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# Choice of Decomposition Model in Output Growth Analysis: Evidence from the Nepalese Crop Sector

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## INTRODUCTION

In agriculture, the decomposition analysis has been used by several researchers such as Minhas and Vaidyanathan (1965), Minhas (1966), Dayal (1966), Sagar (1980), Narain (1977), and Yadav (1987) to determine the sources of output growth in the agricultural sector. There are major two types of decomposition model – the additive model and the multiplicative model - that have been frequently used in the past to decompose out put growth into cropped area, yield, cropping pattern, price and their interaction terms.

The multiplicative model as compared to the additive model is theoretically preferred to analyse the output growth pattern in the agriculture sector, because it uses a compound output growth rate instead of a linear output growth rate. However, evidence on the empirical comparison between these two models is still lacking, especially with same set of data. Therefore, this paper compares the effectiveness of these models empirically and provides meaningful insight into the pattern of output growth in the Nepalese crop sector.

In agricultural growth analysis, prices are used to aggregate agricultural output in value terms. Therefore, they reflect the relative importance assigned to different agricultural produce. Prices are influenced by several demand and supply factors. As these factors are likely to change over time, prices are bound to change resulting and over time change in the relative importance assigned to each agricultural produce. Therefore, the price together with area, yield and cropping pattern is included in the additive and multiplicative models to analyse its contribution to the output growth.

## DECOMPOSITION MODELS

A general additive decomposition model that takes into account area, yield and price can be described in the following steps. The value of gross agricultural output, Qt, can be written as:

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$$Q_t = \sum_i A_{it} y_{it} p_{it} = A_t \sum_i (A_{it} / A_t)\, y_{it}\, (p_{it} / P_t)\, P_t = A_t \sum_i a_{it} y_{it} q_{it} P_t \qquad (1)$$

$$= A_t Y_t P_t \text{ where } Y_t = \sum_i a_{it} y_{it} q_{it} \text{ and } P_t = \left( \frac{\sum_i p_{it} x_{io}}{\sum_i p_{io} x_{io}} \right)$$

Where $A_{it}$, $y_{it}$ and $p_{it}$ represent, respectively, the area, yield and current price of the i-th crop; $a_{it}$ $(=A_{it}/A_t)$ is the proportion of area under the i-th crop to the gross cropped area; $q_{it}$ $(=p_{it}/P_t)$ is the deflated price of the i-th crop; $P_t$ which is used to deflate crop prices is the Laspeyres index number of crop prices; $x_{io}$ is the physical output of the i-th crop during the base period; $Y_t$ is suitably weighted gross partial agricultural (land) productivity in value terms and at deflated current prices; and t is the time subscript.

In equation (1), the value of gross agricultural output is described in terms of gross cropped area, gross partial agricultural productivity and the overall level of crop prices. Therefore, an increase in the value of gross agricultural output from the base period, t=0, can be expressed as:

$$Q_t - Q_o = (A_t - A_o) Y_o P_o + A_o (Y_t - Y_o) P_o + A_o Y_o (P_t - P_o) + (A_t - A_o)(Y_t - Y_o) P_o \qquad (2)$$
$$+ (A_t - A_o) Y_o (P_t - P_o) + A_o (Y_t - Y_o)(P_t - P_o) + (A_t - A_o)(Y_t - Y_o)(P_t - P_o)$$

The index number of change in output is sum of index numbers of change in area, change in gross partial agricultural productivity, change in crop prices and four interaction terms involving changes in these pure components. Each series of these index numbers is used to fit a linear time-trend, $Y = A + bT$, to obtain its growth rate (G) as $G = (dY/dT)/Y = b/Y$.

The growth in the gross partial agricultural productivity component, $(Y_t - Y_o)$, can be further decomposed into seven crop structural components, viz., cropping pattern, yield structure and price structure, and their interactions as follows (Sagar 1980):

$$(Y_t - Y_o) = \sum_i (a_{it} - a_{io})\, y_{io} q_{io} + \sum_i a_{io} (y_{it} - y_{io}) q_{io} + \sum_i a_{io} y_{io} (q_{it} - q_{io}) \qquad (3)$$

$$+ \sum_i (a_{it} - a_{io})(y_{it} - y_{io})\, q_{io} + \sum_i (a_{it} - a_{io})\, y_{io} (q_{it} - q_{io})$$

$$+ \sum_i a_{io} (y_{it} - Y_{io})(q_{it} - q_{io}) + \sum_i (a_{it} - a_{io})(y_{it} - Y_{io})(q_{it} - q_{io})$$

Regarding the multiplicative model, the original Minhas-type model which does not include price structure and a modified multiplicative model which is modified to include price structure are presented respectively in equation (4) and (5).

$$\frac{Q_t}{Q_o} = \frac{A_t \sum_i a_{it} y_{it} p_i}{A_o \sum_i a_{io} y_{io} p_i} \tag{4}$$

$$= \left(\frac{A_t}{A_o}\right)\left(\frac{\sum_i a_{io} y_{it} p_i}{\sum_i a_{io} y_{io} p_i}\right)\left(\frac{\sum_i a_{it} y_{io} p_i}{\sum_i a_{io} y_{io} p_i}\right)\left[\left(\frac{\sum_i a_{it} y_{it} p_i}{\sum_i a_{io} y_{it} p_i}\right)\left(\frac{\sum_i a_{io} y_{io} p_i}{\sum_i a_{it} y_{io} p_i}\right)\right]$$

$$\frac{Q_t}{Q_o} = \frac{A_t \sum_i a_{it} y_{it} q_{it} P_t}{A_o \sum_i a_{io} y_{io} q_{io} P_o} \tag{5}$$

$$= \left(\frac{A_t}{A_o}\right)\left(\frac{\sum_i a_{io} y_{it} q_{io}}{\sum_i a_{io} y_{io} q_{io}}\right)\left(\frac{\sum_i a_{it} y_{io} q_{io}}{\sum_i a_{io} y_{io} q_{io}}\right)\left(\frac{P_t}{P_o}\right)\left[\left(\frac{\sum_i a_{it} y_{it} q_{it}}{\sum_i a_{io} y_{it} q_{io}}\right)\left(\frac{\sum_i a_{io} y_{io} q_{io}}{\sum_i a_{it} y_{io} q_{io}}\right)\right]$$

where notations have the same meaning as in equation (1) except $p_i$ which represents the constant price weight assigned to the i-th crop.

The identity (4) expresses the index number of output as a multiple, respectively, of the index numbers of area, change in crop yields, change in cropping pattern and a residual component representing the interaction between cropping pattern and yield components. Identity (5) implies that the index number of output is a multiple, respectively, of the indices of area, yield, cropping pattern, crop prices and residual component involving interaction between yield, cropping pattern and price components. Further, each series of these index numbers in both multiplicative models is used to fit an exponential time-trend, $Y = Ae^{bT}$, to obtain an additive scheme for growth as:

$$G = G_A + G_y + G_a + G_{ay} \qquad \text{[for equation (4)]} \tag{6}$$

$$G = G_A + G_y + G_a + G_p + G_{ayp} \qquad \text{[for equation (5)]} \tag{7}$$

where G, $G_A$, $G_y$, $G_a$, and $G_p$ are respectively the growth rates of gross agricultural output, gross cropped area, yield, cropping pattern and price components; $G_{ay}$ which is obtained residually by subtracting $G_A + G_y + G_a$ from G is the growth rate of interaction term involving cropping pattern and yield components; and $G_{ayp}$ is the growth rate of interaction term involving cropping pattern, yield and price components.

In previous decomposition studies, the Laspeyres indexing procedure has been used to index crop prices. However, the index procedure has some limitations. The major limitation is that the index is associated with a linear production function that assumes perfect substitutability between factors of production. In agriculture production processes, factors are typically not perfect substitutes and, therefore, use of a linear production function is not a good approximation of the real world. On the other hand, the Divisia indexing procedure as compared to the Laspeyres indexing procedure is considered to be superior one in the sense that the Divisia index underlies the flexible form (translog) production function that does not put prior restriction on the value of elasticity of substitution. Besides this, the Divisia indexing procedure has been widely used in present agricultural productivity analysis. Therefore, the additive and multiplicative models are modified by replacing the Laspeyres indexing procedure by the Divisia indexing procedure to decompose output growth in the Nepalese crop sector. Following Christensen (1975), the Divisia price index can be written as:

$$\ln\left(\frac{p_t}{p_{t-1}}\right) = \sum_i \overline{W}_i \ln\left(\frac{p_{it}}{p_{(i,t-1)}}\right) \quad (8)$$

where $\overline{W}_i = \frac{1}{2}\left(W_{it} + W_{(i,t-1)}\right)$ 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.

## Estimation and Results

In this paper, three different types of decomposition model described in Table 1 were estimated to compare the results of the additive and multiplicative models and to examine any changes in results due to inclusion of price structure into the decomposition model. The data used in the estimation of the models are obtained from DFAMS (1972, 1983 and 1989). Results of the estimated models that were made comparable by using same base period 1961/62 and same Divisia price index are presented in Table 2.

**Table 1**

**Description of the Additive and Multiplicative Decomposition Model**

| Model | Description |
|---|---|
| I | Additive model with price structure. |
| II | Multiplicative model with price structure. |
| III | Multiplicative model without price structure. |

The difference between annual growth rates of the total value of crop production derived from the price structured additive and multiplicative models is observed to be small. However, the annual growth rates of area, price structure and the interaction terms derived from the additive model are sufficiently different from those derived from the multiplicative model.

The annual growth rate of the total value of crop production derived from the additive model is 7.42 percent which is slightly lower than the one that derived from the multiplicative model. Similarly, the growth rates of the area effect and price effect derived from the additive model are observed to be relatively smaller than those estimated from the multiplicative model. Surprisingly, the interaction effect derived from the additive model is significantly higher than the one derived from the multiplicative model. The contribution of the interaction effect to the total value of crop production is 0.9 percent in the multiplicative model and 29.6 percent in the additive model. A further decomposition of the interaction effect in the additive model shows that the higher value of interaction effect is mainly caused by the interaction effect between area and price structure. All other interaction effects between the gross partial crop productivity (Y) and other pure components are observed to be negative and relatively very small.

In case of the additive model, the direct effects of the crop yield and cropping pattern to the growth rate of the total value of crop production could not be examined as the terms representing the crop yield and cropping pattern do not appear in equation (2). Nevertheless, their indirect effects to the total value of crop production have been examined by further decomposing the gross partial crop productivity into seven components as shown in equation (3) and then examining the influences of crop yield and cropping pattern on the gross partial crop productivity. The yield effect to the gross partial crop productivity and therefore, to the total value of crop production is negative in both the additive and multiplicative models (Table 2). However, the magnitude of such effect in the additive model is relatively smaller than the one in the multiplicative model. Moreover, the effect of cropping pattern to the gross partial crop productivity in the additive model is positive and relatively small but almost same as the effect of cropping pattern to the total value of crop production in the multiplicative model.

Moreover, the effects of price and interaction terms to the gross partial crop productivity are respectively positive and negative.

**Table 2**

**Annual Growth Rates of Crop Production and Its Components 1961/62 - 1987/88**

(in Percentage)

| Item/Model | Additive Model | Multiplicative Model | |
|---|---|---|---|
| | I | II | III |
| **Total Value of Crop Production (TVCP)** | 7.42 (100) | 7.62 (100) | 1.56 (100) |
| **Decomposition of TVCP:** | | | |
| Area Effect | 0.62 (8.4) | 1.77 (23.2) | 1.77 (113.4) |
| Yield Effect | - - | -0.32 (-4.2) | -0.32 (-20.5) |
| Cropping Pattern Effect | - - | 0.02 (0.3)* | 0.02 (1.3)* |
| Price Effect | 4.66 (62.8) | 6.08 (79.8) | - - |
| Gross Partial Agricultural Productivity | -0.06 (-0.8) | - - | - - |
| Interaction Effect | 2.20 (29.6) | 0.07 (0.9) | 0.09 (5.8) |
| **Decomposition of Interaction Effect:** | **2.20 (29.6)** | | |
| ΔAΔY | -0.03 (-0.4) | | |
| ΔAΔP | 2.58 (34.8) | | |
| ΔYΔP | -0.24 (-3.2) | | |
| ΔAΔYΔP | -0.11 (-1.5) | | |
| **Decomposition of Gross 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 | | | |
| ΔaΔy | 0.02 (0.3) | | |
| ΔaΔq | -0.03 (-0.4) | | |
| ΔyΔq | -0.01 (-0.1)* | | |
| ΔaΔyΔq | 0.00 (0.00) | | |

Note: All the estimated growth rates are significant at 0.05 level except one with the star sign (*) on it which is significant at 0.10 level only. The number shown in parenthesis is the percentage contribution to the annual growth rate of the total value of crop production.

Regarding the choice between the additive model and multiplicative model, it is very difficult to discriminate one versus another, especially, without an appropriate statistical technique to do so. However, a general comparison of the results derived from each of these models indicates that the multiplicative model as compared to the additive model is more realistic in analysing the output growth in agricultural sector. The estimated growth rate of output quantity, which is defined as the growth rate of the total value of crop production minus the growth rate of the price effect, shows that the growth rate is 1.54 percent in case of the multiplicative model and 2.76 percent in case of the additive model. That is, the output growth rate derived from the additive model seems to be overestimated given the characteristics of the Nepalese crop sector for the last three decades and the negative growth rates of the crop yield during the 1960s and 1970s. In Nepal, the crop sector is characterised by traditional method of production, undeveloped infrastructure and relatively small degree of commercialisation.

Unlike in the additive model, the interaction effect in the multiplicative model is relatively small implying that the multiplicative model as compared to the additive model is more capable to isolate the effects of each pure component at a greater degree. As mentioned earlier, the multiplicative model is also theoretically superior than the additive model as it deals with a compound output growth rate rather than a linear output growth rate. Thus, the multiplicative model as compared to the additive model is considered to provide better understanding of agricultural growth analysis and, therefore, the model is chosen for further analysis.

Results derived from the multiplicative models II and III were compared to find out any changes in the results due to inclusion of price structure in the model. According to the results derived from the price constancy model III, the total value of crop production during 1961/62 to 1987/88 increased annually by 1.56 percent. The major contributor to such an increase in the value of crop production is area which increased annually by 1.77 percent. During the same period, the yield effect is negative and effects of cropping pattern and interaction term are relatively very small. When price structure is included in the multiplicative model as described by model II, the annual growth rate of the total value of crop production increased significantly to 7.62 percent primarily due to increase in crop prices. The crop prices increased by more than six percent per annum during 1961/62 to 1987/88. In other words, if the contribution of the crop prices is excluded from the annual growth rate of the total value of crop production, then the annual growth rate of the crop production remains almost same as in case of price constancy model III.

The annual growth rates of area, yield and cropping pattern did not change as a result of inclusion of price structure into the multiplicative models. However, the percentage contribution of each of these factors to the total value of crop production did change significantly. Unlike in price constancy model III, area in the price structure models did not remain a major element to the growth of the total value of crop production. Rather, it is the crop prices that have major contribution to the growth of the total value of Nepalese crop production. Results also imply that the magnitude and direction of the yield effect did not change as a result of inclusion of price structure into the multiplicative models.

In the absence of an appropriate statistical technique, it is very difficult to choose between the price structure model II and the price constancy model III. However, the price structure model as compared to the price constancy model provides relatively better understanding of growth trends in the sense that the model lets one to examine the influence of crop prices on the growth of the total value of crop production. The model also provides the relative contribution of all factors including crop prices to the growth of the total value of crop production so that appropriate policy recommendations can be made to achieve the maximum growth of the total value of crop production. Thus, the price structure model has been chosen to carry out a periodical analysis of output growth in the Nepalese crop sector.

The analysis period 1961/62 to 1987/88 is divided into three different sub-periods, viz. 1961/62 to 1970/71, 1971/72 to 1980/81 and 1981/82 to 1987/88, to compare the annual growth rates of the total value of crop production in these periods. Results presented in Table 3 indicate that the lowest growth rate of the total value of crop production is observed during the 1970s, mainly due to the negative effects of yield rate and cropping pattern and a slow growth rate of the crop prices. The positive area effect but negative yield effect during the 1960s and 1970s could have been resulted from the transfer of marginal land into crop land and the lack of improved technology during those periods. The crop area grew annually by 1.85 percent in the 1960s and 1.30 percent in the 1970s, whereas the adoption rate of improved technology defined by HYV seeds and chemical fertilisers during these periods were very low (Table 4).

The use of HYV seeds in the Nepalese crop sector really started only around mid-sixties. In 1965/66, the HYV seeds which include major three crops - paddy, wheat and maize - covered only 0.54 percent of the total cropped area, and it remained as low as 7.95 percent at the end of the year 1970/71. Although 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 during most years of the 1970s. Similarly, the consumption of chemical fertiliser in the Nepalese crop sector was as low as 0.23 kg/ha in 1965/66 and it did not go above 8.88 kg/ha during entire 1960s and 1970s.

**Table 3**

**Annual Growth Rates of Crop Production and Its Components 1961/62 - 1987/88**

(in Percentage)

| Period | Total Value of Crop Production | Area Effect | Yield Effect | Cropping Pattern Effect | Price Effect | Interaction Effect |
|---|---|---|---|---|---|---|
| 1961/62 to 1970/71 | 8.47 (100) | 1.85 (21.8) | -0.64 (-7.5) | 0.12 (1.4) | 7.27 (85.8) | -0.13 (-1.5) |
| 1971/72 to 1980/81 | 3.76 (100) | 1.30 (34.6) | -0.80* (-21.3) | -0.13 (-3.5) | 3.20 (85.1) | 0.19 (5.1) |
| 1981/82 to 1987/88 | 12.93 (100) | 3.42 (26.4) | 0.56** (4.3) | 0.06** (0.5) | 9.05 (70.0) | -0.16** (-1.2) |
| 1961/62 to 1987/88 | 7.62 (100) | 1.77 (23.2) | -0.32 (-4.2) | 0.02* (0.3) | 6.08 (79.8) | 0.07 (0.9) |

Note: All the estimated growth rates are significant at 0.05 level except the star sign.
* Significant at 0.10 level only.
** Not significant even at 0.10 level.
The number shown in parenthesis is the percentage contribution to the annual growth rate of the total value of crop production.

**Table 4**

**Total Area Under HYV Seeds and Total Consumption of Chemical Fertiliser 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 Fertiliser Total (MT) | Consumption of Fertiliser Rate (kg/ha) |
|---|---|---|---|---|---|
| 1961/62 | 1919.4 | NA | 0.00 | 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
Source: DFAMS (1972, 1983, 1989)

Table 3 also indicates that the period 1981/82 to 1987/88 was remarkably successful period for the Nepalese crop sector as compared to other two periods. The total value of crop production during the period grew by 12.93 percent per annum with positive effects from all pure components. That is, yield rate had also a significant positive contribution to the output growth during the period. The positive yield effect may have been resulted from an increase in the use of improved technology. The percentage of the total cropped area under HYV seeds increased above 45.47 percent during the period, whereas the consumption of chemical fertiliser also increased 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. 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. The negative cropping pattern effect during the 1970s may have been resulted from a proportionate increase in area under low-value crops, especially, wheat. The wheat area increased from 228 thousand hectares in 1970/71 to 392 thousand hectares in 1980/81, giving an increase in area by almost 72 percent (DFAMS 1989).

## CONCLUSION

The total value of crop production is decomposed into cropped area, yield, cropping pattern, price and their interaction terms in order to determine the contribution of each of these components to the output growth rates in the Nepalese crop sector. A general comparison of the results derived from the additive and multiplicative models implies that the later model is more realistic with respect to estimated output growth rates and the capability of the model to isolate the effects of pure components to the output growth at a greater degree. The output growth rate derived from the additive model seems to be overestimated given the prevailing characteristics of the Nepalese crop sector for the last three decades and the negative yield trend during the 1960s and 1970s. Moreover, the interaction effect in the additive model as compared to the multiplicative model is very high implying that the additive model as compared to the multiplicative model is very high implying that the additive model as compared to the multiplicative model is relatively less capable of isolating the effects of pure components at a greater degree. Further, the price structure multiplicative model as compared to the price constancy model allows one to examine the influence of crop prices on the output growth and provides the relative contribution of all factors including crop prices to the output growth. Thus, the most preferred model to carry out decomposition analysis in agriculture is the multiplicative price structure model.

Results derived from the multiplicative price structure model II conclude that the annual growth rate of the total value of crop production increased significantly to 7.62 percent during 1961/62 to 1987/88 mainly contributed by an increase in crop prices. The effects of area, yield and cropping pattern to the output growth during the period were respectively positive, negative and positive.

A periodical analysis of output growth shows that the highest and lowest output growth is observed respectively during the 1980s and 1970s. A slow output growth in the 1970s has been caused by the negative effects of yield and cropping pattern and a slow growth in crop prices. On the other hand, the highest output growth during the 1980s has been resulted from the positive effects of area, yield, cropping pattern and crop prices. Moreover, the positive area effect but negative yield effect during the 1960s and 1970s are likely to be resulted from the transfer of marginal land into crop land and the lack of improved technology during those periods. The positive sign of cropping pattern during the 1960s and 1980s implies a proportionate shift in cropped area from low-value crops to high-value crops.

In sum, the positive output growth in the Nepalese crop sector during the 1980s provides a good indication for Nepalese policy decision makers and planners concerning the importance of continued output growth in crop sector. Therefore, any future plans and policies that are designed to increase output growth in the Nepalese crop sector must emphasis on increasing the adoption rate of new technology and facilitating farmers with some agricultural pricing policies to switch from low-value crops to high-value crops.

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