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THE ECONOMIC ANALYSIS OF PRODUCTION AND PRODUCTIVITY GROWTH IN THE NEPALESE CROP SECTOR

BY

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ABSTRACT

In this study, production trends, production structure, and productivity growth in the Nepalese crop sector over the past three decades are estimated and analyzed. The total factor productivity growth is observed to be negative in the 1960s and 1970s and positive in the 1980s. The positive growth in the 1980s resulted primarily from a faster growth in crop output. A decomposition analysis of output growth indicates that area is the major contributing factor to the growth of crop output quantity, whereas real crop output price is the major contributing factor to the growth of real crop output value.

The terms of trade for the Nepalese crop sector declined for the last three decades. However, the decline in terms of trade was relatively small in the 1980s compared to the 1960s and 1970s. Similarly, the growth rate of returns to cost is observed to be negative in the 1960s and 1970s and positive, but very small, in the 1980s.

The production structure in the Nepalese crop sector is found to be non-homothetic, whereas the technical change is land-saving, labour-using and fertilizer-using. A substitutability relationship is found between all input pairs. Fertilizer and land are observed to have respectively the highest and lowest degree of price elasticity of factor demand. The study also observed a significant relationship between rainfall and crop output.

In conclusion, continuation of a positive growth rate in Nepalese crop productivity is likely depend on an increase in investment on basic infrastructure (especially irrigation and transportation), on strengthening of agricultural research capacity, and on changes in existing agricultural policies and macroeconomic policies.

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I myself claim full responsibility for any errors in and omissions from this thesis.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

The major concern of this study is to analyze theoretically and measure empirically the productivity growth in the Nepalese crop sector over the period 1961/62 to 1986/87 and to carry out decomposition analysis of growth trends in order to determine the sources of output growth in that sector. As well, the study also analyses the influence of weather conditions on crop productivity in order to explain the possible short-run variation in crop productivity in Nepal.

In the absence of quality data on input prices, especially for land and bullocks, the geometric index procedure pioneered by Solow (1957) has been used to measure productivity growth and technical change biases in the Nepalese crop sector. However, an attempt has been made to proxy land prices and costs of bullocks in order to use the flexible weight Divisia index procedure to measure productivity growth, and also to compare its results with the results derived from the geometric index procedure. Regarding the decomposition analysis, the multiplicative model of Minhas (1966) has been modified to take account of the contribution of price changes in output growth together with the contributions of cropped area, yield and cropping pattern. The study also examines the influence of weather conditions on Nepalese crop output by using simple and doable analytical techniques. Furthermore, the productivity and decomposition analyses of this study are carried out at the national level. In the absence of a sufficiently long time series on regional data on crop outputs and inputs, the analyses could not be done at the regional level. The regional data on crop outputs and inputs which are available only for the period of 1969/70 to 1980/81 strictly limit a long-term regionwise analysis of productivity growth in the Nepalese crop sector.

1.2 Background to the Problem

Agriculture is the mainstay of the Nepalese economy, providing direct or indirect employment to about 94 percent of the population, contributing nearly 60 percent to the GDP and generating above 40 percent of export earnings (ADB/M 1982, Vol.II, p.20). Moreover, the Nepalese agricultural sector is largely dominated by the crop sector which alone provides about 55 percent of the total agricultural GDP and contributes more than 90 percent to the total agricultural exports (Svejnar and Thorbecke 1984). Paddy (rice after threshing and before milling), maize and wheat are the principal foodgrain crops in Nepal accounting for 85 percent of the total cropped area in 1981/82 and about 93 percent of the country's total cereal production (ADB/M 1982, Vol.II, p.35 and Appendix 2.2). Millet, barley and potato, mostly grown in the hills and mountains, account for about eight percent of the total cropped area, whereas the remaining seven percent of the total cropped area is planted with cash crops, such as oilseeds, sugarcane, jute and tobacco, which are mostly grown in the Tarai plains (ADB/M 1982, Vol.II, Appendix 2.2). Thus, the crop sector plays a vital role in the overall performance of the Nepalese agricultural sector, especially to meet the food demand for the rapidly increasing population of Nepal and to increase export earnings in order to satisfy the country's demand for foreign currencies to carry out overall economic development activities.

In Nepal, any further increase in crop production through an expansion in area is severely constrained by the limitation on land availability for agriculture. Only 16.4 percent of the total physical area is under cultivation, and bringing any additional land under cultivation is likely to be costly due to geographical constraints (APROSC 1986, p.6). About 77 percent of the country's physical area is covered by mostly steep, rugged and less fertile hills and mountains where marginal lands have already been brought under cultivation (ADB/M 1982, Vo.II, p.1). The country's forest area that could be transformed into agricultural land is also limited. At the most, about 38 percent of the existing forest area (that is, about 16 percent of the country's total physical area) could be transformed into agriculture land without a considerable adverse effect to the agricultural environment (APROSC 1986, p.91). However, any attempt to transform forest area into agriculture land beyond that level is certain to bring adverse effects to the agricultural environment. Moreover, even if the Covernment of Nepal agrees to transform 38 percent of its existing forest area into agriculture land, the total agriculture land alone is less likely to meet the country's total food demand in future, especially at the existing rate of population growth of 2.7 percent per annum. Therefore, the only realistic alternative to increase crop production in Nepal is to increase crop productivity per unit of area.

1.3 Nature of the Problem

The government of Nepal has well realized the above fact since the early 1960s when it introduced its first five year plan emphasizing policies and programmes that were directly related to increasing agriculture productivity and production, especially in the crop sector. Since then, the crop sector has always been given a top priority in the national plans. In this regard, there are three different types of direct programmes that are being launched each year to increase the crop productivity and production in all three major crop production regions of Nepal, viz. the Hills, Kathmandu Valley and Tarai. The Intensive Programme provides an integrated supply of inputs such as extension services, improved seeds, fertilizer and credits to irrigated land in the Tarai. The Pocket Programme delivers a concentrated supply of inputs to specified pockets of the Hills, Kathmandu Valley and Tarai with potential irrigation facilities. The Normal

Program encourages farmers to use improved seeds in partially irrigated areas or rainfed areas in the Hills, Kathmandu Valley and Tarai. In addition, the Government of Nepal is also emphasizing the development of fruit and vegetable crops in the Hills.

However, the performance of the crop sector in Nepal has been very disappointing for the last two and half decades. According to Table 1.1, the production and yield of major crops has declined during 1961/62 to 1980/81. Though the cropped area and

TABLE 1.1

ANNUAL GROWTH RATES OF AREA, PRODUCTION AND YIELD OF CEREAL CROPS IN NEPAL: 1961/62 TO 1980/81

(In Percentage)

Crops	Area	Production	Yield
Paddy	0.99	0.90	-0.09
Maize	0.24	-0.66	-0.90
Wheat	8.34	8.00	-0.33
Millet	3.48	4.18	0.68
Barley	0.48	-0.55	-1.02
Total Cereals	1.69	1.10	-0.58

Adapted from Yadav (1987).

production of paddy during the period has increased respectively by 0.99 and 0.90 percent per annum, its partial productivity measured in terms of yield rate has gone down by 0.09 percent per annum. Similarly, with the exception of millet, the annual yield rate of other major cereals has also declined during the period 1961/62 to 1980/81 (Table 1.1). The annual decline in the yield rate during the period is 0.90 percent in maize, 0.33 percent in wheat, 1.02 percent in barley and 0.58 percent in total cereals. Thus, the preceding information implies that the performance of the crop sector in Nepal has been poor.

However, these yield statistics which deal with only partial productivity are very crude approximations of overall crop productivity and, therefore, are less likely to present an accurate picture of productivity change in the Nepalese crop sector. A true picture on the productivity front can be visualized only through the estimates of total factor productivity which are still lacking in Nepal. Therefore, the important questions that are being frequently raised among Nepalese planners and policy decision makers are: (a) whether productivity growth in Nepalese crop sector has indeed declined for the period 1961/62 to 1986/87 and, if so, to what extent; (b) what are the magnitudes of contribution of cropped area, yield, cropping pattern and price to the crop output growth in Nepal; (c) do the weather conditions have any influence on crop productivity and, if so, what are the magnitude and direction of such influence in Nepal, and (d) do government policies in different periods, viz. the 1960s, 1970s and 1980s, seem to have an impact on the growth trends of crop output and productivity in Nepal. In absence of the answers to these questions, Nepalese planners and policy decision makers are still unable to judge the aggregate effects of their past policies and programmes in the crop sector. That is, information in this regard has been felt very necessary for the purpose of evaluating their policies and programmes and designing future policy alternatives.

1.4 Importance of the Study

As mentioned above, the crop sector which is the pivot of the Nepalese agricultural sector has traditionally been and continues to be the most important sector in the economy with respect to its share of the total GDP, employment and export earnings. Its share in the country's total employment has remained well over 90 percent for the last two decades, and an increase in GDP of the non-agricultural sector has not been successful in raising employment correspondingly. Therefore, the crop sector is not only the primary employer but has greater potentiality to absorb the growing labour force in years to come.

Further, the contribution of the Nepalese agricultural sector to the country's total export earnings has remained very significant since the mid-fifties. As shown in Table 1.2, the share of the sector remained well over 50 percent of the total earnings until

TABLE 1.2

TOTAL EXPORTS AT CURRENT PRICES AND THE PERCENTAGE SHARES OF THE AGRICULTURAL AND FOODGRAINS SECTOR RESPECTIVELY IN THE TOTAL EXPORTS AND THE TOTAL AGRICULTURAL EXPORTS

Year	Total Exports (Million Rs)	Share of Agri. in Total Exports (%)	Share of Foodgrains in Total Agri. Exports (%)
1956/57	95.7	78	98
1960/61	209.7	77	98
1965/66	375.1	51	96
1970/71	400.6	67	99
1975/76	1185.8	68	99
1980/81	1608.6	40	92

Adapted from Svejnar and Thorbecke (1984, Table A4, Appendix A).

1975/76. However, after then it decreased to 40 percent mainly due to a decline in yield and exportable surplus, an increase in non-agricultural (hand-crafts) exports and an increase in the level of foodgrain production in India. Moreover, foodgrain exports are the major component in the total agricultural exports. Their share in the total agricultural export earnings has remained well over 90 percent in the last three decades. Thus, it is apparent that the economic development of the country is heavily dependent on the development of its agricultural sector which itself depends on the performance of its crop sector. Therefore, this study which relates to productivity problems in the crop sector has great importance in the economic development of Nepal.

Further, the farmers of Nepal are continuously being encouraged to adopt modern farming technology through input subsidy policies and intensive extension programmes. The technological change and input substitution induced by the changes in the relative factor prices may have led to major changes in the input mix in Nepalese crop sector. The use of labour input may have been reduced as a result of the use of bullocks and/or HYV seeds; or the use of labour may have been increased due to application of fertilizer. Thus, this transition in input use raises important questions with respect to the nature of factor substitution, input demand and, especially, the nature of technical change. Therefore, this study which also aims to measure the effects of technical change on factor use in the Nepalese crop sector has considerable importance for planners, policy decision makers and other related personnel who are directly or indirectly involved in the process of agricultural development in Nepal.

1.5 Objectives of the Study

The major overall objective of this study is to analyze and measure production and productivity growth in the Nepalese crop sector. The following are the more specific objectives of the study:

(a) to estimate the growth of total factor productivity in the Nepalese crop sector,

(b) to estimate the production structure of the Nepalese crop sector in order to examine the substitutability and complementary relationships between input factors in the sector,

(c) to measure the effect of technical change on factor use in the Nepalese crop sector,

(d) to decompose the growth of crop output into area, yield, price, cropping pattern and their interaction terms,

(e) to analyze the possible influence of weather conditions on crop output in Nepal, and

(f) to derive some policy implications relating to crop productivity in Nepal.

1.6 Hypotheses of the Study

Since the study focuses on productivity growth and technical change, the major hypotheses to be tested are as follows:

(a) The rate of total factor productivity growth in the Nepalese crop sector has been declining since the early sixties.

(b) During the period of 1961/62 to 1987/88, technical change in the Nepalese crop sector has been labour-using technical change.

(c) During the period of 1961/62 to 1987/88, the area effect is the major factor influencing in the growth of Nepalese crop output quantity and real value, whereas the growth of nominal crop output value during the same period is influenced by the growth of nominal crop output price.

(d) A weather variable measured in terms of rainfall has a significant short-run influence on the Nepalese crop output.

1.7 Outline of the Study

There are eight chapters in this study. Chapter 1 deals with the background and nature of the problem and the objectives, hypotheses and importance of the study. A review of the institutions and policies relating to the agricultural development in Nepal is presented in Chapter 2. Chapter 3 presents a detailed discussion on the definition, classification and measurement of total factor productivity. The chapter also discusses the procedures of estimating the factor shares and production structure in the Nepalese crop sector. The nature, sources and measurement of the input and output data which are used to estimate the total factor productivity and the production structure of the Nepalese crop sector are discussed in Chapter 4. The chapter presents trend analysis of the prices and quantities of inputs and outputs in the Nepalese crop sector.

The decomposition analysis of the output growth in the Nepalese crop sector is presented in Chapter 5. Chapter 6 is the major chapter of this study and includes a detailed analysis of the total factor productivity and production structure of the Nepalese crop sector. In Chapter 7, regional rainfall data were used to examine the influence of weather on Nepalese crop output. Chapter 8 is the last chapter of the study and presents summary and conclusions.

CHAPTER 2

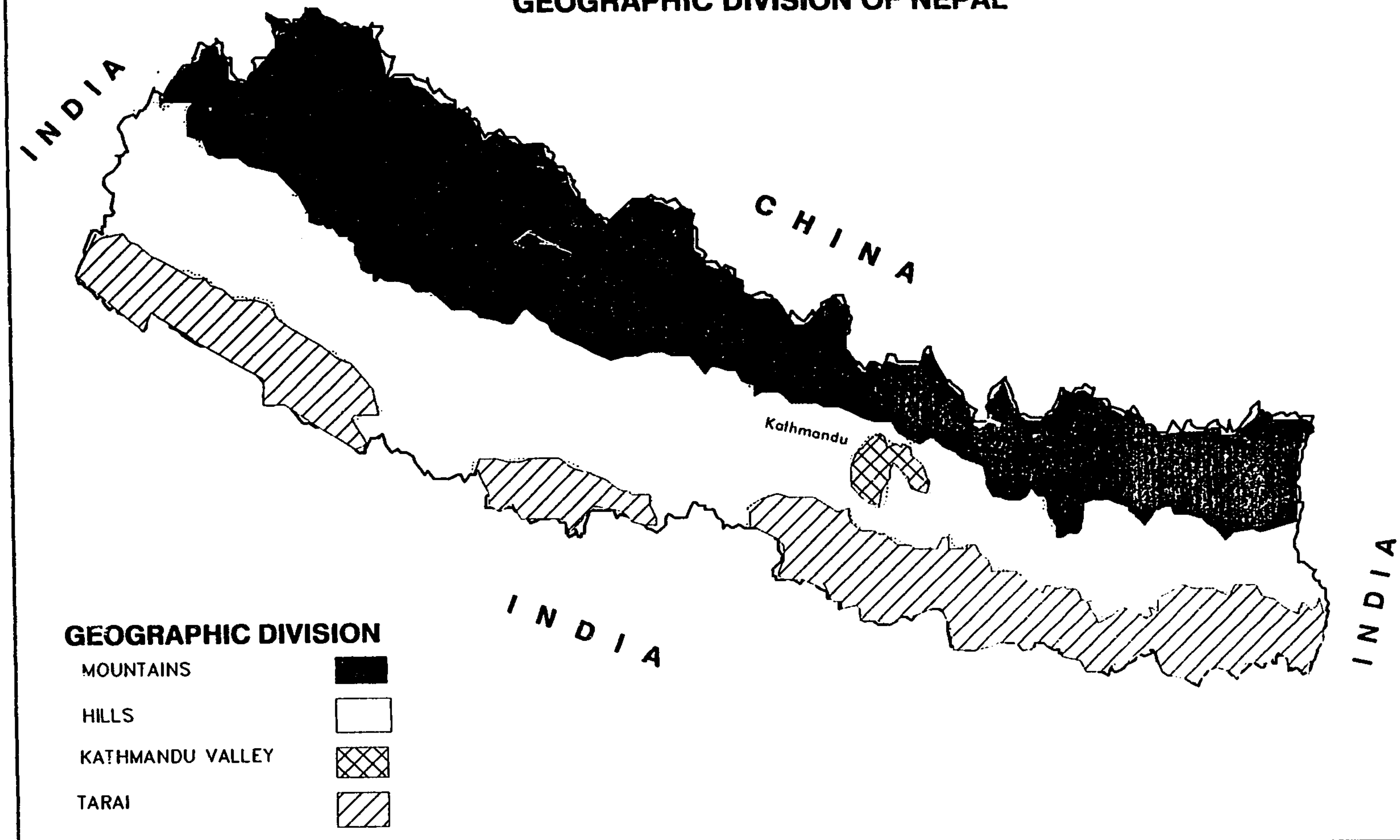
INSTITUTIONS AND POLICIES RELATING TO THE AGRICULTURAL DEVELOPMENT IN NEPAL: A REVIEW

2.1 Introduction

Nepal is a small landlocked country bounded by India on its east, west and south side and by China on its north side (Figure 2.1). The country which is only 141,000 square kilometers in size is geographically divided into three regions, viz. the Tarai, the Hills and the Mountains. The Tarai is a part of the Gangetic plain and lies on the southern side of the country covering 23 percent of the country's total physical area. Moreover, the region is also a prime source of foodgrain supply in Nepal. On the other hand, the Hills region which covers 43 percent of the total physical area includes hills with ridges and steep slopes and also several small valleys which play an important role in foodgrain supply for the region. Unlike the Tarai and Hills, the Mountains which covers 34 percent of the country's total physical area consists of mountains with an altitude above 3,000 meters. Livestock production has remained a major economic activity in this region.

The current population of Nepal is estimated to be 19 million with a population density of 106 persons per square kilometer of surface and 472 persons per square kilometer of cultivable land (CBS 1981). As mentioned in section 1.2, the agricultural sector still dominates the employment structure in the Nepalese economy. The industrial sector which constitutes only about 0.4 percent of the country's total employment level is still at its early stage of development. In recent years, the agro-based industrial sector which constitutes more than 75 percent of all industrial establishments in Nepal is playing an important role in strengthening the country's agricultural sector (ADB/M 1982, Vol.II, p.20). Further, the cottage industrial sector and the tourism sector

FIGURE 2.1
GEOGRAPHIC DIVISION OF NEPAL



are also expanding in Nepal since the early seventies. However, their contributions to the country's total employment and GDP are still very low. The cottage industrial sector employs only about 0.7 percent of the total employed labour force, whereas the tourism sector contributes only 2 percent to the GDP (ADB/M 1982, Vol.II, p.20).

In Nepal, the economy is solely based on its principal natural resource, land. Nepal also has plentiful water resources which if exploited properly can produce a huge amount of hydropower. However, the resource has remained untapped mainly due to lack of markets and investment resources.

2.2 Agricultural Institutions

2.2.1 Land Tenure System and Institutions

The Ministry of Land Reform (MLR) and the Ministry of Forest and Soil Conservation (MFSC) are two major institutions which are principally responsible to use and manage agricultural land in Nepal. The MLR is responsible for administration, survey and measurement of lands, whereas the MFSC is responsible for activities that have direct or indirect effect on the Nepalese agricultural sector, such as the formulation of forest policy, survey, measurement, mapping and demarcation of district and other forests, forest protection, afforestation and utilization of forests. Moreover, the MFSC is also involved in planning and implementation of resettlement programmes in the Tarai region.

Since land is the principal productive resource in Nepal, the major objective of the Nepalese government, especially after the revolution of 1951, has always remained to achieve more equitable distribution of land. Prior to 1964, the Government tried to achieve such an objective by reforming the Nepalese agrarian structure from time to time. However, all those reforms were not successful, mainly due to lack of a strong institutional foundation to manage and control the land and also due to inadequate land use planning in the country (ADB/M 1982, Vol.II, p.104).

In December 1964, a comprehensive and countrywide land reform act, the Lands Act 1964, was adopted in order to: (i) distribute the country's cultivable land more equitably, (ii) improve living conditions of actual tillers by providing them with technology and resources necessary to increase their production, and (iii) divert unproductive capital and human resources from land to other sectors of the economy. According to the Lands Act 1964, the Zamindari system under which Zamindars (landlords) used to collect land revenue from land holders on behalf of the Government was abolished and ceilings were fixed on ownership of land at 17 hectares in the Tarai, 4.11 hectares in the Hills and 2.67 hectares in Kathmandu valley. Land above the ceilings was to be confiscated and redistributed to the tillers and landless. The Lands Act 1964 also provides tenancy rights to all those who had tilled the land as tenants for one main crop season. According to tenancy rights, no tenant could be evicted as long as he continued to fulfill the conditions laid down by law.

In absence of relevant data, effects of the Lands Act 1964 on land use, productivity and living conditions of tillers could not be precisely evaluated. However, a few micro-level individual studies, notably by K.C. (1979), have shown that the achievements of the land reform are not satisfactory. As against the original estimate of 26 percent, the combined area of all officially registered holdings that exceeded the land ceilings was found to be only three percent of the total cultivated area and only 33 percent of such registered area was actually redistributed, perhaps very little to the poor (K.C. 1979). The major reasons for such unsatisfactory achievements are believed to be the lack of cooperation between government agencies, the resistance of land owners and the bureaucratic procedures relating to implementation of Lands Act 1964.

Despite the Lands Act 1964, the land holding pattern in Nepal has not changed very much. Results from the National Survey of Agricultural Census of 1961 and 1971 presented in Table 2.1 clearly indicate that the distribution of land in Nepal is still skewed. About 56 percent of the total households hold less than 12 percent of the total land area with an average holding size of 0.21 hectare per household, whereas only six percent of the total households hold almost 44 percent of the total land area with an average holding size of 6.8 hectare per household (Table 2.1). Such a land holding pattern is more likely to change in future as a result of the recent democratization of Nepal's polity. The present democratic government of Nepal is believed to be introducing effective and practical land reforms in order to achieve more equitable distribution of cultivable land in the country.

TABLE 2.1

LANDHOLDINGS PATTERN IN NEPAL IN 1961 AND 1971

	Census Year 1961			Census Year 1971		
	Percentage of			Percentage of		
Size of Holdings (ha)	House-holds	Area Covered	Average Holdings	House-holds	Area Covered	Average Holdings
0.10 - 0.41	48.7	8.8	0.20	55.8	11.8	0.21
0.42 - 2.67	43.4	42.3	1.08	37.8	44.3	1.17
2.68 - 10.0	6.9	31.2	5.03	5.7	31.6	5.57
10.0 and above	1.0	17.7	18.94	0.7	12.3	16.46

Adapted from CBS (1961 and 1971).

2.2.2 Agricultural Research and Extension Institutions and Their Policies

Agricultural research in Nepal is solely carried out in the public sector. The major agencies involved in agricultural research are the Department of Agriculture (DOA), the Department of Livestock Development and Animal Health and the Department of Forest. The DOA carries out the crop research through its six technical disciplinary divisions which are respectively related to agronomy, agricultural botany, entomology, plant pathology, soil chemistry and agricultural chemistry. These divisions conduct and coordinate research activities in their respective areas and also provide technical supervision and guidance to researchers in their related programmes.

The agricultural research in Nepal has remained neglected from the very beginning when the DOA was first established in 1924. The negligence was due primarily to the assumption that agricultural technologies can be easily transferred from other countries. Because of such an assumption, research expenditures have always been kept at a low level, thereby restricting research activities in the agricultural sector.

Although the Nepalese agricultural sector has been receiving a relatively and increasingly large share of the national budget, only a small fraction of the national budget has been allocated for agricultural research. The share of the agricultural sector in the total national expenditure increased from 10.1 percent in 1967/68 to 22.8 percent in 1984/85 (HMG 1972 and 1984). However, the share of the total expenditure allocated to agricultural research in the total expenditure of the agricultural sector decreased in real terms from 13.6 percent in 1970/71 to 5.4 percent in 1980/81 (Yadav 1987). Moreover, the total expenditure allocated to crop research at 1972/73 constant prices was only NRs 5.6 million in 1970/71 and NRs 6.7 million in 1980/81 which respectively turn out to be 5 and 2 percent of the total expenditure of the agricultural sector in those respective years (Yadav 1987). Thus, the real expenditure in agricultural research, especially in crop research, is not only a small portion of the total national expenditure but it is also declining in recent times.

Regarding the extension system, the DOA is also solely responsible for crop extension services in Nepal. It carries out the extension services through its five regional offices and 75 district offices. At the field level, the Junior Technicians (JTs) and Junior Technical Assistants (JTAs) are the core extension agents directly involved in diffusing technical knowledge among farmers. Besides the DOA, agencies, such as the Jute Development Corporation, the Tobacco Development Corporation and the Tea Development Corporation, also provide extension services to the farmers with respect to production, processing, marketing and credit for some specific commodities.

In absence of empirical evidence, it is very difficult to conclude whether or not the extension system has been effective in raising crop productivity in Nepal. However, it is generally argued that the system have been more or less ineffective due to several constraints, such as very low JTA-farmer ratio (one JTA per 2500 farm families), financial difficulties to increase the quality and quantity of JTA training and the lack of incentives and job advancement for JTAs.

2.2.3 Supply of Agricultural Inputs and Institutions

The Agricultural Inputs Corporation (AIC), a public sector undertaking, is the major source of supplying modern agricultural inputs in Nepal. The AIC procures farm inputs from international and domestic markets in order to distribute them among the Nepalese farmers. Sometimes, farmers do obtain the HYV seeds from sources other than the AIC, such as leading farmers, local dealers and in some cases directly from India.

In case of the HYV seeds, the AIC obtains the foundation seeds from the DOA in order to use them for multiplication purposes. The multiplication of these seeds is being done on selected contract farmers' fields under strict supervision of crop scientists. Thus produced, HYV seeds are processed and stored in the AIC's own facilities and, then, distributed to farmers for adoption. Recently, the Government of Nepal has implemented the Seed Production and Input Storage Project (SPISP) in 25 hill districts of Nepal in order to minimize the risk of quality deterioration and timely unavailability of HYV seeds in the Hills. The SPISP with a small-scale seed processing plant is designed to produce, process, store and distribute 50 to 200 tons of HYV seeds to farmers of its surrounding area. The project is aimed towards achieving a higher adoption rate of HYV seeds in the Hills of Nepal and, thereby, to increase productivity and production of the region.

2.2.4 Financial Institutions and Credit Policy in the Nepalese Agricultural Sector

The Nepalese agricultural credit market is still dominated by non-institutional credit which is mainly provided by money-lenders, landlords and traders. Nevertheless, institutional credit has been playing an important role in agricultural development in Nepal since 1968 when the Government of Nepal established a national level credit institution, the Agricultural Development Bank (ADB/N), in order to provide institutional credit facilities to Nepalese farmers. As a result, the share of institutional credit in the total agricultural credit increased from 21 percent in 1969/70 to 42 percent in 1976/77 (NRB 1980). The ADB/N alone provides about 85 percent of the total institutional credit to the agricultural sector. Its major sources of funds for lending are the repayment of its loans, refinancing from the central bank and external assistance (especially, from the Asian Development Bank and the World Bank). The shares of these major sources in the total funds for lending in 1982/83 were respectively 47.3, 18.5 and 15.0 percent (ADB/M 1982, Vol.II, p.143).

Besides the ADB/N, Sajhas (village level cooperative societies) and commercial banks are the other major sources of institutional credit to Nepalese farmers. Sajhas are designed to provide credit and input facilities to the farmers in Nepal in order to increase their agricultural production and standard of living. During the early 1980s, Sajhas covered 1350 village panchayats in 30 districts of Nepal including all the Tarai districts. The management of Sajhas at the village level is controlled by a managing committee whose members are elected by and among the cooperative members. However, at least two-thirds of such elected members need to be small farmers, basically to ensure that the Sajhas do not neglect the well-being of small farmers. At the national level, the Department of Cooperatives is responsible to coordinate all the village level Sajhas in Nepal.

On the other hand, the commercial banks which are the third major source of institutional agricultural credit in Nepal were directed by the central bank to invest at least 5 percent of their total deposit liabilities in agriculture and other priority sectors, such as cottage industries (NRB 1982). Such a reservation policy of the central bank is designed to increase the supply of rural credit and to bring rural lending into the mainstream of commercial bank lending rather than letting the rural sector remain as an inferior sector consisting of special institutions. The policy is also supported by the argument of Krishna (1982) that institutions, such as commercial banks, with a large high-return can bear some low-return turnover more easily than institutions, such as the ADB/N, forced to specialize in low-return turnover. The percentage of the total deposit liabilities of the commercial banks to be invested in the agricultural and priority sectors was raised to 7 percent in 1976 and to 10 percent in 1982. The total outstanding agricultural loans of commercial banks in January 1982 was NRs 61.6 million (NRB 1982).

In Nepal, the major constraint in agriculture financing is the overdue loans which could have resulted from the fact that the cheap institutional credit is being used either for consumption purposes or for non-productive activities. In 1979/80, the overdue loans of the ADB/N were estimated to be 47.05 percent of its total loan disbursement (ADB/M 1982, Vol.II, p.141). Because of such a large amount of overdue loans, the central bank curtailed its disbursement of refinance to the ADB/N from NRs 128 million in 1978/79 to NRs 27 million in 1978/79 and to NRs 18 million in 1980/81 (ADB/M 1982, Vol.II. Appendix 4.36). As a result, the total credit that was distributed to farmers in those years shrank sharply, thereby resulting in an adverse effect on the agricultural sector in Nepal. However, in recent years the ADB/N has been improving its financial situation by putting much emphasis on loan recovery and also by monitoring farmers' use of credit closely. Moreover, the improved fund management system of the ADB/N and the willingness of the central bank to increase its refinancing to the ADB/N seem to have reduced the problem of overdue loans to a large extent.

2.3 Agricultural Price Policy

As discussed in section 1.4, the economic development of Nepal is highly dependent on the performance of its agricultural sector, especially the foodgrain sector. The food balance situation in the country started deteriorating since the mid-sixties and became deficit in years 1979/80 and 1982/83 (DFAMS 1985, p.74). The deficit balance of foodgrains further resulted in several economic problems, such as a higher inflation rate, a deficit trade balance and a decline in the Government's revenue in foreign exchange. Therefore, the major objective of agricultural price policy in Nepal has remained to increase food production in order to meet the mounting internal food requirements and also to build up an exportable surplus. Moreover, the Nepalese agricultural price policy is also aimed towards achieving equitable distribution of foodgrains across the different geographical regions of Nepal. All these major objectives have been well reflected in the Nepalese agricultural price policy through its three major elements, viz. the output price support policy, the input price subsidy policy and the food security and price subsidy policy. These policies are discussed in following sub-sections.

2.3.1 Output Price Support Policy

The output price support policy was first introduced in 1976/77 by announcing the Minimum Support Prices (MSPs) for coarse paddy and wheat. The MSP policy which ensures farmers that the market prices are not allowed to fall below the level of support prices provides incentives to farmers to raise their production level. The MSPs are fixed by the Central Food Management Committee on the basis of several factors, such as the cost of production, the general foodgrain production situation, prices in adjoining Indian border markets, market prices in the main foodgrain producing areas, transportation costs from producing areas to border markets, and the Indian output support prices. Because of the open border with India, the Indian output support prices play the most important role in determining the level of output support prices in Nepal.

So far, the MSP policy has not been effective in achieving its objective, mainly due to the unavailability of sufficient funds to procure enough foodgrains in order to have a positive impact on prices and production (APROSC 1986A, pp.4-5; Wallace 1987). During the period 1980/81 to 1984/85, less than two percent of the total grain produced was procured by the concerned agency (Wallace 1987). The other reasons for such ineffectiveness of the MSP policy are the untimely announcement of the support prices and that the level of support prices was kept below the level of prevailing market prices. Since the MSPs in the past were announced well after harvests, the policy had no effects either on farmers' planting decisions or decisions relating to use of HYV seeds and fertilizer. It is only from 1984 onwards that the Government of Nepal started announcing the MSPs before crop harvest. However, the announcement is still made well after crop planting, thereby, having no effect at all on planting decisions of farmers. Thus, the MSP policy has failed to provide any incentive to farmers to raise their production level and amount of marketable surplus.

2.3.2 Input Price Subsidy Policy

Among the inputs used in the Nepalese crop sector, fertilizer is the most important input in the sense that the input has to be purchased either by paying cash or by obtaining loans from the institutional and/or non-institutional credit markets. Therefore, a change in fertilizer price directly affects the farmers' cost of production and profitability. As a result, farmers have always raised their voices against any increase in fertilizer prices in Nepal. In other words, the fertilizer price policy has remained one of the most politically sensitive agricultural policies in Nepal.

Regardless of differences in transportation costs across the districts and regions of Nepal, the Government of Nepal sets uniform selling prices of fertilizer through out the country and also provides heavy subsidies on those selling prices. In addition to price subsidies, the Government of Nepal provides transportation subsidies to the farmers of the Hills while transporting fertilizer and the HYV seeds from the Tarai markets. The transportation subsidy policy is designed to increase the adoption rate of modern technology in the Hills and, thereby, to increase production and productivity of the hill farmers. The rate of subsidy on fertilizer price fluctuates between 30 to 50 percent of the total cost, whereas the transportation subsidy on the HYV seeds goes as high as 100 percent (ADB/M 1982, Vol. II, Appendices 4.24 and 4.25). Thus, the Nepalese fertilizer price policy in a sense includes both efficiency and equity objectives. The efficiency objective is to encourage farmers to use more fertilizer and, therefore, to increase their crop production; whereas the equity objective is to ensure that poor farmers, especially those living in the Hills, do not get hurt by the fertilizer price policy.

However, the fertilizer price policy in Nepal is not well defined in the sense that the Government does not have definite criteria to determine the level of fertilizer prices. Generally, fertilizer prices are kept equal to, or slightly higher than, the prices prevailing in the neighboring country, India, in order to prevent outflow of imported subsidized fertilizers from Nepal to India. The level of the fertilizer price subsidies provided by the Nepalese Government depends largely on world prices and also on retail prices of fertilizer in adjoining Indian markets. The level of subsidies also varies by type of fertilizer and year of subsidy.

The input subsidy policies have been very costly to the Government of Nepal, because the sale prices do not cover the costs of importing and transporting inputs, especially fertilizer, to the Hills of Nepal. The Government does not have any budgetary provision to finance such a fertilizer price subsidy program. Therefore, the AIC which is responsible to procure and distribute fertilizer in Nepal has been suffering losses of more than NRs 100 million a year since 1973/74 (Wallace 1987). Nevertheless, such losses in the past were being minimized by the earned profits on grant-supplied fertilizer and also by the financial support from the World Bank and the Asian Development Bank.

In recent times, the Government of Nepal with recommendations from the local and international agencies has declared a policy that indicates a gradual phase out of the existing input subsidy programmes in Nepal and to make inputs available to the

Nepalese farmers at cost price. In other words, the subsidy aspect will not remain as a major element in the Nepalese input price policy in near future. However, as a result of an open border with India, the Nepalese input price policy will remain much influenced by the input price policy in India.

2.3.3 Food Security and Price Subsidy Policy

The Ministry of Agriculture (MOA), the Department of Food and Agricultural Marketing Services (DFAMS) and the Nepal Food Corporation (NFC) are the major public agencies concerned with formulating and executing food security and price subsidy policies in Nepal. The DFAMS annually identifies surplus and deficit districts by preparing districtwise food balance sheets for whole country and provides policy recommendations to the MOA relating to food procurement and distribution. The MOA with the approval from the cabinet executes the adopted food security and price subsidy policies through the NFC.

The NFC procures grains on the open markets and distributes to consumers in food deficit areas at prices below the prevailing market prices. The distribution is made through Sajhas, private traders and in some cases through its own selling depots. During 1974 to 1985, the NFC distributed over 400,000 metric tons of foodgrains in Nepal. About 54 percent of such distribution were carried out in Kathmandu valley, 39 percent went to the Hills and the remaining seven percent went to the Mountains (Wallace 1987).

The food price subsidy policy has remained the major element of the food procurement and distribution policies in Nepal. The major objective of food price subsidy policy is to eliminate food deficits and to stabilize market prices in the country. However, the policy seems to be effective only to supply subsidized foodgrains to certain groups of consumers, such as residents of Kathmandu and government officials in the food deficit areas of Nepal, rather than eliminating food deficits and stabilizing the market prices. The major reason for such ineffectiveness of the food price subsidy policy seems to be the limitation of resources, especially the financial resource. In the absence of funds to procure sufficient amount of foodgrains, the NFC's food distribution never satisfies the total food deficit in the country. During 1974 to 1985, the percentage of the total food deficit satisfied by the NFC's food distribution was 34 percent in Kathmandu valley, 19 percent in the Hills and only seven percent in the Mountains (Wallace 1987). The remaining portion of the total food deficit was satisfied by the traders from the Tarai and/or the Indian border markets at prices sufficiently higher than the prices of the NFC.

In addition to price subsidy, the Government of Nepal provides partial transportation subsidy on the NFC's foodgrain distribution. Since the transportation costs to the Mountains are higher than those to the Hills, the foodgrain prices tend to be higher in the Mountains than those in the Hills. Therefore, a large portion of the actual subsidy per ton of foodgrain distribution goes to the remote districts in the Mountains of Nepal.

2.4 External Trade and Agricultural Trade Policy

Nepal has much easier access to India than to China due to topography. Due to the existence of the high Himalayas and mountains on the north side of the country, Nepal finds it difficult and costly to promote trade with China. Therefore, India has remained the major trading partner of Nepal for both exports and imports.

As shown in Table 1.2 of Chapter 1, the agricultural exports which include export items, such as rice, raw jute and jute products, hold major share in the total Nepalese exports. However, the agricultural exports are declining in recent years, mainly due to a decline in agriculture surplus as a result of an increase in the domestic demand for food in Nepal, a decline in agricultural productivity and also due to India's self-sufficiency in foodgrains. The exports declined from NRs 809.9 million in 1974/75 to NRs 483.4 million in 1981/82 (Svejnar and Thorbecke 1984). As a result of such decline in agricultural exports, the country's total trade deficit has increased from NRs 925 million in 1974/75 to NRs 3,464.3 million in 1981/82 (ADB/M 1982, Vol.II, p.26).

It is believed that the open border between India and Nepal has resulted in a massive amount of unrecorded trade between these two countries. Agricultural outputs and inputs that are being carried out on both sides of the border, especially for own consumption purposes, are not being recorded by the officials at the border. The unofficial trade between these two countries could be as high as 75 percent of their total trade (Wallace 1987).

Though Nepal is a foodgrain exporting country, it has also been seen as a net foodgrain importing country in years of unfavorable monsoon, such as 1982/83. Therefore, the agricultural trade policies in the past included a ban on exports of foodgrains in food deficit years. Moreover, following the food deficit in 1986/87, the Government of Nepal adopted a trade regulation that restricts the export of foodgrains from Nepal. Nevertheless, a significant volume of foodgrains is believed to have been smuggled out each year from the Tarai - a food surplus region in Nepal - to India. The open border together with the higher foodgrain prices in India and a well developed transportation system linking the Tarai and India may have encouraged a large scale smuggling of foodgrains from the Tarai to India.

The movement of foodgrains across the border also occurs due to factors other than those mentioned above. In absence of adequate road facilities across the different regions of Nepal, the costs of transporting foodgrains from the Tarai to the far western Hills and Mountains are higher than the costs of importing foodgrains in those regions from their adjoining Indian border markets. Therefore, while grains are being exported from Nepal to India in the Tarai region, grains are also being imported from India to Nepal in the far western Hills and Mountains of Nepal. Similarly, in case of restrictions on interstate movement of foodgrains in India, the foodgrains move from Uttar Pradesh of India into the central Tarai region of Nepal, east along Nepal's roads, and back into Indian states, such as Bihar and West Bengal.

Thus, the agricultural trade policies in Nepal have remained highly influenced by its open border with India and the existing transportation facilities inside the country. The open border has both advantages and disadvantages to Nepalese agricultural trade. However, it is very difficult both politically and practically to close the border with India. Nevertheless, the Government of Nepal has been giving priority to the development of transportation system in the country in order to establish commercial linkages between regions and also with India. However, the pace of such development is very slow. Therefore, these two issues need to be carefully addressed in order to make the Nepalese agricultural trade policy more effective in future.

2.5 Macroeconomic Policy

Besides the agricultural price policies and trade policies, the economic development of Nepal is also influenced by macroeconomic policies, such as the interest rate policy and the exchange rate policy. Though the major objectives of macroeconomic policies in Nepal are other than to facilitate the development of the agricultural sector, these policies are more likely to have some direct and indirect effects on the agricultural sector. The interest rate policy and the exchange rate policy are discussed in the following subsections.

2.5.1 Interest Rate Policy

Despite a low intensity of mechanized farming in Nepal, farmers do borrow money to purchase improved inputs. Therefore, the interest rate plays an important role in determining the cost of production and the level of farm income in the Nepalese agricultural sector. In Nepal, the Government has been adopting a lower interest rate policy in agricultural credit in order to encourage the use of modern technology and, thereby, to increase production and productivity of the Nepalese farmers. However, the lower interest rate policy results the concentration of credit in the hands of relatively few users (Hayami and Ruttan 1985, p.400). In developing countries, 70 to 80 percent of small farmers has virtually no access to institutional credit (World Bank 1975, p.5). Realizing this fact, the Government of Nepal started implementing the Small Farmers' Credit Programmes (SFCPs) in 1975 in order to provide subsidized institutional credit to the marginal and small farmers of Nepal. The subsidized credit is provided to encourage the use of modern agricultural inputs and, thereby, to increase the production level of the marginal and small farmers.

Regarding the interest rates in the agricultural sector, the rates of non-institutional credit are higher than the rates of institutional credit. The annual interest rates charged for the non-institutional credit vary from 15 percent to 150 percent depending upon the credit risk perceived by money-lenders on each individual borrower (ADB/M 1982, Vol.II, p.139). If a borrower is a large farmer with valuable land in collateral, then the rate could drop to 15 percent per annum; whereas the rate could go as high as 150 percent per annum in the case of marginal and small farmers with no collateral. On the other hand, the interest rates for the institutional credit which are fixed by the central bank range from 6 to 13 percent per annum depending upon the purpose of loans and the type of borrower (ADB/N 1987). The interest rates charged to the marginal and small farmers are lower than the interest rates charged to the large and medium farmers. The policy of charging differential interest rates to the different types of farmers is designed to increase the productivity and production and, thereby, the living standard of the marginal and small farmers.

The annual interest rates charged by the ADB/N to farmers during the period of 1982/83 to 1985/86 was 11 percent for production loans, 13 percent for mechanization loans, 8 percent for irrigation and livestock loans, 7 percent for agricultural industry loans and 6 percent for horticulture and tea loans (ADB/N 1987). Moreover, the nominal interest rates on the institutional credit have always remained unchanged for a long period of time while the inflation rate keeps on increasing over the period. As a result, the real interest rates (nominal rates less inflation) in some years have been observed as negative in Nepal (Wallace 1987). Such a negative real interest rate as a result of cheap institutional credit is also observed in the case of Brazil (Hayami and Ruttan 1985, p.401). As a result, large farmers who hold a large portion of the total agricultural loan generally misuse the subsidized credit. Therefore, it is very difficult for the Government to achieve the objectives of the agricultural credit policy in Nepal. Moreover, only 42 percent of the total credit borrowed by the agricultural sector was made available by the institutional sources in 1976/77 (NRB 1980). The remaining 58 percent was supplied by the non-institutional credit markets where the Government does not have any influence on the interest rate. Therefore, the interest rate policy in Nepal could be more effective in achieving its objectives in the agricultural sector only when the Government of Nepal adopts regulations that increase the volume of institutional agricultural credit considerably, especially from the commercial banks, and prevent the misuse of credit by the large farmers. In addition to these, the institutions involved in agricultural lending should function as borrower-chasing institutions

(Krishna 1982). In other words, most farmers in developing countries are illiterate and unable to prepare a feasible scheme or to apply a loan application. Therefore, the lending institutions which have manpower and capability to prepare schemes should prepare and finance feasible schemes for poor farmers in order to make the credit programmes more effective within a short period of time.

2.5.2 Exchange Rate Policy

The Nepalese Rupee (NR) which was first issued in paper form in 1945 is the medium of exchange in Nepal. In April 1960, the fixed exchange rate system was adopted against the Indian Rupee and US Dollar while other currencies were allowed to float with respect to the Nepalese Rupee. However, the Nepalese Rupee was devaluated from time to time with respect to the Indian Rupee. According to the current exchange rate, one Nepalese Rupee is equivalent to about 0.60 Indian Rupees and 0.03 US Dollar.

During the period 1961 to 1977, the Government of Nepal had adopted the exchange entitlement scheme in order to promote and diversify its exports. According to the scheme, an exporter exporting goods to a country other than India was entitled to use a certain percentage of the convertible currency receipts from his exports to import goods into the country. Since the percentage of the convertible currency as well as the categories of goods to be imported were periodically fixed by the Government of Nepal, the scheme was occasionally manipulated by politically influential exporters-cum-importers to import a large volume of unessential commodities which have a very high and quick return in Nepal. Therefore, the exchange entitlement scheme was replaced in 1978 by the fixed dual exchange rate system for the US Dollar in order to discourage such an import of unessential commodities and to encourage Nepalese exports in the foreign markets other than India. According to the fixed dual exchange rate system, payments for merchandise exports and imports (except for the import of highly essential commodities such as petroleum, fertilizers, etc. for which payments were made at basic rate) were made at a higher rate of NRs 16 per US Dollar as against the basic rate of NRs 12 per US Dollar which applied to all other payments (ADB/M 1982, Vol.II, p.27). The rate of NRs 16 per US Dollar was reduced to NRs 14 per US Dollar in 1980. The dual exchange rate system also allowed the Nepalese exporters earning in Dollars to exchange their Dollar earnings into Nepalese Rupees at a premium (of 33 percent until February 1980, then 17 percent) over the normal exchange rate (Wallace 1987). However, the effectiveness of the system to encourage agricultural exports is still a matter of empirical investigation. Since almost all of the agricultural exports are being done to India and in Indian Rupees (rather than in Dollars), the Nepalese exporters of agricultural products did not receive any incentive from the dual exchange rate system to increase their exports which dominates the country's total exports. As a result, the system could not raise the total exports in Nepal. Therefore, the system was again unified in September 1981 at NRs 13.20 per US Dollar.

The fixed unified exchange rate system with respect to the US Dollar was replaced by the floating exchange rate system in 1983. During the period 1983 to 1986, the Government of Nepal used a basket of currencies approach under its exchange rate system. According to the approach, the basket of currencies contained only two currencies, viz. the Indian Rupee and all other foreign currencies combined together. The Indian Rupee was kept fixed with respect to the Nepalese Rupee while all the other foreign currencies were allowed to float. In June 1986, the fixed exchange rate system with respect to the Indian Rupee was also replaced by the floating exchange rate system.

Thus, the Nepalese exchange rate policy which has been changing over the period is basically designed to increase the country's non-agricultural exports rather than agricultural exports. Nevertheless, the policy seems to have a reasonable impact on agricultural exports as the agricultural exports in Nepal dominate the country's total exports. According to available literature, there exists an inverse relationship between a country's exchange value of domestic currency and its agricultural exports (Schuh 1976, Van Duyne 1979, Chambers and Just 1981, Gardner 1981 and Longmire and Murey 1983). Therefore, the time to time devaluation of Nepalese Rupee with respect to the Indian Rupee may have increased the Nepalese agricultural exports to India. In addition to this, the shift from fixed exchange rate system to the floating exchange rate system in Nepal may have increased the importance of exchange rate policy in the agricultural sector. It is because such a shift in exchange rate system opens a new channel for transmitting the macroeconomic policy shocks to the traded goods sector, such as agricultural sector. According to the conventional thinking, a change in exchange rate as a result of a change in macroeconomic policy in a country results a change in exports and imports of that country. A decrease in the exchange value of a country's currency not only increases exports of that country, as mentioned above, but it also increases the prices of its imports in domestic currency terms. Therefore, such a decrease in the exchange value of domestic currency is more likely to reduce a competitive pressure on those domestic industries which produce importable goods. Thus, the floating exchange rate policy in Nepal seems to have influence on the country's export sector, such as agricultural sector, and sector involved in producing importable goods.

2.6 Summary

The agriculture sector which uses the land resource has remained the leading sector of the Nepalese economy. Therefore, the sector is given top priority in the country's development plans. In December 1964, Nepal adopted a comprehensive land reform act in order to bring more equitable distribution of cultivable land. However, achievements of such land reform are not satisfactory due to several factors, such as the resistance of land owners, lack of cooperation between government agencies and bureaucratic procedures relating to implementation of the land act.

In Nepal, the effectiveness of agricultural research and extension services to increase the production and productivity of the crop sector is severely restricted by the financial difficulties and the attitude of Government towards agricultural research. Agricultural research has remained neglected on the assumption that agricultural technologies can be easily transferred from other countries, whereas the financial difficulties to increase the quality and quantity of field technicians are the major constraints in extending the agricultural extension services through out the country.

The Agricultural Development Bank (ADB/N), Sajhas and the commercial banks which are the major sources of institutional credit in the Nepalese agricultural sector provide subsidized credit to farmers. However, such subsidized credit is generally misused by large farmers. As a result, the lending institutions, especially the ADB/N and Sajhas, are facing a problem of overdue loans which has led the central bank to curtail drastically its disbursement of refinance to these institutions. This has further resulted in a decline in the total credit that was being distributed to farmers in those years and, thereby, resulted in an adverse effect on the agricultural sector. However, in recent years the ADB/N and Sajhas have improved their financial situation by putting greater emphasis on loan recovery and monitoring farmers' use of credits more closely.

In Nepal, the agricultural price policy has three major elements, viz. the output price support policy, input price subsidy policy and food security and consumer price subsidy policy. The output price support policy which provides incentives to farmers to raise their production level is highly influenced by the output support price policy in India, mainly due to the open border between these two countries. Since the very beginning, the policy has not been very successful in achieving its objective, mainly due to unavailability of sufficient funds to procure enough foodgrains in order to have positive impacts on prices and production and also due to untimely announcement of the support prices. Similarly, the food subsidy policy which has been adopted to eliminate food deficits and to stabilize market prices in the country has not been very successful mainly due to financial limitations.

Regarding the input price policy, the Government of Nepal sets uniform selling prices of fertilizer through out the country and also provides heavy subsidies on those selling prices. Besides this, the Government also gives transportation subsidy while transporting fertilizer and HYV seeds from the Tarai to the Hills. However, the cost of such input subsidy policy in Nepal remains very high. Therefore, the Government of Nepal has recently declared a policy that indicates a gradual phase out of the existing input subsidy programmes in Nepal. Hence, the subsidy aspect will not remain as a major element in the Nepalese input price policy in the near future. However, as a result of the open border with India, the Nepalese input price policy will remain much influenced by the input price policy in India.

Agricultural exports have remained the dominant export items in Nepal. However, these exports have declined in recent years, especially due to a decline in the country's agriculture surplus and also due to foodgrain self-sufficiency in India. Moreover, following the food deficit in 1986/87, the Government of Nepal adopted a trade policy that restricts the export of foodgrains from Nepal. Nevertheless, the open border with India and higher foodgrain prices in India have resulted in a significant volume of foodgrains being smuggled out from the Tarai to India. The movement of grains across the border also occurs due to non-price factors. In absence of adequate road facilities across the different regions of Nepal, foodgrains are exported from Nepal to India in the Tarai region while foodgrains are also imported from India to Nepal in the far western Hills and Mountains of Nepal. Similarly, whenever there is some restrictions on interstate movement of grains in India, movement of foodgrains occur from one state of India into Nepal, along Nepal's roads, and back into other Indian states. Thus, the agricultural trade policies in Nepal have remained highly influenced by the country's open border with India and existing transportation facilities within the country. Therefore, these issues need to be carefully addressed in future agricultural trade policy in order to make the policy more effective.

The Government of Nepal has been adopting a lower interest rate policy in agricultural credit in order to encourage the use of modern inputs and, thereby, to increase production and productivity of the agricultural sector. However, the subsidized credit is being misused on a large scale, especially by large farmers. Therefore, the future credit policy must address this issue in order to achieve its major objectives.

Regarding exchange rate policy, the fixed exchange rate system which was adopted in 1960 was latter replaced by the floating exchange rate system against the US Dollar in 1983 and against the Indian Rupee in June 1986. The Nepalese exchange rate policy which is basically designed to increase the country's non-agricultural exports rather than agricultural exports seems to have a reasonable impact on agricultural exports. It is argued that the shift from fixed exchange rate system to the floating exchange rate system in Nepal may have opened a new channel for transmitting the macroeconomic policy shocks to the traded goods sector such as agricultural sector. According to the conventional thinking, a change in exchange rate as a result of a change in macroeconomic policy in a country results a change in exports and imports of that country. Therefore, the floating exchange rate policy in Nepal seems to have influence on the country's export sector such as agricultural sector and sector involved in producing importable goods.

CHAPTER 3

PRODUCTIVITY AND PRODUCTION STRUCTURE: REVIEW AND SPECIFICATION

3.1 Definition of Technical Change and Total Factor Productivity

In this study, the word technical change has been frequently used for total factor productivity, because total factor productivity growth and technical change are considered to be the same. This equivalence is commonly assumed, although it does overlook the point that estimated productivity growth may include influences beyond pure technical change such as scale effects.

In the development economics literature, technical change is mainly defined under two conceptual approaches: the productivity index approach and the production function approach (Peterson and Hayami 1977). Under the productivity index approach, technical change is defined as an increase in output per unit of input, whereas in the latter approach it is defined as an upward shift in the production function. However, both conceptual approaches are considered to be entirely consistent with each other. That is, each productivity index implies the existence of a particular production function and vice versa (Afriat 1972; Diewert 1976; Pollak 1971; Samuelson and Swamy 1974).

3.2 Classification of Productivity Measurements

There are two types of productivity measurements. One is partial productivity and the other is total factor productivity. When productivity is expressed in terms of output per unit of a single input, it is called partial productivity. On the other hand, when productivity is expressed in terms of output per unit of total inputs, it is called total factor productivity.

Partial productivity measures such as yield per acre or output per person often do not provide a good picture of economic growth because they do not take the effect of other factor inputs into account. Moreover, such partial productivity measures do not measure the specific contribution of an individual factor to the production process, rather they reflect the joint effect of a number of interrelated influences on the use of the factor in the production process, such as technological change, factor substitutions, and managerial and organizational skills. In other words, there exists a problem of measurement error in partial productivity. Therefore, the concept of total factor productivity has been developed to overcome such problems. Total factor productivity, which is generally defined as the ratio of output to all inputs combined together, is the preferred device to measure technical change in an economy.

3.3 Measurement of Total Factor Productivity: A Review

There are two approaches to total factor productivity measurement: the growth accounting (index number) approach and the econometric approach (Antle and Capalbo 1988, pp. 48-63). The growth accounting approach is based on the neoclassical theory of production and distribution which states that payments to factors exhaust total product under the assumptions of competitive equilibrium and constant returns to scale. Therefore, in the presence of technological advance, payments to factors would not exhaust total production, rather there remains a residual output not explained by total factor input. And, this residual output is used as the basis for measuring and explaining the productivity growth in the growth accounting approach. On the other hand, the econometric approach to productivity measurement is based on estimation of the production technology. According to this approach, technological change can be described by shifts in a production function. Therefore, if scale effects and efficiency effects (the efficiency with which the input resources are utilized) are assumed to be constant at a certain level, then the shift in the production function associated with technological change can be directly used as measurement for productivity change.

However, difficulties arise when choosing one approach over another, because each of these approaches has strengths and limitations. The index number approach generally puts several strong assumptions about the technology of production, such as Hicks-neutral technical change, constant returns to scale and long run competitive industry equilibrium. Since these assumptions may not be true in many cases, the conclusions derived under this approach may mislead. These assumptions can be relaxed in the econometric approach by estimating a translog production function, but then the approach can be used only under the strong assumption of separability. That is, while estimating the aggregate production function, the outputs must be aggregated into a single index. Therefore, the assumption of input-output separability must be imposed. Moreover, in case of large number of inputs and for a relatively small sample size, the approach becomes infeasible as sufficient degrees of freedom are lost in estimating a translog production function.

A translog production function with five input factors and one time variable includes a total of 27 variables on the right hand side of the production function: five input variables, one time variable, six square terms involving five inputs and one time variable, ten interaction terms involving five inputs, and five interaction terms involving five inputs and one time variable. Thus, estimation of translog production functions for each of three production regions, viz. the Hills, Kathmandu Valley and Tarai, is not possible in this study as the regional time-series data are available only for 12 years (from 1969/70 to 1980/81). This problem of losing degrees of freedom can sometimes be solved by aggregating input data into a small number of categories, but this was not possible in this case.

In addition to the above limitations, another limitation of the econometric approach involves the description of technical change with respect to time. That is, the approach strongly assumes that the technical change is a function of time only. Thus, it is very difficult to choose one approach over another simply on the basis of their strengths and limitations Nevertheless, as in several previous productivity studies, the proposed study intends to use the growth accounting approach to measure the technical change in the Nepalese crop sector. This will make the results of this study comparable to the results of those studies that are carried out in neighboring nations (especially India and China) using the same index number approach. Moreover, as mentioned above, the small sample size (N=27) with five factor inputs, viz. land, labour, bullocks, fertilizer and High Yielding Variety (HYV) seeds, as well as one time variable, restricts the use of the translog production function and for that matter translog cost function under the econometric approach whenever the degrees of freedom become insufficient.

Further, the growth accounting approach and the econometric approach are believed to have linkages with one another. However, such linkages are not crystal clear in the existing literature of productivity measurement. Therefore, in the latter part, the study intends to estimate share equations representing a translog cost function to measure technical effects and production structure in the Nepalese crop sector.

According to the growth accounting approach, two indices are computed, one for total output and the other for all factor inputs; with this, the ratio of the output index to the aggregate input index is obtained. There is no controversy among economists with respect to this overall framework. However, they do disagree with respect to methods used to implement the framework. They basically differ on the choice of an index number procedure used to aggregate outputs and inputs.

There are three major indexing procedures that have been frequently used in most previous productivity studies such as Abramovitz (1956), Ruttan (1956 and 1957), Schultz (1953 and 1961), Solow (1957), Kendrick (1961), Chandler (1962), Christensen and Jorgenson (1973), Veeman and Fantino (1985), Capalbo and Denny (1986), Rahuma and Veeman (1988), Wong (1989) and Lin (1990) in order to measure technical change in developed and developing countries. These are the arithmetic index, the geometric index and the flexible weight index. The first procedure uses a linear aggregation of various inputs with market factor prices as weights. The second one uses geometric aggregation with factor shares in total output as weights, and the third procedure which uses factor share in total cost as weights does let the share vary with respect to time. In addition, each of these indices represents a particular production function. The first, second and third indices respectively represent a linear, Cobb-Douglas and translog production function. Detailed discussion of each of these index procedures is provided in the following sections.

3.3.1 The Arithmetic Index of Productivity

The arithmetic index, which was first introduced by Abramovitz (1956) and Kendrick (1961), expresses all variables of an underlying production function as index numbers with a common base period and appropriate weights. The productivity index I with two inputs is defined as:

$$(3.1) \qquad I = \frac{\frac{Q}{Q_0}}{\left(\frac{P_{k0}K_0}{Q_0}\right)\left(\frac{K}{K_0}\right)+\left(\frac{P_{l0}L_0}{Q_0}\right)\left(\frac{L}{L_0}\right)} = \frac{Q}{P_{k0}K + P_{l0}l}$$

where Q/Q_0, K/K_0 and L/L_0 represent indices of output, capital and labour, respectively; P_{k0} and P_{l0} are base year prices of capital and labour; and the weights used for capital and labour are their respective base-year shares in output.

The direct association of this index with respect to a linear production function can be seen by rewriting equation (3.1) into the form of equation (3.2) which shows output is a linear combination of the inputs.

(3.2) $$Q = I(P_{k0}K + P_{l0}L)$$

The most common indexing formulas involving the arithmetic index are the Laspeyres formula and the Paasche formula. The former uses base year weights and the latter uses end-year weights. The Paasche formula is relatively less popular as compared to the Laspeyres formula. One of the reasons may be that the formula has the effect of biasing upward the measure of output per unit of input (Ruttan 1954). On the other hand, the Laspeyres formula has been widely used by researchers, such as Barton and Cooper (1948), Kendrick (1961), Loomis and Barton (1961), Ruttan (1956 and 1957) and Schultz (1953 and 1961). The most common form of presenting the conventional Laspeyres quantity index (Christensen 1975) is given in equation (3.3) in which fixed base period prices are used as weights.

(3.3) $$I_t = \frac{Q_t}{Q_0} = \frac{\sum_i P_{i0} Q_{it}}{\sum_i P_{i0} Q_{i0}}$$

where I_t is the aggregate input (output) quantity index in period t and, P's and Q's are prices and quantities of various inputs (outputs) with subscript o and t indicating the base period and comparison period respectively. Equation (3.3) can be re-written as:

(3.4) $$I_t = \frac{\sum_i \left(\frac{Q_{it}}{Q_{i0}}\right) P_{i0} Q_{i0}}{\sum_i P_{i0} Q_{i0}} = \sum_i W_{i0}\left(\frac{Q_{it}}{Q_{i0}}\right), \qquad \text{where} \qquad W_{i0} = \frac{P_{i0} Q_{i0}}{\sum_i P_{i0} Q_{i0}}$$

Further, if the base period prices and quantities are allowed to change in each successive indexing peri..., then the conventional Laspeyres quantity index becomes the Laspeyres chained quantity index which can be written as:

$$(3.5) \qquad I_t = \frac{Q_t}{Q_{t-1}} = \frac{\sum_i P_{i,t-1} Q_{it}}{\sum_i P_{i,t-1} Q_{t-1}}$$

Because of its ease of use and intuitively appealing interpretation, the Laspeyres index became very popular during the sixties and seventies. In case of the conventional Laspeyres quantity index presented in equation (3.3) and (3.4), prices are kept constant at their base period levels. Therefore, it is only the matter of quantities of outputs or inputs for the period of study that are required to construct index numbers. However, in recent times several problems and limitations have been cited with respect to this index procedure.

As mentioned above, the Laspeyres index is associated with a linear production function implying perfect substitutability between factors of production. That is, the elasticity of substitution between the two factors in any input pair is considered to be infinity. However, in agriculture production processes, factors are typically not perfect substitutes. Therefore, the Laspeyres index procedure which underlies a linear production function seems to be an inappropriate procedure to estimate the total factor productivity growth in the real world. A theoretical problem arises in the linear production function. Marginal productivities of inputs in such a function (equation 3.2) change only through changes in the productivity constant, I, and the ratio of marginal productivities (i.e. marginal rate of substitution) remains the same regardless of how fast one input is growing in relation to the other (Yotopoulos and Nugent 1976). That is, under the assumption of perfect competition, marginal productivities of inputs become equal to their respective prices; and since prices are fixed at their base period, therefore, the index does not associate changes in marginal productivities with changes in input ratio (factor proportions). Thus, any index procedure based on such a function is less likely to be an appropriate procedure to study productivity growth. Rather, the total factor productivity measured with such a procedure is likely to be underestimated (Ruttan 1954). Hence, the Laspeyres index or the arithmetic index of productivity is less preferable at the present time.

3.3.2 The Geometric Index of Productivity

Solow (1957) was a pioneer in using the geometric index to measure technical change in productivity analysis. As compared to the arithmetic index, the geometric index is a more appropriate procedure to measure technical change as it allows prices of inputs and, therefore, their marginal productivities to vary. The geometric index of productivity can be derived by assuming an aggregate production function of the following form:

$$Q = A(t)f(K,L) \tag{3.6}$$

For simplicity, the production function in this section has been expressed in terms of only two inputs: capital (K) and labour (L). However, the function can be extended to any number of inputs. The technology function A(t) indicates that the technology is a function of time only, and it is independent of capital and labour. Therefore, the technology is both disembodied and Hicks-neutral. That is, the technical change does not affect the marginal rate of substitution between factors of production. It simply shifts the production function obtainable for a given level of factor inputs.

By differentiating equation (3.6) totally, a change in total output with respect to a change in amounts of factor inputs can be obtained as follows:

$$dQ = f(K,L)\left(\frac{\partial A(t)}{\partial t}\right)dt + A(t)\left[\left(\frac{\partial f}{\partial K}\right)dK + \left(\frac{\partial f}{\partial L}\right)dL\right] \tag{3.7}$$

When time is introduced as an element into the above equation and when K and L are allowed to be functions of time, equation (3.7) becomes:

$$(3.8) \qquad \frac{dQ}{dt} = f(K,L)\left(\frac{\partial A(t)}{\partial t}\right) + A(t)\left[\left(\frac{\partial f}{\partial K}\right)\left(\frac{dK}{dt}\right) + \left(\frac{\partial f}{\partial L}\right)\left(\frac{dL}{dt}\right)\right]$$

$$= f(K,L)\left(\frac{\partial A(t)}{\partial t}\right) + A(t)\left[f_1\left(\frac{dK}{dt}\right) + f_2\left(\frac{dL}{dt}\right)\right]$$

where f_1 and f_2 are the marginal productivities of capital and labour respectively. Equation (3.8) indicates that an increase in total output over time can be decomposed into three parts, each giving the changes resulting, respectively, from changes in technology, capital input and labour input.

The technology function A(t) could be as simple as a constant, a simple linear function like $A(t) = \alpha + \beta T$, or it could be an exponential function like $A(t) = \alpha e^{\beta t}$, so that its effect on the productive efficiencies of the input factors may increase through time. In any case, considering $A = A(t)$ and $(dQ/dt) = \dot{Q}$, $(dA(t)/dt) = \dot{A}$, $(dK/dt) = \dot{K}$ and $(dL/dt) = \dot{L}$, equation (3.8) can be re-written as:

$$(3.9) \qquad \dot{Q} = \dot{A} f(K,L) + A f_1 \dot{K} + A f_2 \dot{L}$$

When equation (3.9) is divided throughout by Q [=Af(K, L)], it becomes:

$$(3.10) \qquad \left(\frac{\dot{Q}}{Q}\right) = \left(\frac{\dot{A}}{A}\right) + A f_1\left(\frac{\dot{K}}{Q}\right) + A f_2\left(\frac{\dot{L}}{Q}\right)$$

Further, assuming that factors are paid according to their marginal products, the shares of capital and labour in a linear homogeneous production function of type (3.6) are obtained as:

$$(3.11) \qquad S_k = \frac{(KAf_1)}{Q} \quad \text{and} \quad S_l = \frac{(LAf_2)}{Q}$$

where S_k and S_l are the respective shares of capital and labour in total output according to their marginal productivities. Substituting these share equations into equation (3.10), the standard Solow growth accounting equation can be obtained:

$$(3.12) \qquad \left(\frac{\dot{Q}}{Q}\right) = \left(\frac{\dot{A}}{A}\right) + S_k\left(\frac{\dot{K}}{K}\right) + S_l\left(\frac{\dot{L}}{L}\right)$$

By rearranging the terms, the "residual" contribution to growth, commonly identified as technical change or productivity growth, can be isolated on the left hand side:

$$(3.13) \qquad \left(\frac{\dot{A}}{A}\right) = \left(\frac{\dot{Q}}{Q}\right) - S_k\left(\frac{\dot{K}}{K}\right) - S_l\left(\frac{\dot{L}}{L}\right)$$

Thus, the percentage change in technology can be estimated as the percentage change in output less the proportionate change in capital input and proportionate change in labour input. In the case of a Cobb-Douglas (CD) type of production function, $Q = Ae^{rt}K^{\alpha}L^{\beta}u^{\gamma}$, the coefficients α and β simply become the shares of capital and labour, respectively. Therefore, equation (3.13) becomes:

$$(3.14) \qquad \left(\frac{\dot{A}}{A}\right) = \left(\frac{\dot{Q}}{Q}\right) - \alpha\left(\frac{\dot{K}}{K}\right) - \beta\left(\frac{\dot{L}}{L}\right) - \gamma\left(\frac{\dot{u}}{u}\right)$$

where u is an error term representing omitted variable(s). If each and every factor is paid according its marginal product and output is totally exhausted, then the contribution of the error term u to the total factor productivity is $(A/\dot{A})$. That is, $\gamma(\dot{u}/u) = (\dot{A}/A)$.

Further, Solow's geometric index can be also used to decompose the increased output per man-hour into increase in productivity $(\dot{A}/A)$ and increase in capital per man-hour. Under the assumption of constant returns to scale, that is $(\alpha + \beta) = 1$, and dividing each variable in equation (3.14) by L, we get:

$$(3.15) \qquad \left(\frac{\dot{q}}{q}\right) = \left(\frac{\dot{A}}{A}\right) + \alpha\left(\frac{\dot{k}}{k}\right)$$

where q = (Q/L) and k = (K/L).

Thus, equation (3.15) explains how much of the increase in output per man-hour is due to increased productivity and how much is due to an increase in capital per man-hour.

The geometric index procedure has been used by several researchers, such as Chandler (1962), Lave (1964), Evenson and Jha (1973), Krueger and Tuncer (1980), Wong (1989) and Lin (1990), in their productivity studies. Despite a wide use of the procedure, it carries three possible sources of bias in the magnitude of the residual $\dot{A}/A$ and its stability (Nadiri 1970; Kennedy and Thirlwall 1972). The first one is misspecification of the form of production function which, in the case of the CES function, may result in an underestimate or overestimate of $\dot{A}/A$ depending on the elasticity of substitution (σ), that is, whether σ is greater or less than zero (Yotopoulos and Nugent 1976, p.156). The second one is errors of measurement in K and L. In other words, if K and L are misspecified by a multiplicative factor which is used to adjust quality improvement over time, the residual becomes the weighted average of the quality changes embodied in the misspecified inputs (Yotopoulos and Nugent 1976, p.156). Thirdly, the bias may arise when some pertinent variables are omitted from the production function. In such case, the residual $\dot{A}/A$ overestimates the true increase in productivity. Besides these biases, the basic assumptions of the geometric index that the technical change is neutral and disembodied are, in fact, far from reality (Mundlak and Razin 1969).

3.3.3 Flexible Weight Index of Productivity

The flexible weight index of productivity is based on the cost share concept. The underlying production function of this index is the flexible form (translog) production function which does not put prior restriction on the value of the elasticity of substitution;

whereas the production functions which underlie the geometric index do put prior restriction on the value of the elasticity of substitution. In other words, the CD function restricts the value of elasticities of substitution to unity implying the constancy of factor shares. On the other hand, the CES function is relatively superior to the CD function in the sense that it can be used to derive values of elasticities of substitution other than one and it can link movements of factor shares with magnitude of factor substitution. However, the function becomes highly restrictive when dealing with more than two inputs. Moreover, it is difficult to examine complementary relationships using the CES function as it can not generate negative values of elasticities of substitution coefficients. Similarly, the Leontief function is less preferred because there is no possibility of input substitution with the consequent elasticities of substitution of zero. However, these disadvantages are omitted in a flexible functional form which allows for any value of elasticity of substitution between input pairs and which can consider a large number of inputs in the function. That is, the flexible functional forms consider both substitutability and complementarity relationships between input pairs in a production process.

A wide use of flexible forms started in 1971 with the development of the transcendental logarithmic (translog) function by Christensen, Jorgenson and Lau (1971) and the Generalized Leontief function by Diewert (1971). Later, other functional forms were also developed by different writers such as the Generalized CD function by Diewert (1973), the Quadratic function by Lau (1974), and the Generalized Concave function by McFadden (1978). These several flexible forms have one important common mathematical property that each of them can provide a second order local approximation to any twice differentiable production, cost or utility function, therefore, it becomes difficult to choose the best among these flexible forms on theoretical grounds (Berndt, Darrough and Diewert 1977). Several researchers such as Kiefer (1975), Berndt, Darrough and Diewert (1977) and Appelbaum (1979) have tried to compare these different flexible forms empirically, but their results are neither conclusive nor comparable in the sense that they have used different manufacturing data. Therefore, it is difficult to choose the best flexible form on the basis of available empirical studies. Nevertheless, the translog function has been widely used in agricultural studies by researchers, such as Binswanger (1973 and 1974a), Brown (1978), Chotigeat (1978), Kako (1978), Islam (1982), Adamowicz (1986) and Rahuma (1989); and the function has yielded consistently meaningful results.

As mentioned above, recent developments in the area of productivity indexes have shown that each index procedure represents a particular production function. The Tornqvist index, which was first mentioned by Fisher (1922) and shown as applicable for indexing output or inputs by Tornqvist (1936), Theil (1965) and Kloek (1966), is exactly associated with the homogeneous translog production function as proposed by Christensen, Jorgenson and Lau (1971 and 1973). As discussed earlier, inputs do not have to be perfect substitutes in a translog function. Therefore, as the relative price of an input increases, its use will decrease (replaced by cheap inputs) until all marginal productivities are proportional to new prices. Thus, the Tornqvist (Divisia) index representing the translog function is indeed capsulizing the essence of marginal productivities of both periods through prices of both base period and comparison period. Therefore, the Tornqvist index procedure has been widely used by researchers in Canadian and American agriculture such as Islam (1982), Veeman and Fantino (1985), Manning (1984 and 1985), Ball (1985), Capalbo and Denny (1986) and Rahuma (1989), while indexing quantity and prices of outputs and inputs to measure technical change. Moreover, use of a translog cost function to estimate biases of technical change with many factors of production has been shown by Binswanger (1974b). The Tornqvist index procedure that underlies the translog production function is described in the following paragraphs.

The Tornqvist index is an approximated form of Divisia index which is defined in continuous time by the line integral (Christensen 1975) as shown in equation (3.16).

$$\frac{Q_t}{Q_0} = \exp\left(\int \sum_i W_{it}\left(\frac{\dot{Q}_{it}}{Q_{it}}\right)\right), \qquad \text{where} \qquad W_{it} = \frac{P_{it}Q_{it}}{\sum_j P_{jt}Q_{jt}} \tag{3.16}$$

W_{it} denotes the share factor in total cost or the share of the i-th output in total value product dur t. P's and Q's are prices and quantities of inputs (or outputs) under conside . Further, discrete approximations to the Divisia index converge to the Divisia index as the discrete units of time become relatively small (Christensen 1975). Though there are many ways of approximating the Divisia index, the weighted log-change (arithmetic average) index as shown in equation (3.17) has remained the one used most widely in recent studies (Christensen 1975).

$$\ln\left(\frac{Q_t}{Q_0}\right) = \sum_i \overline{W}_i \ln\left(\frac{Q_{it}}{Q_{i0}}\right) \qquad \text{where} \qquad \overline{W}_i = \frac{(W_{it} + W_{i0})}{2} \tag{3.17}$$

The Divisia index presented in equation (3.17) is a fixed base Divisia index because the base weight (W_{i0}) and quantity (Q_{i0}) remain fixed through out the index series. If the base period is allowed to change for each successive period, the index can be called the Divisia chained index which can be written as:

$$\ln\left(\frac{Q_t}{Q_{t-1}}\right) = \sum_i \overline{W}_i \ln\left(\frac{Q_{it}}{Q_{i,t-1}}\right) \qquad \text{where} \qquad \overline{W}_i = \frac{(W_{it} + W_{i,t-1})}{2} \tag{3.18}$$

The aggregate output and input thus obtained through the Tornqvist index procedure is further used to estimate the growth of total factor productivity which is defined as the residual difference between the rate of growth of aggregate output and the rate of growth of all inputs.

3.4 Choice of Productivity Index Procedure

Following from the above discussion, the flexible weight index is relatively superior to the arithmetic and geometric indices in measuring total factor productivity. Its major advantage over the other two indices is the flexibility in its associated functional form. As discussed earlier, the flexible functional form allows any value of elasticity of substitution and also allows cost shares to vary with respect to time. However, selecting a model is not only a matter of theoretical interest. A model should also be judged on the basis of its practicality. In this regard, the flexible weight index procedure becomes practically feasible only when good quality time series data on both quantities and prices of each input and output are available for empirical analysis. That is, the method is meaningful in a country where the data base is qualitatively and relatively better. Unfortunately, Nepal does not have a good data base. In the case of Nepal, data on quantity for each input and output are readily available together with data on output prices since the early 1960s. However, it is very difficult to obtain time series data on input prices, especially prices of land and bullocks. Moreover, the available data on wage rates are also not sufficient to cover the entire intended study period. Therefore, it becomes rather difficult to use the flexible weight index to measure total factor productivity in Nepal. In such a situation, the geometric productivity index becomes the most feasible and appropriate index to use, because it does not need input price data and it is superior to the arithmetic index. Therefore, the geometric index procedure has been chosen to measure total factor productivity in the Nepalese crop sector. Moreover, the procedure also makes productivity growth rates estimated in this study comparable to the growth rates estimated for other LDCs, especially India and China. It is because the productivity studies relating to these countries have also used the same geometric index procedure.

Further, the advantages of the flexible weight index procedure over the arithmetic and geometric index procedure are so great that most researchers of recent times have used this procedure in their productivity analysis. Therefore, an attempt has been made to proxy land prices and costs of bullocks in order to use the flexible weight index procedure in this study and, hence, to compare its results with those derived from the geometric index procedure. The procedures of approximating prices of land and bullocks as well as the procedure of extrapolating wage rates are discussed in Chapter 4, whereas the empirical estimation and analysis of the total factor productivity with respect to flexible weight index procedure are presented in Chapter 6.

3.5 Estimation of Factor Shares and Production Structure

3.5.1 Estimation of Factor Shares

Factor shares in the flexible weight index procedure can be easily calculated using the formula for factor share given in equation (3.16). However, calculation of factor shares in the geometric index procedure requires an estimation of an aggregate production function underlying the Nepalese crop sector. As in most previous productivity studies that used the geometric index procedure, this study also uses the Cobb-Douglas production function to estimate factor shares in total output of the Nepalese crop sector. The aggregate production function given in equation (3.6) that assumes the disembodied and Hicks-neutral technical change is extended to include five factor inputs as follows:

(3.19) $$Q = A(t)\,f(R, L, B, F, S)$$

where R, L, B, F and S respectively represent the total cropped area, labour, bullocks, fertilizer and HYV seeds.

Assuming the underlying production function is a Cobb-Douglas and the technology function is an exponential function of time (T), equation (3.19) can be re-written as:

(3.20) $$Q = Ae^{\beta_7 T} R^{\beta_1} L^{\beta_2} B^{\beta_3} F^{\beta_4} S^{\beta_5}$$

Technical change has been assumed to be disembodied and Hicks-neutral. Further, the production function is often assumed to be linearly homogeneous of degree one. This property of the production function is tested by formulating the null hypothesis as: $H_0\colon\ \beta_1 + \beta_2 + \ldots + \beta_5 = 1$.

The production function presented in equation (3.20) treats all inputs as variable inputs and, thus, underlies a long run production function. Therefore, the production function may not truly represent a situation of the short run in which some inputs such as land remain fixed. Issues relating to variable and fixed inputs have been recently discussed by many writers such as Chambers (1988, pp. 100-9) and Debertin (1986, pp. 18-20).

In the agriculture production literature, a variable input is generally defined as an input for which a farmer (or farm manager) has control over the level of input use in the production process, whereas a fixed input is defined as an input for which he or she does not have control over the amount of input available. However, these distinctions of variable and fixed input have remained muddy and confused (Debertin 1986, p. 19). The confusion arises in defining short run and long run with respect to length of time. In other words, whether an input is fixed or variable depends upon the time period. If the time period is sufficiently long, then all inputs become variable inputs and, if the time period is relatively very short, then many of the agricultural inputs will be fixed inputs. Therefore, any classification of inputs based on a given time period is somewhat arbitrary and, therefore, results derived from such classification could be misleading. Moreover, this study emphasizes crop production in which input decisions are made prior to planting. At that stage of decision making, a farmer can rent additional land or buy or sell his bullocks. Therefore, it is assumed in this study that all crop inputs are treated as variable inputs and, thus, the production function (3.20) is taken as a properly specified production function to estimate factor shares in the Nepalese crop sector. The aggregate Cobb-Douglas production function and the factor shares in the total crop output are estimated and presented in Appendix 2.

3.5.2 Estimation of Production Structure

3.5.2.1 Elasticities of Substitution and of Factor Demand

According to duality theory, the production function and the cost function, given some specific properties, are dual to each other. Therefore, a production structure can be known either estimating the parameters of the underlying production function directly or estimating the parameters indirectly from the cost function data. In recent times, most production technology studies have used the translog cost function to estimate important parameters of the underlying production structure. Therefore, this study also uses the translog cost function under the duality approach to estimate the production structure of the Nepalese crop sector.

The translog cost function which takes technical change into account is generally written as (Chambers 1988, p.197; Binswanger 1974b):

$$(3.21) \qquad lnTC = \alpha_0 + \alpha_Y lnY + (1/2)\gamma_{YY}(lnY)^2 + \sum_i \beta_i lnP_i + (1/2)\sum_i \sum_j \gamma_{ij} lnP_i lnP_j$$
$$+ \sum_i \alpha_i lnY\, lnP_i + \theta_T T + (1/2)\theta_{TT}T^2 + \theta_{TY} T\, lnY + \sum_i \theta_i T\, lnP_i + u_i$$

where TC is total cost of production, Y is aggregate output, P's are input prices, T is the time variable, u is the error term and i represents inputs land, labour, bullocks, fertilizer and HYV seeds.

Using Shephard's lemma (1953), the cost-minimizing derived demand equations (3.22) can be obtained by logarithmically differentiating total cost in equation (3.21) with respect to input prices. The derived demand equations, each with explanators which are a function of time, can be then used as a set of input cost share equations to estimate the parameters of the underlying production function using time series data.

$$\frac{\partial \ln TC_t}{\partial \ln P_{it}} = s_{it} = \beta_i + \sum_j \gamma_{ij} \ln P_{jt} + \alpha_i \ln Y_t + \theta_i T_t + u_t \qquad (3.22)$$

where $s_{it} = [(P_{it} X_{it}) / \sum P_{it} X_{it}]$ is the share of i-th input in total cost in period t and u is the error term.

The estimates derived from equation (3.22) become meaningful only when the equation satisfies five major conditions: adding-up, monotonicity, concavity in input prices, homogeneity of degree zero in input prices and symmetry . For this, the adding-up, homogeneity and symmetry restrictions need to be imposed in equation (3.22), whereas the monotonicity and concavity restrictions are usually checked in the estimated model rather than imposing them in the estimation process (Antle and Capalbo 1988, p.76). The procedures of checking the monotonicity and concavity restrictions are discussed in Chapter 6. The imposed restrictions are:

$$\sum_i \beta_i = 1 \quad \sum_i \gamma_{ij} = 0 \quad \sum_i \alpha_i = 0 \quad \sum_i \theta_i = 0 \quad \text{(Adding-up criterion)} \qquad (3.23)$$

$$\sum_j \gamma_{ij} = 0 \quad \text{(Homogeneity of degree zero in input prices)} \qquad (3.24)$$

$$\gamma_{ij} = \gamma_{ji} \quad \text{(Symmetry criterion)} \qquad (3.25)$$

Regarding the estimation of the share equations, the adding-up condition of equation (3.23) is imposed, so that one of the share equations must be omitted in the estimation process. Dropping one of the share equations, the remaining four share equations are estimated as a system. An appropriate econometric method of estimating such a system with such large number of cross equation constraints is Zellner's Seemingly Unrelated Regression method (Zellner 1962). The modified version of this method has been discussed in detail by Berndt and Christensen (1974).

Further, the linear homogeneity constraints have also been incorporated into the above share equations, therefore, the parameters for the dropped out share equation can be obtained using the constraints given in equation (3.23) to (3.25).

The γ_{ij} coefficients which have little economic meaning of their own can be converted into point estimates of Allen partial elasticities of substitution (σ_{ij}) and of price elasticities of factor demand (η_{ij}) as follows (Binswanger 1974 a and Johnston 1984, p.336):

(3.26) $$\sigma_{ij} = \frac{\gamma_{ij}}{s_i s_j} + 1 \qquad \text{(for all } i \neq j\text{)}$$

(3.27) $$\sigma_{ii} = \frac{1}{s_i^2}(\gamma_{ii} + s_i^2 - s_i) \qquad \text{(for all i)}$$

(3.28) $$\eta_{ij} = \frac{\gamma_{ij}}{s_i} + s_j \qquad \text{(for all } i \neq j\text{)}$$

(3.29) $$\eta_{ii} = \frac{\gamma_{ii}}{s_i} + s_i - 1 \qquad \text{(for all i)}$$

Unlike in the CES function, these elasticities vary with changes in the values of cost shares. Therefore, values of σ and η are estimated for different subperiods in order to examine the changes in σ and η over time in the Nepalese crop sector.

3.5.2.2 Embodied Technical Change Biases and Scale Effects

The technical change discussed so far is Hicks-neutral and disembodied technical change. However, as mentioned earlier, such technical change is less likely to prevail in the real world. Rather, a technical change is more likely to be embodied and have a factor bias toward a certain input. The nature of a technical change is examined by estimating parameters of a translog production function or translog cost function that includes a technology variable presented in terms of a time trend. In the case of the translog cost function which is given in equation (3.21), the estimated coefficient of time variable T as well as the coefficients of the interaction terms between time (T) and input prices (P_i) indicate the nature and direction of the technical change. In other words, if the estimated coefficient $\theta_i = 0$ and $\theta_T \neq 0$, then the technical change is disembodied and Hicks-neutral; and if the estimated coefficient $\theta_i \neq 0$, then the technical change is embodied and has a factor bias towards the i-th input. In fact, $\theta_i > 0$, $\theta_i < 0$ and $\theta_i = 0$ represent respectively the i-th input-using, input-saving and input-neutral technical change.

Similarly, the scale effects which imply the effects of a change in output level on the demand of input factors can be obtained by examining the sign of the estimated coefficients of the interaction terms between aggregate output (Y) and input prices (P_i) in equation (3.21). That is, the estimated coefficient α_i in equation (3.21) gives the scale effect with respect to the i-th input factor in the underlying production structure. The $\alpha_i > 0$ implies that the scale effect is i-th input-using, $\alpha_i < 0$ implies that the scale effect is i-th input-saving, and $\alpha_i = 0$ implies that the scale effect is neutral with respect to the i-th input. The technical effects and scale effects underlying the production structure of the Nepalese crop sector are estimated and analyzed in Chapter 6.

CHAPTER 4

QUANTITIES AND PRICES OF CROP OUTPUTS AND INPUTS: DATA AND THEIR MEASUREMENT AND ANALYSIS

4.1 Introduction

As stated in section 1.5, the major objective of the study is to measure the total factor productivity growth and to estimate the production structure of the Nepalese crop sector for the period of 1961/62 to 1987/88. Therefore, time series data on quantities and prices of crop outputs and inputs are required to estimate the total factor productivity and production structure of the Nepalese crop sector. This chapter deals with the quantity and price data on crop outputs and inputs and their measurement and analysis.

The study includes all ten major crops that are being produced in Nepal together with six major crop inputs, viz. land, labour, bullocks, fertilizer and HYV seeds. Data on quantities and prices of outputs and inputs were gathered from Nepalese sources, such as the Department of Food and Agricultural Marketing Services (DFAMS), Central Bureau of Statistics (CBS), Agricultural Inputs Corporation (AIC) and the Agricultural Projects Services Centre (APROSC). In May 1987, the author returned to Nepal to collect all the available data required for this study. Mostly published secondary data have been used in this study.

4.2 Crop Output Quantity Data: Measurement and Analysis

The cropwise output quantity data which are measured in metric tons are presented in Table A1.1 of Appendix 1. Since the output quantity data on barley, potato, oilseeds, sugarcane and tobacco are not available for the first three years of the study period, these data are generated by extrapolating the actual output quantity data of 1964/65 to 1987/88 on the basis of an exponential function $Y = Ae^{bt}$. The validity of such extrapolated data is checked by comparing the actual data in adjacent years with the data which are predicted on the basis of the estimated exponential function. The complete output quantity data are presented in Table A1.1 of Appendix 1.

Further, a simple output quantity index series for each individual crop is constructed by considering output quantity of year 1961/62 as 100 in order to analyze the output growth trend of each individual crop in Nepal. The crop output quantity indices representing the period of 1961/62 to 1987/88 are presented in Table 4.1.

According to Table 4.1, the output growth rates are observed to vary from crop to crop during the period of 1961/62 to 1987/88. The highest output growth rate during the period is observed in the case of wheat followed by sugarcane which is a cash crop in Nepal. The output of wheat and sugarcane increased respectively by 7.04 and 6.90 percent per annum. The output growth rates of paddy, millet, potato and oilseeds are positive but relatively low as compared to the output growth rates of wheat and sugarcane. During the period, maize, barley, jute and tobacco have negative output growth rates which may have been caused by factors, such as a shift in area from one crop to another and also a decline in yield rates of these crops. Moreover, Table 4.1 also indicates that the output of paddy, maize, barley, potato and oilseeds grew relatively at a faster rate during the 1980s than in the 1960s and 1970s, whereas the output growth rates of wheat, millet, sugarcane, jute and tobacco are observed to be relatively higher during the 1960s than in the 1970s and 1980s. Further, the output growth rates of tobacco have remained negative since the beginning of the 1960s.

TABLE 4.1

CROP OUTPUT QUANTITY INDEX BY CROP: NEPAL, 1961/62 TO 1987/88

(1961/62 = 100)

Year	Paddy	Maize	Wheat	Millet	Barley
1961/62	100.00	100.00	100.00	100.00	100.00
1962/63	100.00	100.00	100.00	101.51	99.40
1963/64	100.05	100.71	100.72	64.90	98.81
1964/65	104.41	101.30	91.30	63.88	99.69
1965/66	104.70	101.54	106.52	121.68	107.35
1966/67	95.21	97.75	115.22	121.68	107.35
1967/68	100.52	88.44	147.79	115.06	86.80
1968/69	103.33	90.72	168.62	122.68	89.28
1969/70	106.32	94.29	191.80	127.22	93.48
1970/71	109.31	98.85	140.12	131.12	97.30
1971/72	111.19	90.00	161.72	131.32	97.61
1972/73	95.37	97.51	226.44	137.25	95.14
1973/74	114.63	96.51	223.51	143.89	98.26
1974/75	116.33	98.06	239.73	144.19	98.15
1975/76	123.52	88.71	280.43	144.60	94.55
1976/77	113.20	94.58	262.21	139.94	78.81
1977/78	108.28	87.84	298.04	131.33	86.07
1978/79	110.97	88.09	300.87	135.00	86.99
1979/80	97.72	68.32	318.83	121.01	89.33
1980/81	116.90	88.13	345.80	123.23	88.18
1981/82	121.45	89.15	381.07	123.41	89.49
1982/83	86.94	85.20	475.80	122.80	81.28
1983/84	130.79	90.28	459.20	116.51	85.50
1984/85	128.53	97.26	386.74	126.14	90.48
1985/86	133.04	103.65	433.33	139.83	89.72
1986/87	112.52	103.01	507.97	139.53	94.70
1987/88	141.45	106.94	539.57	152.21	93.17
Annual Compound Growth Rates:					
1961/62 to 1970/71	0.72	-0.90	7.09	5.44	-0.97
1971/72 to 1980/81	0.10	-2.06	6.85	-1.26	-1.54
1981/82 to 1987/88	3.54	3.80	3.99	3.81	1.70
1961/62 to 1987/88	0.88	-0.21	7.04	1.50	-0.56

TABLE 4.1 .... (CONTINUED).

Year	Potato	Oilseeds	Sugarcane	Jute	Tobacco
1961/62	100.00	100.00	100.00	100.00	100.00
1962/63	102.53	102.43	107.14	97.30	98.52
1963/64	105.13	104.92	114.80	97.30	97.04
1964/65	87.15	108.72	108.22	105.41	124.36
1965/66	129.79	108.72	164.91	105.41	124.36
1966/67	140.57	119.38	126.26	102.70	69.09
1967/68	115.39	110.49	145.57	123.76	87.01
1968/69	117.02	114.43	162.58	116.87	90.23
1969/70	123.32	122.77	185.25	133.47	92.64
1970/71	127.68	117.02	202.37	143.22	94.78
1971/72	137.46	122.45	210.28	156.92	95.32
1972/73	137.52	127.01	210.99	149.88	97.28
1973/74	142.53	135.61	229.13	108.48	51.75
1974/75	144.08	140.37	215.95	111.76	66.19
1975/76	146.90	145.99	217.33	113.51	66.74
1976/77	126.53	130.84	267.45	121.62	70.91
1977/78	127.39	167.23	332.15	151.35	83.32
1978/79	130.63	197.18	317.74	177.16	75.86
1979/80	130.45	131.89	330.75	182.47	76.00
1980/81	131.45	164.44	412.09	160.23	75.86
1981/82	150.46	168.66	506.76	115.31	66.60
1982/83	174.76	148.34	529.17	105.51	91.75
1983/84	179.50	156.36	437.25	67.70	95.07
1984/85	196.87	179.13	350.66	89.52	88.85
1985/86	167.15	167.68	479.57	165.14	64.67
1986/87	185.14	175.86	529.59	63.38	67.57
1987/88	265.65	201.17	699.51	42.70	61.63
Annual Compound Growth Rates:					
1961/62 to 1970/71	3.00	1.97	7.60	4.13	-1.78
1971/72 to 1980/81	-1.05	3.15	7.48	3.03	-0.68
1981/82 to 1987/88	6.25	3.35	3.79	-11.10	-4.39
1961/62 to 1987/88	2.46	2.40	6.90	- 0.76	-1.49

4.3 Crop Output Price Data: Measurement and Analysis

The output prices of each of the ten crops are presented in Table A1.2 of Appendix 1. The data on output prices which represent the aggregate annual crop prices for the entire country are measured in Nepalese Rupees per kilogram.

As in the case of the crop output quantity index series, a simple crop output price index series for each individual crop is constructed by considering crop output prices for year 1961/62 as 100. The crop output price indices representing the period 1961/62 to 1987/88 are presented in Table 4.2. According to Table 4.2, the growth rates of output prices for all ten crops with an exception of jute in the 1970s are observed to be positive. During the period 1961/62 to 1987/88, the highest growth rate in output prices is observed in the case of oilseeds which grew annually at a rate of 11.20 percent followed by sugarcane, tobacco, millet, maize, paddy, potato, wheat, barley and jute. The output price indices also indicate that the crop output prices of paddy, maize, wheat, potato, oilseeds and jute grew relatively faster in the 1980s than in the 1960s and 1970s, whereas the crop output prices of millet, barley, sugarcane and tobacco grew relatively faster in the 1960s than in the 1970s and 1980s.

4.4 Aggregate Crop Output Quantity and Price Data: Measurement and Analysis

Since the individual crop output analysis presented in section 4.2 does not provide an overall picture of the performance of the Nepalese crop sector, an aggregation of crop outputs at the national level is desired to carry out the aggregate analysis of crop outputs. Moreover, aggregation of crop output quantities and input quantities are also required to measure the total factor productivity of the Nepalese crop sector. Therefore, measurement and analysis of the aggregate crop output quantity and price data as well as the aggregate crop input quantity and price data are discussed in this chapter. The

TABLE 4.2

CROP OUTPUT PRICE INDEX BY CROP: NEPAL, 1961/62 TO 1987/88

(1961/62 = 100)

Year	Paddy	Maize	Wheat	Millet	Barley
1961/62	100.00	100.00	100.00	100.00	100.00
1962/63	95.38	106.45	84.85	98.18	97.73
1963/64	118.46	190.32	104.04	136.36	136.36
1964/65	138.46	182.26	141.41	150.91	150.00
1965/66	173.85	177.42	165.66	185.45	184.09
1966/67	164.61	166.13	149.49	192.73	179.55
1967/68	169.23	195.16	244.44	229.09	188.63
1968/69	184.62	179.03	157.58	187.27	193.18
1969/70	201.54	195.16	156.57	216.36	184.09
1970/71	193.85	191.94	145.45	205.45	204.55
1971/72	216.92	212.90	167.68	223.64	222.73
1972/73	253.85	272.58	231.31	307.27	238.64
1973/74	270.77	274.19	249.49	330.91	236.36
1974/75	275.38	314.52	314.14	338.18	265.91
1975/76	267.69	329.03	253.54	367.27	259.09
1976/77	244.62	300.00	219.19	321.82	209.09
1977/78	295.38	351.61	248.48	363.64	238.64
1978/79	255.38	348.39	251.52	390.91	275.00
1979/80	263.08	364.52	254.55	443.64	275.00
1980/81	281.54	393.55	280.81	476.36	329.55
1981/82	330.77	401.61	285.86	530.91	331.82
1982/83	390.77	479.03	354.55	572.73	347.73
1983/84	440.00	554.84	358.59	618.18	365.91
1984/85	407.69	464.52	317.17	667.27	384.09
1985/86	461.54	583.87	392.93	720.00	404.55
1986/87	541.54	611.29	421.21	776.36	422.73
1987/88	675.38	703.23	491.92	838.18	445.45
Annual Compound Growth Rates:					
1961/62 to 1970/71	8.46	6.03	6.83	9.02	8.05
1971/72 to 1980/81	1.47	5.46	2.73	6.24	2.87
1981/82 to 1987/88	10.15	7.93	7.37	7.61	4.91
1961/62 to 1987/88	5.93	6.34	5.30	7.60	4.90

TABLE 4.2 .... (CONTINUED).

Year	Potato	Oilseeds	Sugarcane	Jute	Tobacco
1961/62	100.00	100.00	100.00	100.00	100.00
1962/63	97.67	112.20	100.00	104.26	110.26
1963/64	137.21	125.61	116.67	108.51	121.45
1964/65	151.16	140.24	116.67	112.77	133.80
1965/66	137.21	152.44	133.33	275.89	218.18
1966/67	119.77	179.27	133.33	85.106	143.36
1967/68	105.81	200.00	200.00	74.468	127.51
1968/69	116.28	218.29	200.00	146.10	189.98
1969/70	125.58	236.58	200.00	141.13	217.48
1970/71	165.12	265.85	200.00	142.55	220.51
1971/72	159.30	279.27	200.00	158.16	249.18
1972/73	175.58	357.32	200.00	187.94	296.04
1973/74	231.40	441.46	200.00	141.13	309.32
1974/75	204.65	564.63	283.33	147.52	414.45
1975/76	195.35	423.17	383.33	182.27	486.48
1976/77	213.95	431.71	383.33	199.29	515.85
1977/78	252.33	657.32	383.33	226.95	404.66
1978/79	253.49	648.78	316.67	177.31	532.05
1979/80	224.42	806.10	483.33	153.90	5[illegible]
1980/81	294.19	814.63	533.33	138.30	547.32
1981/82	287.21	940.24	516.67	168.09	605.13
1982/83	298.84	1052.44	566.67	226.95	636.13
1983/84	376.74	1176.83	616.67	329.79	666.90
1984/85	325.58	1315.85	666.67	660.99	697.90
1985/86	398.84	1471.95	716.67	262.41	728.90
1986/87	552.33	1646.34	783.33	220.57	759.91
1987/88	519.77	1841.46	850.00	273.05	790.91
Annual Compound Growth Rates:					
1961/62 to 1970/71	2.57	10.92	9.33	2.65	8.21
1971/72 to 1980/81	5.10	10.75	11.04	-0.05	8.80
1981/82 to 1987/88	10.95	11.20	8.18	4.18	4.46
1961/62 to 1987/88	5.91	11.20	8.42	4.09	8.36

aggregate crop output quantity and price data are analyzed in this section, whereas the aggregate input quantity and price data are discussed in sections 4.5 and 4.6.

The aggregate crop output value for the Nepalese crop sector is obtained by multiplying each crop output quantity by its respective current price and summing them over ten crops. The output quantities and prices for each crop are given respectively in Table A1.1 and A1.2 of Appendix 1, whereas the calculated aggregate crop output values for the period 1961/62 to 1987/88 are presented in Table 4.3. Moreover, these aggregate crop output values are used to construct a simple crop output value index series by considering the aggregate crop output value of the year 1961/62 as 100. The simple crop output value index series is also presented in Table 4.3.

The crop output value index provides a measure of output in terms of value. It does not provide a measure of output in physical terms. Therefore, a Divisia output quantity index series which gives a measure of output in physical terms is constructed using output quantity and price data given respectively in Table A1.1 and A1.2 of Appendix 1. Moreover, the same data set is used to construct a Divisia crop output price index series in order to analyze the growth trends of the aggregate crop output prices in the Nepalese crop sector. The Divisia crop output quantity and price indices are presented in Table 4.3. Further, the crop output value index and the Divisia crop output quantity and price indices are plotted over time in Figure 4.1 in order to examine their respective growth trends graphically.

According to Table 4.3 and Figure 4.1, the aggregate crop output value measured at current prices increased annually by 7.62 percent during 1961/62 to 1987/88. However, almost 80 percent of such an increase in the aggregate crop output value came from an increase in the crop output prices and only 20 percent is contributed by an increase in the crop output quantities. The crop output quantities and prices which

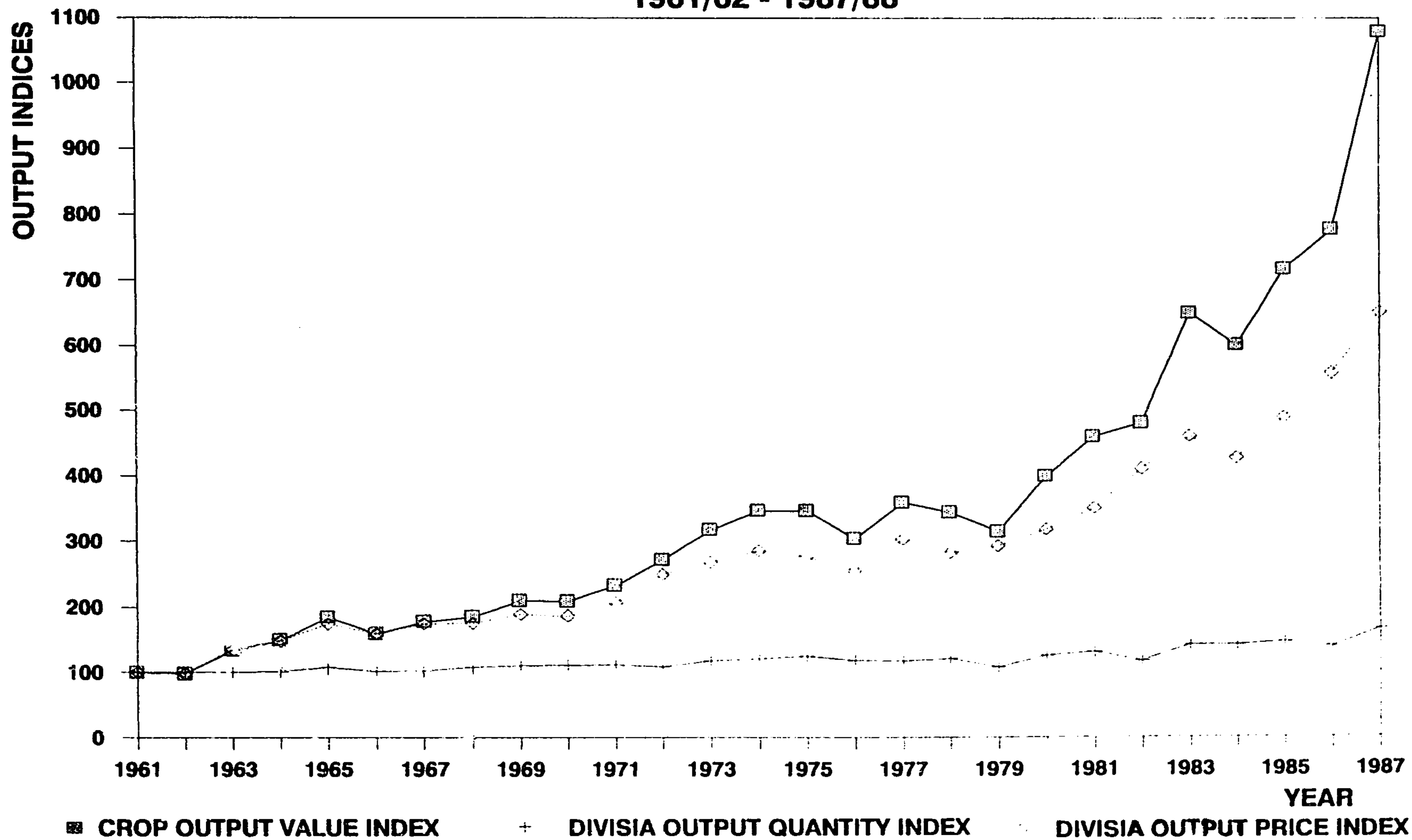
TABLE 4.3

AGGREGATE CROP OUTPUT VALUE AND ITS INDEX, AND DIVISIA CROP OUTPUT QUANTITY AND PRICE INDICES: NEPAL, 1961/62 TO 1987/88

Year	Aggregate Crop Output Value (Million Rs)	(1961/62 = 100) Crop Output Value Index	Divisia Indices of Crop Output Quantity	Divisia Indices of Crop Output Price
1961/62	2407.402	100.00	100.00	100.00
1962/63	2366.610	98.31	100.21	98.10
1963/64	3248.844	134.95	99.83	135.18
1964/65	3614.710	150.15	100.88	148.84
1965/66	4463.590	185.41	106.27	174.47
1966/67	3860.280	160.35	100.52	159.52
1967/68	4300.295	178.63	102.12	174.91
1968/69	4481.079	186.14	105.99	175.62
1969/70	5059.829	210.18	110.72	189.84
1970/71	5048.630	209.71	111.64	187.84
1971/72	5626.999	233.74	112.75	207.30
1972/73	6560.430	272.51	108.53	251.09
1973/74	7679.795	319.01	118.74	268.67
1974/75	8384.800	348.29	121.45	286.77
1975/76	8374.846	347.88	125.74	276.67
1976/77	7351.334	305.36	119.33	255.90
1977/78	8676.585	360.41	118.58	303.95
1978/79	8305.843	345.01	121.77	283.33
1979/80	7585.650	315.10	107.61	292.81
1980/81	9623.935	399.76	125.71	318.00
1981/82	11065.330	459.64	131.27	350.14
1982/83	11581.120	481.06	117.20	410.47
1983/84	15630.070	649.25	141.21	459.79
1984/85	14461.140	600.69	140.88	426.39
1985/86	17276.100	717.62	146.68	489.24
1986/87	18710.000	777.19	139.51	557.09
1987/88	25973.190	1078.89	165.73	651.00
Annual Compound Growth Rates:				
1961/62 to 1970/71	8.47	8.47	1.20	7.27
1971/72 to 1980/81	3.76	3.76	0.56	3.20
1981/82 to 1987/88	12.93	12.93	3.88	9.05
1961/62 to 1987/88	7.62	7.62	1.54	6.08
		(100)	(20.21)	(79.79)

Figure in parenthesis represents the percentage contribution to the growth of crop output value.

FIGURE 4.1
INDICES OF AGGREGATE CROP OUTPUT VALUES, QUANTITIES AND PRICES: NEPAL, 1961/62 - 1987/88



are denoted respectively by the Divisia crop output quantity and price index increased respectively by 1.54 and 6.08 percent per annum during the period 1961/62 to 1987/88.

Moreover, the estimation of growth rates across three different periods in Table 4.3 and the trend analysis in Figure 4.1 indicate that the aggregate crop output values, quantities and prices all grew at a faster rate during the 1980s than in the 1960s and 1970s. But the rate at which the crop output quantities increased during the period is relatively small as compared to the rates at which the crop output prices and, therefore, the crop output value increased. In sum, the growth of crop output quantities in the Nepalese crop sector for the last three decades is marginal, and a higher growth rate observed in the case of the crop output value during the period is mainly due to a higher growth rate attained in crop output prices in that period.

4.5 Crop Input Quantities: Data and Measurement

4.5.1 Land Inputs

In this study, land inputs are defined as the total actual cultivated land area under each of the ten crops produced in the Nepalese crop sector. Therefore, this measure of land inputs does not include area under fallow and minor crops. The area under fallow and minor crops in 1985 was as low as 2.2 percent of the total cropped area (APROSC 1986B, Vol.II, p.21). In Nepal, productivity does vary by land type, viz. irrigated and unirrigated land. Therefore, a productivity analysis based on land type makes results more usable for policy implication. However, such an analysis is not possible in the case of Nepal as the data on crop inputs and outputs are not available by land type. For instance, it is not currently possible to distinguish the output of irrigated land from that of rainfed land. Nor was reliable year to year data on the total amount of irrigated land, particularly the non-governmental component, readily available to the author. As a consequence, the choice was made to treat land as a single input variable in this study. The cropwise data on stock of land inputs which are measured in hectares are presented in Table A1.3 of Appendix 1. The aggregate land area which is defined as the sum of the cropped area under all ten crops is given in Table A1.4 of Appendix 1.

4.5.2 Labour Inputs

In a productivity study, the measurement of labour inputs poses both conceptual and empirical difficulties. The use of man hours data as compared to data on persons employed is argued to provide a better estimate for the labour index (Islam 1982). However, such man hours data on labour inputs employed in the Nepalese crop sector are not available. Therefore, the total persons employed in crop production are used as labour inputs in this study. As discussed in Chapter 1, the crop sector totally dominates the Nepalese agricultural sector. Therefore, the total agricultural labour force is used for the total persons employed in the Nepalese crop sector.

It is likely that the labour productivity in Nepal varies by region, labour type (i.e. cooperative vs. hired) and crop season (peak vs. off-season). Therefore, any productivity analysis based on such classification of labour is likely to provide a better estimate of productivity growth and can be considered more useful in deriving policy implications. However, as in the case of land input, the time-series data on labour under those different classifications are simply not available in Nepal. Therefore, the labour input is also treated as a single variable in this study.

While obtaining the data on the agricultural labour force in Nepal, the total population presented by the CBS (1988) is first transformed into the economically active population by multiplying it by the percentage share of the economically active population in the total population and then converting the total economically active population into the total agricultural labour force. Data on the percentage of economically active population in the total population are available only for seven different years as shown Table 4.4. Therefore, these data were used to fit an exponential

TABLE 4.4

PERCENTAGE OF ECONOMICALLY ACTIVE POPULATION IN THE TOTAL POPULATION IN NEPAL BY YEAR

Year	Percentage of Economically Active Population	References
1961/62	54.40	Banskota and Lohani (1982, p.18)
1969/70	53.20	DFAMS (1972, p.1)
1971/72	55.10	Banskota and Lohani (1982, p.18)
1975/76	48.29	ADB/M (1982, Vol.II, p.10)
1979/80	45.72	ADB/M (1982, Vol.II, p.10)
1981/82	45.60	APROSC (1986B, Vol.II. p.6)
1984/85	46.63	ADB/M (1982, Vol.II, p.10)

function in order to construct a continuous series of the percentage of economically active population in the total population for the period of 1961/62 to 1987/88. The percentage of economically active population in the total population and the estimated total economically active population are presented in Table A1.5 of Appendix 1. In Table 4.4, the percentage of economically active population may have declined due to a relative increase in the population of children and old persons over the period as a result of change in fertility, mortality and life expectancy rates in Nepal.

Further, the total economically active population is converted into the total agricultural labour force by multiplying it by the percentage share of the agricultural labour force in the total economically active population. The data on the percentage share of agricultural labour force in the total economically active population are available only for three different years in the entire study period. These are 93.82 and 94.38 percent respectively in years 1961/62 and 1971/72 (ADB/M 1982, Vol.II, P.11) and 91 percent in year 1981/82 (APROSC 1986B, Vol.II, p.7). Considering a slow or no change in the structure and technology in the Nepalese crop sector, such percentage shares of the agricultural labour force can be assumed to remain fairly constant over a period of ten years. Therefore, these data on the percentage share of the agricultural labour force in the total economically active population for year 1961/62, 1971/72 and 1981/82 are used to estimate the total agricultural labour force respectively for the periods of the 1960s, 1970s and 1980s. The total agricultural labour force which is measured in thousand persons are presented in Table A1.4 and A1.5 of Appendix 1.

The input quantity and price data are required to construct Divisia input quantity and price indices in order to estimate the total factor productivity of the Nepalese crop sector under the flexible weight index procedure. Since the price of labour is given in terms of the NRs per personday, it is necessary to transform the total persons employed in the crop sector into the total persondays used in the crop sector. The average number of days a person works annually in the Nepalese crop sector is observed to be 195 days (ADB/M 1982, Vol. II, Appendix 1.10). Though this figure represents year 1981/82, the figure is assumed to represent other periods included in this study, primarily because labour changing technological change is believed to have been minimal in the Nepalese crop sector over the last three decades. Thus, the total agricultural labour force is multiplied by 195 in order to convert the total agricultural labour force into the total persondays used in the Nepalese crop sector. The calculated total persondays employed in the sector are presented in Table A1.4 of Appendix 1.

4.5.3 Bullock Inputs

In Nepal, bullocks are used for ploughing land, threshing harvested crops and transporting crop outputs and inputs to and from market centers. Therefore, bullocks that include adult oxen and he-buffaloes are considered to be one of the major inputs in crop production.

The bullock input used in this study is measured in terms of total bullocks employed in crop production. Data on the total bullock population in Nepal are gathered from CBS (1982), DFAMS (1972 and 1983) Joshi (1977, pp.50-51), ADB/M (1982, Vol.II, Appendix 2.18) and APROSC (1986B, Vol.II, pp.306-12). The actual data for year 1987/88 is not available at present, therefore, the data for that period is extrapolated on the basis of actual data of 1961/62 to 1986/87. The bullock population which measured in thousand head is presented in Table A1.4 of Appendix 1.

Since the use of bullocks in the Nepalese non-crop sector is negligible, the adult population of bullocks fairly represents the total bullocks employed in the crop sector. In Nepal, almost all of the bullocks that become unusable in the Nepalese crop sector are eventually sold to meat markets in India and Nepal. Buffaloes are sold in the Nepalese and Indian meat markets. However, people within the Nepalese boundary are strictly prohibited to buy or sell oxen for meat consumption purposes. Therefore, those oxen which become unusable in the Nepalese crop sector are sold to the meat markets in India where the restriction on beef consumption does not apply. Thus, the total population of bullocks given in Table A1.4 of Appendix 1 represents the total population of active adult bullocks that are employed in crop sector.

As in the case of labour input, the total population of bullocks is further converted into the total bullockdays used in the Nepalese crop sector in order to use it in constructing the Divisia quantity and price indices of bullock input. The average number of days a bullock works annually in the Nepalese crop sector is observed to be [illegible] days (Hamal 1981, p.176). Moreover, the bullock changing technological change in the Nepalese crop sector is believed to have been minimal since the early 1960s. Therefore, the average number of working days per bullock is used to multiply the total population of bullocks in order to obtain the total number of bullockdays employed in the Nepalese crop sector. This monotonic transformation of the bullock stock yields bullockdays data, presented in Table A1.4 of Appendix 1, which represent the bullock input in service flow terms.

4.5.4 Fertilizer Inputs

Regarding fertilizer inputs, Nepalese crop farmers have traditionally used manure (compost) produced on their own farms. However, these farmers, given the government's fertilizer subsidy policies and agricultural extension programs, started using chemical fertilizer in their crop production in the early 1960s, especially, on modern varieties of paddy and wheat and also in a few cash crops such as tobacco. In Nepal, time-series data on farm manure inputs which are non-traded inputs are not available. Therefore, the study excludes farm manure inputs from the analysis of productivity growth and focuses only on chemical fertilizer which is totally imported from foreign markets.

As discussed in Chapter 2, the Agricultural Inputs Corporation (AIC) is the sole importer and distributor of chemical fertilizer in Nepal. Though Nepal has a long open border with India, fertilizer does not move illegally from India to Nepal. The fertilizer distributed by the AIC is heavily subsidized and, therefore, its price is considerably below the price of fertilizer in adjoining states of India. However, the subsidized fertilizer does not move from Nepal to India, because the AIC through its local offices and Sajhas makes sure that the purchased fertilizer is used by Nepalese farmers on their own land and also because the Government of India strictly prohibits any movement of fertilizer from Nepal to India in order to protect its own fertilizer industry. Thus, the annual volume of chemical fertilizer distributed by the AIC is assumed to represent the total annual consumption of chemical fertilizer in Nepal. Therefore, the volume of fertilizer distributed by the AIC is used as the data basis for the fertilizer input used in the Nepalese crop sector.

The consumption of fertilizer in this study is presented in terms of nutrients, viz. nitrogen (N), phosphorus (P) and potash (K), because fertilizer inputs in nutrient as compared to non-nutrient terms makes more sense in estimating production relationships between crop outputs and inputs. The data on the consumption of fertilizer in nutrient form are measured in metric tons and presented in Table A1.4 of Appendix 1.

4.5.5 High Yielding Variety (HYV) Seeds

In Nepal, most crop farmers process, store and use their own seed from their own produce in order to minimize the risk of not getting seed in time. Therefore, the actual amount of seed consumed annually in the Nepalese crop sector is very difficult to obtain. The only data available on seed consumption are the annual sales of HYV seeds by the AIC which is the sole distributor of HYV seeds in Nepal. Therefore, the AIC's annual sales of HYV seeds which are measured in metric tons are considered as the consumption of improved seeds in the Nepalese crop production. The HYV seed input is presented in Table A1.4 of Appendix 1.

4.6 Crop Input Prices: Data and Measurement

As mentioned in section 3.4 in Chapter 3, an attempt has been made to proxy prices of land and bullocks in order to estimate the total factor productivity under the flexible weight index procedure and, thereby, to compare results of this procedure with those derived from the geometric index procedure. The procedures of approximating land prices and bullock prices as well as the procedure of extrapolating wage rates are discussed in the following sub-sections along with prices of fertilizer and HYV seeds.

4.6.1 Land Prices

Since actual land price data are not available in Nepal, land prices were approximated by relating them to the rent earned on land and, then, to crop output prices for which data are available. In economic terms, land rent is defined as a residual or surplus paid to that unit of land after payments to other factors of production used to work the land are netted out (Hartwick and Olewiler 1986, p.23). That is, rent of a unit of land is the difference between the total revenue and total cost of input factors other than the land incurred in the crop production on that unit of land. Ignoring the discounting dimensions of the formula, the land rent in period t can be algebraically expressed as:

$$(4.1) \qquad P_{Rt} = \sum_i R_{it} - \sum_i C_{it} \qquad \text{where} \quad \sum_i R_{it} = \sum_i P_{it} Y_{it}$$

where PR_t is the land rent in Rupees per hectare in period t; R_{it} is the revenue from the i-th crop in Rupees per hectare in period t; C_{it} is the cost of inputs other than land, which are used to produce the i-th crop, in Rupees per hectare in period t; P_{it} is the price of the i-th crop in Rupees per metric ton in period t; Y_{it} is the yield rate of the i-th crop in metric ton per hectare in period t; and t is the time period. The neglect of discounting considerations should not pose major problems for our eventual regression analysis since rent and price variables, assuming a constant discount rate, would merely be re-scaled.

Further, the equation (4.1) can not be used to determine the land rent in Nepal, because time-series data on cost of production for each individual crops are not available. However, this problem can be simplified by assuming that the cost of production in the Nepalese crop sector remains constant over the period of 1961/62 to 1987/88. Such an assumption may look far from reality in developed countries, but it has some validity in a country like Nepal where methods of crop production are still traditional and not very commercialized. In Nepalese crop production, input factor labour is the second most dominating input factor after land. The share of land in the total cost of production varies from 64 to 84 percent, whereas the share of labour varies from 13 to 29 percent (Table A1.8 of Appendix 1). As compared to shares of land and labour, shares of other input factors are negligible in the total cost of Nepalese crop production. Moreover, the wage rate in the farm sector which uses mostly family and exchange labour generally remains, to some degree, constant over a long period of time (Table A1.6 of Appendix 1). Therefore, the assumption that the cost of input factors other than land remains constant over the period of 1961/62 to 1987/88 in the Nepalese crop sector seems to be a reasonable assumption to simplify the determination of land rent in equation (4.2). A further assumption is that yields have not changed over time.

Thus, the rent of a unit of land in this study is considered to be a simple function of output prices of crops that are being grown in Nepal. As crop output prices vary, so, it is assumed, should land rent and land prices.

The major crops grown in Nepal are paddy, maize, wheat, millet, barley, potato, oilseeds, sugarcane, jute and tobacco. Therefore, the output prices of these crops are used in equation (4.2) to approximate Nepalese land prices.

$$\Pi_{Rt} = w_1 P_{Pt} + w_2 P_{Mt} + w_3 P_{Wt} + w_4 P_{mt} + w_5 P_{Bt} + w_6 P_{pt} + w_7 P_{Ot} + w_8 P_{St} + w_9 P_{Jt} + w_{10} P_{Tt} \quad (4.2)$$

where Π_{Rt} is the proxy for land price per hectare in year t; P_{Pt}, P_{Mt}, P_{Wt}, P_{mt}, P_{Bt}, P_{pt}, P_{Ot}, P_{St}, P_{Jt} and P_{Tt} represent respectively the output prices of paddy, maize, wheat, millet, barley, potato, oilseeds, sugarcane, jute and tobacco respectively in Rupees per metric ton in year t; and w_i $(i = 1, 2, \ldots\ldots, 10)$ is the share of the i-th crop in the total cropped area in year t. The output prices of each crop are given in Table A1.2 of Appendix 1, whereas the shares of each crop in the total cropped area are calculated on the basis of land area data given in Table A1.3 of Appendix 1.

According to equation (4.2), the land price proxy is a linear aggregation of the output prices of all crops grown in Nepal suitably weighted by the share of each respective crop in the total cropped area. The land price thus obtained seems to be more meaningful as it allows crop shares to change over different time periods. Such a procedure of approximating land prices should capture much of the variation in the actual land price series, in line with the on-going changes in crop output prices which are reflected in changing land rents. The derivation of land prices in this manner admittedly involves relatively heroic assumptions, but it is the best that can be done in the absence of actual land price data.

Further, the land prices so proxied are converted into a simple index by considering the land price of year 1961/62 as 100. The index series of land prices is presented in Table A1.6 of Appendix 1 and also in Table 4.6. Moreover, the average current price of cropped land in the Tarai region of Nepal during 1980/81 is observed to be NRs 14,793 per hectare (Hamal 1981). About 59 percent of the total cropped area is in the Tarai and the remaining 41 percent of the total cropped area comes from the Hills, Mountains and Valley where land prices are approximately half of the land prices in the Tarai. Therefore, the weighted average of those two prices [that is, 0.59(14,793.00)+0.41(7396.50) = NRs 11,760.44] is taken as a conservative estimate of the average current price of land for the entire country in 1980/81 and, thus, the price is further used to convert the land price index series of Table A1.6 into the current land price series which is also presented in Table A1.6 of Appendix 1. Such an estimation of current land prices is a very crude approximation, because it does not take into account the regional variation in land prices which is likely to be caused by the differences in factors such as land quality, population density and technical change. However, in the absence of data on those factors, the best one can do is to estimate the current land prices as crudely as mentioned above.

4.6.2 Wage Rates

Data on wage rates which are obtained from DFAMS (1983) and Pokhrel and Shivakoti (1986) represent the national agricultural wage rates paid to hired labour. These wage rates are not adjusted for family labour. Since the wage rate data for 1961/62 to 1964/65 are not available, an exponential function, $Y = Ae^{\beta t}$, is used to extrapolate back to derive wage rates for those years and, thereby, to obtain a series of wage rates for the period 1961/62 to 1987/88. Data on wage rates which are presented in Table A1.6 of Appendix 1 are expressed in Rupees per personday employed in the Nepalese crop sector.

4.6.3 Bullock Prices

As mentioned in section 4.5.3, bullocks in Nepal are mainly used in heavy activities such as ploughing crop land, threshing the harvested crops and transporting crop inputs and outputs to and from market centers. Since the time-series data on the service price of bullocks are not available in Nepal, the service prices are obtained on the basis of some prior information about the relationship between the wage rate and the service price of bullocks. The service price of a bullock in Nepal has been observed to be approximately the same as the ongoing wage rate (Hamal 1981). Therefore, wage rates are used as the basis for the service prices (or costs) of bullocks in this study. Though such a procedure of approximating the service price of bullocks is very crude and does not take into account factors such as regional variation in bullock prices, the procedure is likely to provide, to some extent, a reasonable estimate of the service price of bullocks over the period of 1961/62 to 1987/88.

The above procedure of obtaining the service price of bullocks is likely to result in a collinearity problem in the estimation of the production structure under the cost function approach. However, such a problem has been overcome by imposing a linear restriction on the coefficients of the wage rate and service price of bullocks on the basis of prior knowledge about the relationship between the wage rate and the service price of bullocks. The restriction required in the estimation of the system of share equations in section (6.3) of Chapter 6 is that the coefficients of the ongoing wage rate and the service price of bullocks are equal, because the prices of these two inputs considered in this study are assumed to be equal.

Further, the collinearity problem is also overcome by dropping out the price of bullocks as an explanatory variable in the estimated system of share equations. That is, the production structure under the cost function approach is also estimated by dropping out price of bullocks in the system of share equations, especially to find out whether or not the estimated parameters change as a result of such exclusion of price of bullocks in the system of share equations. A detailed discussion of the estimation of the system of share equations with or without price of bullocks is presented in section (6.3) of Chapter 6, whereas the service prices of bullocks proxied by the ongoing wage rate are presented in Table A1.6 in Appendix 1.

4.6.4 Prices of Fertilizer

Since the AIC is the sole distributor of chemical fertilizer in Nepal, its actual sale prices of fertilizer are considered as the prices of fertilizer in this study. Moreover, over 70 percent of the total fertilizer used in the Nepalese crop sector is nitrogen which comes from urea. Therefore, the price of urea has been used as the price of fertilizer in this study. The fertilizer prices are measured in Rupees per metric ton and are presented in Table A1.6 of Appendix 1.

4.6.5 Prices of HYV Seeds

As discussed in an earlier section, the AIC is also the sole distributor of HYV seeds in Nepal. Therefore, its sale prices of HYV seeds are considered as the prices of input HYV seeds in the productivity analysis of this study. The price data are measured in Rupees per metric ton and presented in Table A1.6 of Appendix 1.

4.7 Analysis of Aggregate Crop Input Quantity and Price Data

The aggregate crop input quantity data presented in Table A1.4 of Appendix 1 are further used to construct simple input quantity indices in order to analyze the trend of inputs used in the Nepalese crop sector. The input quantity indices which are constructed by considering input quantities of year 1961/62 as 100 are presented in Table 4.5 along with the estimated growth rates of inputs used in the Nepalese crop sector. The growth rates of inputs used are estimated using an exponential function of time. Furthermore, the input quantity indices are plotted against year in Figures 4.2 and 4.3 in order to compare the trends of inputs used in the Nepalese crop sector.

According to Table 4.5 and Figures 4.2 and 4.3, the use of fertilizer and HYV seeds during the period 1961/62 to 1987/88 grew relatively at higher rates than the use of other inputs. The annual consumption growth rates of land, labour, bullock, fertilizer and HYV seeds during the period were respectively 1.77, 1.37. 2.67, 18.73 and 17.16 percent. Table 4.5 also indicates that the annual consumption growth rates of land and labour are relatively higher during the 1980s than in the 1960s and 1970s, whereas the growth rates of bullocks, fertilizer and HYV seeds are relatively higher in the 1960s than in the 1970s and 1980s. As a matter of fact, the consumption growth rate of HYV seeds during the period of the 1980s is negative. One of the reason for such a negative growth rate in the use of HYV seeds could be that the farmers may have started to obtain HYV seeds from sources other than the AIC since the early 1980s. In recent times, the private sector is observed being active in producing, processing and distributing HYV seeds in the Nepalese crop sector.

The wide variation in the quantity sold of HYV seeds after 1977 may have been caused by supply side and demand side problems. In the absence of a well developed transportation system, the AIC sometimes becomes unable to distribute the HYV seeds

TABLE 4.5

CROP INPUT QUANTITY INDICES: NEPAL, 1961/62 TO 1987/88 (1961/62 = 100)

Year	Land	Labour	Bullocks	Fertilizer	HYV Seeds
1961/62	100.00	100.00	100.00	100.00	100.00
1962/63	100.40	100.86	103.98	120.21	133.33
1963/64	99.83	101.72	107.92	57.01	166.67
1964/65	99.88	102.59	111.85	89.29	150.00
1965/66	104.10	103.47	115.83	68.02	604.17
1966/67	103.89	104.36	123.56	219.16	1258.33
1967/68	109.00	105.26	126.20	412.37	3208.33
1968/69	111.19	106.16	128.73	482.65	3033.33
1969/70	114.21	107.07	131.29	691.55	2754.17
1970/71	116.25	107.99	134.41	815.38	1979.17
1971/72	118.02	112.53	135.15	1201.81	4729.17
1972/73	116.39	113.80	136.42	1652.04	8679.17
1973/74	121.31	115.08	137.72	1974.06	7608.33
1974/75	123.64	116.37	158.16	1909.20	8058.33
1975/76	125.56	117.68	160.24	1666.52	8562.50
1976/77	126.45	119.00	161.91	2053.39	9479.17
1977/78	129.44	120.34	163.66	2634.54	10587.50
1978/79	129.92	121.70	167.11	2796.83	10091.67
1979/80	128.08	123.07	171.05	3161.99	12162.50
1980/81	131.72	124.45	174.99	3387.48	14629.17
1981/82	133.08	128.52	178.97	3593.21	10691.67
1982/83	137.91	130.72	182.91	4717.95	15170.83
1983/84	139.81	132.95	186.85	5625.94	12500.00
1984/85	146.72	135.23	190.78	6459.88	8820.83
1985/86	154.02	137.54	194.72	6547.21	10270.83
1986/87	153.47	139.89	198.66	6795.48	10045.83
1987/88	165.15	142.28	202.56	8066.82	11208.33
Annual Compound Growth Rates:					
1961/62 -1970/71	1.85	0.85	3.40	28.83	43.94
1971/72 -1980/81	1.30	1.12	3.02	10.17	9.01
1981/82 -1987/88	3.42	1.70	2.06	11.81	-3.14
1961/62 -1987/88	1.77	1.37	2.67	18.73	17.16

FIGURE 4.2

QUANTITY INDICES OF CROP INPUTS USED IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88

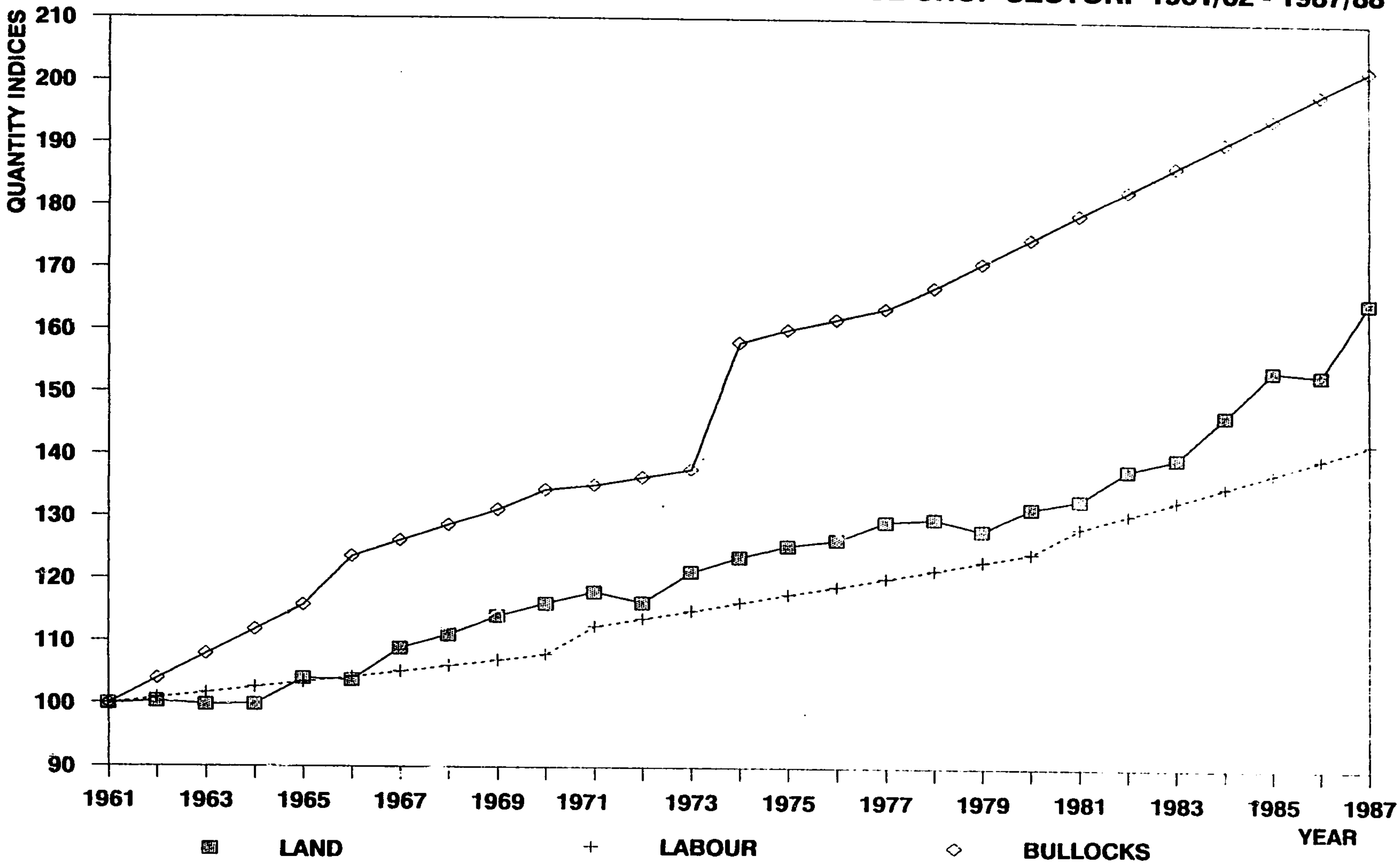
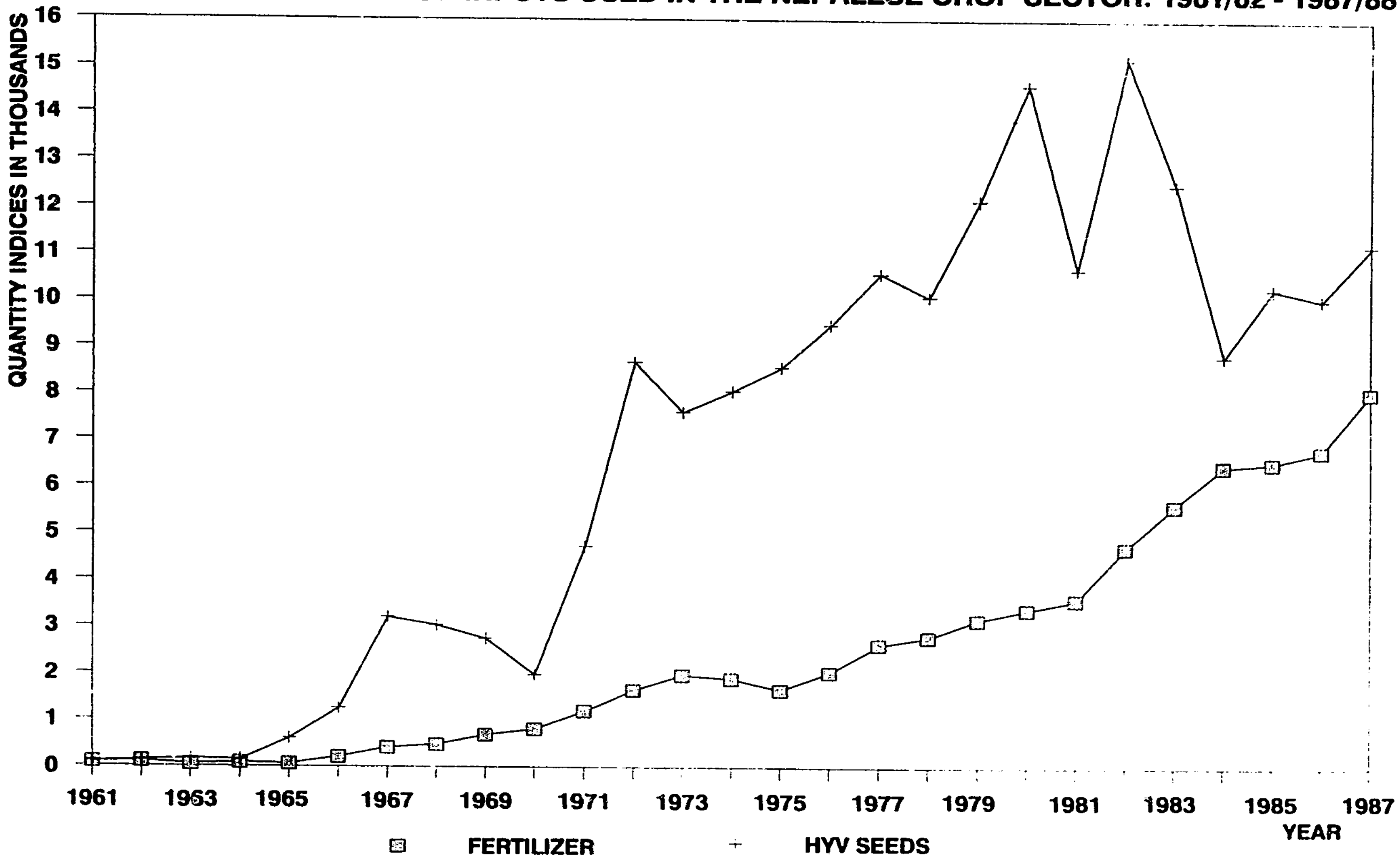


FIGURE 4.3
QUANTITY INDICES OF CROP INPUTS USED IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88



in time. As a result, the annual sales of the AIC's HYV seeds in those particular years in which it is unable to distribute HYV seeds in time decline sharply. In addition to this, the country's weather conditions also influence the variation in the sale of HYV seeds. In a year of bad monsoon, the demand for HYV seeds in Nepal is likely to decline considerably.

Regarding the analysis of crop input prices, simple price index series were constructed for each crop by considering prices of year 1961/62 as 100. The input price indices are presented in Table 4.6 and are also plotted over time in Figure 4.4. According to Table 4.6 and Figure 4.4, the prices of all crop inputs grew positively during 1961/62 to 1987/88. The growth rates of input prices of land, labour, bullocks, fertilizer and HYV seeds during the period are respectively 6.57, 10.86, 10.86, 6.26 and 5.43 percent. Moreover, Table 4.6 and Figure 4.4 also imply that the prices of labour and bullocks have always been remained at higher level than the prices of other inputs and that the annual growth rates of input prices of labour and bullocks during all three periods, viz. 1960s, 1970s and 1980s, are observed to be relatively higher than the annual growth rates of input prices of other inputs.

4.8 Summary

Chapter 4 deals with the quantity and price data on crop outputs and inputs and their measurement and analysis. Data on quantities and prices of outputs and inputs are used to construct simple output quantity and price indices by considering output quantities and prices of year 1961/62 as 100. According to the output quantity indices, the highest output growth rate during the period 1961/62 to 1987/88 is observed in the case of wheat closely followed by sugarcane. The output growth rates of paddy, millet,

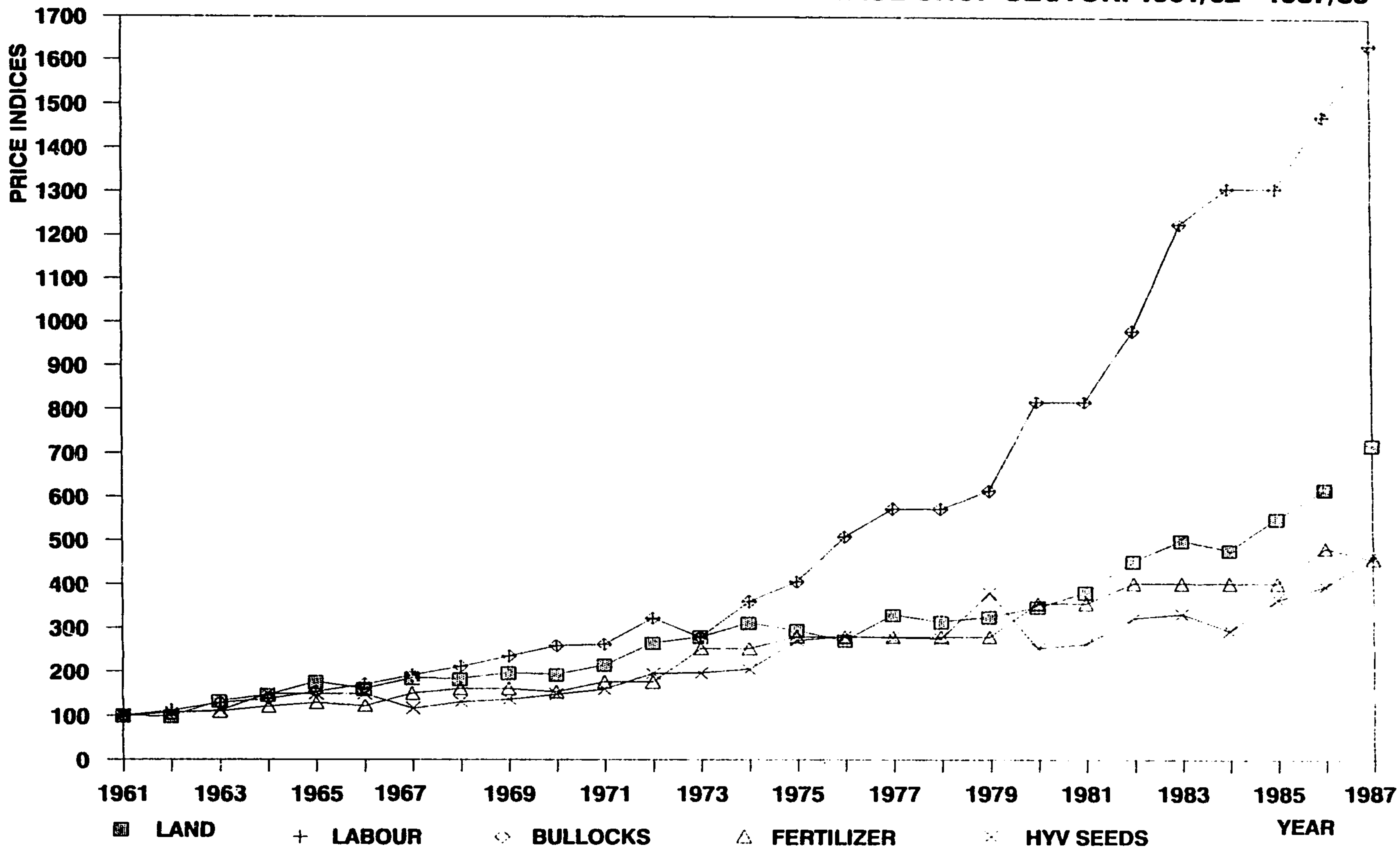
TABLE 4.6

CROP INPUT PRICE INDICES: NEPAL, 1961/62 TO 1987/88 (1961/62 = 100)

Year	Land	Labour	Bullocks	Fertilizer	HYV Seeds
1961/62	100.00	100.00	100.00	100.00	100.00
1962/63	98.65	111.48	111.48	106.45	105.77
1963/64	133.44	128.69	128.69	109.68	111.92
1964/65	147.42	138.52	138.52	120.62	149.62
1965/66	176.26	154.10	154.10	128.46	149.90
1966/67	161.57	171.31	171.31	122.12	149.62
1967/68	184.87	190.98	190.98	151.27	116.63
1968/69	183.16	212.30	212.30	161.29	131.73
1969/70	197.65	236.07	236.07	161.29	137.79
1970/71	194.20	259.02	259.02	154.61	148.94
1971/72	216.11	263.11	263.11	176.84	160.77
1972/73	266.83	322.95	322.95	176.84	195.87
1973/74	280.38	279.51	279.51	252.65	196.44
1974/75	312.42	361.48	361.48	252.65	204.90
1975/76	295.22	405.74	405.74	281.11	271.92
1976/77	272.32	509.02	509.02	281.11	281.63
1977/78	330.76	573.77	573.77	281.11	279.33
1978/79	315.48	573.77	573.77	281.11	276.92
1979/80	326.78	614.75	614.75	281.11	380.77
1980/81	349.42	819.67	819.67	357.14	255.29
1981/82	383.00	819.67	819.67	357.14	264.13
1982/83	454.21	983.61	983.61	403.23	323.46
1983/84	501.58	1229.51	1229.51	403.23	333.75
1984/85	479.61	1311.48	1311.48	403.23	295.58
1985/86	551.66	1311.48	1311.48	403.23	367.98
1986/87	619.69	1475.41	1475.41	483.87	396.25
1987/88	721.80	1639.34	1639.34	459.68	461.92
Annual Compound Growth Rates:					
1961/62 -1970/71	7.89	10.54	10.54	5.69	3.33
1971/72 -1980/81	3.89	12.09	12.09	6.32	6.97
1981/82 -1987/88	9.35	10.55	10.55	4.01	7.79
1961/62 -1987/88	6.57	10.86	10.86	6.26	5.43

FIGURE 4.4

PRICE INDICES OF CROP INPUTS USED IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88



potato and oilseeds are positive but relatively low, whereas the output growth rates of maize, barley, jute and tobacco are negative. Moreover, the output growth rates of paddy, maize, barley, potato and oilseeds were relatively higher during the 1980s than in the 1960s and 1970s, whereas the output growth rates of wheat, millet, sugarcane, jute and tobacco were relatively higher during the 1960s than in the 1970s and 1980s.

Similarly, the crop output price indices indicate that the highest growth rate in output prices during the period 1961/62 to 1987/88 is observed in the case of oilseeds followed by sugarcane, tobacco, millet, maize, paddy, potato, wheat, barley and jute. The crop output prices of paddy, maize, wheat, potato, oilseeds and jute grew relatively faster in the 1980s than in the 1960s and 1970s, whereas the crop output prices of millet, barley, sugarcane and tobacco grew relatively faster in the 1960s than in the 1970s and 1980s.

The aggregate crop output value, quantity and price data are also analyzed in this chapter. The annual aggregate crop output values are used to construct a simple crop output value index series by considering the aggregate crop output value of year 1961/62 as 100. Moreover, the output quantity and price data are used to construct the Divisia output quantity and price indices in order to analyze the growth trends of the aggregate crop output quantities and prices in the Nepalese crop sector.

According to the output value index, the aggregate crop output value, measured at current prices, increased annually by 7.62 percent during the period 1961/62 to 1987/88. However, almost 80 percent of such an increase in the aggregate crop output value came from an increase in the crop output prices and only 20 percent is contributed by an increase in the crop output quantities. Moreover, the estimated growth rates of the aggregate crop output values, quantities and prices are observed to be relatively higher during the 1980s than in the 1960s and 1970s.

Regarding the input quantity data, inputs land, labour and bullocks represent respectively the total actual cultivated land area under all ten crops produced, total persons employed and total bullocks employed in the Nepalese crop sector. On the other hand, inputs fertilizer and HYV seeds include respectively the chemical fertilizer in nutrient terms and HYV seeds sold by the AIC. Inputs land, labour, bullock, fertilizer and HYV seeds are measured respectively in thousand hectares, thousand persons, thousand heads, metric tons and metric tons.

Further, an attempt has been made to proxy prices of land and bullocks in order to use the flexible weight index procedure in the productivity analysis. The actual land prices are proxied by the indices of land prices which are constructed by linearly aggregating the output prices of all ten crops grown in Nepal suitably weighted by the share of each respective crop in the total cropped area. The index seems to be more meaningful as it allows crop shares to change over different time periods.

In Nepal, the service price of a bullock has been observed to be approximately same as the ongoing wage rate. Therefore, wage rates are used as the basis for the service costs of bullocks in this study. Further, over 70 percent of the total fertilizer used in the Nepalese crop sector is nitrogen which comes from urea. Therefore, the price of urea has been used to proxy the price of fertilizer in this study. Moreover, the AIC's price of HYV seed has been used as the price of HYV seeds in this study. The prices of labour, bullock, fertilizer and HYV seeds are measured respectively in NRs/Personday, NRs/Bullockday, NRs/MT and NRs/MT.

Simple input quantity and price indices are constructed by considering input quantities and prices of year 1961/62 as 100. According to the input quantity indices, the use of fertilizer and HYV seeds during the period of 1961/62 to 1987/88 grew relatively at a higher rate than the use of other inputs. Moreover, the annual growth rates of land and labour use are relatively higher during the 1980s than in the 1960s and 1970s, whereas the growth rates of bullock, fertilizer and HYV seeds use are relatively higher during the period 1960s than in the 1970s and 1980s. Similarly, the input price indices indicate that the prices of all crop inputs grew positively during 1961/62 to 1987/88 and that the prices of labour and bullocks grew more rapidly than the prices of other inputs.

CHAPTER 5

DECOMPOSITION ANALYSIS OF GROWTH TRENDS

5.1 Introduction

Decomposition of growth trends has become increasingly important to determine the sources of output growth in the agricultural sector. Output growth is generally decomposed into components, such as cropped area, yield, cropping pattern, price and their interaction terms, in order to determine the contribution of each of these components to growth trends. In Nepal, empirical evidence on the growth pattern vis-a-vis its components is rather weak. Recently, Yadav (1987) used the original Minhas-type multiplicative decomposition model to decompose the growth of Nepalese crop production for the period of 1961/62 to 1980/81. However, the model does not take the price effect into account. In agricultural growth analysis, output prices are used to obtain the money value of crop production. Therefore, they reflect the relative importance assigned to different crops. In an economy, output prices are influenced by several demand and supply factors including tastes and preferences as well as technical and physical constraints. Since these factors are likely to change over time, output prices are bound to change. As a result, the relative importance assigned to each crop will change over time. The model used by Yadav (1987) does not include a price component as a contributor to output growth. Therefore, the model can not be used to examine the contribution of price to output growth trends. The present study which extends the decomposition model to include the price component together with area, yield, cropping pattern and interaction term is more likely to provide meaningful insight into the pattern of Nepalese agricultural growth. Besides this, the study includes a period of analysis longer than that of Yadav (1987) and carries out a sensitivity analysis so as to choose the most suitable price indexing procedure and base period in order to analyze the output growth under the price structure multiplicative decomposition model.

5.2 Decomposition Models

The decomposition model which was first introduced by Minhas and Vaidyanathan (1965) has been used by several writers, such as Dayal (1966), Minhas (1966), Narain (1977), Sagar (1977, 1980) and Yadav (1987). There are two types of decomposition model, viz. the additive decomposition model and multiplicative decomposition model. These models are discussed in the following subsections.

5.2.1 Additive Decomposition Model

The additive decomposition model was first used by Minhas and Vaidyanathan (1965) to decompose the crop output growth in India into four components: area, yield, cropping pattern and a residual term showing interaction between cropping pattern and yield. The model was later extended by Minhas (1966) in the framework of seven components to bring the residual effect out in the open to the maximum possible extent. According to the available literature, the additive model and multiplicative model have always ignored two important factors: technological change and price structure. Regarding technological change, no study has so far attempted to introduce technological change into the decomposition analysis. Minhas and Vaidyanathan (1965) did mention the importance of inclusion of technological change into their decomposition model, but they did not introduce it specifically. On the other hand, Sagar (1977) is the first to introduce price structure into the Minhas-Vaidyanathan type additive decomposition model.

Following Sagar (1980), a general additive decomposition model that takes all three factors, viz. area, yield and price, into account can be derived in the following equations.

$$(5.1) \qquad Q_t = \sum_i A_{it} y_{it} p_{it}$$

where Q_t indicates the value of agricultural output during time period t and A_{it}, y_{it} and p_{it} represent, respectively, the area, yield and current price of the i-th crop during period t. The identity (5.1) can be written as:

$$(5.2) \qquad Q_t = A_t \sum_i \left(\frac{A_{it}}{A_t} \right) y_{it} \left(\frac{p_{it}}{P_t} \right) P_t = A_t \sum_i a_{it} y_{it} q_{it} P_t$$

where a_{it} $(= A_{it}/A_t)$ is the proportion of area under the i-th crop to the total cropped area during period t; q_{it} $(= p_{it}/P_t)$ is the relative price of the i-th crop during period t; and $P_t \left(= \sum_i p_{it} x_{i0} / \sum_i p_{i0} x_{i0} \right)$ is the conventional Laspeyres index number of crop prices during period t that is being used to deflate individual crop prices and x_{i0} is the physical output of the i-th crop during the base period. Equation (5.2) can be re-written as:

$$(5.3) \qquad Q_{it} = A_t Y_t P_t \qquad \text{where} \qquad Y_t = \sum_i a_{it} y_{it} q_{it}$$

Y_t is suitably weighted partial agricultural (land) productivity in value terms and at deflated current prices in period t.

According to equation (5.3), the value of agricultural output thus can be described in terms of macro components, such as cropped area, partial agricultural productivity and the overall level of crop prices. Therefore, an increase in the value of agricultural output from the base period, t=0, can be expressed as:

$$(5.4)\qquad Q_t - Q_0 = \Delta A Y_0 P_0 + A_0 \Delta Y P_0 + A_0 Y_0 \Delta P + \Delta A \Delta Y P_0 + \Delta A Y_0 \Delta P + A_0 \Delta Y \Delta P + \Delta A \Delta Y \Delta P$$

where Δ implies the difference operator. By substituting $\Delta A = (A_t - A_0)$, $\Delta Y = (Y_t - Y_0)$ and $\Delta P = (P_t - P_0)$ in equation (5.4), the additive decomposition model can be written as:

$$(5.5)\qquad Q_t - Q_0 = (A_t - A_0) Y_0 P_0 + A_0 (Y_t - Y_0) P_0 + A_0 Y_0 (P_t - P_0) + (A_t - A_0)(Y_t - Y_0) P_0 + (A_t - A_0) Y_0 (P_t - P_0) + A_0 (Y_t - Y_0)(P_t - P_0) + (A_t - A_0)(Y_t - Y_0)(P_t - P_0)$$

The first three components on the right hand side of equation (5.5) give the contributions of area, agricultural partial productivity and output price to the growth of agricultural output value, whereas the remaining four components measure the effects of interaction terms on output value growth. Equation (5.5) also implies that the index number of output value is the sum of index numbers of area, partial agricultural productivity, crop output prices and of four interaction terms involving changes in the pure components. Therefore, when each series of these index numbers is used to fit a linear time-trend, $Y = A + \beta T$, the growth rate (G) for each series of index numbers can be obtained as $G = (dY/dT)/Y = \beta/Y$.

Further, the growth in partial agricultural productivity component, $Y_t - Y_0$, can be similarly decomposed into seven crop structural components, viz. cropping pattern, price structure, yield structure and their interactions (Sagar 1980):

$$(5.6)\qquad Y_t - Y_0 = \sum_i (a_{it} - a_{i0}) y_{i0} q_{i0} + \sum_i a_{i0}(y_{it} - y_{i0}) q_{i0} + \sum_i a_{i0} y_{i0}(q_{it} - q_{i0})$$
$$+ \sum_i (a_{it} - a_{i0})(y_{it} - y_{i0}) q_{i0} + \sum_i (a_{it} - a_{i0}) y_{i0}(q_{it} - q_{i0})$$
$$+ \sum_i a_{i0}(y_{it} - y_{i0})(q_{it} - q_{i0}) + \sum_i (a_{it} - a_{i0})(y_{it} - y_{i0})(q_{it} - q_{i0})$$

The interaction term between cropped area and partial agricultural productivity incorporates the effect of area extension on productivity and, therefore, on output net of its contribution if one-to-one correspondence between area and output is maintained (Sagar 1980). The interaction terms involving the price component become relatively more useful for policy implications, especially when the decomposition analysis includes some other sectors such as livestock and poultry together with the crop sector. In such a situation, the price interaction terms may help to explain terms of trade between sectors and its effect on sectoral growth.

5.2.2 Multiplicative Decomposition Model

The multiplicative decomposition model has also been used in agricultural growth analysis, notably by Minhas (1966), Dayal (1966) and Yadav (1987). Following Minhas (1966), the multiplicative decomposition model is expressed as:

$$(5.7)\qquad \frac{Q_t}{Q_0} = \frac{A_t \sum_i a_{it} y_{it} p_i}{A_0 \sum_i a_{i0} y_{i0} p_i} = \left(\frac{A_t}{A_0}\right)\left(\frac{\sum_i a_{i0} y_{it} p_i}{\sum_i a_{i0} y_{i0} p_i}\right)\left(\frac{\sum_i a_{it} y_{i0} p_i}{\sum_i a_{i0} y_{i0} p_i}\right)$$
$$\left[\left(\frac{\sum_i a_{it} y_{it} p_i}{\sum_i a_{i0} y_{it} p_i}\right)\left(\frac{\sum_i a_{i0} y_{i0} p_i}{\sum_i a_{it} y_{i0} P_i}\right)\right]$$

where notations have the same meaning as in equation (5.2) except p_i which represents the constant price weight assigned to the i-th crop.

This identity (5.7) expresses the index number of output value as a multiple, respectively, of the index numbers of cropped area, crop yield, cropping pattern and a residual component which represents the interaction between cropping pattern and crop yield. Further, these index number series are used to fit an exponential function of time-trend, $Y = Ae^{\beta T}$, in order to obtain an additive scheme for growth as:

(5.8) $$G = G_A + G_y + G_a + G_{ay}$$

where G, G_A, G_y, G_a, and G_{ay} represent respectively the growth rate of crop output quantity, area, yield, cropping pattern and interaction term involving cropping pattern and crop yield. The G_{ay} is obtained residually by subtracting $G_A + G_y + G_a$ from G.

5.3 Choice and Specification of Decomposition Model

Regarding the choice of decomposition model for agricultural growth analysis, the multiplicative model seems to be more realistic than the additive model. It is because the former model deals with a compound rate of output growth rather than a linear rate of output growth which is the key feature of the latter model. Moreover, the multiplicative model, like in an additive model, includes a residual component which is used to determine the effect of interaction term on the output growth. In this study, the multiplicative model is also preferred to analyze output growth in the Nepalese crop sector, because results derived from this model can be directly compared to the results derived in previous studies, such as Yadav (1987). Therefore, the multiplicative decomposition model has been chosen to analyze the pattern of output growth in the Nepalese crop sector.

However, as mentioned in section 5.1, the multiplicative decomposition model in previous studies including Yadav (1987) does not take price effect into account. In these studies, price is used merely as a weighting device. Therefore, the original Minhas-type multiplicative model has been modified in order to analyze the contribution of output price to the growth of crop output in Nepal. Moreover, a comparison of results derived respectively from the original Minhas-type multiplicative model and the modified multiplicative model is likely to provide some insight with respect to the inclusion of price structure in the multiplicative decomposition model. Following equation (5.2), the multiplicative decomposition model which is modified to include the price structure can be written as:

$$(5.9) \qquad \frac{Q_t}{Q_0} = \frac{A_t \sum_i a_{it} y_{it} q_{it} P_t}{A_0 \sum_i a_{i0} y_{i0} q_{i0} P_0} = \left(\frac{A_t}{A_0}\right)\left(\frac{\sum_i a_{i0} y_{it} q_{i0}}{\sum_i a_{i0} y_{i0} q_{i0}}\right)\left(\frac{\sum_i a_{it} y_{i0} q_{i0}}{\sum_i a_{i0} y_{i0} q_{i0}}\right)$$

$$\left(\frac{P_t}{P_0}\right)\left[\left(\frac{\sum_i a_{it} y_{it} q_{it}}{\sum_i a_{i0} y_{it} q_{i0}}\right)\left(\frac{\sum_i a_{i0} y_{i0} q_{i0}}{\sum_i a_{it} y_{i0} q_{i0}}\right)\right]$$

where notations have the same meaning as in equation (5.2). According to equation (5.9), the index number of crop output value is a multiple of index numbers of area, yield, cropping pattern, crop output price and an interaction term involving cropping pattern, crop yield and crop output price.

As discussed above, when an exponential time-trend is fitted to each series of index numbers, an additive scheme of growth is generated as follows:

$$(5.10) \qquad G = G_A + G_y + G_a + G_p + G_{ayp}$$

where G, G_A, G_y, G_a, G_p and G_{ayp} are the growth rates respectively of crop output value, area, yield, cropping pattern, output price and an interaction term involving cropping pattern, yield and output price.

Further, the original Minhas-type multiplicative decomposition model (5.7) and the modified multiplicative decomposition model (5.9) are used to carry out sensitivity analysis with respect to base period and price indexing procedure. The base periods chosen for the sensitivity analysis are the year 1961/62 and 1971/72, whereas the price indexing procedures considered in the sensitivity analysis are the conventional Laspeyres price index (CLPI), Laspeyres chained price index (LCPI) and Tornqvist approximation to the Divisia price index (DPI) which are given in equation (5.11) to (5. 13).

(5.11) $$CLPI = \frac{\sum_i p_{it} x_{i0}}{\sum_i p_{i0} x_{i0}}$$

(5.12) $$LCPI = \frac{\sum_i p_{it} x_{i,t-1}}{\sum_i p_{i,t-1} x_{i,t-1}}$$

(5.13) $$\ln(DPI) = \sum_i \overline{W}_i \ln\left(\frac{p_{it.}}{p_{i,t-1}}\right)$$

$$\text{where } \overline{W}_i = \frac{W_{it} + W_{i,t-1}}{2} \text{ and } W_{it} = \frac{p_{it} x_{it}}{\sum_i p_{it} x_{it}}$$

where p_{it} and x_{it} represent respectively the current price and quantity of the i-th crop during period t.

The multiplicative models considered in the sensitivity analysis are described in Table 5.1. The models (I) and (II) represent the price constancy model, whereas the models (III) to (VIII) represent the price structure model. The crop output is measured in quantity terms in the price constancy models (I) and (II) and in value terms in the price structure models (III) to (VIII).

TABLE 5.1

DESCRIPTION OF THE MULTIPLICATIVE DECOMPOSITION MODEL IN THE SENSITIVITY ANALYSIS

Model	Inclusion of Price Structure	Base Year	Price Scenario
I	No	1961/62	Prices of 1961/62 are used as constant prices.
II	No	1971/72	Prices of 1971/72 are used as constant prices.
III	Yes	1961/62	Conventional Laspeyres price index is used.
IV	Yes	1971/72	Conventional Laspeyres price index is used.
V	Yes	1961/62	Laspeyres chained price index is used.
VI	Yes	1971/72	Laspeyres chained price index is used.
VII	Yes	1961/62	Divisia-related price index is used.
VIII	Yes	1971/72	Divisia-related price index is used.

Further, no study has compared results derived from the additive and multiplicative model on the basis of the same data set. Therefore, this study compares the results of the modified additive and multiplicative decomposition model in order to examine the similarity in those results. The additive model presented in equation (5.5) is modified by replacing the conventional Laspeyres price index by the Tornqvist approximation to the Divisia price index.

5.4 Results of Decomposition Analysis

The models presented in Table 5.1 were estimated on the basis of data on crop output quantity, output price and area which are given in Appendix 1. The annual growth rates of crop output and its components estimated from the decomposition models are presented in Table 5.2. According to Table 5.2, the crop output quantity under the price constancy multiplicative model (I) increased annually by 1.56 percent during the period of 1961/62 to 1987/88. The major contributing factor to such an increase in the crop output quantity is the area which increased annually by 1.77 percent during the period. On the other hand, the yield effect during the same period is observed to be negative, whereas the effects of cropping pattern and the interaction term are observed to be positive but relatively very small. These results of the price constancy multiplicative model are approximately same as those obtained by Yadav (1987) who also used the same price constancy model. The negligible difference in the growth rates of crop output quantity derived in this study and Yadav (1987) seems to be the result of the differences in the length of study period and in the choice of the constant price base. Yadav (1987) used the output prices of the year 1975/76 as constant prices in his decomposition analysis for the period of 1961/62 to 1980/81, whereas the output prices of the year 1961/62 are used as constant prices in this study to estimate the price constancy model (I) for the period of 1961/62 to 1987/88.

TABLE 5.2

ANNUAL GROWTH RATES OF NOMINAL CROP OUTPUT VALUE AND ITS COMPONENTS IN PERCENTAGE: NEPAL, 1961/62 - 1987/88[1]

Model	Nominal Crop Output Value	Area Effect	Yield Effect	Cropping Pattern Effect	Price Effect	Interaction Effect
I	1.56 (100)	1.77 (113.4)	-0.32 (-20.5)	0.02* (1.3)	-	0.09 (5.8)
II	1.40 (100)	1.77 (126.4)	-0.27 (-19.3)	-0.21 (-15.0)	-	0.11 (7.9)
III	7.62 (100)	1.77 (23.2)	-0.32 (-4.2)	0.02* (0.3)	6.20 (81.4)	-0.05* (-0.7)
IV	7.62 (100)	1.77 (23.2)	-0.27 (-3.5)	-0.21 (-2.8)	6.18 (81.1)	0.15 (2.0)
V	7.62 (100)	1.77 (23.2)	-0.32 (-4.2)	0.02* (0.3)	6.09 (79.9)	0.06 (0.8)
VI	7.62 (100)	1.77 (23.2)	-0.26 (-3.4)	-0.21 (-2.7)	6.09 (79.9)	0.23 (3.0)
VII	7.62 (100)	1.77 (23.2)	-0.32 (-4.2)	0.02* (0.3)	6.08 (79.8)	0.07 (0.9)
VIII	7.62 (100)	1.77 (23.2)	-0.26 (-3.4)	-0.21 (-2.7)	6.08 (79.8)	0.24 (3.1)

1. All the estimated growth rates are significant at 0.05 level except ones with the star sign (*) which are significant at 0.10 level only. The number shown in parenthesis is the percentage contribution to the annual growth rate of crop output.

Similarly, the results derived from models (I) and (II) imply that changes in base period and constant prices in the price constancy model alter the contribution of area and cropping pattern to the crop output quantity. As a result of such changes in base period and constant prices, the contribution of area to the crop output quantity increased from 113.4 percent to 126.4 percent, whereas the contribution of cropping pattern changed from positive to negative. Moreover, the changes in base period and constant prices also brought a small decline in the growth rate of crop output quantity.

However, when price structure is included in the multiplicative decomposition models (III) to (VIII), the annual growth rates of the nominal crop output value are observed increasing by 7.62 percent per annum during the period of 1961/62 to 1987/88, mainly due to an increase in nominal crop output price. The nominal crop output price increased by more than six percent per annum during that period. Results also indicate that the annual growth rates of the nominal crop output value in the price structure models (III) to (VIII) after deducting the contribution of the nominal crop output price become approximately the same as those in the case of price constancy models (I) and (II). Moreover, the inclusion of price structure into the multiplicative decomposition models did not change the annual growth rates of area, yield and cropping pattern, but it did change the percentage contributions of these factors to the nominal crop output value. Unlike in the price constancy models, area in the price structure models did not remain as a major contributing factor to the growth of nominal crop output value in the Nepalese crop sector. Rather, it is the nominal crop output price which is observed to have a major contribution to the growth of nominal crop output value in Nepal. The study also concludes that the inclusion of price structure into the multiplicative decomposition models did not change the magnitude and direction of yield effect.

Regarding the choice of model, it is very difficult to choose between the price constancy model and price structure model as such, because there lies a fundamental difference between these models with respect to the measurement of crop output. As discussed in section (5.3), the price constancy model includes the crop output in quantity terms, whereas the price structure model considers the crop output in nominal value terms. Nevertheless, the price structure model as compared to the price constancy model is believed to provide a better understanding of output growth in the sense that the model permits one to examine the influence of crop output price on the growth of crop output value. Besides this, the model helps to obtain the relative contributions of all factors including price structure to the growth of crop output value. Therefore, the price structure model has been chosen for further analysis.

Results derived from the price structure models in Table 5.2 lead one to conclude that the price indexing procedure influences the interaction effect and, to some extent, the price effect. However, it does not have any influence on area effect, yield effect and cropping pattern effect. Among the price structure models, it is very difficult to choose one versus another as such. However, the model that includes the Divisia-related price index has some theoretical advantages over the other models with respect to the price indexing procedure. As mentioned in section (3.3.3) of Chapter 3, the Divisia-related index procedure has several merits including one that it permits changes in output value shares (and input cost shares) over time. In addition to this, the Divisia-related price index procedure has been widely used in recent agricultural productivity studies. Therefore, the models (VII) and (VIII) are selected to analyze the output growth in the Nepalese crop sector.

In this study, the influence of a change in base period on growth components under a price structure model is also examined by comparing results of models (III) and (IV), (V) and (VI), and (VII) and (VIII) in Table 5.2. Results indicate that the change in base period from the year 1961/62 to 1971/72 did not affect the growth rates of nominal crop output value, area and nominal output price, but it affected the growth rates of cropping pattern and crop yield. The change in the growth rate of crop yield is observed to be minimal. However, the growth rate of cropping pattern changed from positive to negative. Such a change in the sign of the cropping pattern effect may have resulted from the fact that the year 1961/62 as compared to the year 1971/72 had relatively a large cropped area under high-value crops.

Regarding the choice of base period, it does not make much difference whether the year 1961/62 or 1971/72 is chosen for output growth analysis in Nepal, because the major contributors to the growth of nominal crop output value, such as area and nominal output price, do not change as a result of a change in base period. Nevertheless, the year 1961/62 as compared to 1971/72 is believed to provide a better estimate of output growth in the Nepalese crop sector, because the year is considered to be relatively a normal year with respect to agricultural environment. Moreover, the year 1961/62 represents the beginning of the period when use of modern inputs, such as HYV seeds and chemical fertilizer, started in the Nepalese crop sector. Therefore, the year 1961/62 is chosen as the base year to analyze the output growth in the Nepalese crop sector. Since the price structure model (VII) includes the year 1961/62 as base period, the model has been selected for further analysis in this study.

Further, the additive decomposition model presented in equation (5.5) is modified by replacing the conventional Laspeyres price index by the Divisia-related price index and, then, the model is estimated in order to compare its results with those obtained from the multiplicative decomposition model (VII). Moreover, the results were made comparable by using the same base period and price indexing procedure in both the additive and multiplicative model. Results of the additive and multiplicative model are presented in Table 5.3.

According to Table 5.3, the difference between the additive model and multiplicative model with respect to the output growth rate is small. However, these models differ considerably with respect to the growth rates of area, price and interaction terms. The annual growth rate of nominal crop output value derived from the additive model for the period of 1961/62 to 1987/88 is observed to be 7.42 percent which is slightly lower than the one obtained from the price structure multiplicative model (VII). Similarly, the growth rates of area and price derived from the additive model are observed to be relatively smaller than those estimated from the multiplicative model. Surprisingly, the growth rate of the interaction term derived from the additive model is relatively higher than the one derived from the multiplicative model. The contribution of the interaction term to the growth of nominal crop output value is observed to be 0.9 percent in the case of the multiplicative model and 29.6 percent in the case of the additive model. However, a further decomposition of the interaction term in the additive model shows that the higher growth rate of the interaction term in the model is mainly caused by the interaction effect between area and price.

The decomposition of partial crop productivity in the additive model implies that the yield effect to the partial crop productivity is negative. However, the magnitude of such a yield effect in the additive model is relatively smaller than the yield effect to the crop output value in the multiplicative model. Table 5.3 also indicates that the cropping pattern effect to the partial crop productivity in the additive model is positive and relatively small, but the effect is almost the same as the effect of cropping pattern to the crop output value in the multiplicative model. Moreover, the effects of yield, nominal output price and interaction term on the partial crop productivity in the additive model

TABLE 5.3

ANNUAL GROWTH RATES OF NOMINAL CROP OUTPUT VALUE AND ITS COMPONENTS IN PERCENTAGE: NEPAL, 1961/62 - 1987/88[1]

Item	Multiplicative Decomposition Model (VII)	Additive Decomposition Model
Nominal Crop Output Value	**7.62 (100)**	**7.42 (100)**
Decomposition of Crop Output Value:		
Area Effect	1.77 (23.2)	0.62 (8.4)
Yield Effect	-0.32 (-4.2)	-
Cropping Pattern Effect	0.02 (0.3)*	-
Price Effect	6.08 (79.8)	4.66 (62.8)
Partial Agri. Productivity (Y_t)	-	-0.06 (-0.8)
Interaction Effect	0.07 (0.9)	2.20 (29.6)
Decomposition of Interaction Effect:		**2.20 (29.6)**
$\Delta A.\Delta Y$		-0.03 (-0.4)
$\Delta A.\Delta P$		2.58 (34.8)
$\Delta Y.\Delta P$		-0.24 (-3.2)
$\Delta A.\Delta Y.\Delta P$		-0.11 (-1.5)
Decomposition of Partial Agricultural Productivity:		**-0.06 (-0.8)**
Cropping Pattern Effect		0.01 (0.1)*
Yield Effect		-0.08 (-1.1)
Price Effect		0.03 (0.4)
Interaction Effect:		-0.02 (-0.3)
$\Delta a_t.\Delta y_t$		0.02 (0.3)
$\Delta a_t.\Delta q_t$		-0.03 (-0.4)
$\Delta y_t.\Delta q_t$		-0.01 (-0.1)*
$\Delta a_t.\Delta y_t.\Delta q_t$		0.00 (0.0)[N]

1. All the estimated growth rates are significant at 0.05 level except ones with the star sign (*) which are significant at 0.10 level only. The number shown in parenthesis is the percentage contribution to the annual growth rate of crop output value.

2. N = Not significant.

are respectively negative, positive and negative.

A comparison of results derived from the additive and multiplicative models indicates that the latter model as compared to the former seems to be relatively more realistic in analyzing the output growth in the Nepalese crop sector. It is because the interaction effect is relatively larger in the additive model than in the multiplicative model. This implies that the additive model as compared to the multiplicative model is unable to isolate the effects of each pure component to a greater degree. As mentioned in section 4.3, the multiplicative model is also theoretically superior to the additive model as it deals with a compound growth rate of output rather than a linear growth rate of output which is the key feature of the latter model. Thus, the multiplicative model as compared to the additive model seems to provide a better understanding of output growth in the agricultural sector. Therefore, the model is chosen to analyze the crop output growth in Nepal.

The crop output price and crop output value used in the above decomposition models are presented in terms of nominal value. Therefore, results derived from those models do not provide the effect of real crop output price on the real crop output value. It is likely that the real crop output price may have declined over the period of 1961/62 to 1987/88, perhaps resulting in a decline in the real crop output value. In other words, the higher growth in nominal output prices in the above models may have been associated with a high inflation rate during the period. In such a case, the growth in real crop output value may have been negative over the period. Therefore, the multiplicative decomposition model (VII) is again estimated by including the real crop output price and real crop output value in order to analyze the effect of real crop output price on the real crop output value in Nepal. In addition to this, the multiplicative decomposition model (VII) is also estimated for three different sub-periods, viz. 1961/62 to 1970/71, 1971/72 to 1980/81 and 1981/82 to 1987/88, in order to compare the annual growth rates of the real crop output value and its contributing factors between these periods.

The national urban consumer price index which is published in NRB (1988) is the only consumer price index available in Nepal. Therefore, the index is used to deflate the nominal crop output value and nominal crop output price in order to obtain respectively the real crop output value and real crop output price. Then, these real crop output value and real crop output price are further used to estimate the multiplicative decomposition model (VII). The growth rates of the crop output value and crop output price in both nominal and real terms are presented in Table 5.4, whereas the effects of the growth components and their percentage contributions to the real crop output value are shown in Table 5.5.

According to Table 5.4, the high growth rate of the nominal crop output price in Nepal during the period of 1961/62 to 1987/88 was associated with a high inflation rate in the country. During the period, the rate of inflation was 8.95 percent per annum while the real crop output price decreased by 2.87 percent per annum. As a result, the nominal crop output value increased by 7.62 percent per annum, but the real crop output value decreased by 1.32 percent per annum. Similarly, a high inflation rate and a negative growth in the real crop output price during the 1960s and 1970s resulted in a decline in the real crop output value by 2.81 and 4.34 percent per annum in those respective decades. However, the growth in real crop output value in the 1980s is observed to be positive, mainly due to the fact that the real crop output price declined at a lesser rate in the 1980s than in the 1960s and 1970s and was more than offset by growth in crop output quantity.

TABLE 5.4

ANNUAL GROWTH RATES OF REAL CROP OUTPUT VALUE AND REAL CROP OUTPUT PRICE: NEPAL, 1961/62 - 1987/88[1]

Period	Nominal Crop Output Value	Crop Output Prices			Real Crop Output Value
		Nominal	Inflation	Real[2]	
1961/62 - 1970/71	8.47	7.27	11.28	-4.01	-2.81
1971/72 - 1980/81	3.76	3.20	8.10	-4.90	-4.34
1981/82 - 1987/88	12.93	9.05	9.23	-0.18[N]	3.70*
1961/62 - 1987/88	7.62	6.08	8.95	-2.87	-1.32

1. All the estimated growth rates are significant at 0.05 level except the one with the star sign (*) which is significant at 0.10 level only.
2. Real = Nominal - Inflation.
3. N = Not significant.

TABLE 5.5

ANNUAL GROWTH RATES OF REAL CROP OUTPUT VALUE AND ITS COMPONENTS IN PERCENTAGE: NEPAL, 1961/62 - 1987/88[1]

Period	Real Crop Output Value	Area Effect	Yield Effect	Cropping Pattern Effect	Real Output Price Effect	Interaction Effect
1961/62 -1970/71	-2.81 (100)	1.85 (-65.8)	-0.64 (22.8)	0.12 (-4.3)	-4.01 (142.7)	-0.13 (4.6)
1971/72 -1980/81	-4.34 (100)	1.43 (-32.9)	-1.64 (37.8)	-0.08* (1.8)	-4.90 (112.9)	0.85 (-19.6)
1981/82 -1987/88	3.70* (100)	3.42 (92.4)	0.56[N] (15.1)	0.06[N] (1.6)	-0.18[N] (-4.9)	-0.16[N] (-4.3)
1961/62 -1987/88	-1.32 (100)	1.77 (-134.1)	-0.34 (25.8)	0.02* (-1.5)	-2.87 (217.4)	0.10 (-7.6)

1. All the estimated growth rates are significant at 0.05 level except ones with the star sign (*) which are significant at 0.10 level only. The number shown in parenthesis is the percentage contribution to the annual growth rate of real crop output value.
2. N = Not significant.

According to Table 5.5, cropped area, crop yield and real crop output price are the major influences on the growth of real crop output value. During the period of 1961/62 to 1987/88, the real crop output price had the largest and positive effect on the negative growth of real crop output value, whereas the cropped area during the same period had a counter effect on the negative growth of real crop output value. As in the case of real crop output price, the crop yield contributed positively in the decline of real crop output value during the period of 1961/62 to 1987/88.

Further, the positive growth in crop area and negative growth in crop yield during the period of the 1960s and 1970s could have resulted from the transfer of marginal land into crop land and could also be due to lack of improved technology during those periods. The crop area grew annually by 1.85 percent in the 1960s and by 1.43 percent in the 1970s, whereas the adoption rates of improved technology defined by HYV seeds and chemical fertilizer, as presented in Table 5.6, were very low in those periods.

According to Table 5.6, the use of HYV seeds in the Nepalese crop sector really started only around the mid-sixties. The HYV seeds which include major three crops, viz. paddy, wheat and maize, covered only 0.54 and 7.95 percent of the total cropped area respectively in 1965/66 and 1970/71. Though the percentage of the total cropped area under HYV seeds increased substantially from 9.64 percent in 1971/72 to 33.98 percent in 1980/81, the adoption rate of HYV seeds remained fairly low throughout the 1970s. Similarly, the consumption of chemical fertilizer in Nepal was as low as 0.23 kg/ha in 1965/66 and it did not increase above 8.88 kg/ha during the entire period of the 1960s and 1970s.

TABLE 5.6

TOTAL AREA UNDER HYV SEEDS AND TOTAL CONSUMPTION OF CHEMICAL FERTILIZER BY NUTRIENT (N, P, K)

Year	Total Cropped Area ('000' ha)	Total Area Under HYV Seeds ('000' ha)	Percentage of Total Cropped Area Under HYV Seeds	Consumption of Fertilizer	
				Total (MT)	Rate (kg/ha)
1961/62	1919.4	NA	-	663	0.35
1965/66	1998.0	10.7	0.54	451	0.23
1970/71	2231.3	177.3	7.95	5406	2.42
1971/72	2265.2	218.3	9.64	7968	3.52
1980/81	2528.2	859.0	33.98	22459	8.88
1981/82	2554.3	1161.5	45.47	23823	9.33
1987/88	3169.9	NA	NA	53483	16.87

NA = Not Available
Adapted from DFAMS (1972, 1983, 1988).

On the other hand, the positive growth in the real crop output value during the 1980s resulted from the positive effects of area, yield and cropping pattern (Table 5.5). An increase in the fertilizer consumption rate and in the area under HYV seeds in the 1980s (Table 5.6) likely caused the positive growth in crop yield in Nepal in this period. Slightly above 45 percent the total cropped area was covered by HYV seeds during the year 1981/82 and the consumption rate of chemical fertilizer increased from 9.33 kg/ha in 1981/82 to 16.87 kg/ha in 1987/88.

The positive sign of cropping pattern during the 1960s and again in the 1980s implies a proportionate shift in cropped area from low-value crops to high-value crops. In other words, the positive cropping pattern effects during these periods indicate that the proportion of cropped area under high-value crops, such as sugarcane, jute and tobacco, increased significantly as compared to the cropped area under low-value crops, such as paddy, wheat and maize. On the other hand, the negative cropping pattern effect during the 1970s may have been resulted from a proportionate shift in area from high-value crops to low-value crops, especially wheat. The wheat area increased from 228,400 hectares in 1970/71 to 391,800 hectares in 1980/81, giving an increase in wheat area by almost 72 percent (Table A1.3 of Appendix 1). The major reason for such an increase in the wheat area is the green revolution in which major yield gains could be achieved.

In addition to the green revolution, the shift from high-value crops to low-value crops may have also been influenced by farmers' risk attitude, consumption behavior and ability to purchase modern inputs in order to produce high-value crops. In Nepal, small and marginal farmers carry a higher degree of absolute risk aversion and perceive a higher degree of risk in modern crop inputs (Hamal 1981; and Hamal and Anderson 1982). Therefore, these farmers might have initially shifted from low-value to high-value crops in order to maximize their profits. However, when they realized that their survival is at risk if modern inputs required for the high-value crops are not used in time and in appropriate combination, they might have shifted back to low-value crops. Beside this, small and marginal farmers prefer to produce foodgrains rather than cash crops in order to minimize the risk of not getting foodgrains in time and also to minimize their travel time while bringing foodgrains from the nearby market centres. In the absence of a well developed transportation system, farmers in the remote areas of Nepal have to travel up to 10 to 15 days to bring foodgrains from market centres.

5.5 Summary and Conclusions

The crop output value is decomposed into cropped area, yield, cropping pattern, crop output price and their interaction terms in order to determine the sources of output growth in the Nepalese crop sector. The sensitivity analysis with respect to the base period and price indexing procedure showed that the multiplicative decomposition model with the Tornqvist approximation to the Divisia price index and base year 1961/62 is the most preferred model to carry out output growth analysis in the Nepalese crop sector. Moreover, the modified additive decomposition model, modified with respect to price indexing procedure, is also estimated in this study to compare its results with those derived from the multiplicative decomposition model.

Results derived from the price constancy model are very similar to results obtained by Yadav (1987) and indicate that the crop output quantity during the period of 1961/62 to 1987/88 increased annually by 1.56 percent with a significant positive area effect, negative yield effect and relatively small effects of cropping pattern and interaction term. The study also concludes that a change in base period and constant prices in a price constancy model changes the contribution of area and cropping pattern to the crop output quantity.

According to the results of the price structure multiplicative model, the growth rate of nominal crop output value during the period of 1961/62 to 1987/88 increased annually by 7.62 percent, mainly due to an increase in nominal crop output price. About 80 percent of the increase in the nominal crop output value came from an increase in nominal crop output price, whereas 23.2 percent was contributed by an increase in the cropped area. The yield effect during the period was negative.

The sensitivity analysis leads one to conclude that a change in price indexing procedure does not influence the growth rates of output, area, yield and cropping pattern. However, it does have some influence on interaction effect and price effect. Moreover, a change in base period is observed to have an influence only on cropping pattern. The analysis also indicates that the Divisia-related price index and base period 1961/62 are the most preferred price indexing procedure and base period to analyze the output growth in the Nepalese crop sector.

A comparison of results derived from the modified additive and multiplicative decomposition model shows a very small difference in annual output growth rates derived from those models. However, the difference in growth rates of cropped area, crop output price and interaction term derived from those two types of model is observed to be sufficiently large. Moreover, a further decomposition of the interaction term in the additive model shows that the higher interaction effect in the model is mainly caused by the interaction term involving crop area and crop output price. Similarly, the decomposition of the partial crop productivity in the additive model indicates that the effects of cropping pattern and crop output price on the partial crop productivity are positive, whereas the effect of crop yield on the partial crop productivity is negative.

Further, the price structure multiplicative decomposition model (VII) is estimated by considering the real crop output price and real crop output value in order to analyze the effect of real crop output price on the growth rate of real crop output value. According to the results, the real crop output value during the period of 1961/62 to 1987/88 decreased by 1.32 percent per annum, mainly due to decrease in real crop output price and crop yield. Nevertheless, a periodical analysis of the output growth trend indicates that the growth rate of real crop output value in Nepal was negative in the 1960s and 1970s but positive in the 1980s. The negative growth rate of real crop output value in the 1960s and 1970s was mainly caused by a sharp decline in the real crop output price during those periods, whereas the positive growth rate of real crop output value in the 1980s was contributed by an increase in cropped area and a relatively smaller decline in the real crop output price in the 1980s than in the 1960s and 1970s.

CHAPTER 6

ESTIMATION OF TOTAL FACTOR PRODUCTIVITY, TERMS OF TRADE, RETURNS TO COST AND PRODUCTION STRUCTURE

6.1 Introduction

Chapter 6 deals with the estimation of total factor productivity, terms of trade, returns to cost and production structure in the Nepalese crop sector. In addition, the chapter also presents the estimation of annual growth rates of crop output, inputs and total factor productivity. In this chapter, the total factor productivities are estimated under both the geometric and flexible weight index procedures which have been discussed in detail in Chapter 3.

6.2 Estimation of Total Factor Productivity, Terms of Trade and Returns to Cost

6.2.1 Estimation of Total Factor Productivity under the Geometric Index Procedure

The total factor productivity under the geometric index procedure is estimated using equation (3.13) of Chapter 3. The equation is further extended to include five inputs as:

$$(6.1) \qquad \left(\frac{\dot{A}}{A}\right) = \left(\frac{\dot{Q}}{Q}\right) - \left(\frac{\dot{X}}{X}\right) \quad \text{where} \quad \left(\frac{\dot{X}}{X}\right) = \sum_i s_i \left(\frac{\dot{X}_i}{X_i}\right) \qquad (i = R, L, B, F, S)$$

where X_i and s_i denote the quantity of the i-th input and the share of the i-th input in total output. The shares of inputs in the total output are obtained by estimating an aggregate Cobb-Douglas production function for Nepal. The estimation procedure and results of the aggregate Cobb-Douglas production function are presented in Appendix 2. The estimated shares of land, labour, bullocks, fertilizer and HYV seeds in the total output are observed to be respectively 0.281, 0.651, 0.042, 0.014 and 0.012.

The estimated factor shares and the input quantities given in Table A1.4 of Appendix 1 were used in equation (6.1) to construct an aggregate input quantity index under the geometric index procedure. Then, the Divisia output quantity index of Table 4.3 of Chapter 4 is divided by the aggregate input quantity index in order to estimate the total factor productivity in the Nepalese crop sector. The choice of the Divisia output quantity index in the estimation of total factor productivity under the geometric index procedure is made on the basis of its superiority over the other output quantity indices, such as the Laspeyres quantity index. The indices of output, input and total factor productivity are presented in Table 6.1 and also plotted over time in Figure 6.1.

According to Table 6.1 and Figure 6.1, the aggregate crop output during the period of 1961/62 to 1986/87 increased by 1.54 percent per annum, whereas the aggregate crop input during the same period increased by 2.07 percent per annum. As a result, the total factor productivity in the Nepalese crop sector decreased by 0.52 percent per annum over the period of 1961/62 to 1987/88. Similarly, the growth rates of the aggregate crop input during the 1960s and 1970s are relatively higher than the growth rates of the aggregate crop output in those corresponding periods. Therefore, the total factor productivity growth in the Nepalese crop sector during those periods is also observed to be negative. The total factor productivity in the Nepalese crop sector decreased annually by 0.10 percent in the 1960s and by 1.21 percent in the 1970s. However, the total factor productivity growth in the sector improved reasonably in the 1980s. During the period, the crop output, input and total factor productivity grew respectively by 3.88, 2.76 and 1.12 percent per annum. One of the possible reason for such an improvement in the total factor productivity growth during the 1980s could be the lag effect of the green revolution that took place during the late 1960s and in the 1970s. In LDCs, the green revolution, especially in the case of rice, is generally assumed to have a lag effect

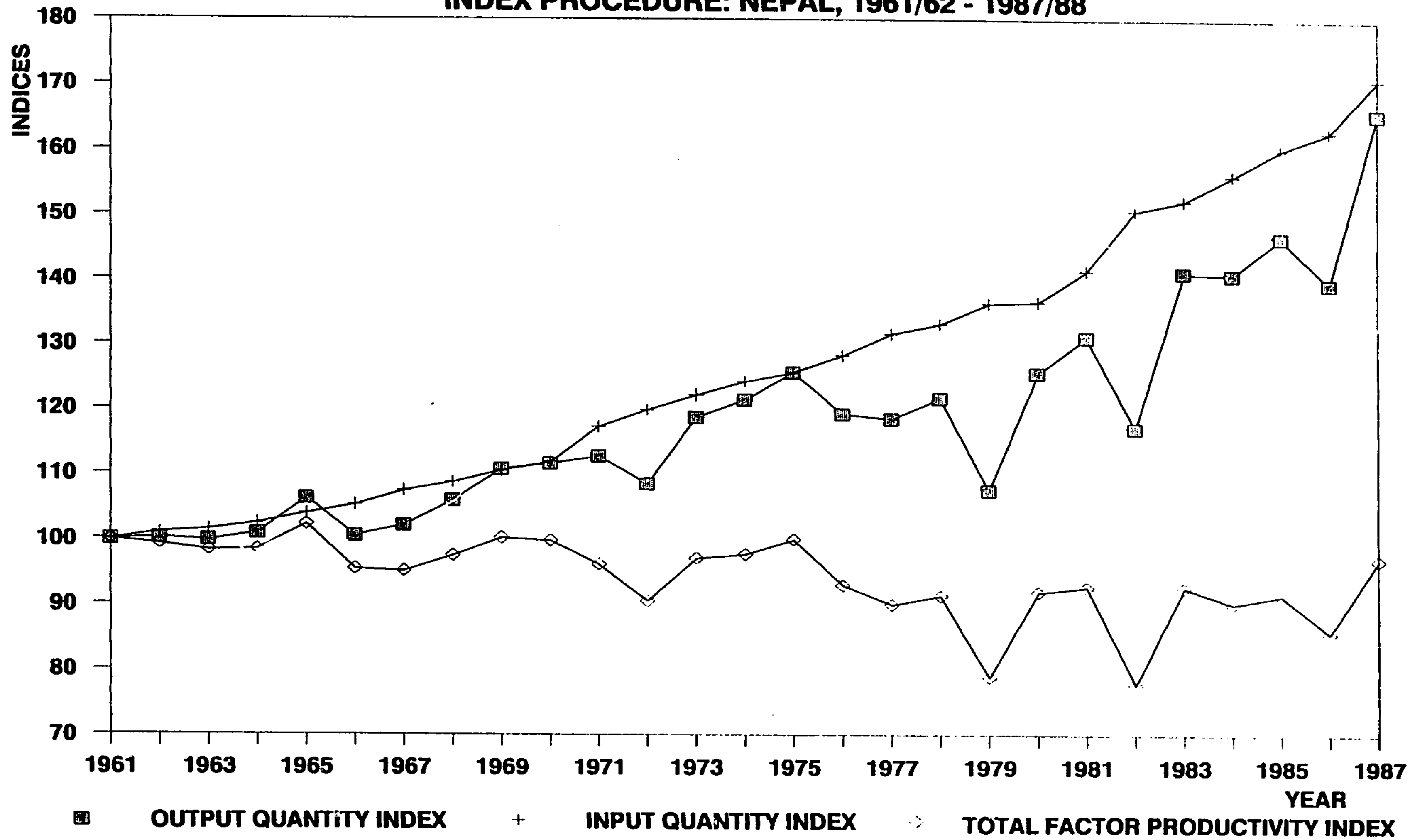
TABLE 6.1
INDICES OF OUTPUT, INPUT AND TOTAL FACTOR PRODUCTIVITY (TFP) UNDER THE GEOMETRIC INDEX PROCEDURE: NEPAL, 1961/62 - 1987/88

(1961/62 = 100)

Year	Output Index (Y)	Input Index (X)	TFP Index (Y/X)	Hayami and Ruttan[1]	
				Input Index	TFP Index
1961/62	100.00	100.00	100.00	100.00	100.00
1962/63	100.21	100.93	99.28	101.77	98.47
1963/64	99.83	101.54	98.32	101.23	98.61
1964/65	100.88	102.46	98.45	103.31	97.64
1965/66	106.27	103.90	102.28	104.45	101.74
1966/67	100.52	105.27	95.49	110.67	90.83
1967/68	102.12	107.42	95.07	118.13	86.45
1968/69	105.99	108.74	97.48	121.30	87.38
1969/70	110.72	110.50	100.19	128.28	86.31
1970/71	111.64	111.87	99.80	132.47	84.28
1971/72	112.75	117.27	96.14	149.29	75.52
1972/73	108.53	119.87	90.54	166.31	65.26
1973/74	118.74	122.24	97.14	175.46	67.67
1974/75	121.45	124.31	97.70	178.74	67.95
1975/76	125.74	125.75	99.99	176.98	71.05
1976/77	119.33	128.34	92.98	191.05	62.46
1977/78	118.58	131.74	90.01	210.71	56.28
1978/79	121.77	133.28	91.36	215.87	56.41
1979/80	107.61	136.43	78.88	234.50	45.89
1980/81	125.71	136.67	91.98	230.71	54.49
1981/82	131.27	141.50	92.77	243.80	53.84
1982/83	117.20	150.79	77.73	299.43	39.14
1983/84	141.21	152.33	92.70	310.15	45.53
1984/85	140.88	156.17	90.21	329.13	42.80
1985/86	146.68	160.25	91.53	338.92	43.28
1986/87	139.51	162.88	85.65	348.22	40.06
1987/88	165.73	170.92	96.96	392.99	42.17
Annual Compound Growth Rates:					
1961/62-1970/71	1.20	1.30	-0.10	3.34	-2.15
1971/72-1980/81	0.56	1.76	-1.21	4.81	-4.25
1981/82-1986/87	3.88	2.76	1.12	6.51	-2.63
1961/62-1986/87	1.54	2.07	-0.52	5.52	-3.98

1. Using factor shares from Hayami and Ruttan (1985, Equation (20), p.145).

FIGURE 6.1
INDICES OF OUTPUT, INPUT AND TOTAL FACTOR PRODUCTIVITY UNDER THE GEOMETRIC INDEX PROCEDURE: NEPAL, 1961/62 - 1987/88



of longer period (presumably 10 years or so), mainly due to a longer time period required to diffuse the modern technology among farmers who are mostly illiterate, subsistence, traditional and risk averse farmers.

Further, the factor shares that were estimated by Hayami and Ruttan (1985, Equation 20, p.145) for 22 LDCs were used to estimate the total factor productivity in the Nepalese crop sector, especially to find out whether the trend of the total factor productivity growth obtained from the factor shares estimated in this study is in line with the trend of the total factor productivity growth obtained from the factor shares of Hayami and Ruttan. The factor shares of Hayami and Ruttan after adjusting for constant returns to scale are observed to be 0.09 for land, 0.55 for labour, 0.16 for bullocks, 0.14 for fertilizer and 0.06 for seeds. The crop input quantity index and total factor productivity index under this factor share scenario are also presented in Table 6.1.

According to Table 6.1, the growth rates of the aggregate crop input quantity in all three periods, viz. the 1960s, 1970s and 1980s, are relatively higher in the case of Hayami and Ruttan's factor shares than in the case of factor shares estimated in this study. It is because the factor shares of bullocks, fertilizer and HYV seeds which have higher growth rates than the growth rates of land and labour during the period 1961/62 to 1987/88 are relatively higher in the case of Hayami and Ruttan's estimation than in the case of factor shares estimated in this study. Therefore, with the same output quantity index series, the total factor productivity estimated using Hayami and Ruttan's factor shares shows relatively a lower growth rate in all the three periods than the growth rate estimated using the factor shares that are obtained in this study. However, such a change in the factor shares did not affect the direction of the total factor productivity growth in the Nepalese crop sector. The direction of the total factor productivity growth during the period 1961/62 to 1987/88 remained the same despite a change in the factor shares.

In Nepal, the farming system is still dominated by the traditional and subsistence farming system with a minimal degree of commercialization. The characteristics of such a farming system are more closely described by the factor shares estimated in this study than by the factor shares estimated by Hayami and Ruttan (1985, Equation 20, p.145) who did not include Nepal in their study. Therefore, the factor shares estimated in this study and, thereby, the total factor productivity in the Nepalese crop sector estimated using those factor shares are considered for further analysis in this study.

6.2.2 Estimation of Total Factor Productivity under the Flexible Weight Index Procedure

As mentioned in section 3.4 of Chapter 3, the advantages of the flexible weight index procedure over the arithmetic and geometric index procedure are so great that an attempt has been made in this section to use the flexible weight index procedure to estimate the total factor productivity in the Nepalese crop sector and, thus, to compare its results to the results derived from the geometric index procedure.

According to the flexible weight index procedure, the Divisia quantity indices of aggregate output and inputs are constructed by fitting the quantity and price data of outputs and inputs, which are given respectively in Table A1.1, A1.2, A1.4 and A1.6, into the equation (3.18) of Chapter 3. An econometric computer programme, SHAZAM (version 6.0), which was developed by White and Horsman (1987, p.171) is used to compute the Divisia quantity indices of output and inputs. The indices which consider the year 1961/62 as the base year are presented in Table 6.2. Furthermore, the Divisia output quantity index is divided by the Divisia input quantity index in order to obtain a Divisia-based estimate of total factor productivity of the Nepalese crop

TABLE 6.2
DIVISIA INDICES OF OUTPUT, INPUT, TOTAL FACTOR PRODUCTIVITY (TFP), TERMS OF TRADE (TT) AND RETURN TO COST: NEPAL, 1961/62 - 1987/88

(1961/62 = 100)

Year	Output Quantity (Y)	Input Quantity (X)	Output Price (P_Y)	Input Price (P_X)	TFP (Y/X)	Terms of Trade (P_Y/P_X)	Return to Cost (P_YY/P_XX)
1961/62	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1962/63	100.21	100.57	98.100	100.92	99.64	97.21	96.86
1963/64	99.83	100.34	135.18	132.55	99.50	101.98	101.47
1964/65	100.88	100.60	148.84	145.79	100.28	102.09	102.38
1965/66	106.27	104.35	174.47	172.24	101.84	101.30	103.16
1966/67	100.52	104.50	159.52	163.26	96.19	97.71	93.98
1967/68	102.12	108.90	174.91	185.92	93.77	94.08	88.22
1968/69	105.99	110.90	175.62	188.22	95.57	93.30	89.18
1969/70	110.72	113.55	189.84	204.31	97.51	92.92	90.61
1970/71	111.64	115.43	187.84	205.36	96.72	91.47	88.46
1971/72	112.75	117.70	207.30	224.23	95.79	92.45	88.56
1972/73	108.53	116.70	251.09	276.48	93.00	90.82	84.46
1973/74	118.74	120.96	268.67	280.14	98.17	95.90	94.15
1974/75	121.45	123.60	286.77	320.78	98.26	89.40	87.84
1975/76	125.74	125.40	276.67	314.35	100.27	88.01	88.25
1976/77	119.33	126.41	255.90	313.49	94.40	81.63	77.06
1977/78	118.58	129.00	303.95	372.96	91.92	81.50	74.91
1978/79	121.77	129.81	283.33	360.34	93.80	78.63	73.76
1979/80	107.61	129.01	292.81	376.84	83.41	77.70	64.81
1980/81	125.71	132.08	318.00	431.62	95.18	73.68	70.12
1981/82	131.27	134.32	350.14	459.13	97.73	76.26	74.53
1982/83	117.20	138.48	410.47	546.48	84.63	75.11	63.57
1983/84	141.21	140.61	459.79	628.54	100.43	73.15	73.46
1984/85	140.88	145.99	426.39	624.71	96.50	68.25	65.86
1985/86	146.68	151.64	489.24	684.72	96.73	71.45	69.12
1986/87	139.51	152.15	557.09	769.62	91.69	72.38	66.37
1987/88	165.73	160.88	651.00	882.76	103.01	73.75	75.97
Annual Compound Growth Rates:							
1961/62 -1970/71	1.20	1.75	7.27	8.39	-0.55	-1.12	-1.67
1971/72 -1980/81	0.56	1.35	3.20	5.92	-0.79	-2.72	-3.51
1981/82 -1987/88	3.88	2.88	9.05	9.76	1.00	-0.71	0.29
1961/62 -1987/88	1.54	1.74	6.08	7.64	-0.19	-1.56	-1.75

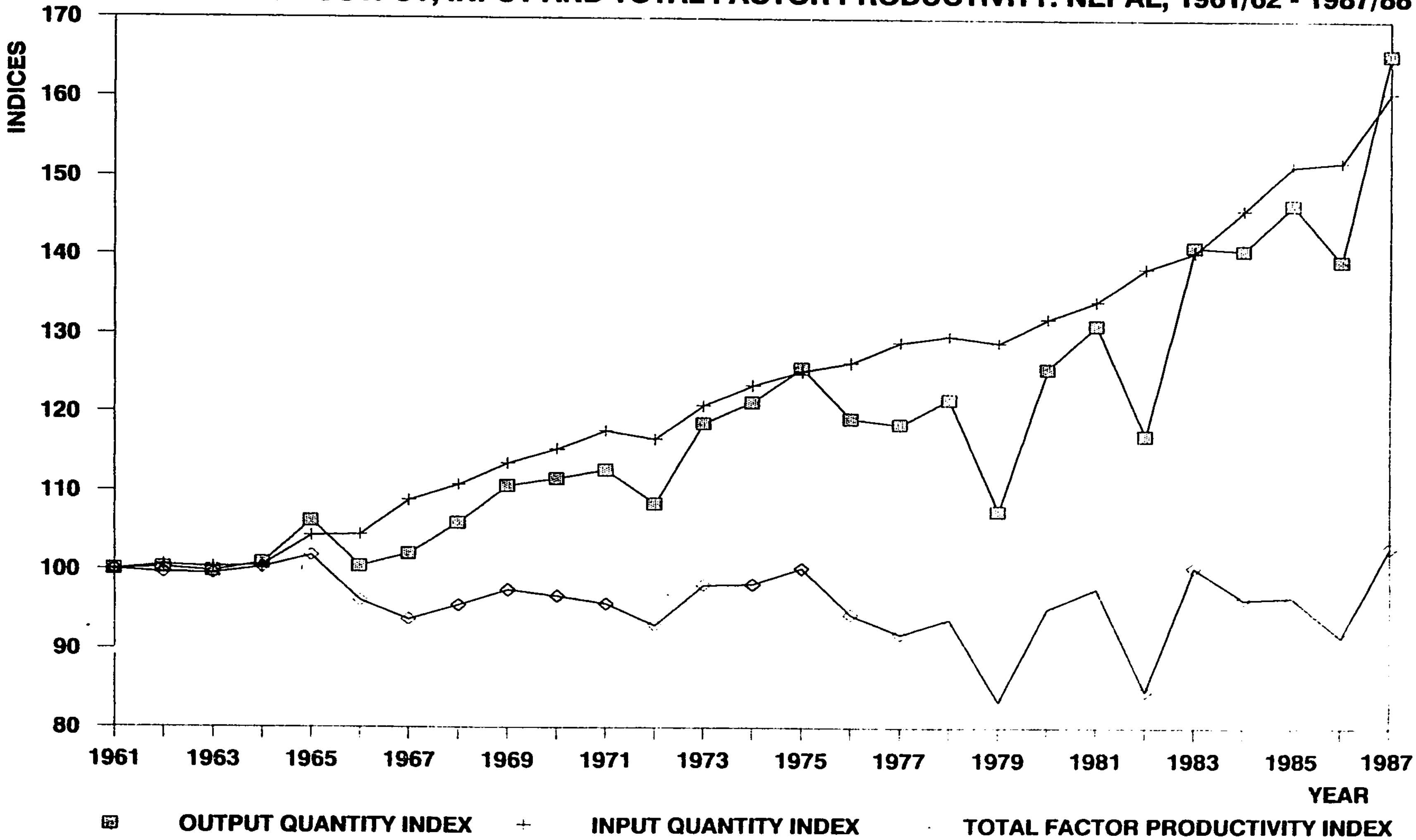
sector. The resultant total factor productivity index is also shown in Table 6.2. Moreover, the Divisia-based indices of crop output, input and total factor productivity are plotted over time in Figure 6.2.

According to Table 6.2 and Figure 6.2, the aggregate output in the Nepalese crop sector grew annually by 1.54 percent during the period of 1961/62 to 1987/88, whereas the aggregate input during the same period grew by 1.74 percent per annum. As a result, the sector's total factor productivity during the period declined by 0.19 percent per annum. The negative growth rate of the total factor productivity during the period of 1961/62 to 1987/88 is mainly caused by a decline in the total factor productivity during the 1960s and 1970s. The total factor productivity during the 1960s and 1970s declined respectively by 0.55 and 0.79 percent per annum. Moreover, such a decline in the total factor productivity in the Nepalese crop sector during the 1960s and 1970s is obviously coming from a higher growth rate of the aggregate crop input used in the sector as compared to the growth rate of the aggregate crop output produced in the sector. The aggregate input and output increased respectively by 1.75 and 1.20 percent per annum during the 1960s and respectively by 1.35 and 0.56 percent per annum during the 1970s.

Results presented in Table 6.2 and Figure 6.2 also indicate that factors that are responsible for such a decline in total factor productivity in the Nepalese crop sector during the 1960s and 1970s were not effective during the 1980s, because the growth rate of aggregate crop output increased from 0.56 percent per annum in the 1970s to 3.88 percent per annum in the 1980s. On the other hand, the growth rate of aggregate crop input increased from 1.35 percent per annum in the 1970s to 2.88 percent per annum in the 1980s. As a result, the total factor productivity in the Nepalese crop sector during the 1980s grew positively at a rate of 1.00 percent per annum.

FIGURE 6.2

DIVISIA INDICES OF OUTPUT, INPUT AND TOTAL FACTOR PRODUCTIVITY: NEPAL, 1961/62 - 1987/88



6.2.3 Comparative Analysis of the Estimated Total Factor Productivity Growth

The estimated growth rates of total factor productivity derived from the geometric index procedure are compared to the estimated growth rates of total factor productivity derived from the flexible weight index procedure. The estimated growth rates presented in Table 6.3 indicate that the direction of the total factor productivity remains the same despite a change in the index procedure to estimate the total factor productivity. The growth rates of total factor productivity estimated under the geometric and flexible weight index procedure show similar negative signs in the 1960s and 1970s and the same positive sign in the 1980s. Moreover, the difference in the magnitude of the total factor productivity growth is not very large across the two index procedures. During the period of 1961/62 to 1987/88, the total factor productivity in the Nepalese crop sector declined annually by 0.52 percent under the geometric index procedure and by 0.19 percent under the flexible weight index procedure. Such a difference in the total factor productivity growth rates is expected, because the factor shares in the geometric index procedure remain the same over the entire period of analysis, whereas the input cost shares in the flexible weight index procedure are allowed to change annually. Thus, the discussion made so far concludes that the estimation of the total factor productivity is theoretically better in the case of the flexible weight index procedure than in the case of the geometric index procedure. However, in a situation where availability of data restricts the use of the flexible weight index procedure, the geometric index procedure gives fairly reasonable estimates of the total factor productivity. The analysis also concludes that the procedure of approximating land prices which is discussed in Chapter 4 appears to be a reasonable approach to approximate land prices in the Nepalese crop sector and, therefore, is a practical and useful alternative in using the flexible weight

TABLE 6.3

CROSS-COUNTRY COMPARISON OF ESTIMATED TOTAL FACTOR PRODUCTIVITY

(1961/62 = 100)

	Nepal[1]		India[2]	China[2]
Year	GIP	FWIP	GIP	GIP
1961/62	100.00	100.00	100.00	100.00
1962/63	99.28	99.64	95.15	95.51
1963/64	98.32	99.50	95.32	92.72
1964/65	98.45	100.28	92.00	96.76
1965/66	102.28	101.84	78.01	86.50
1966/67	95.49	96.19	69.48	81.95
1967/68	95.07	93.77	80.85	76.20
1968/69	97.48	95.57	77.59	76.80
1969/70	100.19	97.51	78.01	67.60
1970/71	99.80	96.72	80.68	73.17
1971/72	96.14	95.79	66.09	67.89
1972/73	90.54	93.00	59.52	58.62
1973/74	97.14	98.17	66.91	56.73
1974/75	97.70	98.26	58.96	58.17
1975/76	99.99	100.27	70.50	56.73
1976/77	92.98	94.40	61.85	54.20
1977/78	90.01	91.92	67.10	49.93
1978/79	91.36	93.80	65.80	45.19
1979/80.	78.88	83.41	56.71	44.57
1980/81	91.98	95.18	57.90	39.22
1981/82	92.77	97.73	64.38	43.02
1982/83	77.73	84.63	59.28	48.59
1983/84	92.70	100.43	69.74	58.05
1984/85	90.21	96.50	.....	.....
1985/86	91.53	96.73	.....	.....
1986/87	85.65	91.69	.....	.....
1987/88	96.96	103.01	.....	.....
Annual Compound Growth Rates:				
1961/62-1970/71	-0.10	-0.55	-2.94	-4.22
1971/72-1980/81	-1.21	-0.79	-0.82	-5.15
1981/82-1986/87	1.12	1.00	4.00 *	14.98 *
1961/62-1986/87	-0.52	-0.19	-2.10 *	-3.93 *

1. GIP = Geometric index procedure, FWIP = Flexible weight index procedure.
2. Adapted from Wong (1987).
* It includes a period until the year 1983/84.

index procedure to estimate the total factor productivity in the agricultural sector.

Further, the total factor productivity growth rates of the Nepalese crop sector estimated under the geometric and flexible weight index procedure are compared to the total factor productivity growth rates of the Indian and Chinese agricultural sector derived under the geometric index procedure by Wong (1987), mainly to find whether or not there exists any differences in the growth rates across the countries. Table 6.3 indicates that the direction of the total factor productivity growth estimated for the Nepalese crop sector are the same as those obtained in the case of India and China. That is, the growth rates of total factor productivity for all three countries are observed to be negative during the 1960s and 1970s, positive during the 1980s and negative during the entire study period.

The change in the productivity growth in China from a negative in the 1960s and 1970s to a positive in the 1980s may have been highly influenced by the change in its policy environment, whereas such a change in the productivity growth in Nepal and India during the same period may have resulted largely from the green revolution. Because of an open border between Nepal and India and also similarity in land fertility between adjoining states of India (Uttar Pradesh, Bihar and Bengal) and Tarai of Nepal, the green revolution may have moved from India to Nepal. As a result, a similarity in the direction of technical change during the 1960s, 1970s and 1980s is observed in the case of these two countries. In Nepal, the direction of the total factor productivity growth is observed to be parallel to the direction of growth in the country's crop yields. As presented in Table 1.1 of Chapter 1 and Table 6.3, the growth rates of total factor productivity and yields in the Nepalese crop sector during the period 1961/62 to 1980/81 are observed to be negative.

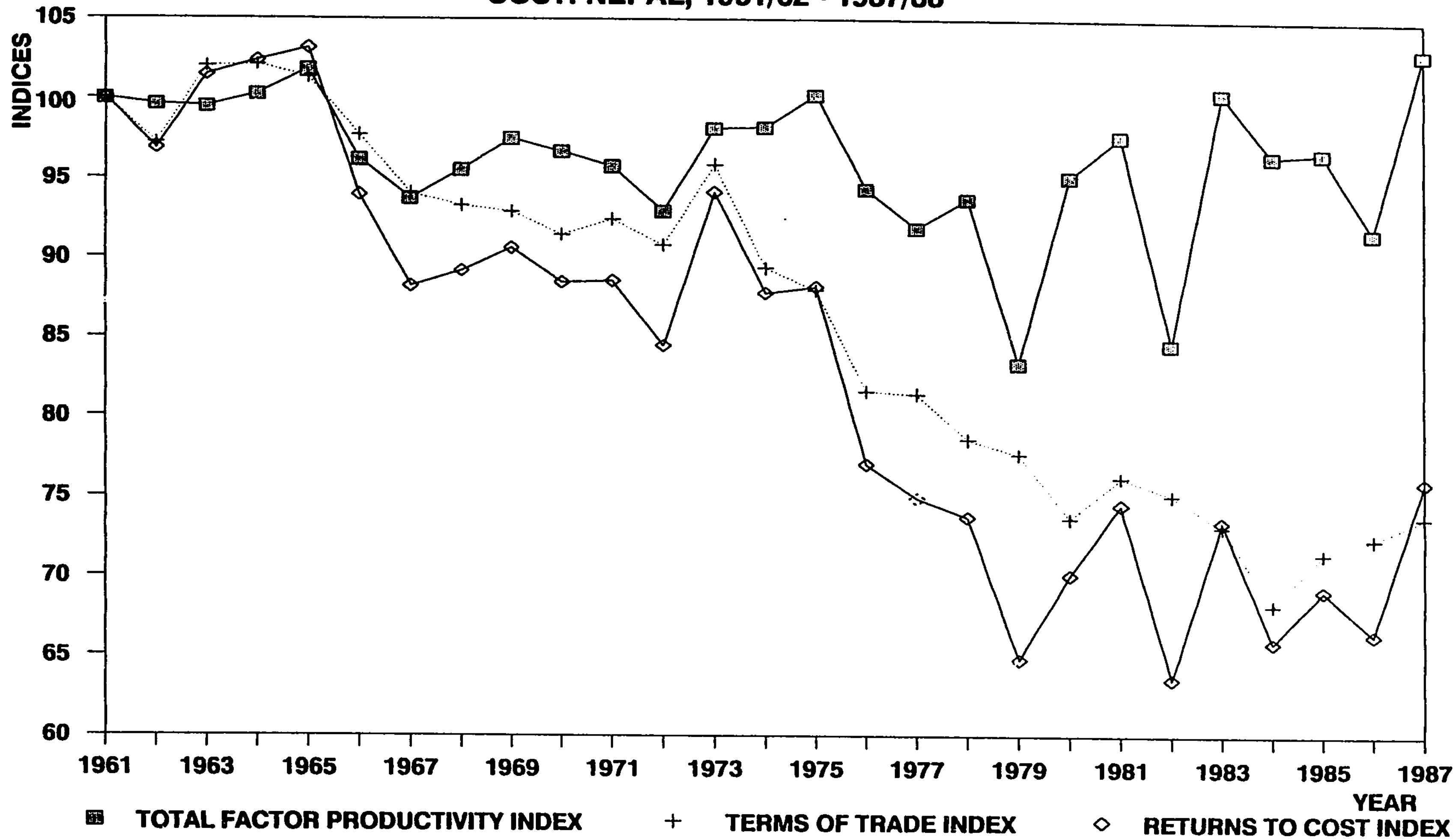
6.2.4 Estimation of Terms of Trade and Returns to Cost

In this section, the terms of trade and the returns to cost ratio for the Nepalese crop sector are calculated in order to assess the terms of trade position of the crop sector as against other sectors of the economy and to assess the financial situation of the Nepalese crop farmers. The terms of trade is defined as the ratio of the index of output prices received by farmers to the index of input prices paid by farmers. In other words, the terms of trade is derived simply by dividing the aggregate output price index by the aggregate input price index. On the other hand, the returns to cost ratio which gives a crude assessment of the welfare position of farmers and also helps to analyze the degree to which productivity improvement in the crop sector might be offsetting adverse movement in its terms of trade (Lawrence and McKay 1980, Islam 1982) is defined as the ratio of index of output value to the index of input value. That is, the returns to cost ratio can be calculated simply by multiplying the total factor productivity by the terms of trade.

While estimating the terms of trade for the Nepalese crop sector, the price indices of aggregate output and input are constructed using the Divisia index procedure. The estimated Divisia price indices of aggregate output and input and the Divisia-based indices of total factor productivity, terms of trade and return to cost are presented in Table 6.2 and also plotted over time in Figure 6.3.

According to Table 6.2, the aggregate input price in the Nepalese crop sector during the period of 1961/62 to 1987/88 increased relatively at a faster rate than the aggregate output price. As a result, the terms of trade for the Nepalese crop sector, as shown also in Figure 6.3, were declining since the year 1961/62 except during the period of 1963/64 to 1965/66. During the period 1961/62 to 1987/88, the aggregate input price

FIGURE 6.3
DIVISIA INDICES OF TOTAL FACTOR PRODUCTIVITY, TERMS OF TRADE AND RETURNS TO COST: NEPAL, 1961/62 - 1987/88



grew annually by 7.64 percent, whereas the aggregate output price increased only by 6.08 percent per annum, thereby, resulting in a decline in terms of trade by 1.56 percent per annum. Moreover, the terms of trade for the Nepalese crop sector during the 1960s, 1970s and 1980s declined respectively by 1.12, 2.72 and 0.71 percent per annum. Moreover, the terms of trade for the sector is observed to be relatively more favorable in the 1980s than in the 1960s and 1970s. The terms of trade as shown in Figure 6.3 is observed moving upward since the year 1984/85.

Further, the estimated returns to cost ratios in Table 6.2 and Figure 6.3 imply that the returns to cost to the Nepalese crop farmers during the period of 1961/62 to 1987/88 are observed to be declining annually by 1.75 percent. However, the periodical breakdown analysis indicates that the returns to cost to the Nepalese crop farmers, though declining in the 1960s and 1970s, are indeed increasing during the 1980s, mainly due to a positive growth rate of the total factor productivity during the period. The annual growth rate of the returns to cost ratio is estimated to be 0.29 percent per annum during the 1980s.

6.3 Estimation of Production Structure

As discussed in section 3.5.2 of Chapter 3, the production structure of the Nepalese crop sector is estimated by using the set of share equations (3.22) of Chapter 3. Since the share of input HYV seeds in the total cost of production in the Nepalese crop sector is minimal (Table A1.8), the input HYV seeds is dropped from the estimation of the production structure. Nor is any related input cost included because of the lack of reliable time series data. Therefore, only input factors land, labour, bullocks and fertilizer are included in total cost and in the system of share equations in order to analyze the production structure of the Nepalese crop sector. Following equation (3.22) of Chapter 3, the share equations for land, labour, bullocks and fertilizer can be written as:

$$(6.1) \qquad s_1 = \beta_1 + \gamma_{11} lnP_1 + \gamma_{12} lnP_2 + \gamma_{13} lnP_3 + \gamma_{14} lnP_4 + \alpha_1 lnY + \theta_1 T + u_1$$

$$(6.2) \qquad s_2 = \beta_2 + \gamma_{21} lnP_1 + \gamma_{22} lnP_2 + \gamma_{23} lnP_3 + \gamma_{24} lnP_4 + \alpha_2 lnY + \theta_2 T + u_2$$

$$(6.3) \qquad s_3 = \beta_3 + \gamma_{31} lnP_1 + \gamma_{32} lnP_2 + \gamma_{33} lnP_3 + \gamma_{34} lnP_4 + \alpha_3 lnY + \theta_3 T + u_3$$

$$(6.4) \qquad s_4 = \beta_4 + \gamma_{41} lnP_1 + \gamma_{42} lnP_2 + \gamma_{43} lnP_3 + \gamma_{44} lnP_4 + \alpha_4 lnY + \theta_4 T + u_4$$

where number 1, 2, 3 and 4 respectively represent input factor land, labour, bullocks and fertilizer; s_i implies the share of the i-th input in total cost; Y and P_i are the Divisia indices respectively of aggregate output quantities and input prices; T is the time variable; and u is the error term.

Regarding the estimation of the share equations, the adding-up condition of equation (3.23) which implies that the cost shares must equal to one is imposed so that one of the share equations must be dropped in the estimation process in order to overcome the problem of over-identification in the model. The fertilizer share equation (6.4) is dropped from the estimation process and the remaining three share equations (6.1) to (6.3) are estimated as a system of seemingly unrelated regression equations.

While estimating the system of share equations, several statistical tests were carried out to detect problems of heteroskedasticity, autocorrelation and multicollinearity. The Breusch-Pagan (BP) test which is discussed in detail in section (A2.1.2) of Appendix 2 is used to detect the heteroskedasticity problem in the system of share equations. The BP test statistics which are calculated using the formula given in equation (A2.5) of Appendix 2 are presented in Table 6.4. BP1 represents the BP test statistic when explanatory variables in share equations are in their original form such as in equations (6.1) to (6.4), whereas BP2 is the BP test statistic when explanatory variables in share equations are in their square form. The BP2 statistic is calculated, because explanatory variables in their square form are more likely to raise heteroskedasticity problem. Results of Table 6.4 lead one to conclude that the problem of heteroskedasticity does not exist in the system of share equations.

TABLE 6.4

RESULTS OF BREUSCH-PAGAN TEST RELATING TO HETEROSKEDASTICITY PROBLEM

Dependent Variable in Share Equations	Calculated Test Statistic		Degree of Freedom	Critical Value of Chi-square[1]	Presence of Heteroskedasticity Problem
	BP1	BP2			
Share of Land	5.374	6.396	6	16.812	No
Share of Labour	5.046	6.482	6	16.812	No
Share of Bullocks	6.822	6.249	6	16.812	No

1. At one percent level of significance.

Regarding the autocorrelation problem, the Durbin-Watson (D-W) test statistics, presented in Table 6.5, indicate that the autocorrelation problem does not exist in the bullocks share equation. Moreover, the test is found to be inconclusive to detect the autocorrelation problem in the case of land and labour share equations. Therefore, the Breusch-Godfrey (BG) test which is discussed in detail in section (A2.1.3) of Appendix 2 is used to find out whether or not the autocorrelation problem exists in the system of share equations. According to the calculated BG test statistics presented in Table 6.6, the presence of autocorrelation problem of first order is confirmed in the system of share equations of land, labour and bullocks.

TABLE 6.5

RESULTS OF DURBIN-WATSON TEST RELATING TO AUTOCORRELATION PROBLEM

Dependent Variable in Share Equation	Calculated d^*	Critical Value at 0.01 Level				Presence of Autocorrelation[1]
		d_L	d_U	$4\text{-}d_L$	$4\text{-}d_U$	
Share of Land	2.360	0.711	1.759	3.289	2.241	Inconclusive
Share of Labour	2.450	0.711	1.759	3.289	2.241	Inconclusive
Share of Bullocks	1.977	0.711	1.759	3.289	2.241	No

1. Test is inconclusive if $d_L < d^* < d_U$ or if $(4-d_U) < d^* < (4-d_L)$; whereas the null hypothesis of no autocorrelation is not rejected if $d_U < d^* < (4-d_U)$.

TABLE 6.6

RESULTS OF BREUSCH GODFREY TEST RELATING TO AUTOCORRELATION PROBLEM

Dependent Variable in Share Equations	Calculated Value of BG	Degree of Freedom	Critical Value of Chi-square[1]	Presence of Autocorrelation
Share of Land	8.959	1	6.635	Yes
Share of Labour	7.819	1	6.635	Yes
Share of Bullocks	13.872	1	6.635	Yes

1. At one percent level of significance.

Further, the presence of possible multicollinearity problems in the system of share equations is initially tested using the correlation coefficient method which implies that an extremely high value of correlation coefficient between two individual variables confirms the presence of a collinearity problem between those two variables. Results presented in Table 6.7 indicate that a collinearity problem exists respectively between prices of labour and bullocks, prices of labour and fertilizer, and prices of bullocks and fertilizer.

TABLE 6.7

ESTIMATED VALUES OF CORRELATION COEFFICIENTS BETWEEN INPUT PRICES

Explanatory Variables in Share Equations	Correlation Coefficient	Presence of Collinearity
Land Price and Labour Price	0.15	No
Land Price and Bullock Price	0.19	No
Land Price and Fertilizer Price	0.33	No
Land Price and Output Quantity	0.46	No
Labour Price and Bullock Price	0.99	Yes
Labour Price and Fertilizer Price	0.97	Yes
Labour Price and Output Quantity	0.85	No
Bullock Price and Fertilizer Price	0.98	Yes
Bullock Price and Output Quantity	0.86	No
Fertilizer Price and Output Quantity	0.91	No

However, the correlation coefficient method is a crude method of detecting any collinearity problem, because the choice of critical value ($r=0.95$) which is used as a cut-off point for determining the presence of collinearity is a matter of subjective judgement. Moreover, the method does not detect collinearity between more than two variables at a time. Therefore, a second method known as the determinant method is used in this study to test the presence of collinearity problems.

According to the determinant method, the presence of collinearity is confirmed if the determinant value of the correlation coefficient matrix of explanatory variables is zero (i.e. X'X=0). In this study the determinant value of the correlation coefficient matrix is observed to be zero implying that the collinearity problem exists in the system of share equations. The major limitation of the determinant method is that it does not identify the variables causing the collinearity problem. Hence, the third method which is called the auxiliary regression method is used in this study to detect the variables that cause the collinearity problem in the system of share equations. According to the method, each of the explanatory variable is regressed on all other explanatory variables and, then, the variable causing the collinearity is confirmed if the estimated regression equation containing the same variable as a dependent variable shows an extremely high value of R^2 and an F value greater than the critical value. Results presented in Table 6.8 indicate that the collinearity exists due to prices of labour and bullocks. As in the case of correlation coefficient method, the auxiliary regression method also uses subjective judgement while choosing the critical value of R^2 in order to use it as cut-off point for determining the collinearity. Nevertheless, all above three methods which are generally used in statistical analysis to determine the collinearity seem to be sufficient to confirm that the collinearity exists as a result of prices of labour and bullocks.

Such a finding is expected because prices of labour have been used to approximate prices of bullocks in this study. As discussed in detail in section (4.6.3) of Chapter 4, the collinearity problem is overcome by imposing restriction $\gamma_{i2} = \gamma_{i3}$ in the estimation of the system of share equations on the prior knowledge about the relationship between these two input price variables. Such a restriction on the coefficients of wage rate and price of bullocks may or may not hold over a long period. Therefore, the collinearity

TABLE 6.8

ESTIMATED VALUES OF R^2 AND F UNDER THE AUXILIARY REGRESSION METHOD

Dependent Variable in Regression Equation	Estimated Value[1]		Presence of Collinearity
	R^2	$F_{4,21}$	
Price of Land	0.76	16.807	No
Price of Labour	0.99	2916.705	Yes
Price of Bullock	0.99	2325.024	Yes
Price of Fertilizer	0.98	314.226	No
Output Quantity	0.86	31.288	No

1. The critical value of $F_{4,21}$ at one percent level of significance is 4.37.

problem is also overcome by dropping out the price of bullocks as an explanatory variable in the system of share equations (6.1) to (6.4). The system of share equations without the price of bullocks is then re-estimated in section 6.3.3 and the estimated parameters were compared with the parameters of the estimated system of share equations which included price of bullocks as an explanatory variable. Such a comparison of estimated parameters will indicate whether or not the estimated parameters change as a result of dropping the price of bullocks from the system of share equations. Results presented up to section (6.3.3) represent results derived from the system of share equations which include price of bullocks as one of the explanatory variables.

While estimating the system of share equations, the autocorrelation problem is corrected by using an auto correction option which is readily available in SHAZAM computer econometric programme under the nonlinear regression method which uses a maximum likelihood estimation procedure to estimate a system of seemingly unrelated regression equations.

As mentioned in section (3.5.2.1), results derived from the system of share equations become meaningful only when these equations satisfy five major restrictions, viz. the adding-up, monotonicity, concavity, homogeneity of degree zero in input prices and symmetry restrictions. Since the adding-up restriction can not be tested as such, it is rather imposed in the model on theoretical grounds. Similarly, the monotonicity and concavity restrictions are not easily handled within the econometric framework, because both involve inequality restrictions on share equations (Antle and Capalbo 1988, p.76). Therefore, these restrictions are usually checked in the estimated model rather than imposing them in the estimation of model. A necessary and sufficient condition for monotonicity in prices is that the cost shares must be greater than zero (Antle and Capalbo 1988, p.77). Therefore, signs of the estimated cost shares are checked in order to find out whether or not the monotonicity restriction holds in the system of share equations. According to Table A1.8 of Appendix 1, the estimated cost shares for all input factors in the Nepalese crop sector are observed to be greater than zero. Therefore, the presence of the monotonicity restriction in the estimated model is confirmed in this study.

On the other hand, the concavity restriction which implies that the cost function is concave in input prices is checked by examining the relevant property of the Hessian matrix of second partials of the cost function with respect to input prices, H_{pp}. If the H_{pp} is negative semidefinite, then the cost function is concave in input prices (Antle and Capalbo 1988, P.77). The negative semidefiniteness of the H_{pp} translates into negative own Allen partial elasticities of substitution (σ_{ii}). Therefore, the concavity restriction is checked by estimating the own Allen partial elasticities of substitution for all inputs. The estimated values of (σ_{ii}), presented in Table A1.10 of Appendix 1, show a negative sign in each instance confirming the presence of the concavity restriction in the estimated system of share equations.

The homogeneity and symmetry restrictions which are testable restrictions are tested in this model by using the Likelihood Ratio (LR) test. According to the LR test, the LR-statistic which has a Chi-square distribution with p degrees of freedom is calculated as:

$$LR = 2[\, lnL(\hat{\theta}_1) - lnL(\hat{\theta}_0)] \quad \sim \quad \chi^2_p \tag{6.5}$$

where $lnL(\hat{\theta}_1)$ and $lnL(\hat{\theta}_0)$ are the log likelihood values, respectively, in the unrestricted and restricted model and p is the number of restrictions imposed in the model. After dropping the share equation (6.4), the unrestricted model to be estimated as a system is represented by equations (6.1) to (6.3), whereas the same model becomes restricted when the homogeneity and symmetry restriction shown in Table 6.9 are imposed into the system of share equations. The estimated LR-statistics presented in Table 6.9 lead to conclude that the homogeneity and symmetry restrictions do not hold in the system of share equations either individually or jointly. Nevertheless, these restrictions must be imposed into the system of share equations in order to force the cost function of the Nepalese crop sector to satisfy the theoretical properties of the neoclassical cost function. Only when the cost function satisfies the theoretical properties of the neoclassical cost function can Shephard's lemma be used to generate a system of well behaved derived-demand equations and, thereby, to estimate parameters underlying the production structure of the Nepalese crop sector. Therefore, homogeneity and symmetry restrictions are imposed while estimating the system of share equations for the Nepalese crop sector.

TABLE 6.9

RESULTS OF THE LR TEST RELATING TO THE HOMOGENEITY, SYMMETRY, HOMOTHETICITY AND HICKS-NEUTRAL RESTRICTIONS: NEPAL, 1961/62-1987/88

Restrictions	Calculated LR Value	Degree of Freedom	Critical Value of Chi-square[1]	H_0: Restrictions Hold
Homogeneity Restrictions: $\gamma_{11}+\gamma_{12}+\gamma_{13}+\gamma_{14}=0$ $\gamma_{21}+\gamma_{22}+\gamma_{23}+\gamma_{24}=0$ $\gamma_{31}+\gamma_{32}+\gamma_{33}+\gamma_{34}=0$	18.828	3	11.345	Reject
Symmetry Restrictions: $\gamma_{12}=\gamma_{21}$ $\gamma_{13}=\gamma_{31}$ $\gamma_{23}=\gamma_{32}$	13.048	3	11.345	Reject
Homogeneity and Symmetry Restrictions Imposed Jointly	31.216	6	16.812	Reject
Homotheticity Restrictions $\alpha_1=0$ $\alpha_2=0$ $\alpha_3=0$	15.174	3	11.345	Reject
Hicks Neutral Technical Change Restrictions: $\theta_1=0$ $\theta_2=0$ $\theta_3=0$	546.386	3	11.345	Reject

1. At one percent level of significance.

Further, the LR test is also used to examine whether the production structure in the Nepalese crop sector is homothetic and Hicks-neutral. A homothetic production function generates cost functions with the property that the elasticity of size and the elasticity of scale are always equivalent (Chambers 1988, p.73). This implies that a change in output level under a homothetic production structure does not affect the respective derived demands for input factors, whereas a change in output level under a non-homothetic production structure does affect the respective derived demands for input factors. On the other hand, the Hicks-neutral technical change, as discussed in section (3.5.2.2) of Chapter 3, implies that the ratio of marginal products of input factors remains constant as a result of a change in technology. The specifications of homotheticity and Hicks-neutral in the production structure are tested separately by formulating null hypotheses as $H_0 : \alpha_i = 0$ and $H_0 : \theta_i = 0$ in the system of share equations (6.1) to (6.3). Results of LR tests, presented in Table 6.9, confirm that the production structure in the Nepalese crop sector is neither homothetic nor Hicks-neutral.

The estimated parameters of the system of share equations along with their respective t-ratio are presented in Table 6.10, whereas statistics relating to goodness of fit of the share equations are shown in Table 6.11. According to Table 6.10, most of the estimated coefficients are statistically significant. Since the estimated γ_{ij} coefficients in the system of share equations have little economic meaning of their own, these coefficients are further converted into point estimates of Allen partial elasticities of substitution and of price elasticities of factor demand. The conversion procedure and the estimated elasticities are discussed in detail in sections (6.3.1) and (6.3.2).

TABLE 6.10

ESTIMATED PARAMETERS OF THE SHARE EQUATIONS IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88

Parameter Name[1]	Estimated Value[2]	T-Ratio[3]
β_1	0.9275 ***	69.237
γ_{11}	-0.0059 **	-1.847
$\gamma_{12} = \gamma_{21}$	0.0028 **	1.702
$\gamma_{13} = \gamma_{31}$	0.0028 **	1.702
$\gamma_{14} = \gamma_{41}$	0.0003	0.076
α_1	0.0063	1.223
θ_1	-0.0102 ***	-8.622
β_2	0.0805 ***	5.272
γ_{22}	-0.0015 *	-1.591
$\gamma_{23} = \gamma_{32}$	-0.0015 *	-1.591
$\gamma_{24} = \gamma_{42}$	0.0001	0.048
α_2	-0.0065 *	-1.365
θ_2	0.0079 ***	8.899
β_3	-0.0085	-0.821
γ_{33}	-0.0015 *	-1.591
$\gamma_{34} = \gamma_{43}$	0.0001	0.048
α_3	0.0007	0.303
θ_3	0.0023 ***	7.551
$\beta_4 (= 1 - \beta_1 - \beta_2 - \beta_3)$	0.0006	0.263
$\gamma_{44} (= -\gamma_{41} - \gamma_{42} - \gamma_{43})$	-0.0005	-0.101
$\alpha_4 (= -\alpha_1 - \alpha_2 - \alpha_3)$	-0.0005	-0.067
$\theta_4 (= -\theta_1 - \theta_2 - \theta_3)$	0.0001	0.066

1. Number 1, 2, 3 and 4 represent respectively land, labour, bullock and fertilizer inputs.
2. * significant at 0.10 level as $t^* = 1.296$ with 60 degrees of freedom[3].
   ** significant at 0.05 level as $t^* = 1.671$ with 60 degrees of freedom[3].
   *** significant at 0.01 level as $t^* = 2.390$ with 60 degrees of freedom[3].
3. Following Johnston (1984, p.339) the degrees of freedom in this model are calculated as: df = (mxn)-K where m is the number of estimated share equation, n is the number of observations on each equation and K is the total number of variables in the estimation system. In this case, df=(3x26)-18 = 60.

TABLE 6.11

STATISTICS RELATING TO GOODNESS OF FIT

Share Equation	R^2	DW (d^*)
Land Share Equation	0.90	1.844
Labour Share Equation	0.89	1.859
Bullock Share Equation	0.91	1.777

R^2 implies the R^2 between observed and predicted values.

6.3.1 Elasticity of Substitution

The Allen partial elasticities of substitution (σ_{ij}) are estimated by fitting the mean value of the cost shares and the estimated γ_{ij} coefficients into equations (3.26) and (3.27) of Chapter 3. The estimated elasticities of substitution are presented in Table 6.12. According to Table 6.12, the substitutability relationship is observed in the case of all input pairs: land and labour, land and bullocks, land and fertilizer, labour and bullocks, labour and fertilizer, and bullocks and fertilizer. Moreover, the elasticity of substitution is relatively higher in the case of input pair bullocks and fertilizer and lower in the case of input pair labour and bullocks. The periodical analysis of elasticities of substitution indicates that the estimated elasticities of substitution of all input pairs except of the input pair labour and bullocks declined over the last three decades. The elasticity of substitution for the input pair labour and bullocks increased from 0.690 in the 1960s to 0.836 and 0.912 respectively in the 1970s and 1980s.

6.3.2 Elasticity of Factor Demand

The cross-price elasticity which measures a change in quantity demanded for a particular input factor with respect to a change in the price of another input factor is estimated for each individual input factor in the Nepalese crop sector by fitting the

TABLE 6.12

ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88

Inputs	1961/62-1970/71	1971/72-1980/81	1981/82-1987/88	1961/62-1987/88
Land and Labour ($\sigma_{12} = \sigma_{21}$)	1.022**	1.019**	1.016**	1.018**
Land and Bullocks ($\sigma_{13} = \sigma_{31}$)	1.115**	1.084**	1.067**	1.084**
Land and Fertilizer ($\sigma_{14} = \sigma_{41}$)	3.206	1.399	1.249	1.431
Labour and Bullocks ($\sigma_{23} = \sigma_{32}$)	0.690*	0.836*	0.912*	0.838*
Labour and Fertilizer ($\sigma_{24} = \sigma_{42}$)	4.926	1.514	1.214	1.547
Bullocks and Fertilizer ($\sigma_{34} = \sigma_{43}$)	21.398	3.315	1.912	3.499

1. $\sigma_{ij} > 0$ implies that the i-th and j-th input factors are substitutes.
2. * and ** indicate that the γ_{ij} coefficient which is used to estimate σ_{ij} is significant respectively at 0.10 and 0.05 level of significance.

estimated γ_{ij} coefficients and the mean value of cost shares into equation (3.28) of Chapter 3. On the other hand, the own-price elasticity which measures a change in quantity demanded for a particular input factor with respect to a change in its own price is estimated for each individual input factor by fitting the estimated γ_{ij} coefficients and the mean value of cost shares into equation (3.29) of Chapter 3. The estimated own- and cross-price elasticities are presented in Table 6.13.

According to Table 6.13, the lowest and highest degrees of own-price elasticity are observed in the case of input factors land and fertilizer. As expected, the estimated own-price elasticities of all input factors are negative in all the three periods, viz. the 1960s, 1970s and 1980s. Further, the periodical analysis of own- and cross-price

TABLE 6.13

OWN AND CROSS PRICE ELASTICITIES OF INPUT DEMAND IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88

Period	Input/Input	Land	Labour	Bullocks	Fertilizer
	Land	-0.194**	0.160**	0.034**	0.001
1961/62-	Labour	0.831**	-0.853*	0.021*	0.001
1970/71	Bullocks	0.907**	0.108*	-1.018*	0.004
	Fertilizer	2.608	0.770	0.644	-4.022
	Land	-0.254**	0.204**	0.048**	0.001
1971/72-	Labour	0.768**	-0.807*	0.037*	0.002
1980/81	Bullocks	0.817**	0.167*	-0.988*	0.003
	Fertilizer	1.055	0.303	0.147	-1.506
	Land	-0.339**	0.270**	0.067**	0.002
1981/82-	Labour	0.680**	-0.740*	0.057*	0.002
1987/88	Bullocks	0.715**	0.242*	-0.961*	0.004
	Fertilizer	0.836	0.323	0.119	-1.279
	Land	-0.256**	0.206**	0.048**	0.001
1961/62-	Labour	0.766**	-0.804*	0.037*	0.001
1987/88	Bullocks	0.815**	0.170*	-0.989*	0.003
	Fertilizer	1.076	0.314	0.155	-1.545

1.The cross-price elasticity (η_{ij}) greater than zero implies that the i-th and j-th input factors are substitutes.

2. * and ** indicate that the γ_{ij} coefficient which is used to estimate σ_{ij} is significant respectively at 0.10 and 0.05 level of significance.

elasticities of input demand indicates that the price elasticities of most input factors are changing over the decades. The absolute values of own-price elasticities of all input factors except land declined considerably over the last three decades. The absolute value of own-price elasticity of land increased from 0.194 in the 1960s to 0.254 and 0.339 respectively in the 1970s and 1980s.

Results presented in Table 6.13 also indicate the presence of substitutability relationships in all input pairs in the Nepalese crop sector. The substitutability relationship between land and labour in the Nepalese crop sector may be supported by the fact that an increase in the price of land may make most Nepalese farmers unable to purchase additional land, mainly because of their low per capita income and the lack of institutional credit facilities to purchase any additional land. Therefore, in such a situation, farmers with relatively more labour input as compared to other inputs are likely to use more labour in their crop production in order to increase the intensity of their cropped land and, thus, to increase their crop output. Similarly, when the price of labour goes up, farmers who were previously using relatively more labour input (because of the low wage rate) in their crop production are more likely to withdraw the overly used amount of labour input from their crop production and use the savings generated from such a withdrawal of labour force to purchase additional land.

6.3.3 Estimation of Technical Change Biases and Scale Effects

The technical change considered in the estimation of the total factor productivity under the geometric index procedure is assumed to be Hicks-neutral. However, the specification of Hicks-neutral technical change is not found in the case of the Nepalese crop sector under the LR test in section (6.3). In other words, the technical change in the Nepalese crop sector is likely to be embodied and factor biased technical change.

As discussed in section (3.5.2.2) of Chapter 3, the technical change biases as well as the scale effects can be derived by estimating parameters of either a translog production function or a translog cost function. In a translog cost function such as the one presented in equation (3.21) of Chapter 3, the coefficient θ_i gives the technical change bias relating to the i-th input factor, whereas the coefficient α_i measures the scale effect in the production process. However, the estimation of such a translog cost function with several explanatory variables requires a large number of observations in order to avoid the problem of loosing degrees of freedom. In this study, the total number of observations available is 27 with six explanatory variables. Therefore, a translog production function or a translog cost function could not be estimated without aggregating some of the input factors, because otherwise the degrees of freedom become insufficient in the estimation process. Nevertheless, the same parameters with some specific properties of the cost function can be obtained by estimating a system of share equations underlying the translog cost function. The system of share equations underlying the Nepalese crop sector has been already estimated earlier in this section. The estimated parameters relating to the technical effects and scale effects are shown again in Table 6.14.

According to Table 6.14, the technical change in the Nepalese crop sector is embodied and non-neutral technical change. In fact, the technical change in the sector is observed to be land-saving, labour-using and bullock-using. These results look reasonable in the sense that the land input as compared to inputs labour and bullocks is a very scarce factor of production in Nepal. Therefore, any technical change that is designed to increase crop output in Nepal is likely to be land-saving and labour- and

TABLE 6.14

TECHNICAL EFFECTS AND SCALE EFFECTS IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88

Input	Technical Effect (θ_i)	Scale Effect (α_i)
Land	-0.0102***	0.0063
Labour	0.0079***	-0.0065*
Bullocks	0.0023***	0.0007
Fertilizer	0.0001	-0.0005

1. $\theta_i > 0$, $\theta_i <$ [illegible] imply that the technical change is respectively i-th input-using, [illegible]ng; and Hicks-neutral technical change, whereas $\alpha_i > 0$, $\alpha_i < 0$ [illegible] imply that the scale effect is respectively i-th input-using, input-sa[illegible] [illegible]al.
2. * and *** indicate [illegible]at the coeffic[illegible]ent is significant respectively at 0.10 and 0.01 level of significance.

bullocks-using technical change. The coefficient of the technical effect with respect to input factor fertilizer is observed to be positive, indicating the likelihood fertilizer-using technical change; however, the estimated coefficient θ_F is not statistically significant.

The scale effect which measures the effect of a change in output level on the demand for an input factor is also estimated for all four input factors and presented in Table 6.14. According to Table 6.14, the statistically significant scale effect is observed only in the case of input factor labour. The scale effect in the Nepalese crop sector is weakly a labour-saving scale effect. In other words, an increase in the level of output will decrease the demand for labour and vice versa.

6.3.4 Estimation of System of Share Equations without Price of Bullocks

In this section, the system of share equations is estimated by including only input factors land, labour and fertilizer in the total cost and the system of share equations, especially to examine changes in the estimated parameters as a result of the exclusion of price of bullocks in the system of share equations. The estimated parameters and statistics relating to goodness of fit of the share equations are presented respectively in Table 6.15 and 6.16. According to Table 6.15, the t-ratios of the estimated coefficients have increased due to the exclusion of the price of bullocks in the share equations. However, Table 6.17 indicates that the signs of elasticities of substitution between input pairs did not change as a result of such exclusion of price of bullocks. In other words, the substitutability relationships between input pairs land-labour, land-fertilizer and labour-fertilizer remain the same with or without price of bullocks in the system of share equations.

Regarding the price elasticities, Table 6.18 indicates that the signs of own- and cross-price elasticities do not change whether or not the price of bullocks is included in the system of share equations. Moreover, magnitudes of the estimated price elasticities remain much the same with or without price of bullocks in the system of share equations. Similarly, the technical effect and scale effect, presented in Table 6.19, also remain reasonably similar with or without price of bullocks in the system of share equations. The technical change with respect to fertilizer input is found to be significant when price of bullocks is excluded from the system of share equations. Table 6.19 indicates that the technical change in the Nepalese crop sector is land-saving, labour-using and fertilizer-using, whereas the scale effect is weakly land-using and labour-saving. Thus, the results derived in this section imply that the estimated parameters underlying the production structure of the Nepalese crop sector do not change considerably as a result of the exclusion of price of bullocks in the system of share equations.

TABLE 6.15

ESTIMATED PARAMETERS OF THE SHARE EQUATIONS IN THE NEPALESE CROP SECTOR: WITHOUT PRICE OF BULLOCKS, 1961/62 - 1987/88

Parameter Name[1]	Estimated Value[2]	T-Ratio[3]
β_1	0.3961***	2.479
γ_{11}	0.0732***	10.357
$\gamma_{12} = \gamma_{21}$	-0.0731***	-10.350
α_1	0.0469*	1.320
θ_1	-0.0050***	-7.030
β_2	0.6031***	3.776
γ_{22}	0.0726***	10.279
α_2	-0.0467*	-1.314
θ_2	0.0049***	6.913
$\beta_3(= 1 - \beta_1 - \beta_2)$	0.0007	0.002
$\gamma_{31}(= - \gamma_{11} - \gamma_{12})$	-0.0001	-0.257
$\gamma_{23}(= - \gamma_{12} - \gamma_{22})$	0.0004	0.938
$\gamma_{33}(= - \gamma_{31} - \gamma_{32})$	-0.0003	-0.024
$\alpha_3(= - \alpha_1 - \alpha_2)$	-0.0002	-0.170
$\theta_3(= - \theta_1 - \theta_2)$	0.0001***	2.523

1. Number 1, 2, 3 and 4 represent respectively land, labour, bullock and fertilizer inputs.
2. * significant at 0.10 level as $t^* = 1.303$ with 42 degrees of freedom[3].
   ** significant at 0.05 level as $t^* = 1.684$ with 42 degrees of freedom[3].
   *** significant at 0.01 level as $t^* = 2.4230$ with 42 degrees of freedom[3].
3. Following Johnston (1984, p.339) the degrees of freedom in this model are calculated as: df = (mxn)-K where m is the number of estimated share equations, n is the number of observations on each equation and K is the total number of variables in the estimation system. In this case, df=(2x26)-10 = 42.

TABLE 6.16

STATISTICS RELATING TO GOODNESS OF FIT: WITHOUT PRICE OF BULLOCKS

Share Equation	R^2	DW (d^*)
Land Share Equation	0.968	2.232
Labour Share Equation	0.967	2.230

TABLE 6.17

ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION IN THE NEPALESE CROP SECTOR: WITHOUT PRICE OF BULLOCKS, 1961/62 - 1987/88

Inputs	1961/62-1970/71	1971/72-1980/81	1981/82-1987/88	1961/62-1987/88
Land and Labour ($\sigma_{12} = \sigma_{21}$)	0.460***	0.559***	0.639***	0.564***
Land and Fertilizer ($\sigma_{13} = \sigma_{31}$)	0.376	0.890	0.934	0.883
Labour and Fertilizer ($\sigma_{23} = \sigma_{32}$)	15.734	2.869	1.754	2.969

1. $\sigma_{ij} > 0$ implies that the i-th and j-th input factors are substitutes.
2. *** indicates that the γ_{ij} coefficient which is used to estimate σ_{ij} is significant at 0.01 level of significance.

TABLE 6.18

OWN AND CROSS PRICE ELASTICITIES OF INPUT DEMAND IN THE NEPALESE CROP SECTOR: WITHOUT PRICE OF BULLOCKS, 1961/62 - 1987/88

Period	Input/Input	Land	Labour	Fertilizer
1961/62-1970/71	Land	-0.074***	0.074***	0.0001
	Labour	0.386***	-0.388***	0.003
	Fertilizer	0.315	2.538	-2.853
1971/72-1980/81	Land	-0.118***	0.117***	0.001
	Labour	0.441***	-0.444***	0.003
	Fertilizer	0.702	0.603	-1.305
1981/82-1987/88	Land	-0.183***	0.181***	0.002
	Labour	0.457***	-0.460***	0.004
	Fertilizer	0.667	0.497	-1.165
1961/62-1987/88	Land	-0.121***	0.120***	0.001
	Labour	0.443***	-0.446***	0.003
	Fertilizer	0.694	0.632	-1.32[illegible]

1. The cross-price elasticity (η_{ij}) greater than zero implies that the i-th and j-th input factors are substitutes.
2. *** indicates that the γ_{ij} coefficient which is used to estimate σ_{ij} is significant at 0.01 level of significance.

TABLE 6.19

TECHNICAL EFFECTS AND SCALE EFFECTS IN THE NEPALESE CROP SECTOR: WITHOUT PRICE OF BULLOCKS, 1961/62 - 1987/88

Input	Technical Effect (θ_i)	Scale Effect (α_i)
Land	-0.0050***	0.0469*
Labour	0.0049***	-0.0467*
Fertilizer	0.0001***	-0.0002

1. $\theta_i > 0$, $\theta_i < 0$ and $\theta_i = 0$ imply that the technical change is respectively i-th input-using, input-saving and Hicks-neutral technical change, whereas $\alpha_i > 0$, $\alpha_i < 0$ and $\alpha_i = 0$ imply that the scale effect is respectively i-th input-using, input-saving and neutral.
2. * and *** indicate that the coefficient is significant respectively at 0.10 and 0.01 level of significance.

6.4 Summary and Conclusions

In the absence of input price data for land and bullocks, the total factor productivity for the Nepalese crop sector is estimated using the geometric index procedure. However, the advantages of the flexible weight index procedure over the arithmetic and geometric index procedure are so great that the former procedure is also used to estimate the total factor productivity in the Nepalese crop sector by approximating prices of land and bullocks.

The total factor productivity estimated under the geometric index procedure indicates that the total factor productivity during the period of 1961/62 to 1987/88 declined by 0.52 percent per annum. Such a negative growth rate of the total factor productivity in the Nepalese crop sector over the entire study period indeed resulted from the negative growth in the total factor productivity during the 1960s and 1970s. The total factor productivity during the 1960s and 1970s declined respectively by 0.10 and 1.21 percent per annum. However, the performance of the sector improved significantly in the 1980s. The total factor productivity in the Nepalese crop sector during the 1980s increased by 1.12 percent per annum. Further, all these findings of the geometric index procedure are also supported by the results obtained from the flexible weight index procedure. Despite a small difference in the magnitude of the total factor productivity growth rates, the direction of the total factor productivity growth derived from these two index procedures remain the same in all the three periods, viz. the 1960s, 1970s and 1980s.

Further, a comparison of results obtained from these two index procedures concludes that the geometric index procedure provides a fairly good estimation of the total factor productivity in the agricultural sector in a situation when the unavailability of input price data makes the flexible weight index procedure undoable. Moreover, results obtained in this chapter also indicate that the pattern of total factor productivity growth estimated in this study are in line with those estimated for India and China.

In this chapter, the terms of trade and the returns to cost ratio in the Nepalese crop sector are also calculated in order to assess the terms of trade position of the crop sector and to assess the financial situation of the Nepalese crop farmers. While estimating the terms of trade for the Nepalese crop sector, the Divisia index procedure is used to aggregate prices of inputs and outputs. According to results, the terms of trade in the Nepalese crop sector always declined since the year 1961/62 except during the period of 1963/64 to 1965/66. The terms of trade during the period of 1961/62 to 1987/88 declined on average by 1.56 percent per annum. Moreover, the terms of trade for the Nepalese crop sector during the 1960s, 1970s and 1980s declined respectively by 1.12, 2.72 and 0.71 percent per annum. Among these three different periods, the terms of trade for the sector is observed to be relatively less unfavorable in the 1980s.

Further, the estimated return to cost ratios imply that the returns to cost to the Nepalese crop farmers during the period of 1961/62 to 1987/88 are declining annually by 1.75 percent. However, the periodical breakdown analysis indicates that the returns to cost to the Nepalese crop farmers, though declining during the 1960s and 1970s, are indeed increasing during the 1980s, mainly due to a positive growth rate of the total factor productivity during the period. The annual growth rate of the returns to cost ratio is estimated to be 0.29 percent per annum during the 1980s.

In sum, the growth rates of the total factor productivity, terms of trade and returns to cost ratio remained negative during the 1960s and 1970s, mainly due to the higher growth rates in input quantities and prices as compared to the growth rates in output quantities and prices. However, the situation is observed to have been changed significantly during the 1980s, especially due to higher growth rates in crop output during the period. The output growth rate during the period is so high that the resultant productivity advance more than offset the adverse movement of terms of trade and resulted in positive growth in the returns to cost to the Nepalese crop farmers.

In this chapter, the production structure of the Nepalese crop sector is also estimated using a system of share equations derived from a translog cost function. While estimating the production structure, only four input factors, viz. land, labour, bullocks and fertilizer, are included in the system of share equations which is estimated as a system of seemingly unrelated regression equations. Moreover, the adding-up, homogeneity and symmetry restrictions are imposed while estimating the system of share equations.

Regarding the estimated coefficients of share equations, most of the coefficients are highly significant. The estimated γ_{ij} coefficients are further converted into point estimates of Allen partial elasticities of substitution and of price elasticities of factor demand at the mean value of the cost shares. According to estimated elasticities, the substitutability relationship is observed in the case of all input pairs: land and labour, land and bullocks, land and fertilizer, labour and bullocks, labour and fertilizer, and bullocks and fertilizer. The periodical analysis of elasticities of substitution indicates that the elasticities of substitution of all input pairs except of input pair labour and bullocks declined over the last three decades.

According to the estimated input price elasticities, the lowest and highest degrees of own-price elasticity are observed in the case of land and fertilizer As expected, the estimated own-price elasticities of all input factors are negative. The periodical analysis indicates that the price elasticities of most input factors are changing over the last three decades.

In this chapter, the production structure is also estimated by dropping out the price of bullocks in the system of share equations, especially to overcome the problem of collinearity between the wage rate and price of bullocks. However, the estimated parameters underlying the Nepalese crop sector remain fairly similar as those estimated under the system of share equations that include the price of bullocks as an explanatory variable. The signs of elasticities of substitution and price elasticities did not change as a result of such exclusion of price of bullocks in the system of share equations.

The Likelihood Ratio (LR) tests lead one to conclude that the production structure in the Nepalese crop sector is neither homothetic nor Hicks-neutral. Rather the estimated system of share equations that excludes price of bullocks indicates that the technical change in the sector is land-saving, labour-using and fertilizer-using, whereas the scale effect is weakly land-using and labour-saving. In Nepal, land as compared to labour and bullocks is a very scarce factor of production. Therefore, the estimated coefficient representing the technical effect clearly implies that farmers in Nepal are using technology that saves the scarce factor of production, land, and uses more of the abundant factors such as labour and fertilizer. Such technical change effects are in accord with the general experience of the initial phase of the green revolution.

CHAPTER 7

ANALYSIS OF CROP-WEATHER RELATIONSHIPS IN THE NEPALESE CROP SECTOR

7.1 Introduction

In Nepal where only 10 percent of the total arable land is irrigated, the crop output is likely to depend heavily on weather conditions. The relationship between crop output and meteorological variables, especially rainfall and temperature, has been observed in several studies, such as Fisher (1924), Stallings (1960 and 1961), Shaw (1964), Oury (1965), Ramamurthy and Banerjee (1966), Doll (1967), Thompson (1969 and 1970), Sreenivasan (1973), Sreenivasan and Banerjee (1973), Shaha and Banerjee (1975), Chowdhury and Sarwade (1985), Kellogg (1988) and Kellogg and Severin (1990). However, such a relationship has not been analyzed in the case of the Nepalese crop sector. It is likely that the short term variation in crop output in Nepal has been considerably influenced by meteorological variables. Therefore, this study analyzes the relationship between meteorological variables and crop output in Nepal. A review of the analytical techniques that were used in previous studies to examine the relationship between crop output and meteorological variables is presented in the following section.

7.2 Analytical Technique: A Review

According to the available literature, there are three major types of analytical techniques that have been frequently used to examine the relationship between crop output and meteorological variables. These are the correlation analysis technique, the multiple regression analysis technique and the weather index technique. A brief discussion on these techniques are presented in the following subsections.

7.2.1 Correlation Analysis Technique

According to the correlation analysis technique, the relationship between crop yield and an individual meteorological variable is examined by estimating a simple correlation coefficient between these variables. The technique as compared to other techniques is a simple technique to analyze crop-weather relationships.

7.2.2 Multiple Regression Analysis Technique

The multiple regression analysis technique involves three different approaches: the multiple linear regression analysis approach, the multiple curvilinear regression analysis approach and the regression integral approach. According to the multiple linear regression analysis approach, the values of selected meteorological variables during the selected 'sensitive' periods are linearly regressed on crop yields. However, the approach becomes less useful if the presumed linear relationship between crop yields and meteorological variables does not hold in reality. This problem has been overcome in the multiple curvilinear regression analysis approach developed by Ezekiel and Fox (1957) and later used by Thompson (1969) and Sreenivasan and Banerjee (1973). According to the approach, the relationship between crop yields and meteorological variables is expressed as:

$$Y = a_0 + a_1^1 f_1(X_1) + a_2^2 f_2(X_2) + \ldots\ldots + a_n^n f_n(X_n) \quad (7.1)$$

where Y denotes the crop yield and X_i (for i = 1, 2, ..., n) represents the i-th meteorological variable. The function $f_i(X_i)$ whose nature and shape can be derived by a process of successive approximations using free-hand curves may take different forms, not necessarily a linear form.

On the other hand, the regression integral approach which was first developed by Fisher (1924) and latter used, notably, by Ramamurthy and Banerjee (1966), Sreenivasan (1973) and Shaha and Banerjee (1975) in their Indian studies takes into account not only the total amount of rainfall during a certain period but also the manner in which it is distributed over the period under consideration.

Following the notation from Shaha and Banerjee (1975), the regression integral approach which uses direct measures of weather variables, such as rainfall and temperature, is expressed in the form of a linear regression equation as:

$$(7.2) \qquad Y = c + a_1 r_1 + a_2 r_2 + \ldots\ldots + a_n r_n$$

where Y is the crop yield and $r_1, r_2, \ldots\ldots, r_n$ are the values of a meteorological variable (r) in the successive intervals (1, 2, ..., n) of time. The intervals could be weekly or monthly breakdown of the total crop season.

7.2.3 Weather Index Technique

The weather index technique which is also a simple technique has been used by several researchers, such as Stallings (1960 and 1961), Shaw (1964), Oury (1965), Doll (1967), Kellogg (1988) and Kellogg and Severin (1990), in their analysis of crop-weather relationships. According to the available literature, there are three major methods of constructing a weather index, viz. the yield series indexing method, the weather response function indexing method and the 'aridity' indexing method. The yield series and weather response function indexing methods measure the effect of weather on crop output directly; whereas a weather index under the 'aridity' indexing method is constructed on the basis of meteorological variables and, then, it is used as an explanatory variable in a yield response function or a production function in order to examine the relationship between weather and crop output. All three methods of constructing a weather index are discussed in the following subsections.

7.2.3.1 Yield Series Indexing Method

The yield series indexing method has been used by Stallings (1960 and 1961) and Shaw (1964). According to this method, the year to year variation in yield data from experiments where practices have been controlled is assumed to be due primarily to weather. Therefore, by fitting a trend to the data in order to describe the yield effect due to changes in factors, such as soil conditions, which were not held constant, the influence of weather can be measured in each year as that year's actual yield as a percentage of the computed trend (Shaw 1964).

One of the major advantages of this method is that the weather indexes can be used to measure the technological change indirectly. In other words, when actual yield per harvested acre is deflated by the weather indexes to adjust for the influence of weather variation, then the year to year variation in the adjusted data simply gives an estimate of the effect of changes in technology. Moreover, such a method of measuring yield trend seems to be superior to the methods under the multiple regression analysis technique, because it does not need to specify functional form to describe the pattern of technological change. That is, the specification problem does not arise in this method. Furthermore, the yield series indexing method also avoids the question of the exact cause and effect relationship between yields and an individual meteorological variable. That is, the problem of specifying important variables and their functional relationships to crop yields is not involved in this method.

7.2.3.2 Weather Response Function Indexing Method

The weather response function indexing method has been developed and used by Doll (1967) in his empirical study. According to the method, yield response is estimated as a function of meteorological variables, a time trend variable and their interaction term and, then, the estimated response function is used to construct a weather index by computing a ratio of the yield predicted for the actual weather that occurred during the year to the yield predicted had the average weather occurred in the year. In this indexing method, Doll (1967) assumes that the Z_{tj} which provides a measure of the impact of meteorological variables (X_{tj}) in the period j of year t is a linear function of X_{tj} but that the yield (y_t) is a quadratic function of the Z_t. That is,

$$(7.3) \qquad Z_{tj} = \sum_{j=1}^{k} \alpha_j X_{tj} \qquad \text{and} \qquad Z_t = \sum_{j=t}^{k} Z_{tj}$$

$$(7.4) \qquad y_t = \beta_0 + \beta_1 Z_t + \beta_2 Z_t^2 + \beta_3 T + \beta_4 T^2 + \beta_5 T^3 + \beta_6 H$$

where Z_{tj} is the cropped area in the period j of year t; T represents the time trend; and H is the interaction term between time trend and weather. Therefore, the weather index (W_t) can be expressed as:

$$(7.5) \qquad W_t = \frac{\hat{y}_t}{\hat{Y}} = \frac{\beta_1 Z_t + \beta_2 Z_t^2 + \ldots + \beta_n Z_n^2}{\beta_1 \overline{Z}_t + \beta_2 \overline{Z}_t^2 + \ldots + \beta_n \overline{Z}_n^2}$$

where $\hat{y}_t$ is the predicted yield for the actual weather; $\hat{Y}$ is the predicted yield for the average weather which is average only for the time period considered; and $\overline{Z}_t$ and $\overline{Z}_t^2$ are the mean values of the Z_{tj} and Z_{tj}^2 for the n-year period.

The major advantage of this method is that the method does not need experiment data on yield series, rather the index can be constructed on the basis of non-experiment secondary data which are readily available. Moreover, the method allows for decreasing returns to meteorological variables within a time period. In equations (7.3) and (7.4), the model displays diminishing marginal returns to meteorological variables in all time periods when $\beta_1 > 0$ and $\beta_2 < 0$ and diminishing total returns in those periods in which $\alpha_i < 0$. In addition to these advantages, the method provides an improved estimate of the meteorological response function because of the inclusion of a polynomial time trend function in the yield response function.

7.2.3.3 The 'Aridity' Indexing Method

The 'aridity' indexing method which was developed by Lang (1920) and later modified and used by de Martonne (1926), Ångström (1936), Oury (1965), Kellogg (1988) and Kellogg and Severin (1990) simply combines rainfall and temperature into a composite 'aridity' index and, then, uses it as an explanatory variable in a yield response function or a production function. In other words, an 'aridity' index is considered as a simple function of rainfall and temperature.

There are two major types of 'aridity' index, the Martonne index and the Ångström index. The only difference between these two indexes is that the later is more appropriate for conditions where the temperature goes below $-10^{0}C$ (Oury 1965). For positive values of temperature, both indexes give the same measure. The Martonne 'aridity' index (W) which is modified by Oury (1965) is expressed as:

$$(7.6) \qquad W = \frac{\dfrac{\sum_{i=1}^{n} P_i \times 12}{n}}{\dfrac{\sum_{i=1}^{n} T_i}{n} + 10}$$

where P_i is the average monthly rainfall for the i-th month in millimeters, T_i is the average monthly temperature for the i-th month in degrees celsius, and n is the total number of months included in the index. The constant 10 is used to avoid negative values of temperature (Oury 1965). Equation (7.6) shows that the index can be computed for any number of cumulated months. Moreover, it indicates that a low 'aridity' index resulting from higher T and low P means more moisture stress, and vice versa.

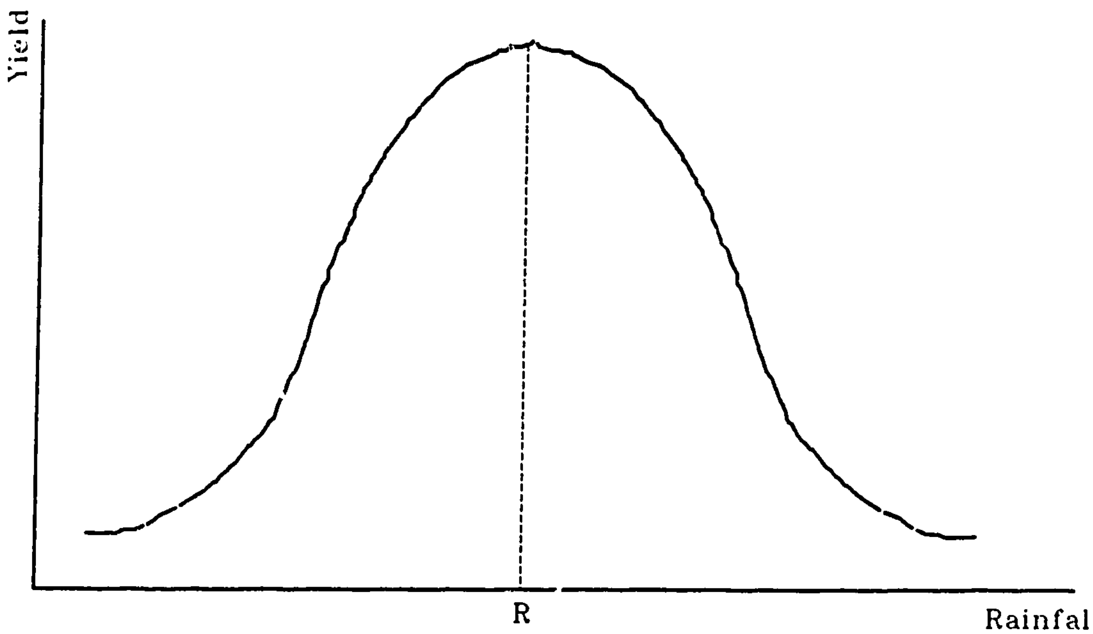
7.3 Choice and Specification of Analytical Technique

Regarding the choice of analytical technique, it is very difficult to choose one over other techniques on theoretical grounds, because all techniques discussed above have both theoretical advantages and disadvantages. The correlation analysis technique, presented in section (7.2.1), is relatively a simple technique to examine the crop-weather relationship. However, the technique is considered to be limited and tentative as it does not provide the effects of more than one meteorological variable at a time. Similarly, the multiple regression analysis technique has some difficulties, especially those associated with the problem of specification (Stallings 1960 and 1961; Shaw 1964; Oury 1965). The specification problem arises while specifying appropriate meteorological variables and their functional relationships with crop yields. It is argued that the yield effects of meteorological variables when considered individually are negligible as compared to their joint effects. The multiple regression analysis technique considers only the individual effects of meteorological variables rather than their joint effects. Therefore, the technique reduces the level of significancy of each meteorological variable on crop yields.

The specification problem also arises while specifying an appropriate functional form in order to examine the relationship between crop yields and meteorological variables. It is generally argued that the relationship between crop yield and an individual meteorological variable is that of a bell-shaped curve as presented in Figure 7.1 (Shaw 1964). According to Figure 7.1, for small levels of rainfall, water is still a scarce factor. Therefore, any additional inches of rainfall will increase crop yield at an increasing rate. On the other hand, at higher levels of rainfall, water becomes less scarce.

FIGURE 7.1

RELATIONSHIP BETWEEN CROP YIELD AND RAINFALL



In such a condition, any additional inches of rainfall will increase crop yield but only at a decreasing rate. And, beyond point R in Figure 7.1, any additional inches of rainfall decrease crop yield. Therefore, a linear regression model which does not describe such a relationship appropriately is less likely to give accurate results regarding the effects of meteorological variables on crop yields. This problem can be solved by using a quadratic functional form to specify meteorological variables. However, the use of a quadratic functional form in a multiple regression model doubles the number of independent variables, thereby, reducing the available degrees of freedom. The total number of observations on rainfall and temperature available in this study is only 12 (from 1969/70 to 1980/81). Therefore, the multiple regression technique involving a quadratic functional form can not be used in this study to analyze the relationship between crop output and meteorological variables.

Similarly, all weather indexing methods under the weather index technique have some difficulties. The yield series indexing method which avoids the problems of specification mentioned above is applicable only when an adequate 'sample' of yield series from experiments is available for the area under consideration. Such experiment data on crop yield series are not available in the case of Nepal. Therefore, the yield series indexing method is rejected in this study. Similarly, the weather response function indexing method is also rejected in this study, because the method, as in the case of quadratic functional form multiple regression model, requires a sufficiently large sample to estimate the quadratic yield response function containing a polynomial time trend. Since Nepalese rainfall data are available only for 12 years, the yield series indexing method becomes impractical to analyze the crop-weather relationship in Nepal.

The 'aridity' indexing method is a relatively simple method to construct a weather index because it does not require yield series data from experiments nor does it involve the specification problems mentioned above. However, the method requires data on both rainfall and temperature in order to construct the 'aridity' index. In Nepal, temperature data are not available for major crop producing regions such as the Hills and Tarai and must be proxied by available data for Kathmandu Valley. The 'aridity' indexing method was attempted in this study to analyze the crop-weather relationship in Nepal, but was found to provide less satisfactory results.

Thus, the most sophisticated analytical techniques are not practical to analyze the crop-weather relationship in Nepal. Therefore, the relationship in this study is analyzed by using simple analytical techniques such as the correlation analysis technique and the multiple linear regression analysis technique. Despite some theoretical difficulties, these techniques are the only doable techniques which can provide reasonable results about the crop-weather relationship in Nepal. The analysis and results of the techniques are presented in the following section.

7.4 Analysis and Results of the Crop-Weather Relationship in Nepal

The data on rainfall which are presented in Table A1.9 of Appendix 1 are available by crop producing regions of Nepal, viz. the Hills, Kathmandu valley and Tarai, and for the period of 1969/70 to 1980/81. Therefore, the crop-weather relationship under the correlation analysis technique is analyzed at the regional level. According to the correlation analysis technique, the correlation coefficients between crop output and rainfall are estimated by using the Divisia crop output quantity data of Table 7.1 and rainfall data presented in Table A1.9 of Appendix 1. In this chapter, the geometric input quantity index is also constructed to estimate the total factor productivity in order to analyze trends of the crop output quantity, total factor productivity and rainfall over time. The crop input quantities and factor shares which were used to construct the geometric input quantity index are given respectively in Table A1.7 of Appendix 1 and Appendix 2. The regional indices of crop output, conventional crop input and the total factor productivity are presented in Table 7.1. Regarding the rainfall index, the index is constructed by considering the monthly rainfall data of the year 1969/70 as 100. The rainfall index includes rainfall of some sensitive months, viz. March rainfall and June rainfall in the case of Hills, March rainfall and August rainfall in the case of Kathmandu Valley and March rainfall in the case of Tarai. The sensitive months of rainfall are identified on the basis of correlation coefficients between monthly rainfall and crop output.

TABLE 7.1

INDICES OF OUTPUT, INPUT, TOTAL FACTOR PRODUCTIVITY AND WEATHER IN THE NEPALESE CROP SECTOR BY REGION: 1969/70 - 1980/81

Region/ YEAR	Divisia Output Quantity Index (Y)	Geometric Input Quantity Index (X)	Total Factor Productivity (Y/X)	Simple Rainfall Index
		Hills		
1969/70	100.00	100.00	100.00	100.00
1970/[illegible]	97.40	100.94	96.49	197.77
1971[illegible]	103.85	101.83	101.99	296.46
1972/[illegible]	80.65	103.57	77.87	158.73
1973/74	67.55	105.49	64.03	167.07
1974/75	72.87	107.10	68.04	99.65
1975/76	86.18	109.25	78.88	182.85
[illegible]76/77	84.57	110.35	76.64	246.84
[illegible]78	71.68	112.97	63.45	144.56
19[illegible]79	126.15	114.47	110.[illegible]	238.64
1979/80	83.90	116.57	71.98	118.61
1980/81	99.99	119.01	84.02	210.42
		Kathmandu Valley		
1969/70	100.00	100.00	100.00	100.00
1970/71	104.81	102.71	102.04	121.12
1971/72	107.69	108.65	99.12	122.69
1972/73	102.86	114.82	89.58	74.56
1973/74	86.75	116.06	74.71	100.07
1974/75	95.40	1[illegible]86	82.34	132.28
1975/76	104.84	117.96	88.88	141.69
1976/77	84.11	126.72	66.37	101.34
1977/78	85.88	124.85	68.7[illegible]	69.31
1978/79	94.85	129.89	73.02	99.17
1979/80	84.37	134.24	62.85	48.50
1980/81	88.27	140.69	62.74	48.68
		Tarai		
1969/70	100.00	100.00	100.00	100.00
1970/71	113.89	103.82	109.70	38.49
1971/72	109.27	107.57	101.58	85.91
1972/73	93.23	109.54	85.11	9.28
1973/74	92.46	113.34	81.58	27.49
1974/75	96.66	117.61	82.[illegible]	97.25
1975/76	74.81	119.14	62.79	33.33
1976/77	106.20	121.82	87.18	6.87
1977/78	87.48	125.59	69.66	0.00
1978/79	130.27	128.86	101.10	143.30
1979/80	68.31	128.39	53.21	0.00
1980/81	114.80	133.24	86.16	68.73

The zero values of rainfall index in the case of Tarai are truncated.

According to results of the correlation analysis technique presented in Table 7.2, March rainfall and June rainfall show the strongest positive influences on crop output in the Hills, whereas crop output in Kathmandu Valley is influenced primarily by March rainfall and August rainfall. Surprisingly, March rainfall is observed to be the only monthly rainfall that has a relatively high positive correlation with crop output in Tarai. Further, these monthly rainfalls representing some specific sensitive months are used to analyze crop-weather relationship under the multiple linear regression analysis technique. In this study, the technique is simplified by assuming the crop output quantity (Y) as a simple linear function of time trend (T), which allows for technological advance, and rainfall (R) only. That is,

$$(7.7) \qquad Y = \alpha + \beta_T T + \beta_R R$$

The major limitation of this model is that the time trend considers only a constant rate of technological change and, therefore, fails to capture the nonlinear movement in technological advance in the country. As discussed earlier, the problem can be overcome by using a polynomial time trend function. However, estimation of such a function is restricted in this study as the sample size is relatively small. Therefore, the simpler multiple linear regression model (7.7) is used to analyze the crop-weather relationship in Nepal.

The model (7.7) is estimated for each region of Nepal and also for the country as a whole. While estimating model (7.7) for Nepal as a whole, the regional data on crop output and rainfall were pooled together. Results of the estimated model are presented in Table 7.3. According to Table 7.3, rainfalls representing some specific sensitive months have a significant positive influence on crop output in Nepal except in Kathmandu Valley. The insignificant relationship between crop output and rainfall

TABLE 7.2
COEFFICIENT OF CORRELATION BETWEEN CROP OUTPUT QUANTITY AND RAINFALL: NEPAL, 1969/70 - 1980/81

Variable Name	Coefficient of Correlation
Hills	
Output Quantity and January Rainfall	-0.52
Output Quantity and February Rainfall	0.05
Output Quantity and March Rainfall	**0.63**
Output Quantity and April Rainfall	0.17
Output Quantity and May Rainfall	-0.07
Output Quantity and June Rainfall	**0.43**
Output Quantity and July Rainfall	-0.02
Output Quantity and August Rainfall	-0.25
Output Quantity and September Rainfall	-0.06
Output Quantity and October Rainfall	-0.06
Output Quantity and November Rainfall	-0.02
Output Quantity and December Rainfall	-0.27
Kathmandu Valley	
Output Quantity and January Rainfall	0.18
Output Quantity and February Rainfall	0.22
Output Quantity and March Rainfall	**0.43**
Output Quantity and April Rainfall	0.34
Output Quantity and May Rainfall	-0.35
Output Quantity and June Rainfall	0.23
Output Quantity and July Rainfall	0.31
Output Quantity and August Rainfall	**0.54**
Output Quantity and September Rainfall	0.24
Output Quantity and October Rainfall	0.38
Output Quantity and November Rainfall	0.25
Output Quantity and December Rainfall	-0.61
Tarai	
Output Quantity and January Rainfall	-0.14
Output Quantity and February Rainfall	-0.17
Output Quantity and March Rainfall	**0.66**
Output Quantity and April Rainfall	0.22
Output Quantity and May Rainfall	0.09
Output Quantity and June Rainfall	0.01
Output Quantity and July Rainfall	-0.55
Output Quantity and August Rainfall	-0.03
Output Quantity and September Rainfall	0.18
Output Quantity and October Rainfall	-0.24
Output Quantity and November Rainfall	-0.38
Output Quantity and December Rainfall	-0.56

TABLE 7.3

STATISTICS OF THE MULTIPLE LINEAR REGRESSION MODEL IN THE NEPALESE CROP SECTOR: BY REGION AND COUNTRY, 1969/70 - 1980/81

Variable Name	Estimated Coefficient	T-Ratio	Standardized Coefficient	Other Statistics
		Hills		
Intercept	63.765	3.874 ***	0.000	n = 12 SEE = 15.681
Time (T)	0.015	0.011	0.003	D-W = 1.454
Rainfall (R)	0.143	1.843 **	0.524	R^2 = 0.28
		Kathmandu Valley		
Intercept	108.260	6.049 ***	0.000	n = 12 SEE = 6.573
Time (T)	-1.225	-1.832 *	-0.497	D-W = 2.194
Rainfall (R)	0.097	1.245	0.338	R^2 = 0.55
		Tarai		
Intercept	104.170	3.908 ***	0.000	n = 12 SEE = 13.353
Time (T)	-0.463	-0.557	-0.096	D-W = 1.810
Rainfall (R)	0.172	1.754 *	0.464	R^2 = 0.52
		Nepal		
Intercept	63.634	6.024 ***	0.000	n = 36 SEE = 0.900
Time (T)	0.874	2.577 ***	0.617	D-W = 1.694
Rainfall (R)	0.142	3.003 ***	0.682	Buse R^2 = 0.22

* Significant at 0.10 level (t^*_9 = 1.383 and t^*_{33} = 1.282).
** Significant at 0.05 level (t^*_9 = 1.833 and t^*_{33} = 1.645).
*** Significant at 0.01 level (t^*_9 = 2.821 and t^*_{33} = 2.326).

in the case of Kathmandu Valley may be due to fact that the cropped land in Kathmandu Valley is the most fertile land in Nepal and contains a high level of moisture. Moreover, a large portion of the total cropped area in Kathmandu Valley is irrigated throughout the year, especially by major rivers such as the Bagmati, Bishnumati and Manahara. In addition to this, any rainfall in the hills which surround Kathmandu Valley raises the water level in all rivers of Kathmandu Valley and, thereby, provides irrigation facilities to a much larger area in the valley. In sum, unlike in the Hills and Tarai, crop output in Kathmandu Valley does not depend solely on rainfall. Thus, an insignificant relationship between crop output and rainfall is more or less expected in the case of Kathmandu Valley.

Furthermore, the crop-weather relationship in the Nepalese crop sector is also analyzed under a Cobb-Douglas production function framework. The Cobb-Douglas production function (A2.1) of Appendix 2, which was used to estimate factor shares in the geometric index procedure in Chapter 6, is estimated by including rainfall as an explanatory variable. In Appendix 2, input factors bullocks, fertilizer and HYV seeds were observed to be insignificant. Therefore, these input factors are dropped out while estimating the production function to analyze the crop-rainfall relationship in Nepal, especially to increase the degrees of freedom in the estimation process. Results of the estimated production function are presented in Table 7.4. According to Table 7.4, rainfall representing some specific sensitive months is observed to have a significant positive influence on Nepalese crop production.

Further, the regional indices of crop output, total factor productivity and rainfall presented in Table 7.1 are plotted over time in Figures 7.2 to 7.4 in order to analyze the crop-weather relationship graphically. Figures 7.2 to 7.4 indicate that the variation

TABLE 7.4

REGRESSION STATISTICS OF THE ESTIMATED COOB-DOUGLAS PRODUCTION FUNCTION IN THE NEPALESE CROP SECTOR: NEPAL, 1969/70 - 1980/81

Variable Name	Estimated Coefficient	T-Ratio (32 DF)	Standardized Coefficient	Other Statistics
Intercept	0.364	2.529 ***	0.000	n = 36
Time (T)	0.020	4.871 ***	0.173	SEE = 0.865
Land (R)	0.491	8.882 ***	0.529	D-W = 1.761
Labour (L)	0.509	9.213 ***	0.447	Buse R^2 = 0.99
Rainfall (R)	0.002	3.393 ***	0.094	

*** Significant at 0.01 level of significance ($t^*_{32} = 2.326$).

in crop output and total factor productivity in all three regions of Nepal are somewhat similar to the variation in rainfall. Therefore, the graphical analysis supports, to some degree, the above finding that there exists a positive relationship between crop output and rainfall in Nepal.

7.5 Summary

In Nepal, only 10 percent of the total arable land is irrigated and the remaining 90 percent is completely rainfed. Therefore, weather conditions are likely to have a great influence on crop output in Nepal. The relationship between weather and crop output in the case of Nepal is analyzed in this study.

There are three major types of analytical techniques, viz. the correlation analysis technique, the multiple regression analysis technique and the weather index technique,

TABLE 7.2
INDICES OF OUTPUT, TOTAL FACTOR PRODUCTIVITY AND RAINFALL IN THE NEPALESE CROP SECTOR: HILLS, 1969/70 - 1980/81

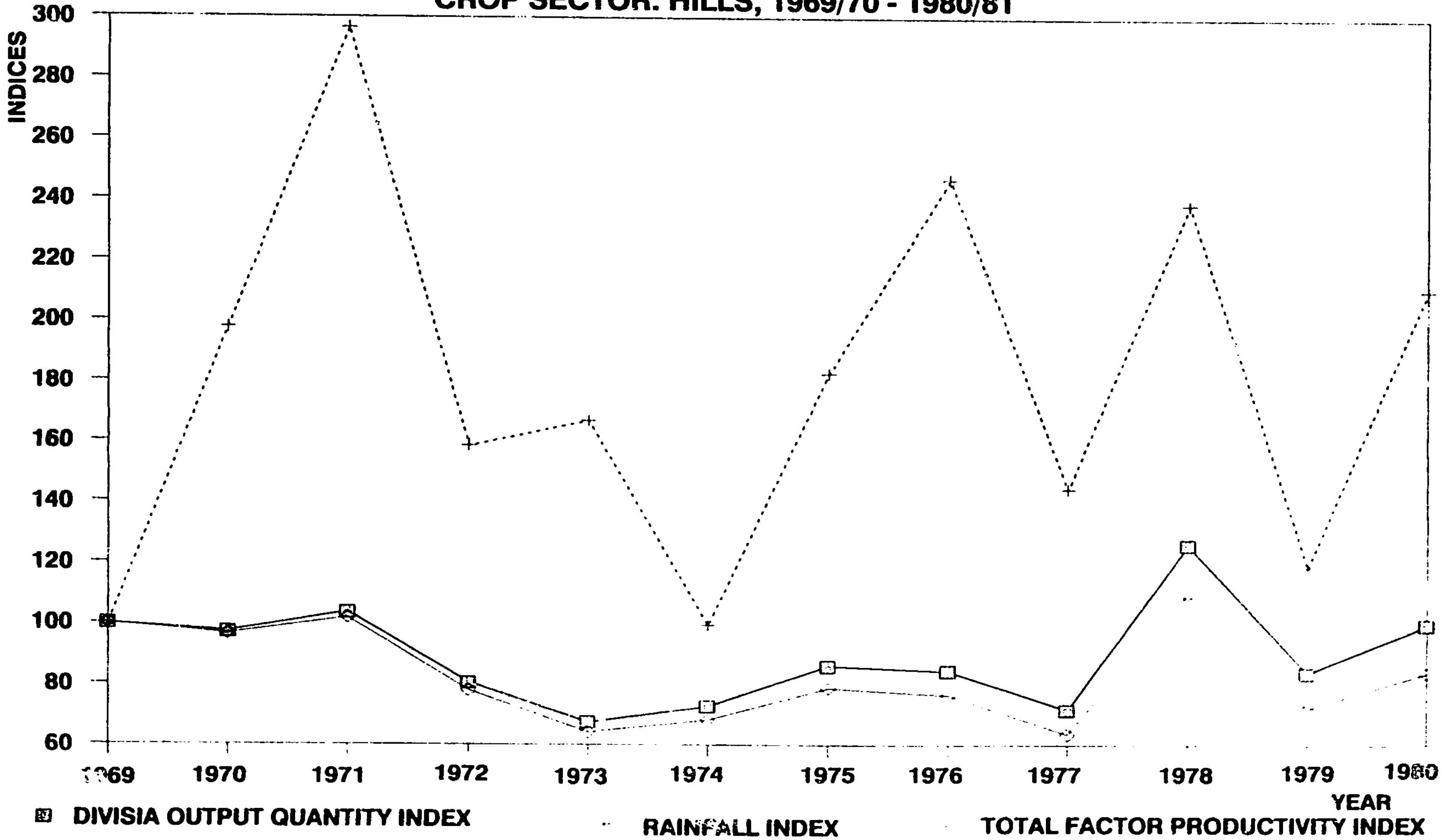


TABLE 7.3
INDICES OF OUTPUT, TOTAL FACTOR PRODUCTIVITY AND RAINFALL IN THE NEPALESE CROP SECTOR: KATHMANDU VALLEY, 1969/70 - 1980/81

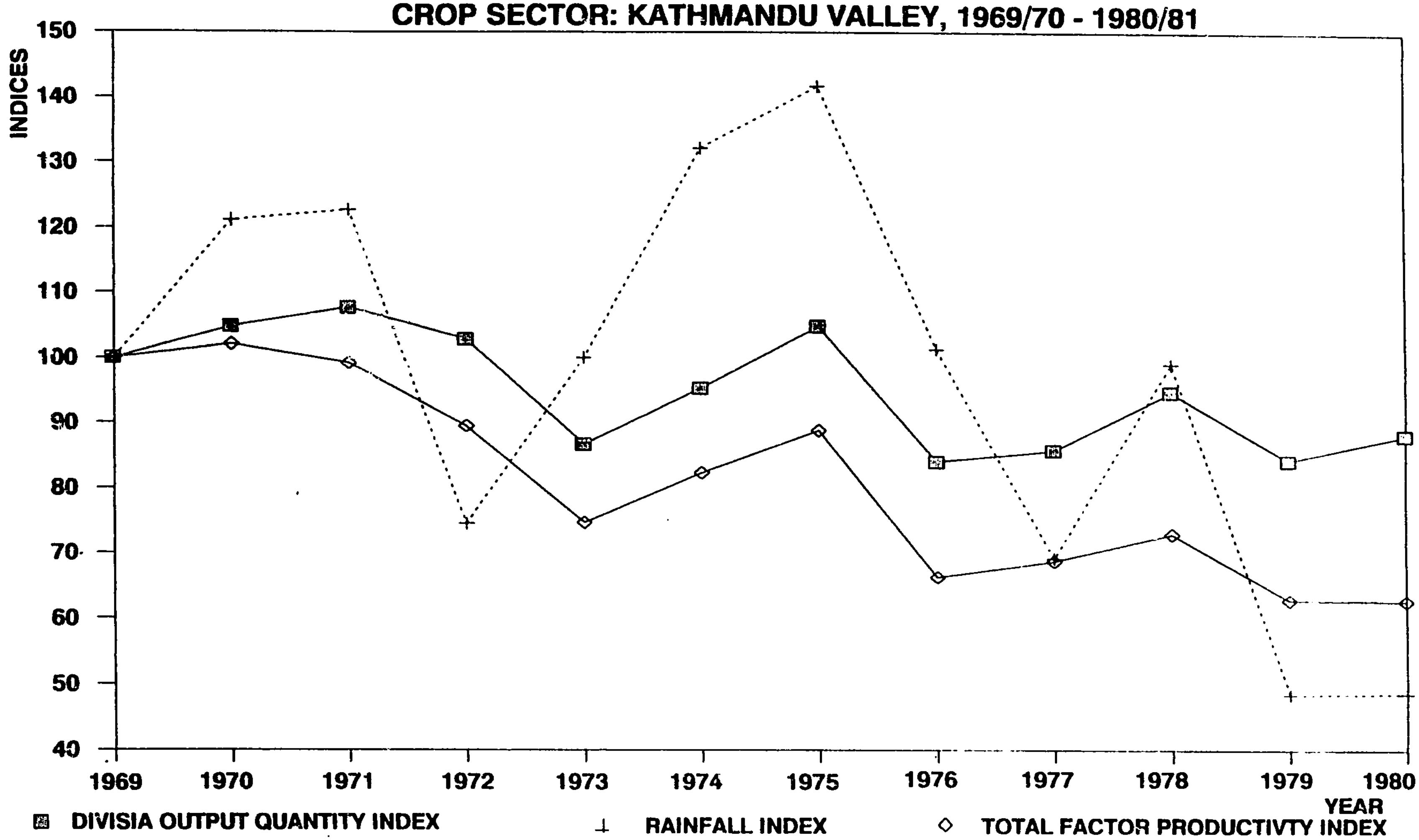
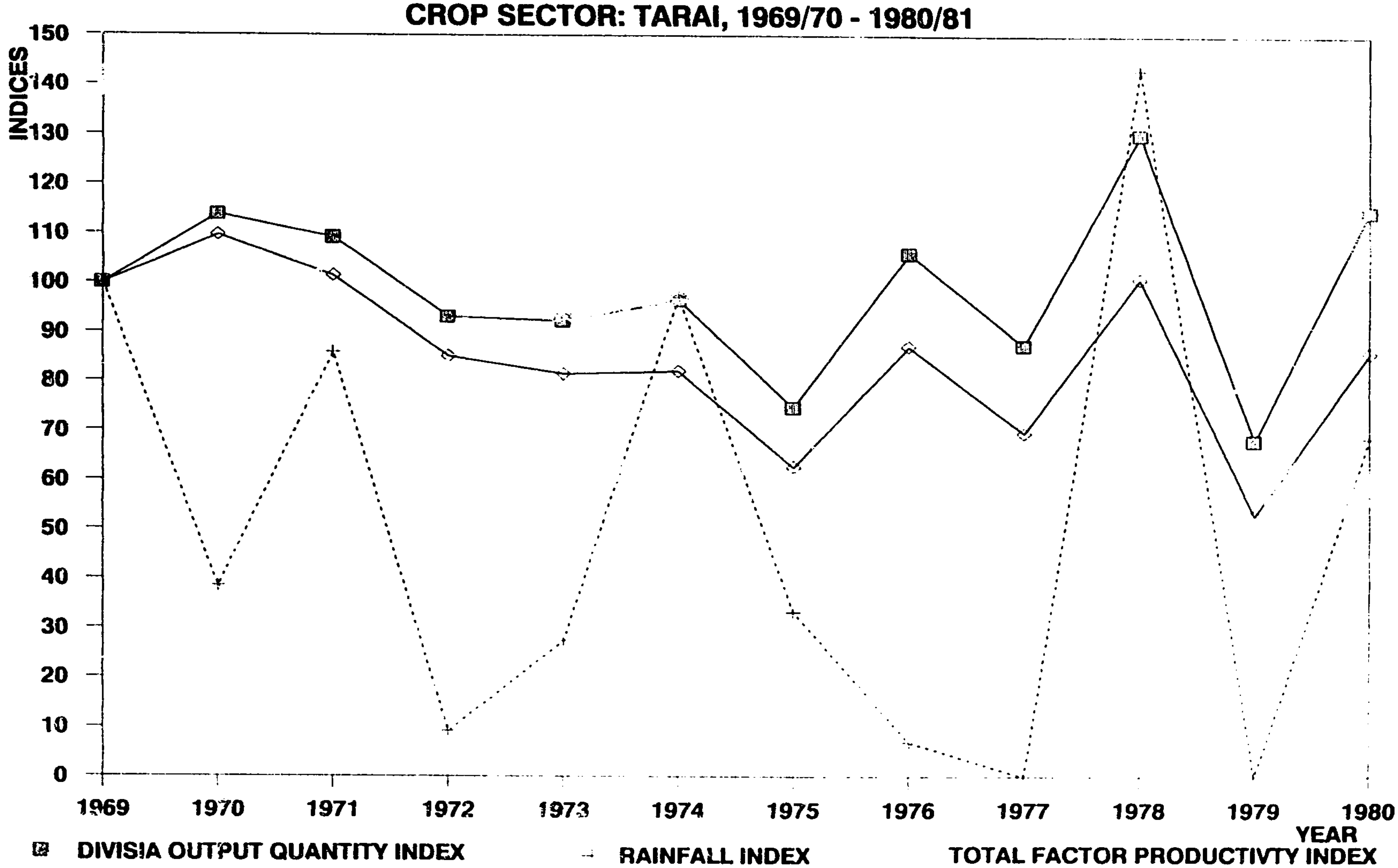


FIGURE 7.4
INDICES OF OUTPUT, TOTAL FACTOR PRODUCTIVITY AND RAINFALL IN THE NEPALESE CROP SECTOR: TARAI, 1969/70 - 1980/81



that have been frequently used in previous studies to examine the crop-weather relationship. However, the most sophisticated analytical techniques such as the multiple quadratic regression analysis technique and the weather index technique are not practical techniques to analyze crop-weather relationship in Nepal, especially due to absence of either a large sample on meteorological variables, or sample on yield series from experiments or sample on temperatures. Therefore, these techniques are not chosen to analyze crop-weather relationship in this study. On the other hand, simple analytical techniques such as the correlation analysis techniques and the multiple linear regression analysis technique seem to be the most doable techniques to analyze crop-weather relationships in Nepal. Therefore, these techniques are chosen in this study.

Results derived from the correlation analysis technique and the multiple linear regression analysis technique indicate that rainfalls representing some specific sensitive months have a significant influence on Nepalese crop output. This finding is also supported when a Cobb-Douglas production function involving rainfall as an explanatory variable is estimated for Nepal.

Moreover, the graphical analysis which is carried out by plotting the regional indices of crop output, total factor productivity and rainfall over time indicates that the trends of growth in crop output and total factor productivity are somewhat similar to the trend of growth in rainfall representing some specific sensitive months in all three regions of Nepal. In other words, the analysis supports, to some degree, the finding of the correlation and multiple linear regression analysis techniques that there exists a positive relationship between crop output and rainfall in Nepal. That an even stronger relationship between weather and crop output has not been found, especially in the graphical analysis, may be due to the fact that the variation in crop output is better explained by a composite index of rainfall and temperature rather than by an index of rainfall alone.

CHAPTER 8

SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

8.1 Introduction

The crop sector plays a vital role in the overall performance of the Nepalese economy. However, the performance of the Nepalese crop sector was very disappointing during the period of 1961/62 to 1980/81 in which the production and yield of major crops declined. Some improvements in yield appear to have occurred in the 1980s. However, these yield statistics do not present an accurate picture of the change in productivity in the Nepalese crop sector. A true picture on the productivity front can be visualized only by estimating the total factor productivity of the crop sector. Therefore, this study estimates and analyzes the total factor productivity growth in the Nepalese crop sector over the period of 1961/62 to 1987/88. In addition, the study decomposes crop output growth into cropped area, yield, cropping pattern, price and their interaction terms in order to determine the contribution of these components to the output growth in the Nepalese crop sector. Besides these objectives, the study analyzes the influence of rainfall on Nepalese crop output.

8.2 Institutions and Policies Relating to the Agricultural Development In Nepal: A Review

The agricultural sector has remained the leading sector of the economy. Therefore, the Government of Nepal through its agricultural institutions and policies has been trying to increase the productivity of its agricultural sector. The Land Reform Act of 1964 was one of the major steps taken by the Government towards achieving greater equity and, it was hoped, improved efficiency in agricultural production. However, achievements of such land reform have not been satisfactory due to several factors, such as the resistance of land owners, lack of cooperation between government agencies, and bureaucratic procedures relating to the implementation of the land act.

In Nepal, the agricultural research and extension services which are designed to increase the production level in the agricultural sector are solely carried out in the public sector. However, the agricultural research and extension services have not been very successful in the past in achieving their objectives. Agricultural research has been neglected on the assumption that agricultural technologies could be easily transferred from other countries. On the other hand, financial difficulties have restricted the effectiveness of agricultural extension services in Nepal.

The Government of Nepal provides subsidized farm inputs in order to increase the productivity of its crop sector. Besides credit subsidies, subsidies are provided on the selling prices of fertilizer and HYV seeds and on the transportation costs of these inputs while transporting them from the Tarai to the Hills. However, cost of the input subsidy programmes is very high and has been increasing rapidly over the years. Therefore, the Government of Nepal has recently declared a policy of gradual phasing out of all input subsidy programmes in Nepal.

In Nepal, the output price support policy was adopted in 1976 in order to raise the production level of Nepalese farmers. However, the policy has not been very successful in achieving its objective, mainly due to unavailability of sufficient funds to procure enough foodgrains and, thereby, to have positive impacts on prices and production. Moreover, financial difficulties have also restricted the effectiveness of the Nepalese food security and subsidy policy which is designed to eliminate food deficits and to stabilize market prices in Nepal. In the absence of sufficient funds, the

Government of Nepal is unable to satisfy the total food deficits in the country. As a result, a large portion of the total food deficit is being satisfied by the private traders and at sufficiently higher prices than prices of the Government's distribution.

Regarding external trade, agricultural exports have remained the dominant export items in Nepal. However, these exports, especially of foodgrains such as rice, have declined in recent years mainly due to increasing foodgrain self-sufficiency in India and a decline in agriculture surplus and productivity in Nepal. Moreover, following the food deficit in 1986/87, the Government of Nepal adopted a trade policy that restricts the export of foodgrains from Nepal. Nevertheless, the open border with India and higher foodgrain prices in Indian border markets have helped to smuggle out a significant volume of foodgrains from the Tarai to India. Besides this, the movement of grains across the border occurs due to non-price factors. In the absence of adequate road facilities across the different regions of Nepal, foodgrains are exported from Nepal to India in the Tarai region while foodgrains are imported from India to Nepal in the far western Nepalese Hills and Mountains. Similarly, whenever there is some restrictions on interstate movement of grains in India, movement of foodgrains occurs from one state of India into Nepal, along Nepal's roads, and back into other Indian states. Thus, the Nepalese agricultural trade policies are highly influenced by the country's open border with India and existing transportation facilities within the country. Therefore, these issues need to be carefully addressed in future agricultural trade policies in order to make the policies more effective.

Besides the agricultural price and trade policies, the development of the agricultural sector is also influenced by macroeconomic policies such as interest rate policy and exchange rate policy. In Nepal, farmers do borrow money at a large scale in order to purchase modern inputs. Therefore, the interest rate plays an important role in determining the cost of production and, thereby, the level of farm income in the Nepalese agricultural sector. The Government of Nepal has been providing subsidized agricultural credit in order to encourage the use of modern inputs in its agricultural sector. However, the subsidized credit is being misused on a large scale, especially by large farmers. Therefore, the future credit policy must address this issue in order to achieve its major objectives.

Regarding exchange rate policy, Nepal adopted the fixed exchange rate system against the Indian Rupee and US Dollar in April 1960. In 1978, the Government implemented the fixed dual exchange rate system for the US Dollar in order to promote Nepalese exports including agricultural exports. However, the system did not encourage agricultural exports, because almost all of the agricultural exports were being made to India and in Indian Rupees. Hence, the dual exchange rate was again unified in September 1981 against the US Dollar. The fixed unified exchange rate system was latter replaced by the floating exchange rate system against the US Dollar in 1983 and against the Indian Rupee in June 1986.

Thus, the Nepalese exchange rate policy which has been changing over the period is basically designed to increase the country's non-agricultural exports rather than agricultural exports. Nevertheless, the policy seems to have a reasonable impact on agricultural exports, because the agricultural exports in Nepal dominate the country's total exports and there exists an inverse relationship between a country's exchange value of domestic currency and its agricultural exports. Besides this, the shift from a fixed exchange rate system to a floating exchange rate system in Nepal may have opened a new channel for transmitting the macroeconomic policy shocks to the traded goods sector such as the agricultural sector. According to conventional thinking, a change in exchange rate as a result of a change in macroeconomic policy in a country results in a change in exports and imports of that country. Therefore, the floating exchange rate policy in Nepal seems to have influence on the country's export sector which is dominated by agriculture as well as on sectors involved in producing importable goods. The above policies are further discussed with respect to the findings of this study in section (8.7).

8.3 Quantities and Prices of Crop Outputs and Inputs: Data, Measurement and Analysis

The time series quantity and price data on crop outputs and inputs are used to test the hypotheses of this study. The study includes major five crop inputs, viz. land, labour, bullocks, fertilizer and HYV seeds. A simple analysis of output quantities and prices indicates that wheat output as compared to outputs of all other major crops grew faster during the period of 1961/62 to 1987/88. The output growth rates of paddy, millet, potato and oilseeds during the period are positive and low, whereas the output growth rates of maize, barley, jute and tobacco are negative. Moreover, the output growth rates of paddy, maize, barley, potato and oilseeds were relatively higher in the 1980s than in the 1960s and 1970s, and the output growth rates of wheat, millet, sugarcane, jute and tobacco were relatively higher in the 1960s than in the 1970s and 1980s.

Similarly, the nominal price of oilseeds as compared to prices of all other crops grew faster during the period of 1961/62 to 1987/88. The nominal prices of paddy, maize, wheat, potato, oilseeds and jute grew relatively faster in the 1980s than in the 1960s and 1970s, whereas the nominal prices of millet, barley, sugarcane and tobacco grew relatively faster in the 1960s than in the 1970s and 1980s.

The crop output quantities and prices of all individual crops are used to construct a simple nominal crop output value index and the Divisia-related indices of crop output quantity and price. According to the indices, the nominal crop output value increased annually by 7.62 percent during the period of 1961/62 to 1987/88. However, almost 80 percent of such an increase in the nominal crop output value came from an increase in the nominal crop output prices and only 20 percent is contributed by an increase in the crop output quantities. Moreover, the nominal crop output value, quantity and price grew relatively at a higher rate in the 1980s than in the 1960s and 1970s.

Further, prices of land and bullocks are not readily available in Nepal. Therefore, an attempt has been made to proxy prices of land and bullocks in order to use the flexible weight index procedure in the productivity analysis. The actual land prices are proxied by the indices of land prices which are constructed by linearly aggregating the prices of all the major ten crops grown in Nepal suitably weighted by the share of each respective crop in the total cropped area. On the other hand, wage rates are used as the basis for approximating the service price of bullocks in this study. The price of bullocks approximated in such manner is likely to result in a collinearity problem in the estimation of production structure under the cost function approach which uses wage rate and price of bullocks as explanatory variables. However, the problem is overcome by imposing a linear restriction on the coefficients of those price variables on the basis of prior knowledge about their relationship and also by excluding the price of bullocks in the system of share equations.

A simple analysis of input quantities and prices indicates that the use of fertilizer and HYV seeds during the period of 1961/62 to 1987/88 grew relatively at a higher rate than the use of other inputs. Moreover, the annual growth rates of land and labour used in the Nepalese crop sector are relatively higher during the 1980s than in the 1960s and 1970s, whereas the growth rates of bullocks, fertilizer and HYV seeds used in the sector are relatively higher in the 1960s than in the 1970s and 1980s. Similarly, the input prices of all crops grew positively during the period of 1961/62 to 1987/88 and the prices of labour and bullocks during the period grew more rapidly than the prices of other inputs.

8.4 Decomposition Analysis of Growth Trends

In this study, several models were used to decompose the growth of crop output quantity and value into components such as cropped area, yield, cropping pattern, price and their interaction terms. Results derived from the price constancy multiplicative model in which the output prices are kept constant at the base period prices indicate that the crop output quantity during the period of 1961/62 to 1987/88 increased annually at a rate of 1.56 percent with a significant positive area effect and negative yield effect. The results also show that a change in the base period and constant prices in a price constancy multiplicative model changes the contribution of area and cropping pattern to the crop output quantity.

On the other hand, the price structure multiplicative model which allows prices to vary and includes the output price as one of the contributing factors to the output growth shows that the annual growth rate of the nominal crop output value increased during the period of 1961/62 to 1987/88 by 7.62 percent per annum, primarily due to an increase in nominal crop output prices. The annual growth rates of area, yield and cropping pattern did not change as a result of such inclusion of price structure into the multiplicative model. Moreover, the price structure multiplicative model is preferred to the price constancy multiplicative model because the former lets one examine the influence of crop prices on output growth.

A sensitivity analysis which was carried out with respect to the price indexing procedure and the base period indicates that a change in price indexing procedure does not affect the growth rates of output, area, yield and cropping pattern, but it does affect the growth rate of the interaction term and, to some extent, the growth rate of nominal crop output price. Moreover, a change in the base period is observed to have an effect only on the cropping pattern. The analysis also implies that the Divisia-related price index with the base period 1961/62 is the most preferred price index to analyze the output growth in the Nepalese crop sector.

Furthermore, the modified additive decomposition model, modified with respect to price indexing procedure, is also estimated in order to compare its results with those derived from the multiplicative decomposition model. Results show that the change in output growth rate as a result of a change in the decomposition model is very small. However, changes in the growth rates of area, price and interaction term as a result of such a change in the decomposition model are observed to be considerably large. Moreover, a further decomposition of the interaction term in the additive model shows that the higher value of the interaction effect is mainly caused by the interaction effect between area and price structure. Similarly, the decomposition of the gross partial crop productivity in the additive model indicates that the effects of cropping pattern and price structure on the gross partial crop productivity are positive, whereas the effect of yield on the gross partial crop productivity remains negative. The comparison of the results derived respectively from the additive model and multiplicative model also implies that the latter model seems to be relatively more realistic in analyzing the output growth in the Nepalese crop sector. It is because the interaction effect is relatively larger in the additive model than in the multiplicative model.

Further, the price structure multiplicative decomposition model is estimated by considering the real crop output price and real crop output value in order to analyze the effect of real crop output price on the growth rate of real crop output value.

According to the results, the real crop output value during the period of 1961/62 to 1987/88 decreased by 1.32 percent per annum, mainly due to decrease in real crop output price and crop yield. A periodical analysis of the growth rates of real crop output value indicates that the growth rate of real crop output value in Nepal was negative in the 1960s and 1970s but positive in the 1980s. The negative growth rate of real crop output value in the 1960s and 1970s was mainly caused by a sharp decline in the real crop output price during those periods, whereas the positive growth rate of real crop output value in the 1980s was contributed by an increase in cropped area and a relatively smaller decline in the real crop output price in the 1980s than in the 1960s and 1970s.

8.5 Productivity, Terms of Trade, Returns to Cost and Production Structure: Model and Estimation

There are three major indexing procedures, viz. the arithmetic, geometric and flexible weight indexing procedure, to measure total factor productivity. The flexible weight indexing procedure is theoretically superior to the arithmetic and geometric indexing procedures as it underlies a translog function, which allows any value of elasticity of substitution, and lets the cost shares vary with respect to time. However, the flexible weight indexing procedure becomes practical only when the time series data on quantities and prices of each input and output are available. Unfortunately, the time series data on prices of land and bullocks are not available in Nepal. Therefore, the geometric indexing procedure which does not need input price data was initially chosen to measure the total factor productivity in the Nepalese crop sector. Nevertheless, as discussed earlier, the advantages of the flexible weight indexing procedure over other two indexing procedures are so great that the flexible weight indexing procedure has also been used in this study by approximating the prices of land and bullocks. Moreover, results derived from the flexible weight indexing procedure were further used to compare with the results derived from the geometric indexing procedure.

The total factor productivity estimated under the geometric indexing procedure indicates that the total factor productivity in the Nepalese crop sector during the period of 1961/62 to 1987/88 declined by 0.52 percent per annum. Such a negative growth rate of the total factor productivity primarily resulted from the negative growth in total factor productivity during the 1960s and 1970s. The total factor productivity during the 1960s and 1970s declined respectively by 0.10 and 1.21 percent per annum. However, the performance of the sector improved favorably in the 1980s when the total factor productivity increased by 1.12 percent per annum. Further, all these findings obtained from the geometric indexing procedure are also supported by the results derived from the flexible weight indexing procedure. Despite a small difference in the magnitude, the direction of the total factor productivity derived from these two indexing procedures remain the same in all the three periods, viz. the 1960s, 1970s and 1980s.

In this study, the terms of trade and the returns to cost ratio for the Nepalese crop sector are also calculated in order to assess the terms of trade position of the crop sector and to assess the financial situation of the Nepalese crop farmers. The terms of trade during the period of 1961/62 to 1987/88 declined by 1.56 percent per annum. The annual percentage decline in terms of trade was 1.12 in the 1960s, 2.72 in the 1970s and 0.71 in the 1980s. That is, the terms of trade is observed to have been relatively less unfavorable during the 1980s.

Similarly, the returns to cost to the Nepalese crop farmers during the period of 1961/62 to 1987/88 declined annually by 1.75 percent. However, the periodical analysis indicates that the returns to cost to the Nepalese crop farmers, though declining during the 1960s and 1970s, increased annually by 0.29 percent in the 1980s, mainly due to the positive growth rate of the total factor productivity during the period.

In this study, the production structure of the Nepalese crop sector is estimated under a system of share equations derived from the translog cost function. Only four input factors -- land, labour, bullocks and fertilizer -- are included in the system of share equations. While estimating the system of share equations, the adding-up, homogeneity and symmetry restrictions are imposed in order to make the estimated parameters more meaningful to explain the underlying production structure of the Nepalese crop sector. The monotonicity and concavity restrictions are observed to be satisfied in the estimated system of share equations.

Since the estimated γ_{ij} coefficients have little economic meaning of their own, these coefficients are further converted into point estimates of Allen partial elasticities of substitution and of price elasticities of factor demand at the mean value of the cost shares. Results indicate that a substitutability relationship holds in the case of all input pairs and the estimated elasticities of substitution of all input pairs except of input pair labour and bullocks declined over the last three decades. Similarly, the estimated input price elasticities indicate that the lowest and highest degrees of own-price elasticity are observed, respectively, in the case of land and fertilizer. As expected, the estimated own-price elasticities of all input factors in all three periods are negative. The periodical analysis shows that the price elasticities of most input factors are changing over the last three decades.

The system of share equations is also estimated by excluding the price of bullocks from the share equations in order to overcome the problem of collinearity between the prices of labour and bullocks. The estimated parameters remain fairly similar as those estimated under the system of share equations which include the price of bullocks as an explanatory variable. The signs of elasticities of substitution and price elasticities did not change as a result of such exclusion of price of bullocks in the system of share equations.

The Likelihood Ratio (LR) tests indicate that the production structure in the Nepalese crop sector is neither homothetic nor Hicks-neutral. Rather the technical change in the sector is land-saving, labour-using and bullocks-using, whereas the scale effect is weakly land-using and labour-saving.

8.6 Analysis of Crop-Weather Relationships in the Nepalese Crop Sector

The relationship between weather and crop output in the case of Nepal was analyzed in this study. There are three major types of analytical technique, viz. the correlation analysis, the multiple regression analysis and the weather index technique, that have been used in previous studies to examine the crop-weather relationship. The correlation analysis technique simply estimates the correlation coefficient between crop output and meteorological variable, whereas the multiple regression analysis technique regresses the values of selected meteorological variables during the selected 'sensitive' periods on crop yields, either linearly or nonlinearly. However, both these techniques have some theoretical difficulties. The correlation analysis technique does not provide the effects of two or more than two meteorological variables at one time and, in the case of the multiple regression analysis technique, a problem of specification arises while specifying appropriate meteorological variables and their functional relationships with crop yields.

Regarding the weather index technique, the technique includes three major alternative methods to construct a weather index, viz. the yield series indexing method, the weather response function indexing method and the 'aridity' indexing method. In the yield series indexing method, the year to year variation in yield data from experiments where practices have been controlled is assumed to be due primarily to weather. Therefore, by fitting a trend to the data in order to describe the yield effect due to changes in factors (such as soil conditions) which were not held constant, the influence of weather can be measured in each year as that year's actual yield as a percentage of the computed trend. However, the method is applicable only when an adequate 'sample' of yield series from experiments is available for the area under consideration. Since the experiment data on crop yield series are not available in the case of Nepal, the yield series indexing method is not chosen to analyze crop-weather relationship in this study. Similarly, the weather response function indexing method which estimates and uses a yield response function of meteorological variables to construct a weather index is rejected in this study, because the number of observations available for this study (n=12) is not sufficient to estimate yield response function with a polynomial time trend. The 'aridity' indexing method which requires both rainfall and temperature data to construct a composite 'aridity' index is also not feasible in this study, because data on temperature are not available in the case of Nepal except for Kathmandu Valley.

Thus, the most sophisticated analytical techniques such as the multiple quadratic regression analysis technique and the weather index technique are not practical techniques to analyze crop-weather relationships in Nepal. The most practical analytical techniques with respect to availability of data are the correlation analysis technique and the multiple linear regression analysis technique. Therefore, despite some theoretical difficulties, these techniques are used to analyze crop-weather relationships in Nepal.

The crop-weather relationships were analyzed both at regional level and national level. Results derived from the correlation analysis technique indicate that the crop output is strongly and positively influenced by March and June rainfalls in the Hills, March and August rainfalls in Kathmandu Valley and March rainfall in the Tarai. Similarly, results derived from the multiple linear regression analysis technique show that monthly rainfalls representing March and June in the case of the Hills, March and August in the case of Kathmandu Valley and March in the case of the Tarai have a significant influence on Nepalese crop output. The positive relationship between crop production and rainfall representing those sensitive months is also observed under a Cobb-Douglas production function framework.

Moreover, the graphical analysis which is carried out by plotting the regional indices of crop output, total factor productivity and rainfall over time indicates that the variation in crop output and total factor productivity are somewhat similar to the variation in rainfall representing the sensitive months in all three regions of Nepal. In other words, the analysis supports, to some degree, the finding of the correlation and multiple linear regression analysis techniques that there exists a positive relationship between crop output and rainfall in Nepal.

8.7 Conclusions and Policy Implications

In Nepal, the growth rates of the real crop output value, total factor productivity, terms of trade and returns to cost ratio remained negative during the 1960s and 1970s. The negative growth rate of the real crop output value during those periods is observed as a result of a sharp decline in the real crop output prices during those periods, whereas the negative growth rates of the total factor productivity, terms of trade and returns to cost during those periods resulted from higher growth rates of input quantities and prices as compared to the growth rates of output quantities and prices.

Unlike in the 1960s and 1970s, the performance of the Nepalese crop sector considerably improved in the 1980s. A higher growth rate of crop output quantity occurred during the period, primarily due to an increase in the cropped area, but also due to modest increases in yield. Positive growth rates of total factor productivity and returns to cost and a less unfavorable growth rate of terms of trade during the 1980s are observed.

The cropped area during the 1980s increased due to factors such as population pressure, Government policies and the green revolution. The population pressure in the Mountains and Hills of Nepal and in the Bihar state of India caused a large influx of migrants into the Tarai where potential for settlement was relatively high during the 1960s and 1970s. As a result, most of the forest area in the Tarai had been converted into crop area by the early 1980s. The transformation of the forest area into crop area was initially supported by the Nepalese Government's policy to resettle its people from the Hills to the Tarai. In the past, the transformation of forest area into crop area was also influenced by Nepalese politics and the personal interest of politicians and bureaucrats. In the mid-eighties, the ruling panchayat government allowed people to convert forest area into crop area in favour for supporting the panchayat system in the referendum which was held to choose between the panchayat system and a more democratic system. Moreover, panchayat politicians and bureaucrats from the very beginning of the panchayat system were mutually exploiting the forest for their personal gain. Thus, all these factors may have caused the crop area to increase at a faster rate, especially since the mid-seventies.

The green revolution, especially with respect to wheat, is another major factor for such an increase in the cropped area during the 1980s. Though the green revolution started as early as 1971/72, it really covered a large cropped area (above 33 percent of the total cropped area) only after 1980/81. One of the major reason for such an increase in the area under the green revolution in the early 1980s seems to be the Government's emphasis on the development of irrigation and extension systems from 1975 (i.e. beginning of Fourth Five Year Plan) onwards. The government continuously increased its irrigation development expenditure at constant prices from NRs 66 million in 1974/75 to NRs 147 million in 1975/76 and NRs 204 million in 1981/82 (Svejnar and Thorbecke 1984, Appendix 3.1; and NPC 1984). Similarly, the extension system, especially the Training and Visit (T & V) system, was implemented in 1975 covering 3 districts of Narayani Zone in the Tarai region. By the end of 1981, the system was further extended to 11 more districts, mostly in the Tarai region. The green revolution, therefore, brought positive pressures to increase the land base and to increase multiple cropping.

In addition to the development of irrigation and extension system, the rural development projects such as the Area Development Projects (ADPs) and the Integrated Rural Development Projects (IRDPs) may have influenced, to some extent, the positive growth of the total factor productivity in the Nepalese crop sector during the 1980s. Though the Nepalese Government implemented these projects as early as 1974 in order to improve living conditions of the majority of Nepalese farmers through a more equitable growth process, benefits from these projects may have started coming to the crop sector only in early 1980s. It is because these projects generally took longer than five years to complete infrastructure facilities such as mule-tracks, roads and irrigation canals which are vital for the development of the crop sector. In 1985, there were seven IRDPs covering 24 percent of the total population and 22 districts of Nepal.

In absence of sufficient quantifiable data, it is very difficult to link the institutional development as well as policy variables of Chapter 2 with the productivity growth estimated in Chapter 6. However, a general assessment of the institutional development, policy variables and productivity growth leads the author to believe that, while some of the policy variables and institutional development have influenced the productivity growth in the Nepalese crop sector, some other did not. The Land Reform Act 1964, which is considered to be the major component of institutional changes in Nepal under the panchayat system, was a failure as the growth of crop productivity remained negative during the 1960s and 1970s. Similarly, the output price support policy, food security and price subsidy policy, exchange rate policy and trade policy, as discussed in Chapter 2, were not positive, and probably negative, influences on the crop productivity growth in Nepal. In fact, the food security and price subsidy policy, exchange rate policy and trade policy were really never designed to favour the crop sector directly. The effectiveness of the output price support policy was also severely limited due to financial and technical difficulties in implementing the policy.

In Nepal, the development of the agriculture financing institutions along with the Government's credit subsidy policy seem to have some positive influences on the productivity growth in the Nepalese crop sector. With the establishment of the Agricultural Development Bank (ADB/N), farmers started getting subsidized credit for their purchase of modern inputs. However, such subsidized credit was limited to a few districts and mostly to large farmers until 1975 when the Government of Nepal implemented the Small Farmers Development Programmes (SFDPs) to ensure credit facilities to small and marginal farmers. By April 1985, the Government expanded 130 such SFDPs in 50 out of 75 districts of Nepal. Moreover, the agriculture credit became more effective in 1980 when the Government brought more democratic process in operation and management of Sajhas (cooperatives) and established separate Sajhas for small and marginal farmers. There were altogether 724 Sajhas including 32 Small Farmers Sajhas at the end of year 1983/84. Thus, it can be concluded that the agriculture financing institutions, though they were established as early as 1968, started benefiting the crop sector to a major extent only towards the beginning of the 1980s. As a result, Nepal may have experienced a positive growth in crop productivity in the 1980s.

Further, the input subsidy policy which provides subsidies on modern inputs such as HYV seeds and fertilizer could also be one of the factor influencing positive growth in the Nepalese crop sector during the 1980s. The input subsidy policy was implemented from the very beginning of the 1960s. However, effectiveness of such policy in the 1960s and 1970s was restricted due to the Nepalese Government's less emphasis on the development of irrigation, extension and transportation systems. As irrigation, extension and transportation systems developed considerably in the early 1980s, the input subsidy policy became more effective to increase the adoption rate of modern inputs in the Nepalese crop sector. Thus, it may be concluded that the positive growth in crop productivity in the 1980s, to some degree, could have been influenced by the input subsidy policy in Nepal.

Furthermore, the output quantity and productivity growth rates during the 1980s are sufficiently high that productivity advance offset the adverse movement of terms of trade and resulted in positive growth in returns to cost to Nepalese crop farmers. Thus, the favorable growth in the total factor productivity, output quantity and output real value in the Nepalese crop sector during the 1980s provides a good indication for

Nepalese policy decision makers and planners concerning the importance of continued productivity growth in crop production. In other words, any future plans and policies that aim towards achieving a higher productivity growth in the Nepalese crop sector must put more emphasis, at least in initial stages of agricultural development, on the development of basic infrastructure such as irrigation canals, roads, mule-tracks and storage. The study shows that the growth of crop output in Nepal is influenced by the weather conditions. Therefore, the development of irrigation will certainly help to reduce variability in Nepalese crop production. Emphasis should also be given to extension and transportation systems and agricultural policies in order to make the systems and policies more effective and practical. In this regard, the private sector needs to be encouraged to develop the transportation system, whereas the public sector must increase its investment per capita on extension services in order to ensure an increase in the number of technicians and their training quality.

Regarding the agricultural policies, continuation of a positive growth in Nepalese crop productivity is likely depend on two major policies: agricultural research policy and crop output price support policy. The study could not succeed to establish a relationship between crop productivity and research expenditure in Nepal due to lack of relevant data. However, studies, such as Schultz (1953), Griliches (1958 and 1986) Evenson (1967), Peterson (1967 and 1971), Minasian (1969), Schmitz and Seckler (1970) and Evenson and Kislev (1975), have shown positive returns of the research and development expenditures in different countries. In Nepal, the agricultural research has remained neglected from very beginning when the Department of Agriculture was first established in 1924. The negligence was due primarily to the assumption that agricultural technologies can be easily transferred from other countries. Because of such an assumption, research expenditures have been always kept at a low level, thereby restricting the research activities in the Nepalese agricultural sector. The share of agricultural research expenditure in the total agricultural sector expenditure decreased in real terms from 13.6 percent in 1970/71 to 5.4 percent in 1980/81 (Yadav 1987). Moreover, the total expenditure allocated to crop research at 1972/73 constant prices was only NRs 5.6 million in 1970/71 and NRs 6.7 million in 1980/81 which respectively turn out to be 5 and 2 percent of the total agricultural sector expenditure of these respective years (Yadav 1987). Thus, it is apparent that the agricultural research expenditure, especially in crop research, is not only a small portion of the total national expenditure but it is also declining in recent times. If such declining trend in the agricultural research expenditure keeps continuing in future, it will certainly have a counter effect on continuation of positive growth in the output and productivity in the Nepalese crop sector. Therefore, the Government of Nepal must realize the importance of its agricultural research expenditure on the growth of output and productivity in its crop sector and, thereby, act accordingly to change its existing policies relating to agricultural research expenditure. Such a change in agricultural research expenditure policies will help to achieve a higher level of technological change in the Nepalese crop sector.

Regarding the crop output prices, farmers, in addition to new technology, must be given the right price for their produce in order to provide them incentive to increase their output and productivity. The existing agricultural output support price policy does not provide such price incentive, because the output prices under the existing output support price policy are suppressed prices which are below the levels of equilibrium prices. In addition to this, a ban on exports of Nepalese agricultural products have reduced farmers' incentive to increase their output and productivity to a large extent. Therefore, the existing price support policy and the agricultural export policy need to be reexamined and redesigned in order to provide price incentives to farmers to increase their output and productivity. Moreover, if the agricultural sector is to be considered as a leading sector in future, then the sector must be emphasized with respect to macroeconomic policies such as interest rate policy and exchange rate policy. In sum, continuation of the positive growth in crop productivity in future necessitates change in existing agricultural policies and, to some extent, macroeconomic policies.

8.8 Limitations and Suggestions for Future Research

In this study, estimates of the total factor productivity growth rates under the geometric index procedure provides an accurate picture of the performance of the Nepalese crop sector for the last three decades. However, one difficulty was experienced while estimating the total factor productivity growth rates under the flexible weight index procedure. The difficulty was to obtain time series price data on input factors land and bullocks. In absence of such input price data on land and bullocks, the total factor productivity under the flexible index procedure was estimated by approximating the prices of land by some index of crop output prices, and prices of bullocks by prices of labour, especially on prior information regarding the relationship between cost of bullocks and wage rate. Therefore, estimates of the total factor productivity growth in the Nepalese crop sector under the flexible index procedure can be improved if time series data on prices of land and bullocks are somehow obtained in the case of Nepal. One possibility is to conduct an extensive survey at village and district levels regarding the prices of land and bullocks. Time series data on land prices are likely to be obtained from the land rent record book of the district government; whereas time series data on prices of bullocks could be obtained from the record book of village panchayats.

Similarly, difficulties were also experienced while trying to establish linkages between crop output and resource degradation. In Nepal, the negative growth in crop yield, output and productivity in the 1960s and 1970s may have been influenced, to some extent, by the factors such as soil erosion and extension of marginal land during those periods. The depletion of forest area, especially in the Hills of Nepal, has caused a severe problem of soil erosion in the region. In addition to this, farmers, pressured by a high population growth rate in the country, are virtually forced to cultivate marginal lands, mostly steep slopes in the Hills. However, in the absence of relevant data, it is difficult to estimate the contribution of resource degradation to the negative growth of crop output and productivity in Nepal. Therefore, a study of this nature would be of great value not only to provide insights on the effects of resource degradation on the crop output and productivity but also to formulate more appropriate future policies to prevent such resource degradation in the country.

BIBLIOGRAPHY

Abramovitz, M. (1956), 'Resources and Output Trends in the United States Since 1870', **American Economic Review** 46(2), 5-23.

Adamowicz, Wiktor (1986), 'Production Technology in Canadian Agriculture', **Canadian Journal of Agricultural Economics** 34(1), 87-104.

ADB/M (1982), **Nepal Agriculture Sector Strategy Study,** Vol. II, Asian Development Bank, Manila, (ADB/M) and His Majesty's Government of Nepal, Nepal.

ADB/N (1987), Unpublished data, Agricultural Development Bank of Nepal (ADB/N), Nepal.

Afriat, S. N. (1972), 'The Theory of International Comparisons of Real Income and Prices', in D. J. Daly (ed), **International Comparisons of Prices and Outputs**, pp. 13-69, National Bureau of Economic Research.

AIC (1988), Consumption of Improved Inputs in Nepal, Unpublished data, Agricultural Inputs Corporation (AIC), Nepal.

Angstrom, A. (1936), 'A Coefficient of Humidity of General Applicability', **Geografiska Annaler,** vol. 18, Stockholm.

Antle, J. M. and S. M. Capalbo (1988), **Agricultural Productivity: Measurement and Explanation,** Resources for the Future Inc.

Applebaum, E. (1979), 'On the Choice of Functional Forms', **International Economic Review** 20(2), 449-58.

APROSC (1986A), **Paddy Price Support Policy in Nepal,** Agricultural Projects Services Centre (APROSC), Nepal.

APROSC (1986B), **Perspective Plan for Agriculture (1985-2005),** Vol. II (Annexes), p.306-11, Agricultural Projects Services Centre (APROSC), Nepal.

Ball, V. E. (1985), 'Output, Input, and Productivity Measurement in U.S. Agriculture, 1948-79', **American Journal of Agricultural Economics** 67(3), 475-86.

Banskota, M. and I. R. Lohani (1982), **Nepalese Agriculture: A Comparative Evaluation,** Centre for Economic Development and Administration (CEDA), Nepal.

Barton, G. T. and M. R. Cooper (1948), 'Relation of Agricultural Production to Inputs', **Review of Economics and Statistics** 30(May), 117-26.

Berndt, E. R. and L. R. Christensen (1974), 'Testing for the Existence of a Consistent Aggregate Index of Labor Input', **American Economic Review** 64(3), 391-404.

Berndt, E. R., M. N. Darrough and W. E. Diewert (1977), 'Flexible Functional Forms and Expenditure Distributions: An Application to Canadian Consumer Demand Functions', **Discussion Paper** No. 77-10, Department of Economics, The University of British Colombia, B.C.

Binswanger, H. P. (1973), 'The Measurement of Biased Efficiency Gains in U.S. and Japanese Agriculture to Test the Induced Innovation Hypothesis', **Unpublished Ph.D. thesis**, North Carolina State University.

Binswanger, H. P. (1974a), 'A Cost Function Approach to the Measurement of Factor Demand Elasticities and of Elasticities of Substitution', **American Journal of Agricultural Economics** 56(2), 377-86.

Binswanger, H. P. (1974b), 'The Measurement of Technical Change Biases with Many Factors of Production', **American Economic Review** 64(6), 964-76.

Brown, R. S. (1978), 'Productivity, Returns, and the Structure of Production in the U.S. Agriculture, 1947-74', **Unpublished Ph.D. thesis**, University of Wisconsin, Madison.

Capalbo, S. M. and M. G. S. Denny (1986), 'Testing Long-run Productivity Models for the Canadian and U.S. Agricultural Sectors', **American Journal of Agricultural Economics** 68(3), 615-25.

CBS (1961), **Sample Census of Agriculture: 1961,** Central Bureau of Statistics (CBS), Nepal.

CBS (1971), **Sample Census of Agriculture: 1971,** Central Bureau of Statistics (CBS), Nepal.

CBS (1981), **Population Census, 1981,** Central Bureau of Statistics (CBS), Nepal.

CBS (1982), **Statistical Pocket Book,** Central Bureau of Statistics (CBS), Nepal.

CBS (1988), Population Statistics, Unpublished data, Central Bureau of Statistics (CBS), Nepal.

Chambers, R. G. (1988), **Applied Production Analysis: A Dual Approach,** Cambridge University Press.

Chambers, R. G. and R. E. Just (1981), 'Effects of Exchange Rate Changes on U.S. Agriculture: A Dynamic Analysis', **American Journal of Agricultural Economics** 63(1), 32-46.

Chandler, C. (1962), 'The Relative Contribution of Capital Intensity and Productivity to Changes in Output and Income', **Journal of Farm Economics** 44(2), 335-48.

Chotigeat, T. (1978), An Econometric Analysis of the Tanslog Function and the Substitution of Capital, Fertilizer, and Labour in Thai Agriculture, 1953-72, **Unpublished Ph.D. thesis**, Southern Illinois University, Carbondale.

Chowdhury, A. and G. S. Sarwade (1985), 'Evaluation of Effect of Technology and Weather Fluctuations on Rice Yields in Punjab', **Mausam** 36(2), 209-14.

Christensen, L. R. (1975), 'Concepts and Measurement of Agricultural Productivity', **American Journal of Agricultural Economics** 57(5), 910-15.

Christensen, L. R. and D. W. Jorgenson (1973), 'Measuring the Performance of the Private Sector of the U.S. Economy, 1929-69', in M. Moss (ed.) **Measuring Economic and Social Performance,** National Bureau of Economic Research, U.S.

Christensen, L. R., D. W. Jorgenson and L. J. Lau (1971), 'Conjugate Duality and the Transcendental Logarithmic Production Function', **Econometrica** 39(July), 255-56.

Christensen, L. R., D. W. Jorgenson and L. J. Lau (1973), 'Transcendental Logarithmic Production Function', **Review of Economics and Statistics** 55(...), 28-45

Dayal, R. (1966), 'Agricultural Growth Rates and Their Components', **Indian Journal of Agricultural Economics** 21(4), 227-37.

Das, A. K. L. (1982), **An Analysis of Total Factor Productivity in Nepalese Agriculture,** Centre for Economic Development and Administration, Nepal.

Debertin, D. C. (1986), **Agricultural Production Economics,** Mcmillan Publishing Company.

DFAMS (1972), **Agricultural Statistics of Nepal,** Department of Food and Agricultural Marketing Services (DFAMS), Nepal.

DFAMS (1983), **Agricultural Statistics of Nepal,** Department of Food and Agricultural Marketing Services (DFAMS), Nepal.

DFAMS (1985), **Agricultural Statistics of Nepal,** Department of Food and Agricultural Marketing Services (DFAMS), Nepal.

DFAMS (1988), **Agricultural Statistics of Nepal,** Unpublished, Department of Food and Agricultural Marketing Services (DFAMS), Nepal.

Diewert, W. E. (1971), 'An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function', **Journal of Political Economy** 79(May), 481-507.

Diewert, W. E. (1973), 'Separability and A Generalization of the Cobb-Douglas Cost, Production, and Indirect Utility Functions', **Technical Report** No. 86, IMSSS, Standford University.

Diewert, W. E. (1974), 'Applications of Duality Theory', in M. Intrilligator and D. A. Kendrick, eds., **Frontiers of Quantitative Economics,** vol. II, Amsterdam, North-Holland.

Diewert, W. E. (1976), 'Exact and Superlative Index Numbers', **Journal of Econometrics** 4(May), 115-45.

Doll, J. P. (1967), 'An Analytical Technique for Estimating Weather Indexes from Meteorological Measurements', **Journal of Farm Economics** 49(1), Part I, 79-88.

Evenson, R. E. (1967), 'The Contribution of Agricultural Research to Production', **Journal of Farm Economics** 49(5), 1415-25.

Evenson, R. E. and D. Jha (1973), 'The Contribution of Agricultural Research System to Agricultural Production in India', **Indian Journal of Agricultural Economics** 28(4), 212-30.

Evenson, R. E. and Y. Kislev (1975), **Agricultural Research and Productivity**, New Haven: Yale University Press.

Ezekiel M. and K. A. Fox (1965), **Method of Correlation and Regression Analysis**, John and Wiley and Sons, N.Y.

Fisher, I. (1922), **The Making of Index Numbers**, Boston Houghton Miffin Co.

Fisher, R. A. (1924), 'The Influence of Rainfall on the Yield of Wheat at Rothamstead', **Philosophical Transactions of the Royal Society of London**, Series B, No. 213, pp. 89-142.

Gardner, B. (1981), 'On the Power of Macroeconomic Linkage to Explain Events in U.S. Agriculture', **American Journal of Agricultural Economics** 63(5), 871-78.

Griliches, Zvi (1958), 'The Demand for Fertilizer: An Economic Interpretation of Technical Change', **Journal of Farm Economics** 40(3), 591-606.

Griliches, (1986), 'Productivity, R&D, and Basic Rsearch at the Firm Level in the 1970's', **American Economic Review** 76(1), 141-54.

Hamal, K. B. (1981), **Risk Aversion and Perception, and Adoption of New Technology and Associated Credit in Nepalese Paddy Production,** Unpublished M. Ec. Thesis, University of New England, Australia.

Hamal, K. B. and J. R. Anderson (1982), 'A Note on Decreasing Absolute Risk Aversion Among Farmers in Nepal', **Australian Journal of Agricultural Economics**, 26(3), 220-25.

Hartwick, J. M. and N. D. Olewiler (1986), **The Economics of Natural Resource Use,** Harper and Row Publishers, New York.

Hayami, Y. and V. W. Ruttan (1985), **Agricultural Development: An International Perspective,** John Hopkins University Press, Baltimore.

HMG (1972), **Agricultural Statistics of Nepal**, Economic Analysis Division, Ministry of Food and Agriculture, His Majesty's Government (HMG) of Nepal.

HMG (1984), **Budget Speech of the Fiscal Year 1984/85**, Ministry of Finance, His Majesty's Government (HMG) of Nepal.

Islam, T. (1982), 'Input Substitution and Productivity in Canadian Agriculture', **Ph.D. thesis**, University of Alberta.

Johnston, J. (1984), **Econometric Methods,** Graw-Hill Book Company.

Joshi, D. D. (1977), **Animal Health, Livestock and Dairy Development Statistics of Nepal,** Agricultural Projects Services Centre, Nepal.

Kako, T. (1978), 'Decomposition Analysis of Derived Demand of Factor Inputs: The Case of Rice Production in Japan', **American Journal of Agricultural Economics** 60(4), 628-35.

K.C., R. B. (1979), 'The Quest for Agrarian Reform in Nepal', in **Planning for Basic Needs for Mobilization of Resources,** Department of Land Reform, Nepal.

Kellogg, R. L. (1988), **Modeling Soviet Agriculture: Isolating the Effects of Weather,** Paper No. SOV88-10054, Directorate of Intelligence, Central Intelligence Agency, USA.

Kellogg, R. L. and B. Severin (1990), **Weather and Soviet Agriculture: Implications of an Economic Model',** A paper presented at the poster session of the American Agricultural Economic Association annual meeting in Vancouver, Canada, August 4-8, 1990.

Kendrick, J. W. (1961), **Productivity Trends in the United States,** National Bureau of Economic Research, U.S.

Kennedy, C. and A. P. Thirlwall (1972), 'Surveys in Applied Economics: Technical Progress', **Economic Journal** 82(March), 11-72.

Kiefer, N. M. (1975), 'Quadratic Utility, Labor Supply, and Commodity Demand', **Working Paper** No. 67, Industrial Relations Section, Princeton University.

Kloek, T. (1966), **Indexciffers: Enige Methodologisch Aspecten,** The Hague: Pasmans.

Kmenta, Jan (1971), **Elements of Econometrics,** MacMillan Publishing Company, New York.

Koutsoyiannis, A. (1981), **Theory of Econometrics,** Second Edition, MacMillan Press Ltd., London.

Krishna, Raj (1982), 'Some Aspects of Agricultural Growth, Price Policy and Equity in Developing Countries', **Food Research Institute Studies** 18(3), 219-60.

Krueger, A. O. and B. Tuncer (1980), 'Estimating Total Factor Productivity Growth in a Developing Country', **World Bank Staff Working Paper** No. 422, World Bank, Washington D. C.

Lang, R. (1920), **Verwitterung und Bodenbildung als Eifuhrung die Bodenkunde,** Stuttgart.

Lau, L. (1974), 'Comments on Application of Duality Theory', in M. D. Intrilligator and D. A. Kendrick (ed.), **Frontiers of Quantitative Economics**, vol. 2, North-Holland Publishing Co., Amsterdam.

Lave, L. B. (1964), 'Technical Change in U.S. Agriculture: The Aggregation Problem', **Journal of Farm Economics** 46(1), 200-17.

Lin, J. Y. (1990), 'Collectivization and China's Agricultural Crisis in 1959-1961', **Journal of Political Economy** 98(61), 1228-52.

Longmire, J. and A. Morey (1983), **Strong Dollar Dampens Demand for U.S. Farm Exports**, Foreign Agricultural Economics Report No. 193, Economic Research Service, USDA.

Loomis, R. A. and G. T. Barton (1961), 'Productivity of Agriculture, United States 1870-1958', **USDA Technical Bulletin** No. 1238.

Manning, T. W. (1984), **The Effects of Rising Energy Prices on Grain Production**, Unpublished paper, Department of Rural Economy, university of Alberta.

Manning, T. W. (1985), **Alberta Agricultural Productivity, 1926 to 1984**, Unpublished paper, Department of Rural Economy, University of Alberta.

de Martonne, Emmanuel (1926), 'Une Nouvelle Function Climatologique: l'Indiced' Aridite', **La meteorologie**, Paris, October.

Mathema, P. R. (1974), **Economic Analysis of Retail Prices of Cereal Grains in Nepal**, Unpublished Ph. D. Thesis, University of Alberta, Canada.

Minasian, J. R. (1969), 'Research and Development, Production Functions, and Rates of Return', **American Economic Review** 59(2), 80-85.

McFadden, D. (1978), 'The General Linear Profit Function', in M. Fuss and D. Mcfadden (ed.), **Production Economics: A Dual Approach to Theory and Application**, vol.1, 269-89, North-Holland, Amsterdam.

Minhas, B. S. (1966), 'Measurement of Agricultural Growth', **Indian Journal of Agricultural Economics**, Repporteur's Report, 21(4), 165-82.

Minhas, B. S. and A. Vaidyanathan (1965), 'Growth of Crop Output in India: 1951-54 to 1958-61: An Analysis by Component Elements', **Indian Society of Agricultural Statistics**, 17(2), 230-52.

Mundlak, Y. and A. Razin (1969), 'Aggregation, Index Numbers and the Measurement of Technical Change', **Review of Economics and Statistics** 51(May), 166-75.

Nadiri, M. I. (1970), 'Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey', **Journal of Economic Literature** 8(Dec.), 1137-77.

Narain, D. (1977), 'Growth of Productivity in Indian Agriculture', **Indian Journal of Agricultural Economics** 32(1), 1-44.

NPC (1984), **Basic Principles of the Seventh Plan (1985-90),** National Planning Commission (NPC), Nepal.

NRB (1980), **Agricultural Credit Review Survey,** Nepal Rastra Bank (NRB), Nepal.

NRB (1982), **Quarterly Economic Bulletin,** January-April issue, Nepal Rastra Bank (NRB), Nepal.

NRB (1988), **Quarterly Economic Bulletin,** January-April issue, Nepal Rastra Bank (NRB), Nepal.

Oury, B. (1965), 'Allowing for Weather in Crop Production Model Building', **Journal of Farm Economics** 47(2), 270-83.

Peterson, W. L. (1967), 'Returns to Poultry Research in the United States', **Journal of Farm Economics** 49(3), 656-69.

Peterson, W. L. (1971), 'Returns to Investment on Agricultural Research in the United States', in W. L. Fishel (ed.), **Resource Allocation in Agricultural Research,** Minneapolis: University of Minnesota Press.

Peterson, W. L. and Yujiro Hayami (1977), 'Technical Change in Agriculture', in L. R. Martin (ed.), **A Survey of Agricultural Economics Literature: Traditional Fields of Agricultural Economics: 1940^{S} to 1970^{S}**, Vol. I.

Pokharel, N. B. and G. P. Shivakoti (1986), **Impact of Development Efforts on Agricultural Wage Labor,** Rural Poverty Research Paper Series, No. 1, Winrock International, Kathmandu, Nepal.

Pollak, R. A. (1971), 'The Theory of the Cost of Living Index', **Research Discussion Paper** No. 11, Office of Prices and Living Conditions, U.S. Bureau of Labor Statistics, Washington D.C.

Rahuma, A. A. and T. S. Veeman (1988), 'Productivity Growth in the Prairie Grain Sector and Its Major Soil Zones: 1960s to 1980s', **Canadian Journal of Agricultural Economics** 36(...), 857-70.

Rahuma, A. A. (1989), **Productivity Growth and Production Technology in Prairie Grain Sector,** Unpublished Ph. D. Thesis, University of Alberta, Canada.

Ramamurthy, K. S. and J. R. Banerjee (1966), 'On the Influence of Weather on Wheat Yields at Dharwar', **Indian Journal of Meteorology and Geophysics** 17(4), 601-6.

Ruttan, V. W. (1954), 'Technological Progress in the Meat Packing Industry', **USDA Marketing Research Report** No. 59.

Ruttan, V. W. (1956), 'The Contribution of Technological Progress to Farm Output: 1950-75', **Review of Economics and Statistics** 38(Feb.), 61-69.

Ruttan, V. W. (1957), 'Agricultural and Nonagricultural Growth in Output Per Unit of Input', **Journal of Farm Economics** 39(Dec.), 1566-75.

Sagar, V. (1977), 'A Component Analysis of the Growth of Productivity and Production in Rajasthan: 1956-61 to 1969-74', **Indian Journal of Agricultural Economics** 32(1), 108-19.

Sagar, V. (1980), 'Decomposition of Growth Trends and Certain Related Issues', **Indian Journal of Agricultural Economics** 35(2), 42-59.

Samuelson, P. A. and S. Swamy (1974), 'Invariant Index Numbers and Canonical Duality: Survey and Synthesis', **American Economic Review** 64(4), 566-93.

Schmitz, A. and D. Seckler (1970), 'Mechanized Agriculture and Social Welfare: The Case of Tomato Harvester', **American Journal of Agricultural Economics** 52(4), 569-77.

Schuh, E. (1976), 'The New Macroeconomics of Agriculture', **American Journal of Agricultural Economics** 58(5), 802-11.

Schultz, T. W. (1953), **Economic Organization of Agriculture**, McGraw-Hill, N.Y.

Schultz, T. W. (1961), 'A Policy to Redistribute Losses from Farm Progress', **Journal of Farm Economics** 43(3), 554-65.

Shaha S. K. and J. R. Banerjee (1975), 'Influence of Rainfall, Humidity, Sunshine, Maximum and Minimum Temperatures on the Yield of Cotton at Coimbatore', **Indian Journal of Meteorology, Hydrology and Geophysics** 26(4), 518-24.

Shaw, L. H. (1964), 'The Effect of Weather on Agricultural Output: A Look at Meteorology', **Journal of Farm Economics** 46(1), 218-30.

Shephard, R. W. (1953), **Cost and Production Functions**, Princeton University Press.

Solow, R. M. (1957), 'Technical Change and the Aggregate Production Function', **Review of Economics and Statistics** 39(Aug), 312-20.

Sreenivasan, P. S. (1973), 'Influence of Rainfall on the Yield of Cotton in Madhya Pradesh', **Indian Journal of Agricultural Sciences** 43(9), 854-59.

Sreenivasan, P. S. and J. R. Banerjee (1973), 'Studies on the Forecasting of Yield by Curvilinear Technique : Rabi Jowar (Sorghum) at Raichur', **Indian Journal of Meteorology, Hydrology and Geophysics** 24(1), 49-56.

Stallings, J. L. (1960), 'Weather Indexes', **Journal of Farm Economics** 42(1), 180-86.

Stallings, J. L. (1961), 'Weather and Crop Yields - A Measure of the Influence of Weather on Crop Production', **Journal of Farm Economics** 43(5), 1153-60.

Svejnar, J. and E. Thorbecke (1984), **Macro-Economic Policies and Agricultural Performance in Nepal**, Second Draft, OECD Development Centre, Paris.

Theil, H. (1965), 'The Information Approach to Demand Analysis', **Econometrica** Vol.33, 67-87.

Thompson, L. M. (1969), 'Weather and Technology in the Production of Corn in the U.S. Corn Belt', **Agronomy Journal** 61(3), 453-56.

Thompson, L. M. (1970), 'Weather and Technology in the Production of Soybeans in the Central United States', **Agronomy Journal** 62(2), 232-36.

Tornqvist, L. (1936), 'The Bank of Finland's Consumption Price Index', **Bank of Finland Monthly Bulletin** No. 10, pp. 1-8.

Van Duyne, C. (1979), 'The Macroeconomic Effects of Commodity Market Disruptions in Open Economies', **Journal of International Economics** 9(4), 559-82.

Veeman, T. S. and A. A. Fanito (1985), 'Productivity Growth in Western Canadian Agriculture: Empirical Measurement, Underlying Causal Influences and Policy Implications', **Technical Report**, Department of Rural Economy/Economics, University of Alberta.

Wallace, M. B. (1987), **Food Price Policy in Nepal,** Research Report Series No. 3, HMG-USAID-GTZ-IDRC-FORD-WINROCK Project, Nepal.

White, K. J. and N. G. Horsman (1987), **SHAZAM: The Econometric Computer Progam, Version 6.0,** Department of Economics, University of British Columbia, Vancouver.

Wong, Lung-Fai (1987), **Agricultural Productivity in China and India: A Comparative Analysis,** Bulletin No. 87-3, Economic Development Center, University of Minnesota.

Wong, Lung-Fai (1989), 'Agricultural Productivity in China and India: A Comparative Analysis', **Canadian Journal of Agricultural Economics** 37(1), 77-93.

World Bank (1975), **Agricultural Credit, Sector Policy Paper,** Washington, D.C.

Yadav, R. R. (1987), 'Agricultural Research in Nepal: Resource Allocation, Structure, and Incentives', **Research Report** No. 62, International Food Policy Research Institute.

Yotopoulos, P. A. and J. B. Nugent (1976), **Economics of Development**, Harper and Row.

Zellner, A. (1962), 'An efficient Method of Estimating Seemingly Unrelated Regressions and Tests of Aggregate Bias', **Journal of American Statistical Association** Vol. 57, 348-68.

APPENDIX 1

DATA ON CROP OUPUTS AND INPUTS

TABLE A1.1
ANNUAL CROP OUPUT QUANTITIES IN NEPAL IN METRIC TONS

Year	Paddy	Maize	Wheat	Millet	Barley	Potato	Oil-Seeds	Sugar-cane	Jute	Tobacco
1961/62	2108000	843000	138000	98617	26082	213416	46911	116425	37000	7237
1962/63	2108000	843000	138000	100108	25926	218819	48050	124742	36000	7130
1963/64	2109000	849000	139000	64000	25771	224358	49217	133653	36000	7023
1964/65	2201000	854000	126000	63000	26000	186000	51000	126000	39000	9000
1965/66	2207000	856000	147000	120000	28000	277000	51000	192000	39000	9000
1966/67	2007000	824000	159000	120000	28000	300000	56000	147000	38000	5000
1967/68	2118939	745578	203957	113470	22640	246271	51831	169483	45792	6297
1968/69	2178255	764796	232690	120986	23287	249741	53681	189281	43243	6530
1969/70	2241233	794906	264680	125464	24381	263185	57591	215680	49385	6704
1970/71	2304204	833318	193360	129310	25377	272490	54895	235611	52995	6859
1971/72	2343800	758700	223174	129500	25459	293370	57444	244820	58059	6898
1972/73	2010446	822004	312494	135354	24815	293500	59580	245640	55454	7040
1973/74	2416307	813600	308442	141900	25627	304190	63618	266760	40136	3745
1974/75	2452268	826653	330825	142200	25600	307480	65848	251425	41350	4790
1975/76	2603761	747785	387000	142600	24660	313510	68487	253030	42000	4830
1976/77	2386280	797300	361853	138000	20555	270030	61380	311380	45000	5132
1977/78	2282470	740470	411300	129510	22450	271870	78450	386710	56000	6030
1978/79	2339280	742590	415200	133130	22690	278790	92500	369930	65551	5490
1979/80	2059930	575900	439990	119340	23300	278400	61870	385070	67514	5500
1980/81	2464310	742940	477200	121530	23000	280540	77140	479780	59284	5490
1981/82	2560080	751500	525870	121700	23340	321100	79120	590000	42663	4820
1982/83	1832600	718200	656600	121100	21200	372970	69590	616090	39039	6640
1983/84	2757000	761100	633700	114900	22300	383080	73350	509070	25048	6880
1984/85	2709400	819900	533700	124400	23600	420160	84030	408260	33124	6430
1985/86	2804500	873800	598000	137900	23400	356720	78660	558340	61102	4680
1986/87	2372000	868400	701000	137600	24700	395110	82500	616580	23452	4890
1987/88	2981800	901500	744600	150100	24300	566950	94370	814400	15800	4460

Adapted from DFAMS (1972, 1983, 1985 and 1988).

TABLE A1.2
ANNUAL CROP OUTPUT PRICES IN NEPAL IN RUPEES PER KILOGRAM

Year	Paddy	Maize	Wheat	Millet	Barley	Potato	Oil-Seeds	Sugar-cane	Jute	Tobacco
1961/62	0.65	0.62	0.99	0.55	0.44	0.86	0.82	0.06	1.41	4.29
1962/63	0.62	0.66	0.84	0.54	0.43	0.84	0.92	0.06	1.47	4.73
1963/64	0.77	1.18	1.03	0.75	0.60	1.18	1.03	0.07	1.53	5.21
1964/65	0.90	1.13	1.40	0.83	0.66	1.30	1.15	0.07	1.59	5.74
1965/66	1.13	1.10	1.64	1.02	0.81	1.18	1.25	0.08	3.89	9.36
1966/67	1.07	1.03	1.48	1.06	0.79	1.03	1.47	0.08	1.20	6.15
1967/68	1.10	1.21	2.42	1.26	0.83	0.91	1.64	0.12	1.05	5.47
1968/69	1.20	1.11	1.56	1.03	0.85	1.00	1.79	0.12	2.06	8.15
1969/70	1.31	1.21	1.55	1.19	0.81	1.08	1.94	0.12	1.99	9.33
1970/71	1.26	1.19	1.44	1.13	0.90	1.42	2.18	0.12	2.01	9.46
1971/72	1.41	1.32	1.66	1.23	0.98	1.37	2.29	0.12	2.23	10.69
1972/73	1.65	1.69	2.29	1.69	1.05	1.51	2.93	0.12	2.65	12.70
1973/74	1.76	1.70	2.47	1.82	1.04	1.99	3.62	0.12	1.99	13.27
1974/75	1.79	1.95	3.11	1.86	1.17	1.76	4.63	0.17	2.08	17.78
1975/76	1.74	2.04	2.51	2.02	1.14	1.68	3.47	0.23	2.57	20.87
1976/77	1.59	1.86	2.17	1.77	0.92	1.84	3.54	0.23	2.81	22.13
1977/78	1.92	2.18	2.46	2.00	1.05	2.17	5.39	0.23	3.20	17.36
1978/79	1.66	2.16	2.49	2.15	1.21	2.18	5.32	0.19	2.50	24.97
1979/80	1.71	2.26	2.52	2.44	1.21	1.93	6.61	0.29	2.17	23.46
1980/81	1.83	2.44	2.78	2.62	1.45	2.53	6.68	0.32	1.95	23.48
1981/82	2.15	2.49	2.83	2.92	1.46	2.47	7.71	0.31	2.37	25.96
1982/83	2.54	2.97	3.51	3.15	1.53	2.57	8.63	0.34	3.20	27.29
1983/84	2.86	3.44	3.55	3.40	1.61	3.24	9.65	0.37	4.65	28.61
1984/85	2.65	2.88	3.14	3.67	1.69	2.80	10.7	0.40	9.32	29.94
1985/86	3.00	3.62	3.89	3.96	1.78	3.43	12.0	0.43	3.70	31.27
1986/87	3.52	3.79	4.17	4.27	1.86	4.75	13.5	0.47	3.11	32.60
1987/88	4.39	4.36	4.87	4.61	1.96	4.47	15.1	0.51	3.85	33.93

Adapted from DFAMS (1972, 1983, 1985 and 1988) and Mathema (1974).

TABLE A1.3
ANNUAL CROPPED AREA IN NEPAL IN HECTARES

Year	Paddy	Maize	Wheat	Millet	Barley	Potato	Oil-Seeds	Sugar-cane	Jute	Tobacco
1961/62	1088000	432000	112000	84796	25540	35525	94089	9311	30000	8127
1962/63	1090000	431000	112000	86769	25617	36461	95416	9721	32000	8111
1963/64	1090000	434000	113000	69000	25694	37421	96761	10148	32000	8095
1964/65	1101000	437000	100000	69000	24000	29000	108000	9000	32000	8000
1965/66	1111000	451000	118000	100000	27000	42000	96000	13000	32000	8000
1966/67	1100000	450000	126000	100000	27000	43000	98000	10000	32000	8000
1967/68	1154290	412050	192255	102080	24873	42735	97435	11010	46922	8481
1968/69	1162015	421510	205665	108330	25643	43300	100710	12303	46025	8674
1969/70	1173170	432910	225575	111005	26379	45605	103440	13490	51685	8818
1970/71	1182478	445800	228400	114795	27296	48570	105510	14385	55000	9090
1971/72	1200800	438600	239183	114745	27522	50935	111355	15112	57845	9110
1972/73	1140153	445533	259388	120797	27127	51140	112264	14890	53411	9280
1973/74	1227007	453312	273925	125200	27500	53130	113920	15869	33097	5420
1974/75	1239853	458027	290859	125049	27500	53750	122000	15200	34218	6720
1975/76	1255845	452500	328600	125500	26478	53284	112991	15080	33000	6740
1976/77	1261600	445400	348300	121794	24900	52290	107750	17990	40000	6964
1977/78	1264060	444960	367200	121110	25500	50650	133060	22880	47000	7990
1978/79	1262650	454140	356180	123410	26160	50700	143980	21990	46853	7590
1979/80	1254200	432300	366860	122800	26020	51330	118130	22420	56714	7520
1980/81	1275522	457450	391800	121780	26700	49580	122280	23960	51959	7210
1981/82	1296530	475500	399900	122100	27000	52010	113900	25170	35320	6840
1982/83	1264800	510800	483800	129100	24300	59200	110340	25410	30400	8960
1983/84	1334200	503800	471800	123900	24800	58880	110700	22740	23666	9050
1984/85	1376900	578700	451900	134400	27600	65540	127820	17480	27200	8550
1985/86	1391000	614700	482800	151100	29300	69960	138460	23010	47191	8680
1986/87	1333400	626700	535500	150800	28600	74310	142890	24910	19840	8820
1987/88	1423300	673800	596800	164800	29100	80180	151490	29520	14450	6470

Adapted from DFAMS (1972, 1983, 1985 and 1988).

TABLE A1.4
TOTAL INPUTS USED IN NEPALESE CROP SECTOR

Year	Land[1] ('000' Hectares)	Labour[2]		Bullocks[2]	
		('000' Persons)	('000' Persondays)	('000' Heads)	('000' Bullockdays)
1961/62	1919.388	4966.064	968383	2691	161460
1962/63	1927.095	5008.648	976686	2798	167880
1963/64	1916.119	5051.598	985062	2904	174240
1964/65	1917.000	5094.916	993509	3010	180600
1965/66	1998.000	5138.605	1002028	3117	187020
1966/67	1994.000	5182.669	1010620	3325	199500
1967/68	2092.131	5227.111	1019287	3396	203760
1968/69	2134.175	5271.934	1028027	3464	207840
1969/70	2192.077	5317.141	1036842	3533	211980
1970/71	2231.324	5362.736	1045734	3617	217020
1971/72	2265.207	5588.309	1089720	3637	218220
1972/73	2233.983	5651.178	1101980	3671	220260
1973/74	2328.380	5714.754	1114377	3706	222360
1974/75	2373.176	5779.045	1126914	4256	255360
1975/76	2410.018	5844.060	1139592	4312	258720
1976/77	2426.988	5909.806	1152412	4357	261420
1977/78	2484.410	5976.292	1165377	4404	264240
1978/79	2493.653	6043.526	1178488	4497	269820
1979/80	2458.294	6111.516	1191746	4603	276180
1980/81	2528.241	6180.271	1205153	4709	282540
1981/82	2554.270	6382.510	1244589	4816	288960
1982/83	2647.110	6491.622	1265866	4922	295320
1983/84	2683.536	6602.599	1287507	5028	301680
1984/85	2816.090	6715.473	1309517	5134	308040
1985/86	2956.201	6830.277	1331904	5240	314400
1986/87	2945.770	6947.044	1354674	5346	320760
1987/88	3169.910	7065.807	1377832	5451	327060

1. Table A1.3 of Appendix 1.
2. Sections (4.5.2) and (4.5.3) of Chapter 4.

(CONTINUED ...... TABLE A1.4)

Year	Chemical Fertilizer[3] (MT)				HYV Seeds[3] (MT)
	N	P	K	Total	
1961/62	495	103	65	663	24
1962/63	597	127	73	797	32
1963/64	345	9	24	378	40
1964/65	370	180	42	592	36
1965/66	342	99	10	451	145
1966/67	1070	279	104	1453	302
1967/68	1839	728	167	2734	770
1968/69	2382	659	159	3200	728
1969/70	3380	1049	156	4585	661
1970/71	4111	1081	214	5406	475
1971/72	5554	1952	462	7968	1135
1972/73	7698	3150	105	10953	2083
1973/74	9003	3167	918	13088	1826
1974/75	8923	2849	886	12658	1934
1975/76	8423	2491	135	11049	2055
1976/77	10694	2778	142	13614	2275
1977/78	13012	3383	1072	17467	2541
1978/79	13746	3341	1456	18543	2422
1979/80	15500	4286	1178	20964	2919
1980/81	16768	5105	586	22459	3511
1981/82	17976	5073	774	23823	2566
1982/83	22882	7459	939	31280	3641
1983/84	28058	8463	779	37300	3000
1984/85	31656	10623	550	42829	2117
1985/86	31698	11053	657	43408	2465
1986/87	32910	11936	208	45054	2411
1987/88	37300	15121	1062	53483	2690

3. Adapted from DFAMS (1972, 1983 and 1985) and AIC (1988).

TABLE A1.5

TOTAL POPULATION, PERCENTAGE OF ECONOMICALLY ACTIVE POPULATION, TOTAL ECONOMICALLY ACTIVE POPULATION AND TOTAL AGRICULTURAL LABOUR FORCE

Year	Total Population[1]	Percentage of Economically Active Population[2]	Total Economically Active Population[2]	Total Agricultural Labour Force[2]
1961/62	9412996	56.23	5293183	4966064
1962/63	9582430	55.71	5338572	5008648
1963/64	9754914	55.20	5384351	5051598
1964/65	9930502	54.69	5430522	5094916
1965/66	10109251	54.18	5477089	5138605
1966/67	10291218	53.68	5524056	5182669
1967/68	10476460	53.18	5571425	5227111
1968/69	10665036	52.69	5619200	5271934
1969/70	10857007	52.20	5667385	5317141
1970/71	11052433	51.72	5715983	5362736
1971/72	11555983	51.24	5921073	5588309
1972/73	11795192	50.76	5987686	5651178
1973/74	12039352	50.29	6055048	5714754
1974/75	12288567	49.83	6123167	5779045
1975/76	12542940	49.37	6192054	5844060
1976/77	12802579	48.91	6261715	5909806
1977/78	13067592	48.46	6332159	5976292
1978/79	13338092	48.01	6403397	6043526
1979/80	13614190	47.56	6475435	6111516
1980/81	13896004	47.12	6548285	6180271
1981/82	15022839	46.69	7013747	6382510
1982/83	15422447	46.25	7133650	6491622
1983/84	15832684	45.83	7255603	6602599
1984/85	16253833	45.40	7379641	6715473
1985/86	16686185	44.98	7505799	6830277
1986/87	17130037	44.57	7634114	6947044
1987/88	17585696	44.15	7764623	7065807

1. Adapted from CBS (1988).
2. Section (4.5.2) of Chapter 4.

TABLE A1.6

AGGREGATE PRICES OF CROP INPUTS IN NEPAL

Year	Land[1] Index	Land[1] (Rs/ha)	Labour[2] (Rs/Personday)	Bullock[3] (Rs/Bullockday)	Fertilizer[4] (Rs/MT)	HYV Seeds[4] (Rs/MT)
1961/62	100.00	3365.69	1.22	1.22	868	1040
1962/63	98.65	3320.42	1.36	1.36	924	1100
1963/64	133.44	4491.04	1.57	1.57	952	1164
1964/65	147.42	4961.82	1.69	1.69	1047	1556
1965/66	176.26	5932.45	1.88	1.88	1115	1559
1966/67	161.57	5437.82	2.09	2.09	1060	1556
1967/68	184.87	6222.13	2.33	2.33	1313	1213
1968/69	183.16	6164.63	2.59	2.59	1400	1370
1969/70	197.65	6652.26	2.88	2.88	1400	1433
1970/71	194.20	6536.14	3.16	3.16	1342	1549
1971/72	216.11	7273.74	3.21	3.21	1535	1672
1972/73	266.83	8980.83	3.94	3.94	1535	2037
1973/74	280.38	9436.75	3.41	3.41	2193	2043
1974/75	312.42	10515.00	4.41	4.41	2193	2131
1975/76	295.22	9936.34	4.95	4.95	2440	2828
1976/77	272.32	9165.38	6.21	6.21	2440	2929
1977/78	330.76	11132.38	7.00	7.00	2440	2905
1978/79	315.48	10618.22	7.00	7.00	2440	2880
1979/80	326.78	10998.36	7.50	7.50	2440	3960
1980/81	349.42	11760.44	10.00	10.00	3100	2655
1981/82	383.00	12890.68	10.00	10.00	3100	2747
1982/83	454.21	15287.19	12.00	12.00	3500	3364
1983/84	501.58	16881.50	15.00	15.00	3500	3471
1984/85	479.61	16142.29	16.00	16.00	3500	3074
1985/86	551.66	18567.33	16.00	16.00	3500	3827
1986/87	619.69	20856.92	18.00	18.00	4200	4121
1987/88	721.80	24293.71	20.00	20.00	3990	4804

1. Section (4.6.1) of Chapter 4.
2. Adapted from DFAMS (1983) and Pokhrel and Shivakoti (1986).
3. Section (4.6.3).
4. Adapted from AIC (1988).

TABLE A1.7
AGGREGATE REGIONAL DATA ON CROP OUTPUT AND INPUTS IN NEPAL

Year	Output[1] (Rs'000000')	Land[1] ('000'ha)	Labour[1] ('000' Persons)	Bullocks[2] ('000' Heads)	Fertilizer[3] (N+P+K) (MT)	HYV Seeds[4] (Rs'000')
			Hills Region			
1969/70	2770.500	682.800	2584.503	1363	257.68	23.320
1970/71	2670.062	702.437	2605.919	1389	104.22	10.046
1971/72	3141.884	696.564	2629.306	1400	256.77	139.094
1972/73	2955.265	707.937	2666.201	1411	611.40	351.493
1973/74	2648.443	752.643	2703.709	1423	665.56	225.244
1974/75	3049.856	755.442	2741.631	1492	750.16	674.929
1975/76	3479.505	763.605	2780.361	1514	1380.87	1816.975
1976/77	3158.145	736.989	2819.743	1526	1623.63	1727.406
1977/78	3179.460	774.545	2859.745	1542	2410.14	2757.940
1978/79	5216.278	794.155	2900.421	1570	2240.66	2175.000
1979/80	3585.306	774.274	2941.765	1594	3346.67	3643.640
1980/81	4640.411	802.229	2983.791	1618	4079.23	3002.178
			Kathmandu Valley			
1969/70	239.2797	72.652	217.144	-	2809.32	165.861
1970/71	248.1491	74.581	219.750	-	3091.64	67.526
1971/72	281.3706	75.083	222.139	-	3759.75	196.124
1972/73	325.5476	72.860	225.396	-	4495.20	345.971
1973/74	293.7759	74.479	228.653	-	4360.93	670.486
1974/75	344.8133	85.786	231.910	-	4198.44	77.722
1975/76	365.6041	73.852	235.167	-	4574.95	146.964
1976/77	271.2782	70.043	238.642	-	5765.22	138.835
1977/78	329.0121	69.090	241.899	-	5378.59	75.936
1978/79	338.7171	66.570	245.373	-	5996.17	71.317
1979/80	311.3874	64.460	249.065	-	6494.20	89.614
1980/81	353.8051	64.580	252.539	-	7260.76	70.331
			Tarai Region			
1969/70	3110.528	1297.400	1288.078	2170	1433.24	1039.100
1970/71	3505.322	1455.265	1280.525	2228	2113.51	832.428
1971/72	3711.381	1346.363	1354.154	2237	3938.19	2065.726
1972/73	3835.746	1302.625	1375.804	2260	5166.91	3246.376
1973/74	4070.324	1355.896	1397.834	2283	6618.76	3076.711
1974/75	4541.693	1391.290	1410.246	2764	7692.32	3994.118
1975/76	3391.133	1468.405	1442.987	2798	6201.84	4621.767
1976/77	4452.933	1446.652	1466.185	2831	7720.59	6035.667
1977/78	4356.687	1488.666	1489.687	2862	9165.03	6510.821
1978/79	6047.830	1665.739	1513.699	2927	9424.33	6563.840
1979/80	3277.361	1408.180	1538.029	3009	10478.30	9443.880
1980/81	5981.468	1496.037	1562.011	3091	11471.00	7974.398

1. Adapted from Das (1982, pp.9-11). Data on output, land and labour in the case of Kathmandu Valley are derived from DFAMS (1972 and 1983).
2. Derived from districtwise population of adult bullocks in DFAMS (1983, p.311). Bullocks are not used in Kathmandu valley because of religious reason.
3. Adapted from Svejnar and Thorbecke (1984, Table A33-A36, Appendix A).
4. Adapted from AIC (1988).

TABLE A1.8

COST SHARES OF INPUTS IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88[1]

Year	Land	Labour	Bullocks	Fertilizer	HYV Seeds	Total
1961/62	82.4085	15.0710	2.5128	0.0073	0.0003	100.0000
1962/63	80.4254	16.6952	2.8697	0.0093	0.0004	100.0000
1963/64	82.5385	14.8337	2.6238	0.0035	0.0004	100.0000
1964/65	82.7349	14.6044	2.6548	0.0054	0.0005	100.0000
1965/66	84.1287	13.3706	2.4955	0.0036	0.0016	100.0000
1966/67	81.0743	15.7931	3.1176	0.0115	0.0035	100.0000
1967/68	82.0170	14.9633	2.9912	0.0226	0.0059	100.0000
1968/69	80.4045	16.2722	3.2898	0.0274	0.0061	100.0000
1969/70	80.1830	16.4196	3.3569	0.0353	0.0052	100.0000
1970/71	78.4836	17.7829	3.6905	0.0390	0.0040	100.0000
1971/72	79.6385	16.9074	3.3858	0.0591	0.0092	100.0000
1972/73	79.3202	17.1655	3.4310	0.0665	0.0168	100.0000
1973/74	82.7177	14.3057	2.8545	0.1081	0.0140	100.0000
1974/75	80.2851	15.9891	3.6232	0.0893	0.0133	100.0000
1975/76	77.4947	18.2549	4.1444	0.0872	0.0188	100.0000
1976/77	71.6078	23.0378	5.2260	0.1069	0.0215	100.0000
1977/78	73.3332	21.6299	4.9044	0.1130	0.0196	100.0000
1978/79	72.2095	22.4973	5.1508	0.1234	0.0190	100.0000
1979/80	70.9464	23.4538	5.4353	0.1342	0.0303	100.0000
1980/81	66.5335	26.9675	6.3223	0.1558	0.0209	100.0000
1981/82	68.1102	25.7452	5.9773	0.1528	0.0146	100.0000
1982/83	68.2147	25.6063	5.9738	0.1845	0.0206	100.0000
1983/84	65.3891	27.8758	6.5317	0.1884	0.0150	100.0000
1984/85	63.5819	29.3057	6.8936	0.2097	0.0091	100.0000
1985/86	67.4384	26.1828	6.1805	0.1867	0.0116	100.0000
1986/87	66.9302	26.5632	6.2896	0.2061	0.0108	100.0000
1987/88	69.1698	24.7515	5.8753	0.1917	0.0116	100.0000

1. Derived from input quantity and price data of Tables A1.4 and A1.6 of Appendix 1.

TABLE A1.9
AVERAGE MONTHLY RAINFALL IN MILLIMETER IN NEPAL BY REGION: 1969/70 - 1980/81

Year	Month 1	2	3	4	5	6	7	8	9	10	11	12
Hills												
1969	19.6	12.5	40.5	84.1	118.8	157.2	363.5	316.5	273.4	127.4	21.6	0.8
1970	36.3	35.9	21.9	31.6	122.9	369.1	520.8	383.8	214.4	20.5	1.0	0.0
1971	3.8	18.6	37.8	186.6	137.5	548.3	301.3	423.0	187.5	161.0	1.8	0.3
1972	30.0	22.3	40.0	40.5	108.0	273.8	506.0	245.0	260.8	64.0	29.8	0.0
1973	37.3	30.3	32.0	35.0	239.0	298.3	312.0	431.0	330.0	94.7	0.7	6.0
1974	21.3	20.5	32.5	47.0	133.5	164.5	330.5	429.0	279.3	55.5	3.5	17.4
1975	28.3	32.8	18.5	65.3	297.0	343.0	428.0	312.3	295.8	29.0	0.0	0.0
1976	32.0	19.0	4.3	61.3	251.7	483.7	500.7	492.7	217.0	47.0	1.3	0.3
1977	20.3	17.0	25.5	166.0	157.8	260.3	515.5	416.3	192.8	90.8	39.5	41.8
1978	10.0	36.0	81.5	97.2	213.0	390.3	446.3	368.0	282.8	40.0	22.0	11.8
1979	9.2	39.8	19.0	67.0	61.5	215.5	487.5	373.7	161.0	58.5	12.5	72.8
1980	0.0	5.0	30.0	9.0	91.0	386.0	384.0	239.0	246.0	8.0	0.0	4.0
Kathmandu Valley												
1969	23.0	3.00	41.8	29.4	117.3	114.1	558.8	510.8	510.5	441.5	86.4	3.2
1970	33.6	43.3	23.6	80.8	147.5	346.5	607.5	645.7	286.0	55.3	4.1	0.0
1971	0.0	6.0	36.0	141.0	81.0	785.0	438.0	642.0	137.0	116.0	0.0	0.0
1972	8.0	21.0	108.0	19.0	42.0	213.0	651.0	304.0	246.0	68.0	98.0	0.0
1973	9.0	5.0	21.0	44.0	252.0	253.0	459.0	532.0	376.0	37.0	0.0	18.0
1974	8.0	28.0	66.0	23.0	214.0	342.3	542.9	665.0	628.0	168.0	14.0	0.0
1975	29.0	40.0	11.0	101.0	149.0	262.0	622.0	772.0	476.0	78.0	0.0	0.0
1976	26.0	13.0	0.0	75.0	301.0	447.0	568.0	559.0	302.0	41.0	0.0	1.0
1977	18.0	8.0	26.0	85.0	156.0	382.0	614.0	357.0	149.0	21.0	33.0	52.0
1978	2.0	22.0	55.0	61.0	136.0	253.0	319.0	493.0	290.0	37.0	0.0	3.0
1979	6.0	43.0	0.0	53.0	33.0	131.0	410.0	267.0	62.0	21.0	9.0	64.0
1980	0.0	5.0	30.0	9.0	91.0	386.0	384.0	239.0	246.0	8.0	0.0	4.0
Tarai												
1969	6.0	3.3	29.1	26.6	67.3	268.6	484.8	535.3	248.3	30.3	0.0	0.0
1970	28.0	3.5	11.2	24.2	106.9	362.0	520.6	357.5	267.6	65.3	0.0	0.0
1971	16.0	22.5	25.0	265.0	176.5	378.0	691.5	517.0	322.5	202.0	0.0	0.0
1972	5.3	29.3	2.7	50.7	11.0	271.0	534.3	230.7	305.3	39.3	2.0	0.0
1973	52.0	33.5	8.0	11.5	50.5	578.0	323.0	254.0	321.5	192.5	0.0	0.0
1974	12.7	4.7	28.3	20.7	70.7	357.0	702.0	621.7	302.0	146.3	0.0	6.0
1975	30.3	11.0	9.7	21.0	135.7	505.3	907.7	280.3	458.0	143.0	0.0	0.0
1976	10.7	17.3	2.0	38.0	115.7	379.0	423.3	475.0	149.7	47.3	0.0	0.0
1977	3.3	5.0	0.0	100.0	118.0	183.3	505.0	605.7	245.7	133.7	50.7	32.0
1978	9.0	22.3	41.7	87.0	83.0	352.7	465.0	330.5	375.0	54.3	6.0	6.7
1979	9.3	29.7	0.0	34.7	53.0	161.0	728.7	385.7	149.0	49.0	23.0	59.0
1980	8.0	9.0	20.0	4.0	44.0	135.0	371.0	252.0	348.0	0.0	0.0	1.0

Adapted from Svejnar and Thorbecke (1984, Tables A41 to A44, Appendix A).

TABLE A1.10

OWN ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION IN THE NEPALESE CROP SECTOR: 1961/62 - 1987/88

Inputs	1961/62-1970/71	1971/72-1980/81	1981/82-1987/88	1961/62-1987/88
Share Equations with Bullock Price:				
Land (σ_{11})	-0.238	-0.336	-0.506	-0.340
Labour (σ_{22})	-5.454	-4.030	-2.783	-3.969
Bullocks (σ_{33})	-33.830	-22.215	-15.382	-22.290
Fertilizer (σ_{44})	-22981.5	-1442.71	-678.036	-1592.76
Share Equations without Bullock Price:				
Land (σ_{11})	-0.089	-0.150	-0.256	-0.154
Labour (σ_{22})	-2.408	-2.115	-1.623	-2.094
Fertilizer (σ_{33})	-15766.2	-1191.67	-578.88	-1292.95

APPENDIX 2

ESTIMATION OF AGGREGATE PRODUCTION FUNCTION IN THE NEPALESE CROP SECTOR

A2.1 Estimation of Aggregate Production Function

The Cobb-Douglas production function given in equation (3.20) in Chapter 3 is estimated in order to use its coefficients as factor shares in constructing the input indices under the geometric index procedure. Despite a small sample size (n=27), the aggregate national data on output and inputs over 1961/62 to 1987/88 were used to estimate the production function (3.20). However, the results were not very satisfactory, and consistent with the results obtained in some other LDCs' studies, such as the one by Hayami and Ruttan (1985, p.145). The major reason for such inconsistency in results could be the smallness of the sample size. Therefore, the sample size is increased by pooling time-series (over a shorter time span) and cross-section (regional) data together. The data on inputs and output for three geographical regions of Nepal, viz. the Hills, Kathmandu valley and the Tarai, which are presented in Table A1.7 in Appendix 1 were pooled together to estimate the production function (3.20). Since the data for each region represents a period of 1969/70 to 1980/81, the total sample size as a result of such pooling of time-series and cross-section data together increased from 27 to 36.

While estimating a production function with the pooled data, one must choose an appropriate model in order to obtain more meaningful results. In this regard, the chosen model must take into account the differences in behavior of the disturbances over cross-sectional units as well as the differences in behavior of the disturbances over time for a given cross-sectional unit, because the behavior of the disturbances over the cross-sectional units is likely to be different than the behavior of the disturbances of a given cross-sectional unit over time (Kmenta 1971, p.508). Therefore, it is necessary to examine the behavior of the disturbances before one selects a model to estimate a production function with the pooled cross-section and time-series data.

There are several models that have been suggested to deal with the pooled cross-section and time-series data. However, these models differ in the assumptions relating to the behavior of disturbances. The major suggested models are the cross-sectionally heteroskedasticity and time-wise autoregressive model, the cross-sectionally correlated and time-wise autoregressive model, the error components model and the covariance model (Kamenta 1971, pp.509-516).

In this study, different types of tests were carried out in order to identify the behavior of the disturbances with respect to the pooled data. That is, the tests were carried out to test whether disturbances across the regions are independent and heteroskedastic, and whether they are time-wise autoregressive. That is,

(A2.1) $E(\epsilon_{it}\epsilon_{jt}) = 0 \quad (i \neq j)$ [cross-sectional independence]

(A2.2) $E(\epsilon_{it}^2) = \sigma_i^2$ [heteroscedasticity]

(A2.3) $\epsilon_{it} = \rho_i \epsilon_{i,t-1} + u_{it}$ [autoregression]

where $u_{it} \sim N(0, \sigma_{ui}^2)$; $\epsilon_{i0} \sim N(0, \frac{\sigma_{ui}^2}{1-\rho_i^2})$ and $E(\epsilon_{i,t-1} u_{jt}) = 0$ for all i and j

and ϵ_{it} is the regression disturbance of the i-th region in the t-th period estimated from the regression equation (A2.4) which is presented below. All these tests are discussed in following subsections.

A2.1.1 Cross-Sectional Independence Test

In case of the pooled data, the regression equation representing the Cobb-Douglas production function (3.20) can be written in a log-linear form as:

$$(A2.4) \qquad lnQ_{it} = lnA + \beta_T T_{it} + \beta_1 lnR_{it} + \beta_2 lnL_{it} + \beta_3 lnB_{it} + \beta_4 lnF_{it}$$
$$+ \beta_5 lnS_{it} + \epsilon_{it} \qquad (i = 1,2,3;\ t = 1,2,\ldots,12)$$

The ordinary least square (OLS) technique is used to estimate equation (A2.4) with respect to the pooled data. Then, the variance and covariance of the disturbances of the estimated regression equation were calculated and presented in Table A2.1.

TABLE A2.1
VARIANCE AND COVARIANCE OF DISTURBANCES ACROSS HILLS, KATHMANDU VALLEY AND TARAI REGION OF NEPAL

	ϵ_1	ϵ_2	ϵ_{31}
ϵ_1	0.018		
ϵ_2	0.004	0.008	
ϵ_3	0.008	0.001	0.024

According to Table A2.1, the estimated covariances of the disturbances across the regions are approximately zero. That is, the disturbances are pairwise uncorrelated which imply that the regions are independent to each other. Hence, any model that is to be used to estimate the parameters of the production function using the pooled cross-section and time-series data must include the characteristic of regional independency.

A2.1.2 Heteroskedasticity Test

The problem of heteroskedasticity is generally observed in a set of cross-sectional data. Therefore, an attempt has been made to test for heteroskedasticity problem in the estimated regression model. A simple test would be to test whether or not the variances of the disturbances across the region are the same. Since the estimated variances of the disturbances across the region are not the same (Table A2.1), there exists the problem of heteroskedasticity in the pooled data. However, this test is a simple test and does not cover a wide range of heteroskedastic situation. Therefore, the Breusch-Pagan (BP) test which is a very general test and covers a wide range of heteroskedastic situation is used in this study to detect the heteroskedasticity problem. In addition, the test does not require a prior identification of variable(s) that causes heteroskedasticity problem in the model.

According to the test procedure (Johnston 1984, p. 300), the OLS residuals ϵ_{it} from above regression equation (A2.4) are used to generate a new variable CT_{it} $(=\epsilon_{it}^2/\hat{\sigma}^2 \text{ where } \hat{\sigma}^2 = \sum \epsilon_{it}^2/n)$ which is then regressed on suspected variable(s). And the sum of square residuals (SSR) of the estimated regression equation is used to calculate the BP statistic as:

$$(A2.5) \qquad BP = SSR/2 \sim \chi^{2*}_{p-1}$$

where p is the number of parameters in the regression model (that is, p-1 implies the number of variables included in the test). The test was conducted on following variables with the null hypothesis stating the absence of heteroskedasticity (that is, $H_0: \alpha_1 = \alpha_2 = \ldots = \alpha_6 = 0$ in equation (A2.6)).

$$(A2.6) \qquad CT = h(\alpha_0 + \alpha_1 T + \alpha_2 lnR + \alpha_3 lnL + \alpha_4 lnB + \alpha_5 lnF + \alpha_6 lnI)$$

Since the computed BP statistic (=12.676) is greater than χ_6^2* (=12.592) at 5 percent level of significance, the presence of heteroskedasticity in the model is confirmed. However, the presence of heteroskedasticity in this form does not necessarily imply that the problem also exists when the explanatory variables are in some other form. The most likely form of explanatory variables that may raise heteroskedasticity problem is their square form. Therefore, the BP test is once again carried out by considering the squares of the explanatory variables in the original model. That is,

$$(A2.7) \qquad GT_{it} = h[\alpha_0 + \alpha_1 T_{it}^2 + \alpha_2 (lnR_{it})^2 + \alpha_3 (lnL_{it})^2 + \alpha_4 (lnB_{it})^2 + \alpha_5 (lnF_{it})^2 + \alpha_6 (lnI_{it})^2]$$

The calculated BP statistic (=16.383) is also greater than the critical value of χ_6^2* (=12.592) at 5 percent level of significance. Therefore, the presence of a heteroskedasticity problem in terms of squared forms of the explanatory variables in the regression model is also confirmed.

A2.1.3 Autocorrelation Test

Regarding the autocorrelation test, the Durbin-Watson (D-W) test seems to be the most desirable test to examine the presence of autocorrelation in the regression model. It is because the model (A2.4) includes a constant term in it and there is no lagged dependent variable on its right hand side. According to the regression results, the estimated value of d is observed to be 2.860 which is greater than two. Therefore, the D-W "bounds test" is essential in this case.

The critical values of d_L and d_U at 5 percent level of significance and for n=36 and K'=6 are respectively 1.175 and 1.799. The estimated value of d (=2.860) shows that the estimated d is greater than the value of 4-d_L. Therefore, the D-W 'bounds test' confirms the presence of negative autocorrelation of first degree in the estimated regression model. However, the D-W test has several shortcomings (Koutsoyiannis 1981, p.215). One of them is that the test tests only for the significance of first order autocorrelation. It does not test the significance of second, third or fourth order autocorrelation in the model. Therefore, the Breusch Godfrey (BG) test (Johnston 1984, pp.319-21) which is more general test and allows to test for any order of autocorrelation has been further used in this model.

According to the BG test, OLS residuals ϵ_{it} from the original model is regressed on $\epsilon_{i,t-1}, \epsilon_{i,t-2}, \ldots\ldots, \epsilon_{i,t-p}$ and all other explanatory variables and, then, the BG statistic is calculated as:

(A2.8) $$BG = nR^2 \sim \chi_p^{2*}$$

where p represents the order of autocorrelation that needs to be tested. The BG tests for first, second, third and fourth order were separately carried out. The calculated BG statistics along with their corresponding critical values of chi-square are presented in Table A2.2. The estimated test statistics conclude the presence of first, second, third and fourth order autocorrelation in the estimated regression model at 5 percent level of significance.

A2.1.4 Choice and Estimation of Regression Model and Its Results

All the tests mentioned in above sections uphold the validity of the regional independency assumption and confirm the presence of cross-sectional heteroskedasticity as well as the time-wise autoregressive nature of the pooled observations. Therefore, the best model to estimate production parameters with the

TABLE A2.2
RESULTS OF BREUSCH GODFREY (BG) TEST

Test	Calculated Value of BG	Degree of Freedom	Critical Value of Chi-Square*	Presence of Autocorrelation
First Order BG Test	10.067	1	3.841	Yes
Second Order BG Test	10.847	2	5.991	Yes
Third Order BG Test	11.626	3	7.815	Yes
Fourth Order BG Test	11.626	4	9.488	Yes

* At 5 percent level of significance.

pooled data is the cross-sectionally heteroskedastic and time-wise autoregressive model as presented in detail by Kmenta (1971, pp.509-512). According to the model, the pooled data are transformed twice. The first transformation is carried out to remove the autocorrelation problem from the pooled data set, whereas the second transformation is done to remove the heteroskedasticity problem from the same data set. After removing these problems, the transformed data set is used to estimate the parameters of the Cobb-Douglas production function using the ordinary least square technique. Moreover, the Cobb-Douglas production function is assumed to be a linearly homogeneous of degree one or, alternatively, constant returns to scale. Therefore, the homogeneity restriction ($\beta_1 + \beta_2 + \ldots + \beta_5 = 1$) is imposed while estimating the production function given in equation (A2.4). The results from the estimated regression model are presented in Table A2.3.

TABLE A2.3

ESTIMATED REGRESSION RESULTS

Variable	Estimated Coefficient	T-Ratio (30 DF)	Standardized Coefficient
Time	0.017*	1.760	0.145
Land	0.281**	4.052	0.303
Labour	0.651**	5.097	0.572
Bullock	0.042	0.877	0.128
Fertilizer	0.014	0.156	0.013
HYV Seeds	0.012	0.327	0.018
Constant	0.492**	2.773	0.000

n = 36 Buse R^2 = 0.997	D-W = 1.995 $F_{5,30}$ = 1557.88	Log Likelihood Value = 27.187

* indicates that the respective coefficient is significant at 0.05 level ($t^*_{0.05,30} = 1.645$).
** indicates that the respective coefficient is significant at 0.01 level ($t^{**}_{0.01,30} = 2.326$).

According to Table A2.3, the estimated t-values of the regression coefficients indicate that input variables land and labour are significant at 0.01 level, whereas the input variables bullocks, fertilizer and HYV seeds are insignificant. In other words, the inputs land and labour are the only inputs that have significant impact on the crop production in Nepal, whereas the influences of inputs, such as bullocks, fertilizer and HYV seeds, on the crop production are still negligible. These results confirm the conventional wisdom that, in traditional agriculture, the two most important inputs are labour and land. Moreover, the results also indicate that the constant term and the technology variable which is proxied by the time trend are highly significant in the Nepalese crop sector.

Regarding the overall significancy of the regression model, the computed value of $F_{5,30}$ (=1557.88) in the estimated regression model implies that the model is significant at the one percent level of significance, because the computed value of F is greater than its critical value ($F^{*}_{5,30}$ = 3.70).

A2.1.5 Multicollinearity Test

Since the estimated regression model contains variables such as land, labour and bullocks, a collinearity problem is likely to exist between these variables. Therefore, the presence of collinearity in the regression model is tested using two different types of method, viz. the correlation coefficient method and the auxiliary regression method. According to the correlation coefficient method, a simple correlation coefficient between each pair of explanatory variables are estimated, and if the estimated coefficient is extremely high then it means that the collinearity exists between those two variables. The estimated correlation coefficients between each two variables are presented in Table A2.4.

According to Table A2.4, there is some evidence that a multicollinearity problem does exist between input pairs land and labour, land and bullocks, and labour and bullocks. However, such a conclusion can not be drawn for sure, because the correlation coefficient method is itself a crude method in the sense that the critical value of the coefficient that one imposes to detect collinearity is very subjective. Moreover, the method does not allow the detection of collinearity between more than two variables. Therefore, a second method, the auxiliary regression method, is applied to test for collinearity in the estimated regression model.

TABLE A2.4

ESTIMATED VALUES OF CORRELATION COEFFICIENTS

VARIABLES	CORRELATION COEFFICIENT	COLLINEARITY
Land and Labour	0.89	May be
Land and Bullocks	0.99	Yes
Land and Fertilizer	-0.14	No
Land and HYV Seeds	0.69	No
Labour and Bullocks	0.95	Yes
Labour and Fertilizer	-0.44	No
Labour and HYV Seeds	0.49	No
Bullocks and Fertilizer	-0.24	No
Bullocks and HYV Seeds	0.64	No
Fertilizer and HYV Seeds	0.50	No

According to the auxiliary method, each explanatory variables is regressed on all other explanatory variables and then the estimated values of R^2 and F in the regression equation are used to test for collinearity. A collinearity problem exists if the estimated value of R^2 is extremely high and if the estimated value of F for over all significance of the regression equation exceeds its critical value. In this study, the estimated values of R^2 and F in each estimated regression equations under the auxiliary method, presented in Table A2.5, indicate the presence of collinearity problem in the regression model, especially due to input variables land, labour and bullocks.

TABLE A2.5

ESTIMATED VALUES OF R2 AND F IN THE AUXILIARY REGRESSION EQUATIONS

Dependent Variable in Regression Equation	R^2	$F^1_{6,29}$	Collinearity
Land	0.98	387.51	Yes
Labour	0.95	151.27	Yes
Bullocks	0.99	660.33	Yes
Fertilizer	0.71	19.02	No
HYV Seeds	0.85	43.22	No

1. The critical value of F4,31 at the one percent level of significance is 4.02.

A2.1.6 Conclusions

Thus, the tests carried out in section A2.1.5 confirm the presence of multicollinearity in the estimated regression model. However, all the tests available for testing the problem of multicollinearity including those two used in this study are not considered as the best tests to indicate the severity of the problem. Moreover, even if one considers the existence of the collinearity problem in the model, there are no best remedies for the problem. Generally, the problem can be overcome either by obtaining more qualitative data and/or by dropping the variables that cause the problem in the regression model. The first solution is not applicable in this study, because the additional data on inputs and output are simply not available in case of the Nerpalese crop sector. Regarding the second solution, none of the three input variables causing the multicollinearity problem can be dropped out, because the study needs the estimated coefficients of all these input variables in order to use them as weights while constructing the input indices in productivity analysis. Moreover, the estimated coefficients seem to be in line with the coefficients estimated by Hayami and Ruttan (1985, Equation (20), p.45) for 22 less developing countries. Therefore, the estimated coefficients of Table A2.3, despite collinearity problem in the model, are used as factor shares in the estimation of the total factor productivity in Chapter 6.