	0.16	0.03

[1] Data not available.

Table 3.14: Yield Variability Measured by APC5

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.03	0.08	0.07	0.12	0.16	0.16	0.21	0.05	0.02
Hubei	0.02	0.03	0.03	0.02	0.07	0.06	0.08	0.05	0.02
Hunan	0.02	0.03	0.13	0.09	0.05	0.15	–[1]	–	0.02
Guangdong	0.01	0.28	–	0.04	0.02	–	–	–	0.01
Gansu	0.07	0.03	0.04	0.03	0.08	0.13	0.08	0.05	0.02
Guangxi	0.01	0.06	0.02	0.03	0.04	–	–	–	0.01
Guizhou	0.02	0.02	0.02	0.02	0.03	–	–	–	0.02
Heilongjiang	0.12	0.05	0.05	0.08	0.04	0.12	0.06	0.06	0.04
Henan	0.02	0.05	0.03	0.04	0.13	0.09	0.03	0.04	0.02
Jiangsu	0.02	0.04	0.03	0.04	0.04	0.10	0.03	0.05	0.02
Liaoning	0.10	0.09	0.08	0.02	0.04	0.04	0.04	0.13	0.05
Ningxia	0.12	0.05	–	0.16	0.04	–	–	–	0.03
Qinghai	0.00	0.03	–	0.03	–	–	–	–	0.04
Shaanxi	0.02	0.05	0.03	0.02	0.04	0.05	0.03	0.03	0.02
Sichuan	0.01	0.02	0.02	0.03	0.03	0.03	–	–	0.01
Shandong	0.02	0.05	0.03	0.03	0.04	0.03	0.03	0.02	0.02
Shanghai	0.02	0.11	0.04	0.57	0.15	–	–	–	0.02
Shanxi	0.04	0.16	0.02	0.03	0.10	0.04	0.02	0.08	0.02
Tianjin	0.14	0.13	0.14	0.09	0.10	0.35	0.21	0.39	0.07
Xinjiang	0.03	0.02	0.02	0.08	0.14	0.06	0.16	0.04	0.02
Zhejiang	0.01	0.08	0.04	0.06	0.03	–	–	–	0.01
Other-regions	0.02	0.04	–	0.08	0.22	–	–	–	0.02
China	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.28	0.01

[1] Data not available.

3.6 Variability of Output

To policy-makers, output instability is the instability that is presumably of greatest concern. Previous research has shown that China's foodgrain production, especially rice, was fairly stable in contrast with India and the United States (Stone and Zhong 1985). This is mainly the result of: (a) labour-intensive farming techniques; (b) a higher prevalence of irrigation: and (c) a central planning system that focused on controlling areas sown.

Figures 3.6 and 3.7 plot outputs by crops. Rice production seems more stable than

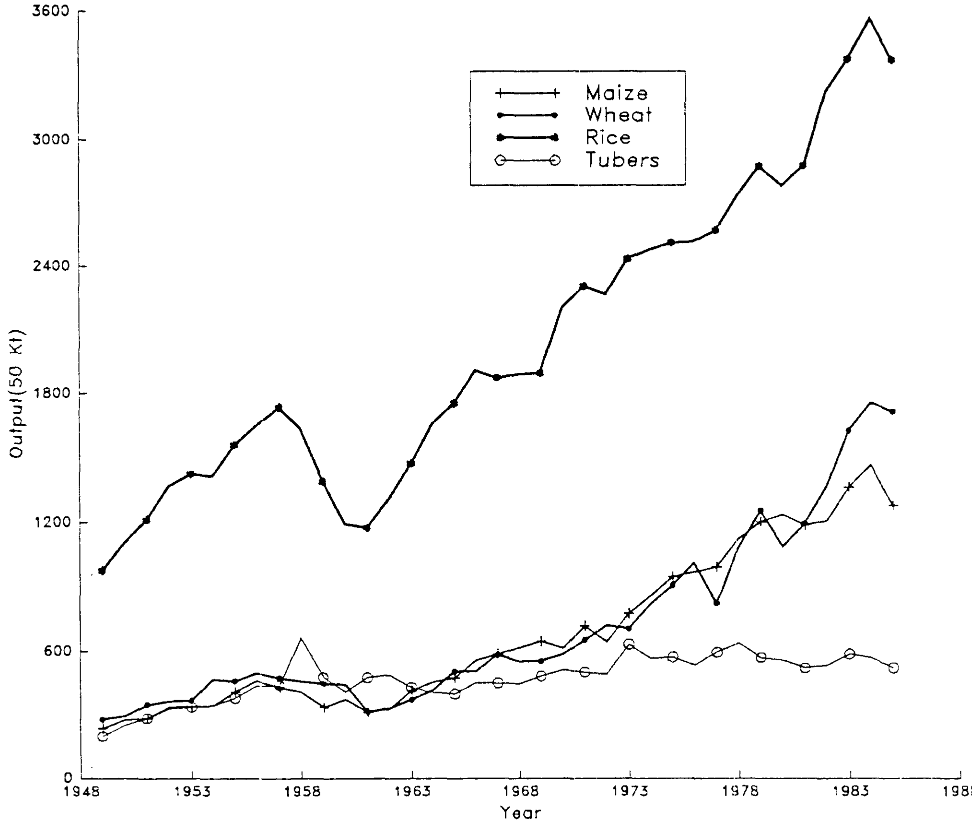

Figure 3.6: China's Outputs of Rice, Wheat, Maize and Tubers.

other crops, and its volume increased more substantially than other crops. On the other hand, output of the other-grains is shown to be least stable. This is not surprising for two reasons: (a) in terms of area sown, governments paid less attention to coarse grains in

Figure 3.7: China's Outputs of Soybeans, Sorghum, Millet and Other-grains.

Table 3.15: Output Variability Measured by CV2

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.37	0.45	0.42	0.35	0.32	0.51	0.43	0.40	0.32
Hubei	0.36	0.38	0.24	0.29	0.20	0.36	0.60	0.24	0.30
Hunan	0.35	0.28	0.22	0.24	0.34	0.27	–[1]	–	0.33
Guangdong	0.26	0.73	–	0.17	0.37	–	–	–	0.25
Gansu	0.20	0.40	0.30	0.17	0.23	0.29	0.18	0.17	0.25
Guangxi	0.35	0.47	0.32	0.30	0.34	–	–	–	0.32
Guizhou	0.16	0.42	0.29	0.37	0.21	–	–	–	0.20
Heilongjiang	0.37	0.56	0.38	0.23	0.19	0.20	0.18	0.17	0.27
Henan	0.42	0.46	0.58	0.32	0.21	0.40	0.23	0.24	0.34
Jiangsu	0.39	0.51	0.33	0.26	0.15	0.63	0.71	0.28	0.36
Liaoning	0.63	0.39	0.50	0.36	0.19	0.24	0.27	0.50	0.32
Ningxia	0.48	0.40	–	0.27	0.28	–	–	–	0.29
Qinghai	0.00	0.49	–	0.21	–	–	–	–	0.25
Shaanxi	0.20	0.31	0.37	0.42	0.16	0.47	0.14	0.12	0.26
Sichuan	0.19	0.51	0.44	0.31	0.23	0.21	–	–	0.26
Shandong	0.70	0.46	0.61	0.29	0.26	0.37	0.37	0.31	0.32
Shanghai	0.30	0.37	0.36	0.88	0.42	–	–	–	0.29
Shanxi	0.54	0.32	0.42	0.25	0.30	0.49	0.13	0.21	0.27
Tianjin	0.46	0.56	0.58	0.34	0.23	0.44	0.39	0.32	0.34
Xinjiang	0.37	0.38	0.33	0.28	0.49	0.18	0.28	0.22	0.33
Zhejiang	0.32	0.40	0.22	0.16	0.14	–	–	–	0.30
Other-regions	0.25	0.44	–	0.38	0.21	–	–	–	0.19
China	0.30	0.44	0.46	0.18	0.12	0.19	0.15	0.16	0.27

[1] Data not available.

general, and to other-grains in particular (cf. section 3.4); (b) most of the other-grains is grown in less developed regions (towards the north and west of China) where management and production conditions are relatively poor. Also, in these regions, unfavourable weather conditions might have caused higher fluctuations in crop yields (cf. section 3.5).

The ten single-variable measures of instability are again calculated for the output data, and the results for CV2, MA and APC5 are presented in Tables 3.15 to 3.17. Variation as measured by the other measures can be found in Appendix A.

Comparing these tables with the corresponding Tables 3.12 to 3.13 based on yield data, some similarities appear. That is, outputs of wheat and sorghum are more unstable than

Table 3.16: Output Variability Measured by MA

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.08	0.15	0.15	0.15	0.23	0.25	0.18	0.15	0.06
Hubei	0.07	0.10	0.08	0.10	0.15	0.21	0.19	0.14	0.06
Hunan	0.05	0.12	0.11	0.14	0.13	0.17	–[1]	–	0.05
Guangdong	0.04	0.21	–	0.08	0.09	–	–	–	0.04
Gansu	0.11	0.08	0.11	0.09	0.13	0.14	0.11	0.11	0.07
Guangxi	0.03	0.24	0.06	0.12	0.14	–	–	–	0.03
Guizhou	0.07	0.15	0.07	0.10	0.12	–	–	–	0.06
Heilongjiang	0.18	0.14	0.16	0.20	0.11	0.14	0.15	0.14	0.12
Henan	0.11	0.10	0.08	0.13	0.17	0.15	0.10	0.12	0.05
Jiangsu	0.06	0.08	0.09	0.12	0.11	0.23	0.25	0.10	0.04
Liaoning	0.14	0.22	0.12	0.17	0.11	0.10	0.13	0.24	0.08
Ningxia	0.11	0.10	–	0.15	0.16	–	–	–	0.10
Qinghai	–	0.08	–	0.10	–	–	–	–	0.07
Shaanxi	0.07	0.11	0.09	0.10	0.12	0.14	0.13	0.09	0.07
Sichuan	0.05	0.08	0.07	0.10	0.08	0.13	–	–	0.05
Shandong	0.25	0.10	0.10	0.08	0.09	0.13	0.11	0.07	0.06
Shanghai	0.07	0.14	0.14	0.26	0.19	–	–	–	0.05
Shanxi	0.12	0.15	0.08	0.12	0.16	0.12	0.08	0.17	0.06
Tianjin	0.30	0.20	0.15	0.18	0.17	0.25	0.20	0.22	0.13
Xinjiang	0.09	0.08	0.07	0.19	0.17	0.10	0.26	0.14	0.06
Zhejiang	0.05	0.12	0.14	0.10	0.10	–	–	–	0.05
Other-regions	0.06	0.11	–	0.13	0.12	–	–	–	0.07
China	0.04	0.06	0.05	0.06	0.07	0.08	0.07	0.12	0.04

[1] Data not available.

Table 3.17: Output Variability Measured by APC5

	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-grains	Food-grain
Anhui	0.04	0.10	0.13	0.22	0.22	0.73	0.23	0.25	0.02
Hubei	0.03	0.05	0.04	0.07	0.15	0.19	0.17	0.08	0.02
Hunan	0.02	0.09	0.09	0.17	0.10	0.20	–[1]	–	0.02
Guangdong	0.01	4.09	–	0.05	0.04	–	–	–	0.01
Gansu	0.10	0.04	0.05	0.04	0.08	0.14	0.08	0.06	0.02
Guangxi	0.01	0.46	0.02	0.06	0.10	–	–	–	0.01
Guizhou	0.03	0.12	0.03	0.06	0.04	–	–	–	0.02
Heilongjiang	0.11	0.07	0.10	0.12	0.05	0.33	0.09	0.07	0.04
Henan	0.08	0.06	0.05	0.12	0.14	0.21	0.06	0.05	0.02
Jiangsu	0.02	0.04	0.03	0.05	0.04	1.53	0.75	0.06	0.01
Liaoning	0.11	0.24	0.14	0.17	0.05	0.12	0.07	4.87	0.05
Ningxia	0.09	0.05	–	0.11	0.11	–	–	–	0.03
Qinghai	0.00	0.04	–	0.05	–	–	–	–	0.02
Shaanxi	0.03	0.06	0.04	0.05	0.06	0.10	0.05	0.03	0.02
Sichuan	0.01	0.03	0.03	0.04	0.05	0.05	–	–	0.01
Shandong	0.99	0.06	0.05	0.03	0.07	0.16	0.11	0.07	0.02
Shanghai	0.03	0.14	0.09	0.58	0.28	–	–	–	0.02
Shanxi	0.06	0.15	0.04	0.06	0.15	0.06	0.02	0.10	0.02
Tianjin	30.57	0.18	0.11	0.36	0.17	0.81	0.27	1.85	0.07
Xinjiang	0.04	0.04	0.02	0.17	0.24	0.04	0.31	0.10	0.02
Zhejiang	0.02	0.08	0.09	0.07	0.05	–	–	–	0.02
Other-regions	0.02	0.06	–	0.13	0.27	–	–	–	0.03
China	0.01	0.03	0.02	0.02	0.02	0.04	0.02	0.12	0.01

[1] Data not available.

other crops, and the variability of a crop is inversely related to its importance. The similarities also indicate that stronger covariability may exist between output and yield than between output and area sown. It is reasonable to expect the covariability to be positive.

3.7 Variabilities of Area Sown, Yield and Output

In the past three sections, variabilities of area sown, yield and output were analysed separately. It seems necessary to put them together in order to reveal any relationships among them.

As noted yield variability is seemingly more strongly correlated with output variability than is sown-area variability. On the other hand, yield is more volatile than area sown. This is reflected in the larger values in Tables 3.12 to 3.14 compared with those in Tables 3.9 to 3.11. However, this does not necessarily lead to a conclusion that yield variability had more influence on output variability. The quantification of the relationship seems in order.

One way to estimate the relationship is to regress values in the columns of Table 3.15 (Table 3.16 and Table 3.17) on the corresponding values in the columns of Table 3.9 (Table 3.10 and Table 3.11) and Table 3.12 (Table 3.13 and Table 3.14). A third variable is the multiplicative interaction between yield and area sown variabilities. The addition of this variable is justified on ground that output variability is not only determined by area sown and yield variations, but also by their interaction.

Let V_{Qi} denote values in column i of Table 3.15, V_{Ai} and V_{Yi} denote values in column i of Tables 3.9 and 3.12 respectively. A linear multiple regression equation of the form

$$V_{Qi} = \beta_0 + \beta_1 V_{Ai} + \beta_2 V_{Yi} + \beta_3 V_{Ai} \times V_{Yi} + \mu \tag{3.1}$$

can be estimated for each crop or column i (i = 1, 2, 3, $\cdots$). This procedure can be repeated when variability is measured by MA (i.e., using Tables 3.16, 3.10 and 3.13) and by APC5 (i.e., using Tables 3.17, 3.11 and 3.14). The results are summarized in Tables 3.18 to 3.20.

Table 3.18: Regression of Output Variability on Sown-Area and Yield Variabilities when Variability Is Measured by APC5

Crop	β_0	β_1	β_2	β_3	R^2	D.F.
Rice	1.05	0.59	0.69	0.00	1.00	18
	(2.77)	(7.95)	(66.12)	(5.58)		
Wheat	3.55	0.44	-0.72	0.27	1.00	19
	(2.13)	(1.77)	(−5.46)	(38.81)		
Maize	1.46	0.64	0.95	-0.03	0.78	15
	(1.16)	(2.23)	(1.74)	(−0.35)		
Tubers	1.54	1.06	0.61	-0.01	0.94	19
	(1.18)	(5.25)	(7.14)	(−7.24)		
Soybeans	1.01	1.21	0.51	-0.02	0.91	18
	(0.69)	(8.79)	(0.97)	(−0.58)		
Sorghum	-1.39	1.12	0.40	0.11	0.97	11
	(−0.26)	(2.00)	(0.70)	(1.97)		
Millet	0.37	1.15	0.47	-0.01	0.99	9
	(0.29)	(6.43)	(10.20)	(−0.84)		
Other-grains	11.95	-1.05	-4.94	1.17	0.99	9
	(1.60)	(−1.99)	(−4.54)	(12.94)		
Foodgrain	-0.87	1.58	4.32	-2.49	0.96	19
	(−3.25)	(15.42)	(4.19)	(−6.87)		

Note: (1) Figures in brackets are t-ratios.

Table 3.19: Regression of Output Variability on Sown-Area and Yield Variabilities when Variability Is Measured by MA

Crop	β_0	β_1	β_2	β_3	R^2	D.F.
Rice	0.86	0.48	0.81	0.01	0.98	18
	(1.27)	(4.89)	(10.74)	(0.61)		
Wheat	-2.12	1.06	1.05	-0.04	0.94	19
	(−1.21)	(6.57)	(3.98)	(−2.01)		
Maize	-2.10	1.10	1.31	-0.09	0.85	15
	(−0.64)	(2.77)	(2.15)	(−1.36)		
Tubers	1.17	0.70	0.65	0.00	0.87	19
	(0.45)	(2.68)	(1.85)	(−0.06)		
Soybeans	2.16	0.79	0.14	0.02	0.86	18
	(0.50)	(2.04)	(0.20)	(0.33)		
Sorghum	3.58	0.21	0.41	0.05	0.93	11
	(0.81)	(0.53)	(0.89)	(1.34)		
Millet	-5.49	1.27	1.70	-0.07	0.93	9
	(−1.59)	(3.77)	(4.39)	(−2.03)		
Other-grains	-4.26	0.92	1.41	-0.03	0.94	9
	(−0.92)	(2.79)	(1.97)	(−0.67)		
Foodgrain	-0.94	1.24	0.48	-0.12	0.95	19
	(−0.67)	(5.87)	(0.70)	(−1.17)		

Note: (1) Figures in brackets are t-ratios.

Table 3.20: Regression of Output Variability on Sown-Area and Yield Variabilities when Variability Is Measured by CV2

Crop	β_0	β_1	β_2	β_3	R^2	D.F.
Rice	1.90	0.87	0.77	0.00	0.87	18
	(0.31)	(3.75)	(2.72)	(−0.43)		
Wheat	15.11	0.58	0.75	-0.01	0.43	19
	(1.06)	(1.53)	(1.23)	(−0.54)		
Maize	16.84	0.33	-0.35	0.03	0.55	15
	(0.70)	(0.43)	(−0.36)	(0.99)		
Tubers	1.54	0.59	0.96	-0.01	0.82	19
	(0.16)	(1.56)	(2.32)	(−0.56)		
Soybeans	15.70	0.26	0.16	0.00	0.19	18
	(1.50)	(0.62)	(0.47)	(−0.12)		
Sorghum	-10.02	0.89	0.80	-0.01	0.60	11
	(−0.48)	(1.39)	(1.33)	(−0.51)		
Millet	-26.27	1.46	1.49	-0.03	0.88	9
	(−1.30)	(1.52)	(3.12)	(−1.56)		
Other-grains	9.65	0.32	-0.09	0.01	0.43	9
	(0.36)	(0.35)	(−0.09)	(0.33)		
Foodgrain	-2.30	0.99	2.55	-0.07	0.76	19
	(−0.38)	(4.27)	(4.08)	(−3.11)		

Note: (1) Figures in brackets are t-ratios.

As expected, most of the coefficients of V_{Yi} and V_{Ai} are positive and significant at the 5 per cent significance level (see Tables 3.18 to 3.20). The only negative β_1 is from the equation for other-grains in Table 3.18. However, it is insignificant. Among the four negative β_2s (two from equations for other-grains, one for wheat and one for maize), two are not significant at any conventional significance level. It is noted that whenever β_2 is insignificant, the corresponding interaction coefficient (β_3) has a relatively large value and is more highly significant than otherwise. This implies that, in such case, the interaction term probably swamped the yield effect on the output variability.

It is rather surprising that the influence of yield variation on output instability is not as large as that of area sown, especially when variability is measured by APC5 (6 out of 9 β_2s are smaller than the corresponding β_1). Also, the t-ratios show that β_2s are generally less significant than β_1s. As one example, in Table 3.19, 6 out of 9 β_2s have smaller t-ratios than the corresponding β_1s do and 5 out of 9 β_2s are not significant at $\alpha = 0.05$ (vs 1 out of 9 for β_1). Further study seems needed to find the explanation to the counter-intuition results.

In examing the interaction terms, it is found that most of the interactions seem to have mitigating effects on output variability as there are 5, 6 and 7 nonpositive coefficients (out of 9) in column 4 of Tables 2.18, 2.19 and 2.20, respectively. However, more than one-half of the negative β_3s are not significant ($\alpha = 0.05$). In fact, most of the interation effects are very small and insignificant, especially as indicated in Table 2.20 (where 8 out of the 9 of β_3 are not significant).

The coefficients of determination indicate that all the models except four in Table 3.20 fit the data quite well.

3.8 Summary

Generally speaking, different single-variable measures do not provide consistent indications of variability. However, CV2, MA and APC5 can represent those measures as listed in Table 3.1 very well. These findings are based on the extensive consistency tests carried out which used a large amount of Chinese foodgrain production data.

Providing that CV2, MA and APC5 are adequate measures of intra-series variability, it can be concluded that (a) sown areas for grain crops in China were fairly stable and their instabilities were negatively related to government's controlling efforts; (b) location-oriented instabilities of yields were present. Yield ariability increased from the south to the north and from the east to the west. This probably resulted from the combined influences of weather conditions, government policies and management skills; (c) variations in area sown asserted larger impact on output variability than did variation in yield, and the interactions of these tended to have a stabilizing effect on output variability.

Chapter 4

COMPONENTS OF FOODGRAIN PRODUCTION VARIABILITY

4.1 Introduction

Relative variability of a single data set was considered in chapter 3. However, many economic variables are composed of the sum or product of more elementary time series. It should be useful for purposes of more insightful policy work to be able to determine a quantitative relationship among the instabilities of the components and the composite variable itself. This process can be called variability decomposition.

The main purpose of this chapter is to reveal the components of instabilities of total area sown and output of China's foodgrain. Since these two variables are simply the sum of their regional counterparts, variability decomposition techniques can be readily utilised.

As in the case of a measure of instability for a single variable, many indicators can be used to quantify the variability of a composite variable and allow for its decomposition. They may provide different results and thus lead to different conclusions. A brief discussion of decomposable measures of instability is presented in the next section. In section 4.3, the problem of data deficiencies will be addressed. Subsequently, the components of covariability contributing to the total variabilities of China's sown area and output of foodgrain are examined in section 4.4, and the regional distributions of the variabilities are explored in sections 4.5 and 4.6. Section 4.7 presents the main findings of this chapter.

4.2 Decomposable Measures of Instability

A composite variable can be defined by identity as

$$Y = f(X) \tag{4.1}$$

or by econometric modelling as

$$Y = f(X) + \mu, \tag{4.2}$$

where $X = (X_1, X_2, \cdots, X_n)$. For the purpose of this chapter, equation (4.1) will be used and is assumed to be a linear additive identity.

Brodsky (1980) classified measures of instability into two groups, namely, arithmetic and geometric measures. If an index is calculated from deviations of a variable from its trend, it is called an arithmetic measure. On the other hand, if an index is calculated from ratios of observed values to trend values, it is called a geometric measure. Whether a measure can be decomposed or not critically depends on the techniques of detrending. If the detrending process holds that the sum of the detrended components equals the detrended value of the composite variable, any arithmetic measure used will be decomposable. Conversely, if it holds that the product of detrended components equals the detrended product of the components, any geometric measure used would be decomposable. With a multiplicative equation, the logarithmic operation should be undertaken to transfer it to an additive equation.

Thus, most of the measures listed in Table 3.1 are decomposable after defining a composite variable net of trend simply as the sum or product of its detrended components. However, the different measures will lead to different outcomes. It may be preferable to seek an approach which results in the same decomposition result invariant to the instability measures employed.

To search for such a measure, Shorrocks (1982) imposed five seemingly reasonable assumptions. These are: (a) variability is zero if and only if the measured data set consists of identical observations; (b) the measure is continuous and provides consistent decomposition results with respect to any permutation of the components; (c) the decomposition results are independent of the level of disaggregation; (d) the contribution of components sums to total variability; and (e) if there are only two components and their distributions are identical, the contributions of the two components should be the same according to the measure used. Shorrocks (1982) has shown that any such variability measure will provide the same assessment of relative contributions to total variability. Such variability measures, however, are limited. The commonly used CV^2 is one of them which will be employed in this study.

The decomposition of CV^2 is based on variance decomposition (Shorrocks 1982). By taking variance on both sides of the equation

$$Y = \sum_{i=1}^{nr}\sum_{j=1}^{nc} X_{ij}, \tag{4.3}$$

the following equation,

$$\begin{aligned} Var(Y) &= \sum_{i=1}^{nr}\sum_{j=1}^{nc} Var(X_{ij}) \\ &+ 2\sum_{i=1}^{nr}\sum_{j=1}^{nc-1}\sum_{k=j+1}^{nc} Cov(X_{ij}X_{ik}) \\ &+ 2\sum_{j=1}^{nc}\sum_{i=1}^{nr-1}\sum_{l=i+1}^{nr} Cov(X_{ij}X_{lj}) \\ &+ 2\sum_{i=1}^{nr-1}\sum_{l=i+1}^{nr}\sum_{j=1}^{nc}\sum_{\substack{k\neq j\\ k=1}}^{nc} Cov(X_{ij}X_{lk}), \end{aligned} \tag{4.4}$$

is obtained where i, l and k, j are region and crop subscripts, nr and nc stand for number of regions and number of crops. In words, equation (4.4) states that total variance equals the sum of variance terms, plus the sum of covariances among crops within regions, plus the sum of covariances among regions within crops, plus the sum of covariances among regions and crops.

Equation (4.4) is inconvenient to deal with in partitioning variability because the covariance terms complicate matters. Shorrocks (1982, equation 3) suggests that a "natural" way to partition these terms is to allocate one-half of each covariance to each contributing variable. This would also appear to be logical given that absolute ignorance prevails with respect to whatever might be the truly appropriate allocation. Such a simplification then enables equation (4.4) to be re-written as

$$Var(Y) = \sum_{i=1}^{nr}\sum_{j=1}^{nc} Cov(Y, X_{ij}). \qquad (4.5)$$

The so-called mean-dependent or unit-dependent feature of variance and covariance is often considered undesirable in measuring variability where comparisions may need to be made across variables of differing means and units. Consequently, equation (4.5) can be transformed by dividing both sides by $\overline{Y}^2$, i.e.,

$$\begin{aligned} CV_Y^2 &= \frac{Var(Y)}{\overline{Y}^2} \\ &= \frac{\sum_{i=1}^{nr}\sum_{j=1}^{nc} Cov(Y, X_{ij})}{\overline{Y}^2}. \end{aligned} \qquad (4.6)$$

The relative contribution of X_{ij} to $Var(Y)$ can be denoted (Shorrocks 1982, equation 4) by $PC(X_{ij})$, where

$$\begin{aligned} PC(X_{ij}) &= \frac{Cov(Y, X_{ij})}{\overline{Y}^2} \div \frac{Var(Y)}{\overline{Y}^2} \times 100\% \\ &= \frac{Cov(Y, X_{ij})}{Var(Y)} \times 100\%. \end{aligned} \qquad (4.7)$$

It should be re-emphasized that this handling of interaction terms is arbitrary and, indeed, alternative methods can be proposed. For example, $Cov(X_i, X_j)$ could be partitioned according to the weights given by $Var(X_i)/(Var(X_i) + Var(X_j))$ and $Var(X_j)/(Var(X_i + Var(X_j))$ (W.E. Griffiths, personal communication, 1987). However, Shorrocks (1982) "natural" method is appealing and is defined as the modified CV^2 decomposition.

While equation (4.7) can be useful in attributing total variation of a composite variable among its components, equation (4.4) is particularly suitable for assessing the importance of

Table 4.1: A Hypothetical Production Table with Missing Data Sets

Region	Crop 1	Crop 2	Crop 3	Crop 4	Residual Crop	Sum
Region 1	R_{11}	M_{12}	R_{13}	M_{14}	RC_1	$R_{1.}$
Region 2	M_{21}	R_{22}	R_{23}	M_{24}	RC_2	$R_{2.}$
Region 3	R_{31}	R_{32}	R_{33}	M_{34}	RC_3	$R_{3.}$
Region 4	M_{41}	M_{42}	R_{43}	R_{44}	RC_4	$R_{4.}$
Residual Region	RR_1	RR_2	RR_3	RR_4	$RRRC$	0
Sum	$C_{.1}$	$C_{.2}$	$C_{.3}$	$C_{.4}$	0	Q

covariability in contributing to total variability. The covariabilities and their compositions can be useful in deriving policy implications as will be demonstrated in section 4.4.

4.3 Data Deficiencies and Variability Decomposition

Before proceeding, the problem of data deficiencies in variability decomposition must be addressed. To facilitate discussion, a hypothetical table is constructed. In Table 4.1, missing data sets are indicated by M_{ij} while R_{ij} is used to represent the available data, where i and j are region and crop subscripts respectively. Without loss of generality, four crops and four regions are assumed.

Two problems appear when applying equation (4.4) to the data of Table 4.1: (a) the sum of variances and covariances based on the data available does not equal the total variance for a crop or a region. For instance, $Var(R_{11}) + Var(R_{13}) + 2\,Cov(R_{11}, R_{13}) \neq Var(R_{1.})$; (b) total covariance within a crop or within a region or between crops and regions cannot be accurately computed, since $Cov(R_{ij}, M_{ij})$ cannot be calculated.

One way to attempt to circumnavigate these problems is to define a residual crop (region) for every region (crop). This residual crop (region) represents the difference between the crop (region) total and the sum of available data for the relevant region (crop). Since residual crop and residual region are artificially constructed, and their totals are nil, the residual region's residual crop ($RRRC$) has to be negative and equal to $(-1) \times \sum_i \sum_j M_{ij}$;

otherwise, Table 4.1 cannot be formulated consistently. While the physical meaning of $RRRC$ is not particularly clear in terms of logic, it does allow variance decomposition to be performed successfully. The value of $Var(RRRC)$ is interpreted as the contribution of missing data to the total variance. It is noted that $Var(RRRC)$ contains not only variances of M_{ij} but also covariances among the M_{ij}.

The problem of data deficiency is less severe in using modified CV^2 decomposition. This is primarily due to the non-existence of interaction terms in this method. In this case, the contribution of a residual crop (region) can be calculated as the difference between the regional (crop) total contribution and the sum of the contributions associated with the available data of the region (crop).

The data deficiency gives rise to an inevitable further problem when detrending is carried out. That is, the detrended regional data may never sum to the detrended national data. More precisely, detrended data cannot be uniquely defined for the residual region's residual crop if the residual region's total and residual crop's total remain zeros. That is because the sum of the detrended residual crops of all the regions cannot be identical to the sum of the detrended crop data of the residual region. To compromise, the detrending takes three steps: (a) At regional level, yield and area sown data are detrended for each crop (including the residual crop), and the detrended output is defined as the product of detrended yield and area sown; (b) The regional total net of trend is defined as the sum of detrended data of all crops including the residual crop of the region. Likewise, crop total net of trend is defined as the sum of detrended data of each region for the crop. However, the residual crop's total and residual region's total must still be set to zero; (c) Define the detrended $RRRC$ ($\widetilde{RRRC}$) as $-\frac{1}{2}(\sum_i \widetilde{RC}_i + \sum_j \widetilde{RR}_j)$ and the detrended national total ($\tilde{Q}$) as $\frac{1}{2}(\sum_i \tilde{R}_{i.} + \sum_j \tilde{C}_{.j})$, where $\sim$ denotes detrending operation. This procedure will produce inconsistent data for the residual crop and the residual region, that is, $\sum_i \widetilde{RC}_i + \widetilde{RRRC} \neq 0$ and $\sum_j \widetilde{RR}_j + \widetilde{RRRC} \neq 0$. Also the total national foodgrain cannot be equal to the sum of individual regions' crops, i.e., $\tilde{Q} \neq \sum_i \sum_j \tilde{R}_{ij} + \sum_i \widetilde{RC}_i + \sum_j \widetilde{RR}_j + \widetilde{RRRC}$. Whether or not any such inconsistencies are negligible or not is an empirical question that is addressed in the following sections.

4.4 Components of Variability

National production of foodgrain and area sown for foodgrain are defined as the sum of outputs and sown areas, respectively, of all crops of all regions. That is,

$$Q = \sum_{i=1}^{nc} \sum_{k=1}^{nr} Q_{ik}, \tag{4.8}$$

$$A = \sum_{i=1}^{nc} \sum_{k=1}^{nr} A_{ik}, \tag{4.9}$$

where Q denotes output, A sown area, and i, k are subscripts respectively for regions and crops. By taking variance on both sides of equations (4.8) and (4.9), the total variance of China's foodgrain production and sown area is shown to be composed of variances of nc crops of nr regions. covariances among crops within regions, covariances among regions within crops and covariances among crops and regions (section 4.2).

Throughout this section, variability is represented by variance and covariability by covariance. They are both calculated from detrended data.

4.4.1 Variability of area-sown and its components

Applying variance decomposition to equation (4.9), components of the total variability of China's foodgrain sown area are calculated. Since the individual variances sum to 2916×10^8 mu^2, which is only about 43 per cent of the total variability, the variance terms alone do not provide an accurate description of the spatial distribution of the total variability of area sown. The full decomposition result is presented in Appendix B, while the summarised outcome is shown in Table 4.2.

Table 4.2 shows that covariance among regions dominates the total covariability and even the total variability. As expected, this value is positive. This is because all regional plans have been based on the central government's plan. The improvement in crop varieties also probably led to simultaneous changes among regions in their sown area for some crops.

The arguments in the preceding paragraph are more evident according to Table 4.3, which gives the percentage contribution to total variability made by each crop in terms of variance and covariance. It is seen that all covariance sums but that for residual grain

Table 4.2: Components of Area Sown Variability
(Percentage)

	Component	Contribution
1.	Total variance	42.95
2.	Covariance	
	Among crops	−20.51
	Among regions	101.85
	Among crops & regions	−24.29
	Sum	57.05
3.	Total variability	100.00

Note: Based on equation (4.4).

Table 4.3: Components of Sown-Area Variability by Crop
(Percentage)

Crop	Sum of Variances	Sum of Covariances	Sum
Rice	4.62	27.21	31.83
Wheat	4.26	7.43	11.69
Maize	5.29	11.14	16.43
Tubers	1.39	2.89	4.28
Soybeans	2.20	7.83	10.03
Sorghum	1.87	8.70	10.57
Millet	1.89	6.42	8.31
Other-grains	11.21	40.34	51.55
Residual grain	10.11	−10.12	−0.01

Note: (1) The sum of variances is the sum of single variance terms of all regions for a given crop. The sum of covariances is the sum of covariances among regions for a given crop

(2) The third column does not sum to 100 since covariances among crops of different regions and covariances among crops and regions are not included in the table.

are positive. More importantly, the covariance dominates the variability of all crops with the residual crop as an exception. Residual crop and residual region are only defined in order to obtain more accurate results, and the decomposition outcomes relevant to them can, it is assumed in this thesis, be ignored. It is worth noting that the large variability of other-grains is probably due to the lack of government control and the variability of rice to its expansion in the 1960s and adjustment in recent years.

The negative covariance among crops in Table 4.2 is as expected. As total area sown is a constant for each season, increases in area sown for some crops will lead to decreases in other crops unless these crops are not planted in the same season. The absolute value of the covariance among crops is the smallest among the components of total variability (Table 4.2). This probably means that changes in allocation of land among crops of a region were made with caution by the regional governments. The root cause of this resulted from the foodgrain self-sufficiency policy of provincial governments.

From Table 4.4, 12 out of 22 regions had negative covariances among crops. On the other hand, all the regions had nonnegative variability as shown in the last column of Table 4.4. Therefore, regional contribution to the total variability of area sown was not dominated by covariabilities. However, some of the positive covariances among crops as shown in Table 4.4 exceed 50 per cent of the row sum and their nature needs further investigation.

The covariance among crops and regions is of slightly greater magnitude than that among crops. It comes as no surprise that this value is also negative since the positive covariance among regions of crops and the negative covariance among crops of regions suggest, on balance, a negative covariance among crops and regions. To explain briefly, as share of sown area for a crop rises, the positive covariance among regions implies that the majority or all of the regions raise shares of area sown for this crop. Meanwhile, the negative covariance among crops indicates that sown areas for some or all of the other crops would decrease. These effects normally lead to a negative correlation of sown areas among crops and regions.

Table 4.4: Components of Sown-Area Variability by Region
(Percentage)

Region	Sum of Variances	Sum of Covariances	Sum
Anhui	1.85	1.63	3.48
Hubei	1.25	-0.70	0.55
Hunan	1.22	-0.45	0.77
Guangdong	0.29	0.18	0.47
Gansu	0.13	-0.11	0.02
Guangxi	0.33	0.03	0.36
Guizhou	0.08	0.01	0.09
Heilongjiang	1.15	-0.03	1.12
Henan	2.40	2.36	4.76
Jiangsu	1.53	-0.12	1.41
Liaoning	0.63	-0.21	0.42
Ningxia	0.01	0.00	0.01
Qinghai	0.00	0.00	0.00
Shaanxi	0.19	-0.01	0.18
Sichuan	1.27	-0.23	1.04
Shandong	2.63	0.82	3.45
Shanghai	0.01	0.00	0.01
Shanxi	0.23	0.04	0.27
Tianjin	0.01	-0.01	0.00
Xinjiang	0.24	0.10	0.34
Zhejiang	0.18	-0.11	0.07
Other-regions	7.01	-3.48	3.53
Residual Region	20.20	-20.20	0.00

Note: (1) The sum of variances is the sum of single variance terms of all crop for a given region. The sum of covariances is the sum of covariances among crops for a given region.

(2) The third column does not sum to 100 since covariances among regions and covariances among crops and regions are not included in the table.

Table 4.5: Components of Output Variability
(Percentage)

	Component	Contribution
1.	Total variance	5.65
2.	Covariance	
	Among crops	2.53
	Among regions	29.16
	Among crops & regions	62.66
	Sum	94.35
3.	Total variability	100.00

Note: Based on equation (4.4)

4.4.2 Variability of output and its components

The dominance of covariance becomes more obvious in the case of output variability than in the case of sown area. A majority of the individual variances' shares are approximately only 0.00 per cent of the total variability (see Appendix B). Under such circumstance, variance decomposition without covariance partition provides very limited information on the regional distribution of variability.

From Table 4.5, it is apparent that covariance among crop outputs shares the least of the total variability (2.53 per cent) and that covariance among crops and regions constitutes the largest share (62.66 per cent) of the total variability or 77.0 per cent of total covariability. This leaves 5.65 per cent of the total variability attributable to individual variances and 29.16 per cent to covariability among regions.

As for sown area variability, covariance of rice output among regions is notably large (Table 4.6). It shares 20.39 per cent, 21.61 per cent and 69.92 per cent of total variability, total covariability and total covariability among regions, respectively. Wheat and maize are close in terms of contribution to total output variability. The other crops share a negligible amount of total variability. This pattern could in part be the consequence of using these mean-dependent measures of variability.

Table 4.6: Components of Total Output Variability by Crop
(Percentage)

Crop	Sum of Variances	Sum of Covariances	Sum
Rice	2.45	20.39	22.84
Wheat	0.61	4.92	5.53
Maize	0.94	4.48	5.42
Tubers	0.23	0.34	0.57
Soybeans	0.01	0.02	0.03
Sorghum	0.02	0.04	0.06
Millet	0.01	0.02	0.03
Other-grains	0.26	0.01	0.27
Residual Grain	1.06	−1.07	−0.01

Note: (1) The sum of variances is the sum of single variance terms of all regions for a given crop. The sum of covariances is the sum of covariances among regions for a given crop

(2) The third column does not sum to 100 since covariances among crops of different regions and covariances among crops and regions are not included in the table.

It appears that the covariance among regions of a crop is positively related to the importance of the crop as indicated by the percentage values in the third column of Table 4.6. This again suggests that the central government concentrated on planning production of major crops and that policy change is one of the most important elements in causing output fluctuations. In China, policy changes over the years from 1949 to 1985 have altered investment, input supply, consumption and prices. The changes in these factors often resulted in more or less similar influence on all regions, as intuitively conforms with casual observation of recent Chinese history. This obviously leads to a positive covariance among regions of rice and other crops' outputs. Other important elements promoting the positiveness of the covariance include technology advancement (especially variety replacement) and environmental factors, e.g., weather, pest, disease, etc.. As in the case of area sown, Table 4.6 shows the predominance of covariance in composing the contribution to total output variability made by each of the three major crops (rice, wheat and maize).

According to Table 4.7, the summed covariance contribution among crops is small for most of the regions. One might expect covariance among crops to be negative, considering the negative covariance of area sown among crops. In the author's opinion, the negative effect of covariance among area sown could be swamped by the positive effect of yield covariance among crops which attributes much to the cyclic nature of weather conditions. The weather influence and small negative covariance of sown areas among crops has, it is thought, led to the small, though positive, covariance among crop outputs of regions.

The large positive output covariance among crops and regions and its negative sown area counterpart mean that yield correlations among crops and regions are positive and strong. Factors affecting these correlations include technology advancement, increased use of modern inputs, policy environment, capital construction and weather conditions. One important element of technology is variety replacement, which may contribute substantially to the positive correlations. Increased use of inputs has, in part, been associated with variety changes, especially in the 1960s when the 'green revolution' was happening. As far as policy is concerned, its influence on crop outputs is substantial and nation-wide in China. One notable example is the enhanced jumps and fluctuations of foodgrain output

Table 4.7: Components of Total Output Variability by Region (Percentage)

Region	Sum of Variances	Sum of Covariances	Sum
Anhui	0.18	0.20	0.38
Hubei	0.25	0.10	0.35
Hunan	0.50	0.07	0.57
Guangdong	0.22	0.04	0.26
Gansu	0.01	0.01	0.02
Guangxi	0.13	0.03	0.16
Guizhou	0.01	0.02	0.03
Heilongjiang	0.08	0.14	0.22
Henan	0.25	0.38	0.63
Jiangsu	0.35	0.41	0.76
Liaoning	0.08	0.08	0.16
Ningxia	0.00	0.00	0.00
Qinghai	0.00	0.00	0.00
Shaanxi	0.02	0.04	0.06
Sichuan	0.29	0.67	0.96
Shandong	0.29	0.39	0.68
Shanghai	0.00	0.00	0.00
Shanxi	0.02	0.04	0.06
Tianjin	0.00	0.00	0.00
Xinjiang	0.01	0.01	0.02
Zhejiang	0.18	0.05	0.23
Other-regions	1.26	1.31	2.57
Residual Region	1.46	-1.46	0.00

Note: (1) The sum of variances is the sum of single variance terms of all crops for a given region. The sum of covariances is the sum of covariances among crops for a given region.

(2) The third column does not sum to 100 since covariances among regions and covariances among crops and regions are not included in the table.

since economic reform started in 1978. These jumps and fluctuations were predominantly caused by the changes in the state foodgrain purchasing policy and price policy.

4.5 Spatial Distribution of Foodgrain Variability

In this section, modified CV^2 decomposition is used to reveal the spatial distribution of variability of total sown area and output. Variability distribution for a given crop or region is also examined. In using the modified CV^2 decomposition technique, the residual crop's contribution is simply the regional contribution minus the contributions made by those crops for which data are available. The residual region's contribution is analogously obtained.

In this section, variability is represented by CV^2.

4.5.1 Spatial distribution of sown-area variability

The distribution of total sown area variability by crops and regions is presented in Table 4.8. The results show that, excluding the other-regions (which is made up of the sum of eight regions), Henan contributed most to the total variability of area sown, followed by Anhui, Shandong, Jiangsu and Sichuan. It is probably not coincidental that these rankings are closely consistent with the rankings of regional population. This is because changes in area sown of a region are mainly attributable to changes in population (Carter and Zhong 1988). Given that the Chinese population was not at all mobile over the period under study, a large population will imply large changes in area sown. The rankings may also be positively related to the density of population and mean level of sown area of a region. This is seen by the negative values for Heilongjiang, Ningxia, Qinhai and Xinjiang, whose population density and/or mean levels of area sown are among the lowest in China.

In terms of crops, a reverse relationship between variability and importance of a crop is again apparent. For instance, other-grains alone accounted for about 40 per cent of the total variability, while both rice and maize are seemingly stabilizing total production. This is also true at the regional level, since the number of negative values decreases from crop column 1 to column 9 in Table 4.8. However, as the central government has already realized that

Table 4.8: Distribution of Sown-Area Variability by Crop and Region (Percentage)

Region	Rice	Wheat	Maize	Tubers	Soy-bean	Sor-ghum	Millet	Other-Grain	Residual Grain	Sum
Anhui	1.52	4.58	0.74	0.74	1.80	1.28	0.30	6.03	0.00	16.99
Hubei	-2.06	0.48	0.40	-0.24	0.52	0.17	0.46	3.59	0.00	3.32
Hunan	-1.33	0.24	-0.10	0.97	0.25	0.01	na	0.00	1.89	1.94
Guangdong	2.15	0.57	na[1]	1.85	-0.01	na	na	0.00	0.62	5.19
Gansu	0.02	-0.65	0.81	-0.15	0.06	0.12	0.40	0.66	0.00	1.27
Guangxi	-0.17	1.04	0.39	1.33	0.03	na	na	0.00	0.54	3.16
Guizhou	0.25	-0.49	0.16	-0.24	0.04	na	na	0.00	0.55	0.27
Heilongjiang	0.30	-4.01	-1.31	0.03	-0.43	1.19	0.45	1.01	0.00	-2.77
Henan	0.51	5.46	-0.51	-0.35	4.00	1.61	1.53	5.50	0.00	17.77
Jiangsu	-0.94	2.75	0.92	0.32	2.17	0.74	0.24	4.23	0.00	10.44
Liaoning	-0.66	0.22	-0.49	0.31	1.20	1.55	1.03	0.55	0.00	3.70
Ningxia	0.04	-0.40	na	-0.07	0.06	na	na	0.00	0.26	-0.11
Qinghai	0.00	-0.20	0.00	0.04	0.00	0.00	na	0.00	0.05	-0.11
Shaanxi	-0.01	0.30	0.34	-0.51	0.66	0.05	0.62	1.48	0.00	2.92
Sichuan	2.28	-1.46	0.64	-0.54	0.38	0.16	na	0.00	4.09	5.54
Shandong	-0.39	2.79	-1.07	-0.68	5.08	2.07	2.94	1.91	0.00	12.65
Shanghai	-0.30	0.12	-0.04	0.02	0.01	na	na	0.00	0.02	-0.17
Shanxi	-0.01	1.16	-0.45	0.02	1.32	-0.10	0.97	0.98	0.00	3.89
Tianjin	0.14	-0.05	-0.15	0.02	0.07	0.06	0.02	0.03	0.00	0.13
Xinjiang	-0.09	-2.86	-0.82	-0.05	-0.02	-0.04	0.00	0.24	0.00	-3.63
Zhejiang	-1.23	0.16	0.44	0.20	0.29	0.00	na	0.00	1.04	0.89
Other-regions	-0.35	-0.94	0.00	5.17	5.83	0.00	0.00	0.00	6.97	16.67
Residual Region	0.00	0.00	-5.22	0.00	0.00	1.97	5.66	13.71	-16.08	0.00
China	-0.34	8.82	-5.29	8.17	23.30	10.83	14.63	39.93	0.00	100.00

[1] Data not available.

Note: Based on equation (4.7).

Source: Calculated from the regional data.

coarse grains are of particular importance in developing animal husbandry and improving nutrition, the reverse relationship is expected to become less significant in the future.

Table 4.8 indicates that, except for the other-regions and Xinjiang, every negative value in crop column 1 corresponds to a positive value in column 2 and every negative value in column 2 corresponds to a positive value in column 1. It is also seen that all the negative values in column 1 are associated with major rice growing regions (southern part of China) and those in column 2 with major wheat growing regions (mostly in the north of China). This shows that local governments are consistent with the central government in directing major attention to major crops and stabilising their sown areas.

It must be mentioned that values in Table 4.8 only indicate the components of national sown-area variability. A variability decomposition for each region or crop may be useful in some cases.

The compositions of sown area variability for each region are presented in Table 4.9. It seems that, for any given region, major crops dominate the regional sown area variability. To illustrate, for the major rice growers such as Hunan, Zhejiang, Guangdong, Guangxi and Shanghai, over 50 per cent of regional sown area variability is due to rice. The same applies to the major wheat growers such as Heilongjiang, Ningxia and Guizhou.

Regional sown area variability was dominated by variations in area sown for other-grains in Gansu, Shaanxi, Jiangsu, Shanxi and Henan. This may be understandable because (a) other-grains were overlooked by the government and its area-sown changed dramatically from year to year; (b) other-grains occupied a substantial share of total sown area in each of the above-mentioned regions. For instance, in 1985 nearly 25 per cent of sown area was planted with other-grains in Gansu. It is noted that area-sown shared by other-grains has been decreasing from 1949 to 1985 in every region; (c) data quality of other-grains were particularly poor. In some cases, these data were pure guesses. Conversely, they were often arbitrarily adjusted in order to keep the overall consistency of regional foodgrain production data.

The mean-oriented variability is even more clear when variability for each crop is decomposed (Table 4.10). For example, five major rice growers (Jiangsu, Hunan, Hubei, Anhui

Table 4.9: Distribution of Regional Sown-Area Variability
(Percentage)

Region	Rice	Wheat	Maize	Tubers	Soy-bean	Sor-ghum	Millet	Other-Grain	Residual Grain	Sum
Anhui	1.55	26.63	3.77	4.26	8.24	9.71	2.07	43.77	0.00	100.00
Hubei	17.55	24.46	6.53	5.82	3.80	1.74	3.32	36.78	0.00	100.00
Hunan	96.76	-0.79	-2.37	6.87	3.08	-0.52	na	0.00	-3.02	100.00
Guangdong	53.07	22.08	na[1]	17.85	1.97	na	na	0.00	5.03	100.00
Gansu	1.22	-30.75	26.40	-7.63	4.65	0.82	21.80	83.50	0.00	100.00
Guangxi	59.94	10.99	16.66	2.48	5.07	na	na	0.00	4.86	100.00
Guizhou	12.29	55.74	1.60	31.67	2.11	na	na	0.00	-3.42	100.00
Heilongjiang	1.45	71.92	28.98	3.29	19.22	-13.05	-2.89	-8.93	0.00	100.00
Henan	-0.31	26.80	-13.92	-4.19	21.18	16.33	12.66	41.45	0.00	100.00
Jiangsu	-26.21	23.27	9.92	3.38	27.02	12.45	3.16	47.01	0.00	100.00
Liaoning	-25.11	5.55	-33.98	8.93	19.77	56.16	41.03	27.64	0.00	100.00
Ningxia	7.56	71.06	na	16.88	3.48	na	na	0.00	1.02	100.00
Qinghai	0.00	33.48	0.00	6.27	0.00	0.00	na	0.00	60.25	100.00
Shaanxi	-2.14	4.91	15.02	-25.28	22.49	-3.13	23.27	64.87	0.00	100.00
Sichuan	30.75	28.04	20.55	11.68	2.04	-1.13	na	0.00	8.06	100.00
Shandong	-3.80	10.16	-28.54	-1.52	46.99	31.34	28.77	16.59	0.00	100.00
Shanghai	91.81	-2.40	3.02	-2.49	-6.99	na	na	0.00	17.06	100.00
Shanxi	-0.58	22.89	-22.09	0.27	28.93	-1.79	30.44	41.93	0.00	100.00
Tianjin	-24.70	47.73	53.85	-2.92	-3.29	21.02	7.39	0.90	0.00	100.00
Xinjiang	3.07	77.47	21.75	0.96	0.88	1.32	-0.03	-5.42	0.00	100.00
Zhejiang	92.42	-1.05	1.16	2.40	-7.99	0.00	na	0.00	13.06	100.00
Other-regions	7.27	4.91	0.00	22.71	28.87	0.00	0.00	0.00	36.24	100.00
Residual Region	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	-0.34	8.82	-5.29	8.17	23.30	10.83	14.63	39.93	0.00	100.00

[1] Data not available.

Note: Based on equation (4.7) where i is given.

Source: Calculated from the regional data.

Table 4.10: Spatial Distribution of Area Sown Variability by Crop (Percentage)

Region	Rice	Wheat	Maize	Tubers	Soy-bean	Sor-ghum	Millet	Other-Grain	Residual Grain	Food-grain
Anhui	8.78	1.93	0.72	6.92	5.61	10.57	1.29	12.35	0.00	16.99
Hubei	13.69	4.35	-1.76	0.82	2.40	1.14	2.52	8.92	0.00	3.32
Hunan	17.46	-0.46	-0.56	7.04	1.13	0.11	na	0.00	0.00	1.94
Guangdong	2.41	4.26	na[1]	6.54	-0.59	na	na	0.00	0.00	5.19
Gansu	-0.01	4.69	-0.82	0.39	0.23	0.39	2.08	2.55	0.00	1.27
Guangxi	8.14	0.93	1.57	7.98	-0.25	na	na	0.00	0.00	3.16
Guizhou	1.02	3.93	0.47	2.25	0.05	na	na	0.00	0.00	0.27
Heilongjiang	0.62	15.74	8.21	0.20	-2.08	6.17	4.36	1.63	0.00	-2.77
Henan	1.74	2.39	11.39	1.89	15.43	13.15	11.79	13.41	0.00	17.77
Jiangsu	13.52	0.79	-2.24	2.39	11.11	6.17	1.51	8.26	0.00	10.44
Liaoning	3.16	-0.49	7.14	1.64	4.34	14.33	9.56	2.45	0.00	3.70
Ningxia	0.03	1.52	na[1]	0.18	0.18	na	na	0.00	0.00	-0.11
Qinghai	0.00	1.42	0.00	0.53	0.00	0.00	na	0.00	0.00	-0.11
Shaanxi	0.23	1.13	0.36	-0.36	3.07	0.30	3.65	4.13	0.00	2.92
Sichuan	4.24	14.53	5.62	8.58	1.11	1.11	na	0.00	0.00	5.54
Shandong	1.72	5.40	17.28	7.88	26.36	20.04	19.33	4.92	0.00	12.65
Shanghai	1.68	0.01	0.02	0.18	0.22	na	na	0.00	0.00	-0.17
Shanxi	0.08	-0.27	4.60	2.41	5.66	0.57	6.15	3.69	0.00	3.89
Tianjin	-0.34	1.43	1.48	0.38	0.45	1.70	0.12	0.09	0.00	0.13
Xinjiang	0.25	7.15	2.72	0.01	-0.09	0.04	0.05	0.74	0.00	-3.63
Zhejiang	6.37	-0.24	-0.60	1.68	1.43	0.00	na	0.00	0.00	0.89
Other-regions	15.20	29.87	0.00	40.46	24.23	0.00	0.00	0.00	0.00	16.67
Residual Region	0.00	0.00	44.39	0.00	0.00	24.22	37.59	36.85	0.00	0.00
China	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00	100.00

[1] Data not available.

Note: Based on equation (4.7) where j is given.

Source: Calculated from the regional data.

and Zhejiang) shared 60 per cent of total rice variability, while two major wheat-growing regions (Heilongjiang and Sichuan) shared 30 per cent of total wheat variability.

It is noted that the available 21-region data explain 84.80, 70.13, 55.61, 59.54, 75.77, 75.78, 65.41 63.15 and 83.33 per cent of the total area sown variabilities of rice, wheat, maize, tubers, soybeans, sorghum, millet, other-grains and total foodgrain, respectively (Table 4.14). This indicates that the analysis of sown area variability of Chinese foodgrain suffers little from the data deficiencies.

4.5.2 Spatial distribution of output variability

Contrary to the case of sown area variability, outputs for important crops are more volatile than those for less important ones. Thus, a positive relationship between the importance

Table 4.11: Distribution of Output Variability by Crop and Region (Percentage)

Region	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other--grain	Residual Grain	Sum
Anhui	3.58	1.46	0.19	0.95	0.18	-0.13	-0.01	-0.23	0.00	5.99
Hubei	4.74	0.82	0.24	0.27	0.00	-0.01	-0.06	-0.17	0.00	5.83
Hunan	6.97	0.08	0.05	0.30	0.05	0.00	na	0.00	0.01	7.46
Guangdong	4.55	0.13	na[1]	0.28	0.04	na	na	0.00	0.02	5.02
Gansu	0.00	1.04	0.29	0.06	0.01	0.03	-0.01	0.05	0.00	1.47
Guangxi	3.53	0.01	0.34	-0.08	0.03	na	na	0.00	0.09	3.92
Guizhou	0.63	0.16	0.57	0.16	0.02	na	na	0.00	0.01	1.56
Heilongjiang	0.22	1.47	1.84	0.08	0.44	0.00	0.14	0.04	0.00	4.22
Henan	0.85	4.06	1.99	1.35	0.08	-0.23	-0.09	-0.21	0.00	7.80
Jiangsu	5.31	1.89	0.51	0.40	-0.08	-0.10	-0.04	0.76	0.00	8.66
Liaoning	1.15	0.01	2.16	-0.06	-0.04	0.63	-0.11	0.03	0.00	3.76
Ningxia	0.12	0.20	na	0.00	0.00	na	na	0.00	0.04	0.37
Qinghai	0.00	0.23	0.00	-0.01	0.00	0.00	na	0.00	0.04	0.26
Shaanxi	0.19	1.05	0.93	0.26	-0.01	0.09	0.02	-0.02	0.00	2.52
Sichuan	3.83	2.01	1.85	1.44	0.07	0.04	na	0.00	0.33	9.57
Shandong	0.38	3.53	3.08	2.06	-0.25	-0.28	-0.29	-0.11	0.00	8.11
Shanghai	0.56	0.05	0.01	-0.01	-0.01	na	na	0.00	0.14	0.75
Shanxi	0.03	0.60	0.94	0.13	-0.04	0.43	0.14	0.09	0.00	2.31
Tianjin	-0.01	0.14	0.23	0.01	0.01	0.06	0.01	0.01	0.00	0.45
Xinjiang	0.10	0.76	0.46	0.00	0.01	0.01	0.00	-0.01	0.00	1.34
Zhejiang	4.07	0.19	0.00	0.13	0.00	0.00	na	0.00	0.19	4.58
Other-regions	6.78	3.12	0.00	-1.45	-0.02	0.00	0.00	0.00	5.70	14.14
Residual Region	0.00	0.00	7.04	0.00	0.00	0.38	0.11	-1.15	-6.48	0.00
China	47.58	23.02	22.73	6.28	0.49	0.93	-0.20	-0.93	0.00	100.00

[1] Data not available.

Note: Based on equation (4.7).

Source: Calculated from the regional data.

of a crop and its variability may exist (Table 4.11). This leads to the conclusion that yield variability played an important role for important crops, while area sown variability played an important role for less important crops. However, the yield variability may be mean-oriented since more important crops yield twice as much or more than the less important ones do. Generally speaking, rice variability dominates the southern regions' output variability and wheat variability dominates the northern regions' output variability. From Table 4.11, Jiangsu rice variability was responsible for 61.31 per cent of the regional contribution, Zhejiang 88.80 per cent, and Hunan 93.43 per cent. In the north, Shandong wheat was responsible for 43.52 per cent of the regional contribution, Henan 52.05 per cent and Heilongjiang 34.83 per cent.

The preceding arguments also hold when decomposition is undertaken for each region

Table 4.12: Variability Distribution of Regional Output (Percentage)

Region	Rice	Wheat	Maize	Tubers	Soy-beans	Sor-ghum	Millet	Other-Grain	Residual Grain	Sum
Anhui	60.01	23.00	3.20	15.61	3.46	-1.67	-0.17	-3.45	0.00	100.00
Hubei	81.31	13.37	4.15	4.73	0.08	-0.19	-1.02	-2.43	0.00	100.00
Hunan	93.37	1.07	0.60	4.15	0.65	0.04	na	0.00	0.12	100.00
Guangdong	91.01	2.53	na[1]	5.33	0.74	na	na	0.00	0.39	100.00
Gansu	0.17	65.91	20.68	4.74	0.76	2.94	0.02	4.78	0.00	100.00
Guangxi	89.76	0.15	8.80	-2.02	0.77	na	na	0.00	2.54	100.00
Guizhou	45.15	8.76	33.91	9.85	1.42	na	na	0.00	0.92	100.00
He longjiang	4.84	31.05	43.95	2.53	10.25	1.29	4.83	1.26	0.00	100.00
Henan	10.89	50.69	25.21	17.71	1.36	-2.67	-0.87	-2.33	0.00	100.00
Jiangsu	61.69	21.70	5.86	4.48	-0.94	-1.08	-0.44	8.74	0.00	100.00
Liaoning	27.84	0.46	57.54	-1.59	-0.56	18.11	-2.57	0.77	0.00	100.00
Ningxia	31.93	53.08	na	-0.46	0.71	na	na	0.00	14.74	100.00
Qinghai	0.00	81.82	0.00	-0.15	0.00	0.00	na	0.00	18.33	100.00
Shaanxi	7.50	41.83	36.61	10.24	-0.27	3.72	0.63	-0.26	0.00	100.00
Sichuan	41.10	20.04	19.01	14.77	0.80	0.46	na	0.00	3.81	100.00
Shandong	4.66	43.53	37.13	25.28	-2.87	-2.95	-3.44	-1.34	0.00	100.00
Shanghai	76.40	6.30	1.90	-0.83	-0.97	na	na	0.00	17.20	100.00
Shanxi	1.10	25.61	40.34	5.54	-1.75	18.91	6.14	4.12	0.00	100.00
Tianjin	3.07	27.65	46.49	1.48	1.52	15.47	1.96	2.36	0.00	100.00
Xinjiang	6.91	58.18	33.77	0.35	0.58	0.68	-0.04	-0.44	0.00	100.00
Zhejiang	88.48	4.26	0.10	2.83	0.12	0.00	na	0.00	4.21	100.00
Other-regions	42.74	18.12	0.00	-1.35	1.38	0.00	0.00	0.00	39.12	100.00
Residual Region	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	47.58	23.02	22.73	6.28	0.49	0.93	-0.20	-0.93	0.00	100.00

[1] Data not available.

Note: Based on equation (4.7) where i is given.

Source: Calculated from the regional data.

separately. This is seen by comparing values in Table 4.12 against those in Table 4.11. It is found that, in both tables, the first three crop columns contain larger values than do other columns and there is only one very small negative value in the first three columns. Also, most of the negative values in Table 4.12 correspond to negative values in Table 4.11 and a large value in column 1 corresponds to a small value in column 2 in Table 4.12. This implies that, unlike in the case of area sown, output covariances between a crop of a region and crops out of the region are not of significant impact on the spatial distribution of output variability. It may alternatively mean that these covariances, though dominating the total variability (cf. Table 4.5), had a balanced impact (i.e., of similar magnitude) on each crop of individual regions [cf. equations (4.10) and (4.11)].

Turning to components of variability for a given crop, the interesting finding is that

Table 4.13: Spatial Distribution of Output Variability by Crop
(Percentage)

Region	Rice	Wheat	Maize	Tubers	Soy-bean	Sor-ghum	Millet	Other-Grain	Residual Grain	Food-grain
Anhui	7.60	6.41	0.80	11.33	10.14	2.69	0.46	1.30	0.00	5.99
Hubei	10.00	3.62	1.04	3.24	0.76	0.38	1.33	2.96	0.00	5.83
Hunan	14.59	0.36	0.20	4.47	1.23	-0.07	na	0.00	0.00	7.46
Guangdong	9.60	0.49	na[1]	3.43	0.19	na	na	0.00	0.00	5.02
Gansu	0.00	4.40	1.24	0.87	0.32	1.85	2.02	0.86	0.00	1.47
Guangxi	7.44	0.02	1.48	0.18	1.00	na	na	0.00	0.00	3.92
Guizhou	1.33	0.68	2.46	2.47	0.61	na	na	0.00	0.00	1.56
Heilongjiang	0.42	6.24	8.06	1.05	16.00	3.38	9.84	0.58	0.00	4.22
Henan	1.80	17.56	8.80	15.09	13.04	2.02	11.69	1.51	0.00	7.80
Jiangsu	11.22	8.26	2.13	4.74	3.85	0.50	1.17	-3.18	0.00	8.66
Liaoning	2.40	0.07	9.56	-0.41	6.40	27.86	7.37	0.33	0.00	3.76
Ningxia	0.26	0.88	na	-0.02	0.24	na	na	0.00	0.00	0.37
Qinghai	0.00	0.96	0.00	0.05	0.00	0.00	na	0.00	0.00	0.26
Shaanxi	0.40	4.63	4.04	2.92	1.48	4.31	0.83	0.40	0.00	2.52
Sichuan	8.07	8.65	7.95	18.51	1.86	0.43	na	0.00	0.00	9.57
Shandong	0.81	15.44	13.49	24.17	10.03	6.38	20.57	1.59	0.00	8.11
Shanghai	1.18	0.23	0.05	-0.03	-0.28	na	na	0.00	0.00	0.75
Shanxi	0.06	2.77	4.18	1.83	3.00	11.13	4.14	0.27	0.00	2.31
Tianjin	-0.02	0.61	0.99	0.10	0.32	3.02	0.38	-0.03	0.00	0.45
Xinjiang	0.20	3.32	1.98	0.09	0.08	0.30	0.05	0.32	0.00	1.34
Zhejiang	8.56	0.82	0.00	2.20	0.19	0.00	na	0.00	0.00	4.58
Other-regions	14.07	13.58	0.00	3.72	29.54	0.00	0.00	0.00	0.00	14.14
Residual Region	0.00	0.00	31.53	0.00	0.00	35.82	40.17	93.07	0.00	0.00
China	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00	100.00

[1] Data not available.
Note: Based on equation (4.7) where j is given.

Source: Calculated from the regional data.

there are very few negative values in Table 4.13. Except the other-grains of Jiangsu (-3.18), all the negative values are of the smallest magnitudes in their columns. These suggest that covariance among regions of a crop are generally positive. Also evident in Table 4.13 is that variabilities of given crops are dominated by several regions including Henan, Jiangsu, Sichuan, Shandong and Anhui.

According to Table 4.14, the available 21-region data explains 85.93, 86.42, 68.47, 98.28, 70.46, 64.18, 59.83 and 85.86 per cent of the total variabilities of rice, wheat, maize, tubers, soybeans, sorghum, millet and national foodgrain output variabilities, respectively. The other-grains variability can be hardly attributed to these 21 regions. This may not be of serious concern as other-grains are unimportant in terms of national production and consumption. On the regional basis, the available data explain over 80 per cent of the

Table 4.14: Percentage of Total Variance Explained by the Available Regional Production Data

Crop	Sown-area	Output
	Percentage	
Rice	84.80	85.93
Wheat	70.13	86.42
Maize	55.61	68.47
Tubers	59.54	98.28
Soybeans	75.77	70.46
Sorghum	75.78	64.18
Millet	65.41	59.83
Other-grains	63.15	6.93
Foodgrain	83.33	85.86

Sources: Calculated from Tables 4.10 and 4.13.

regional variability as tabulated in Table 4.12. Thus, little has been lost in the analysis of variability of China's foodgrain output despite the problem of data deficiency.

In passing, it is noted that Table 4.13 appears more symmetric than other tables. In other words, there is no general trend in terms of the magnitude of values in each row or column. Careful examination reveals that regions with a larger production of a crop were responsible for a larger share in the composition of the crop variability.

4.6 Summary

In this chapter, variance decomposition has been used to assess the importance of covariances in composing the total variance of China's foodgrain output and sown area. It was found that: (a) Total variabilities of both sown area and output are dominated by covariabilities. The dominance in the case of output is stronger than in the case of area sown; (b) Total covariability of area sown is dominated by the covariance among regions and that of output by covariance among crops and regions; (c) Contribution to total variabilities of area sown and output by each crop is dominated by covariance among regions of the crop, while that by each region is dominated by the sum of single variance terms for each crop in the region.

To reveal the spatial distribution of output and sown area variabilities of China's foodgrain, CV^2 decomposition (Shorrocks 1982) was employed. The results show the following: (a) Regional sown area variability is positively related to the population or population density of a region, while regional output variability is mainly proportional to its mean level of production; (b) Important crops had a small share of sown area variability, while less important crops had a small share of output variability. In other words, yield variability played an important role for important crops and area sown variability played an important role for less important crops; (c) When variability of a given region (or a given crop) is decomposed, it appears that contribution of a regional crop to the total variability of the given crop (or given region) is highly attributable to the mean level of the crop's output or sown area. (d) The available data explain a large proportion of China's foodgrain instability (Table 4.14).

It must be mentioned that the inconsistency caused by data deficiency (cf. section 4.3) is not significant. This is seen by the very small values in the last column of the last row of Tables 4.3, 4.4, 4.6 and 4.7. As further evidence, the sum of the second last row and the sum of the second last column in Tables 4.8 and 4.11 are also quite small.