Jour. Ind. Soc. Ag. Statistics
51(2&3), 1998 : 139-146

FAO Index Numbers of Agricultural Production[1]

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SUMMARY

Author's Laspeyres index, alternative to Geary's is stated to be more suitable for calculating the volume index of agricultural production. Geary-Khamis (GK) methodology is in use by the United Nations as it satisfies most of the desirable index number axioms and tests. Other methods proposed as alternatives for the GK method have shortcomings and none of them is fully and consistently additive.

Key words: Laspeyres world volume index, Exchange rate, Consistency principle, Geary-Khamis methodology, EKS method.

1. Introduction

The author was assigned in 1960 by Dr. P.V. Sukhatme the responsibility for organizing and preparing the basic document for the 1961 FAO meeting of experts on index numbers of agricultural production, co-sponsored by the Conference of European Statisticians (CES). The meeting was held in Rome, 6-16 March 1961. In addition to strengthening co-operation between FAO and other regional and international organizations interested in indices of agricultural production, the main achievement of the meeting was the formulation of FAO's international recommendations and standards for the construction of *national* indices of agricultural commodity production based on the FAO World Census of Agriculture concept of an agricultural *holding* and the reconciliation of this concept with that of value added by an agricultural *establishment* as defined in the United Nations (UN) 1953 System of National Accounts (SNA). As reflected in the summary proceedings of the UN Statistical Commission 12th Session, these recommendations were considered by members of the Commission as one of the most important developments in National Accounts

1 The contents of the paper represent author's reminiscences of the major developments in the FAO aggregation methodology for national, regional and world indices during his work at FAO Statistics Division up to his retirement in 1981 and subsequent developments as described in FAO publications. The author was privileged to be associated with Dr. P.V. Sukhatme during his directorship of the Statistics Division, and acknowledges his most valuable encouragement in developing the aggregation methodology currently in use by FAO.

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since the Commission's preceding session. Furthermore, these recommendations contributed appreciably to the initiation of FAO's work in Economic Accounts for Agriculture (EAA) and the preparation of FAO's manual on EAA, which was consistent with and ahead of the UN 1968 SNA as recognized in the report of the CES meeting which considered the final draft of the 1968 SNA.

Participants in the 1961 meeting also discussed improvements to aggregation methods of national agricultural production data to obtain *regional* and *world* production indices and suggested that FAO take account of the recommendations made by its 1952 consultant, R.C. Geary, on this subject, published later as an alternative to market currency exchange rates used for aggregating national output data. Assuming that unknown regional or international average commodity prices P_i $(i = 1, 2, \ldots, N)$ exist for a time period t, they may be defined by the N equations

$$P_i = \sum_j (e_j p_{ij})(q_{ij} / \sum_j q_{ij}) \qquad (1)$$

where e_j is an unknown "exchange rate" for the currency of country j, $(j = 1, 2, \ldots M)$ and p_{ij} and q_{ij} represent the average price and output of commodity i for country j for the same time period t. Equation (1) is the quantity share weighted arithmetic average of the national prices p_{ij} after their conversion to a common currency unit. The unknown "exchange rates" may then be defined by the M equations

$$e_j = \sum_i P_i q_{ij} / \sum_i p_{ij} q_{ij} \qquad (2)$$

As pointed out by the author on many occasions (see, e.g. Khamis [9]), the Geary equations may also be derived through the application of the following intuitive consistency principle for the average prices P_i and the "exchange rates" e_j :

Consistency principle : Any aggregate of output valued at the average prices P_i is equal to the corresponding aggregate valued at the converted prices $e_j p_{ij}$, provided that the P_i and e_i refer to the same time period.

Multiplying both sides of equation (1) by $\sum_j q_{ij}$ and both sides of equation (2) by $\sum_j p_{ij} q_{ij}$ one obtains the equations

$$\sum_j P_i q_{ij} = \sum_j e_i p_{ij} q_{ij} \quad (3)$$

and

$$\sum_i e_j p_{ij} q_{ij} = \sum_i P_i q_{ij} \quad (4)$$

which are equivalent to equations (1) and (2) respectively and satisfy the consistency principle. Furthermore, equations (3) and (4) may be obtained through a weighted least squares minimizing the differences between the average commodity prices P_i and their corresponding converted prices $e_j p_{ij}$ (Khamis [7], [8]).

Geary noted that the M + N homogeneous equations possessed a non-trivial solution and illustrated it in the case of two countries and two commodities. The author (Khamis [5], [6]) provided the necessary and sufficient conditions for the existence of a unique (up to a scalar multiplier) and positive solution. Geary recommended that FAO calculate the "exchange rates" e_j for a basic period o to convert into a common currency unit the national commodity prices for use in a Laspeyres world volume index defined by the equation

$$Q_{on} = \sum_j \sum_i e_{jo} p_{ijo} q_{ijn} / \sum_j \sum_i e_{jo} p_{ijo} q_{ijo} \quad (5)$$

where Q_{on} is the world index of agricultural production of the current year n as compared with the base period o. The n and o subscripts are added to the other symbols in equation (5) to explain the time periods to which they refer. The author illustrated how equation (5) could lead to highly biased regional or international indices. The consistency principle is not applicable here because e_{jo} in equation (5) does not relate to the period n quantities. On the other hand, the use of the average prices P_{io} in the numerator and denominator of equation (5) instead of the converted national prices removes this type of bias (Khamis [6], pp.110-111 and [8] pp. 188-189). In other words, the author's Laspeyres index alternative to Geary's and defined by the equation

$$Q'_{on} = \sum_j \sum_i P_{io} q_{in} / \sum_j \sum_i p_{io} q_{io} \quad (6)$$

is more suitable for calculating the volume index (Q'_{on}) of agricultural production. There is general agreement that for agriculture an average of at least three years be taken for the base period and hence the e_{jo} and P_{io} are

to be calculated using equations (3) and (4) with p_{io} and q_{io} being the base period averages of annual national average commodity producer prices (nearest to farm-gate) and of annual commodity production for the selected base period. Revisions of the base period will, of course, be necessary usually once every five years. Equation (6) is also applicable for regional volume indices with j ranging over the countries in each region.

Experimental work was carried out at FAO to ensure the adequacy of the proposed new methodology with the intention of its implementation possibly in 1971 or 1972 instead of the methodology used at that time. For reasons not within the scope of this paper, the implementation of such a revision was carried out in 1985 (see paragraph 7 below) with the three calendar years 1979-81 as base period and the corresponding prices and quantities being used in equations (3) and (4) (FAO [2], [3], [4]). For details of the earlier history of FAO index numbers of agricultural production, especially for details of adjustments to production data to eliminate duplication of feed and seed and of the nature of producer prices used, reference may be made to successive FAO yearbooks and to a summary in "The FAO agricultural production index" (FAO [4], pp. 1-2).

It should be noted here that Dr. P.V. Sukhatme gave very high priority to the development of appropriate methodology and improvements in the basic data soon after he took over the directorship of FAO statistics in the early fifties and saw to the introduction in 1956 of common commodity wheat-based price relatives as weighing coefficients for the national commodity quantities in a Laspeyres formula. These coefficients better reflected the purchasing power parities (PPPs) of different currency units than the earlier so-called common international prices. The use of the common prices P_{io} in equation (6) is a logical step for the extension of the wheat-based price relatives because the corresponding PPPs reflect the effect of the prices of all agricultural commodities and not only of wheat. In fact, the P_i in equations (3) and (4) for the base period, reduces to the base period wheat-based price relative for commodity i when $N = 1$.

The replacement of the wheat-based price relatives used in the calculation of FAO *country* indices by the corresponding average base period country producer prices, was also planned to be carried out simultaneously with the adoption of equation (6) for regional and world indices. These revised country indices were actually implemented later in 1976 at the time of updating the base period to the three calendar years 1969-71. Unfortunately, for regional and world indices the wheat-based price relatives were replaced at the same

time by the US dollar converted national prices using the IMF official exchange rates for this purpose (FAO 1978) instead of the far superior P_{io} of equation (6). The FAO resort to the already discredited use of official exchange rates for inter-country, regional, international and world indices of agricultural production was described by the author, at an international meeting, as a retrogressive step which might result in misleading indicators (Khamis [7], pp. 178). The organiser and chairman of the meeting was a senior FAO statistician who surprised the participants by announcing that FAO was already taking steps to discontinue the use of the official exchange rates and to adopt the Geary-Khamis (GK) methodology which was already in use by the United Nations in the International Comparison Programme (ICP) (see, e.g., Kravis, Heston and Summers [11], pp. 76-79 and 89-94). The GK aggregation method satisfies most of the desirable index number axioms and tests, including transitivity and, subject to availability of all relevant data, the product test, and leads to additivity of real product over all components of gross domestic product. This is an important property for the regional and world FAO indices and for the analysis of the contributions of the various commodity groups and for inter-country comparisons.

The author's contributions in his 1970 and 1972 papers to the development of the Geary seminal idea outlined above is "widely recognised by many authors" as "having firmly founded the aggregation method of detailed categories for multilateral international comparisons of real products and prices" (Kurabayashi and Sakuma [12], pp. 115). This last reference together with a paper by D.S. Prasada Rao (Prasada Rao [15]) are useful references for those interested in the aggregation methods for inter-country, regional and world real product and price comparisons. Many other methods were or have been proposed as alternatives for the GK method but most of them suffer from shortcomings and none of them is fully and consistently additive. The Statistical Office of the European Community (EUROSTAT) and the Directorate of the Organization for Economic Co-operation and Development (OECD), who previously used the GK method in co-operation with the UNICP, claim that the GK method is subject to the so-called Gerschenkron effect (G-effect) which is claimed to result in higher volume levels for countries whose price structure is very different from the average prices P_i. The two organizations have recently used in addition to the GK method the EKS method for member countries of the OECD, including those in the European Union (EU) (OECD [13], [14]). The author has shown that the EUROSTAT/OECD claim is not valid and that the EKS method leads to serious additivity and other problems. The following table illustrates the important property that comparisons between results of one

method and another are not independent of which country or group of countries is taken as a base for comparison. For any EU country where the GK result exceeds the EKS result for 1993, there is usually a base "country" for which this inequality is reversed (Khamis [10]). Reference may also be made to an earlier illustration due to Peter Hill (EUROSTAT [1], pp. 55-56). These illustrations show that the G-effect claim regarding the GK and the EKS methods is generally incorrect.

Order of magnitudes of EKS and GK multilateral measures of 1993 real GDP for 12 EU/OECD countries for different base 'Countries'.
(OECD Reports, Vols. I and II, first half of Table 1.1)
Notation : $\lessdot\equiv$ EKS $<$GK; $>\equiv$ EKS $>$ GK; $\approx\equiv$ the two types of indices are almost equal

Base 'Countries' $\Rightarrow$	OECD	Den-mark	Ger-many	Greece	Ireland	Nether-lands	Spain
Belgium	>	>	<	>	<	>	>
Denmark	<	...	<	>	<	<	<
France	<	>	<	>	<	>	>
Germany*	>	>	...	>	>	>	>
Greece+	<	<	<	...	<	<	<
Ireland	<	>	<	>	...	>	>
Italy	>	>	<	>	>	>	>
Luxembourg	>	>	<	>	>	>	>
Netherlands	≈	≈	<	>	<	...	<
Portugal+	<	<	<	<	<	<	<
Spain	<	>	<	>	<	>	...
United Kingdom*	>	>	>	>	>	>	>
EU (12)	<	>	<	>	>	>	>

* If USA is taken as a base then the EKS for each of UK and Germany is < GK
+ If Turkey is taken as a base, then the EKS of Portugal and Greece is > GK

In concluding the author acknowledges the highly useful discussions of the GK methodology at the FAO Statistics Advisory Committee of Experts in the 1960s and the encouragement received from its members, especially the

late Dr. V.G. Panse, Prof. David Finney, Dr. Conrad Taeuber and Dr. Gerard Theodore. Also, many helpful comments by Dr. C.R. Rao and the late Dr. K.R. Nair and Dr. Daroga Singh and their staff and students were made during three seminars on the subject given by the author at their respective organizations in Calcutta and Delhi in 1969. Above all, the encouragement and incisive comments by Dr. P.V. Sukhatme at FAO and later during International Statistical Institute sessions and on a number of occasions at the author's home in the UK, were most valuable.

REFERENCES

[1] EUROSTAT, 1982. Multilateral Measurement of Purchasing Power and Real GDP. Statistical Office of the European Communities, Luxembourg.

[2] FAO, 1986 a. 1985 FAO production yearbook. **39**, FAO, Rome.

[3] FAO, 1986 b. Inter-country Comparisons of Agricultural Production Aggregates, Economic and Social Development. Paper 61, FAO, Rome.

[4] FAO, 1986 c. The FAO Agricultural Production Index, Economic and Social Development. Paper 63, FAO, Rome.

[5] Khamis, S.H., 1970. Properties and conditions for the existence of a new type of index numbers. *Sankhyà*, **B 32**, Parts 1 and 2, 81-98.

[6] Khamis, S.H., 1972. A new system of index numbers for national and international purposes. *J. Roy. Statist. Soc.*, **A** *(General)*, **135**, 96-121.

[7] Khamis, S.H., 1983. Applications of index numbers in international comparisons and related concepts. *Bulletin of the International Statistical Institute*, **50**, Book 1, Madrid, 171-188.

[8] Khamis, S.H., 1984. On aggregation methods for international comparisons. The Review of Income and Wealth, **30**, 195-205.

[9] Khamis, S.H., 1996. Consistency in aggregation principle for multilateral comparisons of purchasing power parities and real product. In: International Comparisons of Prices, Output and Productivity, Editors D.S. Prasada Rao and J. Salazar-Carrillo, North Holland, 187-193.

[10] Khamis, S.H., 1998. Measurement of real product: Some index number problems. Paper prepared for the 25th General Conference of the International Association for Research in Income and Wealth, Cambridge, England, 23-29 August 1998.

[11] Kravis, I.B., Heston, A. and Summers, R., 1982. World Product and Income - International Comparisons of Real Gross Product. John Hopkins University Press, Baltimore and London.

[12] Kurabayashi, Y. and Sakuma, I., 1990. Studies in International Comparisons of Real Product and Prices. Kinokuniya Co., Tokyo.

[13] OECD, 1995. Purchasing Power Parities and Real Expenditure. Vol. I, EKS Results - 1993; Statistical Directorate, Organization for Economic Co-operation and Development, Paris.

[14] OECD, 1996. Purchasing Power Parities and Real Expenditure. Vol. II, GK Results-1993; Statistical Directorate, Organization for Economic Co-operation and Development, Paris.

[15] Prasada Rao, D.S., 1997. Aggregation methods for international comparison of purchasing power parities and real income: Analytical issues and some recent developments. *Proceedings of the Bulletin of the International Statistical Institute*, **57**, Book 1, Istanbul, 197-200.