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# SHORT-RANGE FORECASTING OF COFFEE PRODUCTION†

Short-range forecasts of coffee production are important for the formulation of policy by private concerns in the coffee trade, by governments and public agencies of coffee exporting countries, and by the International Coffee Organization. In spite of very large stocks of coffee held in exporting countries, and notwithstanding the International Coffee Agreement, prices of coffee in recent years have responded significantly to major year-to-year changes in production. This response was demonstrated late in 1963 when prices rose sharply with anticipations (later realized) of a record low Brazilian crop for 1964.[1] Again in late 1969 prices rose sharply in response to reports of frost affecting the 1970 Brazilian crop.

A number of econometric models have been developed to relate production of tree crops through adjustments in acreages under trees to price changes and, in certain cases, to relate changes in production to agronomic factors affecting the maturation period before harvesting. Both Bateman and Behrman develop models for cocoa production using some modification of Nerlove's price expectations hypothesis (*4*; *5*; *16*). Ady produces a modification which is applied to both cocoa in West Africa and to coffee in Uganda (*1*). Arak develops a model to determine the desired level of the stock of coffee trees in the state of São Paulo in Brazil making use of some earlier work by French and Bressler on the lemon industry of Southern California (*2*; *10*). The results of these studies have important implications for producer price policy and for government investment policy relating to the production of these tree crops. However, where it is difficult to quantify im-

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[1] This interpretation does not accord with that of Law, who writes in a discussion of an article by Kravis that "the 1964 price jump must be considered the direct result of the coffee agreement, with only minor—if any—assistance from the weather" (*15*, p. 614; *13*). The similarity of the 1969 and the 1963 situations—except insofar as the status of the Agreement is concerned—suggests that emphasis should be on the weather rather than on the Agreement. In addition, it should be noted that the Agreement was a continuation, albeit with much stronger machinery and with the formal participation of importing countries, of earlier agreements among exporting countries to restrict supplies of coffee on world markets (*17*, pp. 202–14). This is not to dismiss the importance of the Agreement. The machinery provided by the Agreement might have been used to offset the effects of the expected decreases in production on prices by temporary increases in export quotas (*17*, p. 271).

portant variables affecting yield, particularly climatic factors, the models developed serve less adequately as a basis for short-range forecasting of a particular season's crop. For coffee, an important variable determining production in a particular year which is difficult to quantify is the degree of frost damage, including no damage, in major coffee-producing states of Brazil.

This paper outlines an alternative approach involving a rather straightforward method which might be used to assist forecasting of a coffee crop some six to nine months before harvesting. It makes use of relationships established on the basis of analysis of production estimates for the period 1945 to 1967 and gives a guide to the assessment of current reports on coffee crop conditions. The contribution of the variability of coffee production in individual countries to variability in world total coffee production is calculated in the first part of the study. For the rest of the discussion only those geographic areas contributing most to year-to-year change in world coffee production are considered: Brazil, Colombia, and Ivory Coast.

Estimates published by the United States Department of Agriculture (USDA) are used in this study as the chief source of data on coffee production in individual countries (Appendix Table I). These estimates, which provide comprehensive coverage, are widely used.[2] Because Brazil occupies such an important position in the international coffee market and because important shifts have occurred in the relative importance of the different producing areas within Brazil, data for individual Brazilian states are also analyzed. As the USDA publishes estimates only for Brazil as a whole, data on coffee registrations published by the Instituto Brasileiro do Café (IBC) are used for individual states. (See Appendix Table II.)[3]

## CONTRIBUTION OF INDIVIDUAL COUNTRIES TO VARIABILITY OF YEAR-TO-YEAR CHANGES IN WORLD COFFEE PRODUCTION

Feller specifies the relationship of total variance to the variance of component parts as follows (*9*, p. 216):

If $X_1, \ldots, X_n$ are random variables with finite variances $\sigma_1^2, \ldots, \sigma_n^2$;

and $S_n = X_1 + \ldots + X_n$; then $\mathrm{Var}(S_n) = \sum_{k=1}^{n} \sigma_k^2 + 2\sum_{j,k} \mathrm{Cov}(X_j, X_k)$,

the last sum extending over each of the $\binom{n}{2}$ pairs $(X_j, X_k)$ with $j < k$.

The last statement may be written as follows:

[2] The Pan-American Coffee Bureau and the Institut National de la Statistique et des Etudes Economiques (INSEE) acknowledge the USDA as the source of most of the production data used in their publications. However, estimates published by the Food and Agriculture Organization of the United Nations (FAO) frequently differ from those published by USDA.

[3] Until the late 1950's IBC registrations covered *produção exportável*, defined to include not only production for export but also shipments to the principal ports destined for consumption in those ports and for Brazilian coastal shipping trade. From 1958/59, IBC registrations were intended to cover all production entering marketing channels. In the earlier years IBC registrations were just above the exportable production estimates published by USDA (production minus current consumption in the exporting country). In later years IBC registrations were in line with total production estimates published by USDA with the exception of years 1958/59, 1963/64, and 1964/65. The differences in the last two years might be explained in terms of producers holding large stocks from the 1963/64 crop for registration during the 1964/65 crop year in anticipation of higher prices as a result of the very small 1964/65 crop.

$$1 = \frac{\sum_{k=1}^{n} \sigma_k^2}{\mathrm{Var}(S_n)} + \frac{2 \sum_{j,k} \mathrm{Cov}(X_j, X_k)}{\mathrm{Var}(S_n)}.$$

The $\frac{\sigma_k^2}{\mathrm{Var}(S_n)}$ terms may be considered as the direct contribution of individual components to total variability, and each of the $\frac{2\,\mathrm{Cov}(X_j, X_k)}{\mathrm{Var}(S_n)}$ terms may be considered as the contribution of the interaction of a pair of components to total variability.[4]

In the first application of this formulation year-to-year changes in production ($Q_t - Q_{t-1}$) in the eight major exporting countries and in "other producing countries" are used as variables "$X_1$" to "$X_9$." The results of this analysis are presented as percentages in Table 1. The "direct contributions" are shown on the diagonal, and the "interaction contributions" are shown below the diagonal. The total of the "direct contributions" is 87.59 per cent and the interactions provide a net positive addition of 12.41 per cent. More important, however, is the observation that Brazil contributes directly 86.13 per cent of total variability in year-to-year change in production. The interaction between changes in Brazilian production and changes in the production of other countries provides an additional 11.84 per cent of total variability. This interaction comes largely from changes in production in Colombia, the world's second largest coffee producer, and changes in production in Ivory Coast, the world's third largest coffee producer, which tend to coincide with changes in production in Brazil. There is no simple explanation as to why these changes should have tended to coincide over the period under study. Insofar as the position of the two-year cycle, weather conditions, and de-

TABLE 1.—CONTRIBUTION OF INDIVIDUAL PRODUCING COUNTRIES TO VARIABILITY OF YEAR-TO-YEAR CHANGES IN WORLD COFFEE PRODUCTION, 1946/47 TO 1966/67*

*(Per cent)*

| | Brazil | Colombia | El Salvador | Mexico | Guatemala | Ivory Coast | Angola | Uganda | Other countries | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Brazil | 86.13 | | | | | | | | | 86.13 |
| Colombia | 5.03 | 0.39 | | | | | | | | 5.42 |
| El Salvador | −0.46 | −0.05 | 0.04 | | | | | | | −0.47 |
| Mexico | 1.93 | 0.09 | 0.03 | 0.05 | | | | | | 2.10 |
| Guatemala | 1.86 | 0.13 | −0.02 | 0.02 | 0.03 | | | | | 2.02 |
| Ivory Coast | 4.20 | 0.27 | −0.15 | 0.03 | 0.07 | 0.52 | | | | 4.94 |
| Angola | −2.86 | −0.05 | −0.02 | −0.06 | −0.02 | −0.05 | 0.08 | | | −2.98 |
| Uganda | 0.75 | −0.05 | −0.03 | 0.00 | 0.03 | 0.15 | −0.01 | 0.07 | | 0.91 |
| Other countries | 1.39 | 0.10 | −0.03 | 0.02 | 0.03 | −0.03 | 0.14 | 0.03 | 0.28 | 1.93 |
| Total | 97.97 | 0.83 | −0.18 | 0.06 | 0.14 | 0.59 | 0.21 | 0.10 | 0.28 | 100.00 |

* Calculations made using the production estimates published by the United States Department of Agriculture (USDA) as presented in Appendix Table I. See text for the equation used. Twenty-one observations are used with $t = 1$ for year 1946/47, $t = 2$ for 1947/48, . . . , $t = 21$ for 1966/67.

[4] See Friedman for an application of this relationship to economic analysis (*11*, pp. 117–32).

TABLE 2.—CONTRIBUTION OF INDIVIDUAL STATES IN BRAZIL TO VARIABILITY OF YEAR-TO-YEAR CHANGES IN IBC REGISTRATIONS, 1946/47 TO 1966/67*

*(Per cent)*

| | São Paulo | Paraná | Minas Gerais | Espírito Santo | Other states | Total |
|---|---|---|---|---|---|---|
| São Paulo | 19.61 | | | | | 19.61 |
| Paraná | 32.97 | 40.64 | | | | 73.61 |
| Minas Gerais | 3.33 | 5.58 | 1.11 | | | 10.02 |
| Espírito Santo | −4.88 | −2.25 | 0.60 | 0.78 | | −5.75 |
| Other states | 0.70 | 1.35 | 0.29 | 0.04 | 0.12 | 2.50 |
| Total | 51.73 | 45.32 | 2.00 | 0.82 | 0.12 | 99.99 |

* Calculations made using data on coffee registrations published by the Instituto Brasileiro do Café (IBC) as presented in Appendix Table II. See text for the equation used. Twenty observations are used with $t = 1$ for year 1946/47, $t = 2$ for 1947/48, . . . , $t = 21$ for 1966/67, omitting observation for $t = 13$ (1958/59).

grees of insect damage are reflected, this coincidence is probably mere chance. However, it may also reflect changes in productive capacity as a result of similar response of plantings (and abandonments) to price changes.

These results underline the importance which must be attached to developments in Brazil in discussion of year-to-year variability in world coffee production. Much of the additional attention should be devoted to Colombia and Ivory Coast—in part because of the coincidence of their production changes with changes in Brazil, in part because of the direct contribution of variability in these two countries to world variability, and in part because of the dominance of these two countries in the production of milds and robustas, respectively.[5]

Table 2 shows a similar analysis for the Brazilian states. Paraná's direct contribution to total Brazilian variability is more than double that of São Paulo, although São Paulo's share of production taken over the period under study was slightly greater than that of Paraná. In addition, the interaction component between these two states is high. If Paraná and São Paulo were to be considered as one unit, the direct contribution of these two states together would be 93.22 per cent of the variability in IBC registrations for Brazil. The only negative interaction components are between Espírito Santo, a state of declining importance, and São Paulo and Paraná, respectively. Thus, within Brazil, attention must be focused upon the states of Paraná and São Paulo.

## FACTORS AFFECTING THE SIZE OF THE COFFEE CROP IN BRAZIL, COLOMBIA, AND IVORY COAST

Both changes in productive capacity and changes in yield from existing capacity contribute to year-to-year changes in the production of coffee. Productive capacity increases with the coming into bearing of plantings made four to seven years earlier, including allowance made for greater yielding power of improved varieties, and with improvements in cultural practices. Productive capacity de-

[5] Colombian and Brazilian coffees are both arabica, but the trade makes a distinction between coffees grown in Brazil which are called "brazils" and all other coffees grown in other parts of Latin America which are called "milds" (*22*, p. 39).

creases with the abandonment of coffee trees, with the incidence of any lasting damage from frost and from plant disease, and with deterioration in cultural practices. Changes in productive capacity are more subject to human control than are variations in yield. Arak has made an important contribution to the discussion of changes in productive capacity in Brazil (*2*, pp. 211–23).

Yields may vary from year to year because of (1) the two-year bearing cycle,[6] (2) changes in weather conditions, with frost and drought reducing output, and with a favorable distribution of rainfall and sunshine increasing output, (3) unusually heavy or light damage from insects and from plant disease, and (4) changes in the availability of labor during the harvesting season.

While writings on coffee production refer to the two-year bearing cycle, no clear explanation of the cause is offered (*12*, pp. 231, 237; *21*, p. 357). It would seem that the coffee tree suffers from the strain of a heavy harvest so that it cannot carry as much fruit the following year, and vice versa. Wellman says that the cycle is much more evident for arabica coffee production than for robusta coffee production (*21*, p. 357). Wellman also notes that within large geographic areas the different local areas have "on" and "off" years more or less independently of each other. From time to time an important weather change may cause conformity to be produced for a few years until local conditions reimpose varied patterns. Thus, the smaller the geographic area considered, the more pronounced the two-year cycle pattern is likely to be.

Flowering, maturing, and harvesting of coffee in Brazil extend throughout much of the year (*7*, pp. 321–22; *8*, pp. 543–52; *21*, pp. 352–57). The weather through the period from May to July when harvesting is being completed is normally dry with the coffee trees acquiring a dormant appearance. Showers, usually beginning in August, bring a profusion of blossoms and renewed vegetative growth to the coffee trees. Blossoming in the most important coffee-growing states —Paraná, São Paulo, Minas Gerais, and Espírito Santo—occurs primarily between the beginning of September and the end of October. Eight or nine months are required for fruit to mature after the blossoming period. In the cooler regions of the south the length of the maturation period may extend to ten months. Harvesting of the coffee cherries thus occurs from March through June or July, and sometimes as late as September (*23*, p. 22).

The flowering, maturing, and harvesting of coffee may be disturbed by three climatic factors: frost occurring from July through mid-September; drought during the blossoming period and in the early maturing season; and rain damage during the harvest season.

Frost damage occurs most frequently in Paraná, but from time to time the damage extends into São Paulo and Minas Gerais. Harvesting is usually completed by the time frost hits, so that there is little or no damage to current production. However, the blossoming and vegetative growth on the coffee trees for the following crop may be seriously damaged. In some years these effects are offset by abundant rainfall during September, October, and November. Some coffee trees may be destroyed completely by frost damage, but most of the trees hit will

[6] Alternatively called a biennial cycle or an "on-off" production pattern.

recover by the second harvest. Thus frost damage is confined primarily to the harvest nine or ten months later.

Drought damage is most frequently reported in São Paulo, although there are occasional reports of similar damage in Espírito Santo, Paraná, and Minas Gerais. Drought during the normal flowering period may both delay and reduce the blossoming. At a later date an extended period of dry weather may hamper the development of the fruit, resulting in small cherries of light weight.

Prolonged heavy rains during the harvesting season may delay the picking of the cherries and cause some crop loss. However, such rains are most beneficial to the following harvest. The USDA reports that there is an old saying in Brazil that a rain-damaged crop is followed by a bumper crop (*18*, FCB 20–54, p. 2).

The pattern of coffee production in Colombia is much more varied than the pattern in Brazil. In the first place, there are two harvest seasons in each area each year—one considered a primary harvest and the other a secondary harvest (*8*, pp. 567–68). Second, the timing of harvests in different parts of the country differs more than in Brazil because of the greater differences in elevation and in climatic conditions in the coffee-producing areas of Colombia. In the departments of Antioquia, Caldas, and Magdelena, the principal harvest occurs from October through January, and the secondary harvest occurs from March through May. In the departments of Valle, Tolima, Cauca, Cundinamarca, and Huila, the principal harvest lasts from March to June and the secondary harvest from October to December (*8*, pp. 567–68). Flowering occurs roughly nine months before harvesting in each region (*7*, pp. 321–22). Drought and rain damage are the climatic factors most frequently reported as affecting production adversely.

In Ivory Coast blossoming usually occurs between February and April and harvesting between October and January (*7*, pp. 321–22). Low production is frequently attributed to drought damage although the reports do not make clear the timing of the drought.

Variations in yields may occur also because of varying degrees of damage inflicted by insects or by plant disease. For Brazil, the most important damage in this category comes from the coffee-bean borer (*Stephanoderes hampei Ferr.*), locally called the *broca* (*7*, p. 286; *12*, pp. 319–20; *20*, pp. 9–29; *21*, pp. 305–7). Broca damage is most severe in warm and dry parts of the coffee-producing regions. The insect lives only on coffee, attacking fruit of any age, and growing fastest on more mature cherries. The insect is considered indigenous to Africa. Vayssière reports that infestation in Brazil occurred about 1913, probably arriving by way of Java (*7*, p. 286). Wickizer indicates that control measures in Brazil in the 1920s and later repressed the broca until serious drought in 1944, coupled with the greater neglect of coffee trees in periods of low prices, produced conditions favorable to broca infestation, especially in São Paulo (*22*, pp. 51–52). By 1947 broca-damaged coffee beans were estimated at over 10 per cent of the São Paulo harvest. More stringent measures of control have helped to curb broca damage in recent years. In Colombia occasional damage from insects such as the *hormigas de amaga* is reported. In Ivory Coast small branch borers from time to time cause significant damage.

In addition, the availability of labor and hence the cost of harvesting, coupled with expected returns, may affect the thoroughness of the harvesting. The amount of tree care, including the amounts of fertilizer applied, if any, may vary from year to year although changes in these practices are likely to be gradual.

### YEAR-TO-YEAR CHANGES IN COFFEE PRODUCTION IN BRAZIL, COLOMBIA, AND IVORY COAST

An attempt is made here to isolate the contribution of the two-year cycle to year-to-year changes in coffee production in Brazil, Colombia, and Ivory Coast, and in each of the major coffee-producing states in Brazil. The model used may be more formally specified by equation (1):

(1) $\Delta Q_t = f\,(\Delta Q_{t-1}, t, u)$

where "$Q$" is coffee production,
"$t$" is the crop year,
"$u$" is a stochastic disturbance term,
and $\Delta Q_t = Q_t - Q_{t-1}$.

Equation (2) is used to approximate this relationship:

(2) $\hat{\Delta Q_t} = a_0 + a_1 \Delta Q_{t-1} + a_2 t$

where "$a_0$," "$a_1$," and "$a_2$" are estimates of three unknown parameters,
and "$\hat{\Delta Q_t}$" is expected change in production for given estimates of "$a_0$," "$a_1$," "$a_2$," "$\Delta Q_{t-1}$," and "$t$."

The crop year variable is omitted where "$a_2$" is not significantly greater than zero at the 5 per cent level using the $t$-statistic (one-tail test). Values for "$a_1$" significantly less than zero are considered as evidence of a two-year bearing cycle in the country (or state) under discussion. The coefficient "$a_0$" gives a value which may be associated with a constant change in production. "$a_0 + a_2 t$" may be considered as making allowance for an increasing (or decreasing) change in productive capacity. The increase (or decrease) in the change is constant according to this formulation. Curvilinear formulations for the "$t$" variable were also tested, and in one case the coefficient is significantly different from zero at the 5 per cent level.[7]

The results of the computations are summarized in Table 3. The regression coefficient in equation (3) for Brazil shows that after allowance is made for the effects of the constant term, approximately three-quarters of any increase or decrease achieved from one year to the next is likely to be reversed the following year. The standard error of this regression coefficient is relatively low: less than one-quarter the value of the coefficient. Similar results are obtained for Colombia and Ivory Coast. It is of interest to note that the regression coefficient in equation

[7] It is admitted that this equation does not provide a satisfactory treatment of change in productive capacity. It is difficult, however, to formulate an appropriate hypothesis, and in turn an appropriate equation, to account for changes in productive capacity. Presumably a lagged price relationship might be used, but neither the specification of the length of the lag nor the justification of this method in terms of producers' expectations is easy. Incorporation of some of the elements from Arak's model might prove useful (2). However, it may be argued that the improvement in results obtained would be outweighed by the disadvantages of working with a much more complex model.

TABLE 3.—ASSOCIATION BETWEEN TWO-YEAR BEARING CYCLE AND YEAR-TO-YEAR CHANGE IN COFFEE PRODUCTION AND IN IBC REGISTRATIONS, 1947/48–1966/67*

*(Thousand bags of 60 kgs.; in parentheses standard error)*

| Number and description of equation | $a_0$ | $a_1$ | $a_2$ | $R^2$ | $S$ |
|---|---|---|---|---|---|
| USDA production estimates: | | | | | |
| (3) Brazil | 1000[a] | −0.745 (0.185) | | 0.48 | 7662 |
| (4) Colombia | 148 | −0.617 (0.176) | | 0.41 | 521 |
| (5) Ivory Coast | 239 | −0.642 (0.214) | | 0.33 | 668 |
| IBC registrations: | | | | | |
| (6) Brazil | −505[a] | −0.791 (0.175) | | 0.56 | 6008 |
| (7) São Paulo | −513 | −0.904 (0.132) | | 0.75 | 2112 |
| (8) Paraná | 52 | −0.590 (0.204) | | 0.34 | 4602 |
| (9) Minas Gerais | −138 | −0.770 (0.201) | | 0.48 | 754 |
| (10) Espírito Santo[b] | 134 | −0.908 (0.107) | −1.176 (0.654) | 0.83 | 363 |
| (11) Other states | −26 | −0.562 (0.148) | | 0.47 | 197 |

* Calculations made using data presented in Appendix Tables I and II. The equation used is $\hat{\Delta Q}_t = a_0 + a_1 \Delta Q_{t-1} + a_2 t$ except for Espírito Santo. See text for its derivation. Each regression equation using USDA production estimates is based on 20 observations with $t = 1$ for year 1947/48, $t = 2$ for 1948/49, . . . , $t = 20$ for 1966/67. Each regression equation using IBC registrations is based on 18 observations with $t = 1$ for year 1947/48, $t = 2$ for 1948/49, . . . , $t = 20$ for 1966/67, with observations $t = 12$ (1958/59) and $t = 13$ (1959/60) omitted because of change in coverage. All the $a_1$ coefficients are significant at .01 level (one-tail test). The $a_2$ coefficient was found to be significant at .05 level (one-tail test) only for Espírito Santo. "$R^2$" is the coefficient of (multiple) determination and "$S$" is the standard error of estimate (adjusted for degrees of freedom).

[a] If the calculations for Brazil using USDA production estimates (equation 3) had been made omitting $t = 12$ and $t = 13$, which were both periods with large increases over the preceding year, $a_0$ would have been negative and of the same general magnitude found for IBC registrations (equation 6).

[b] The equation used is $\hat{\Delta Q}_t = a_0 + a_1 Q_{t-1} + a_2 t^2$. The $a_2$ coefficient for the equation using the linear form of the $t$ variable is not significant at the .05 level.

(5) for Ivory Coast is significant at the 1 per cent level using the $t$-statistic. On the other hand, a similar formulation using data for Angola and Uganda, two other robusta producers, does not provide regression coefficients significant at even the 10 per cent level (*17*, pp. 42–87).

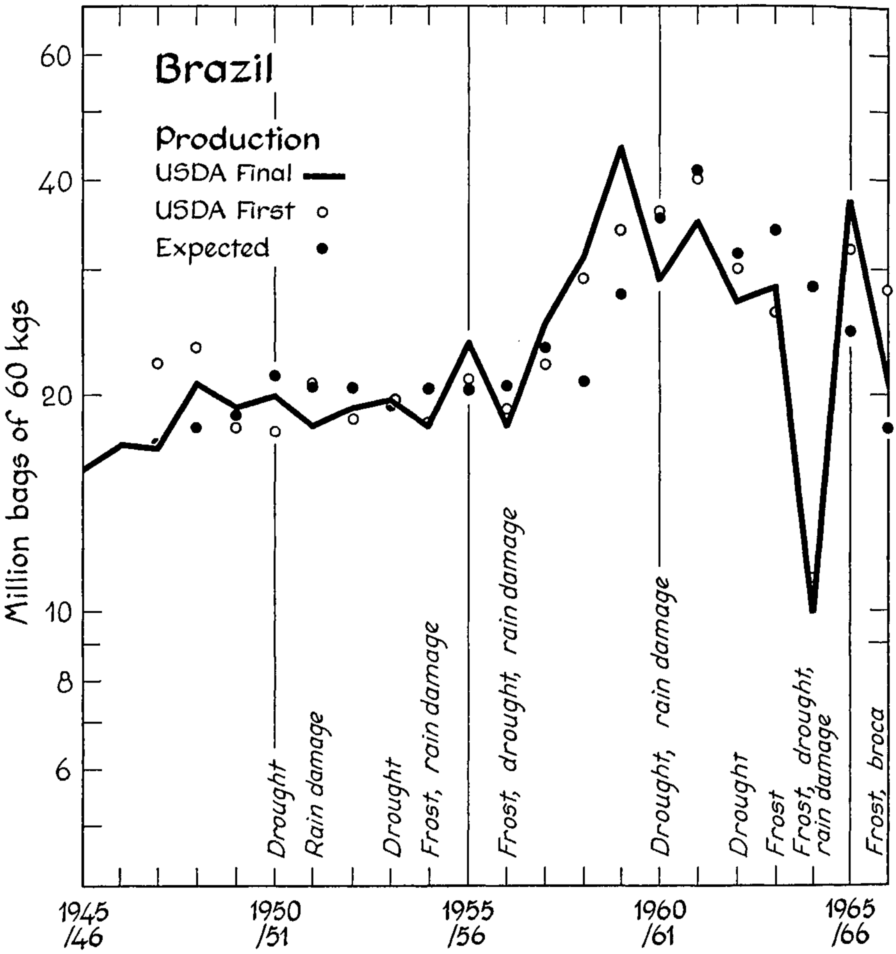
Table 3 also gives the results of regression analysis using IBC registrations. The same procedure was followed as that for the analysis of production estimates published by USDA except that two years of observations were omitted due to change in coverage (see footnote *3*). Only for Espírito Santo is the "$a_2$" coefficient significant at the 5 per cent level using the $t$-statistic test (one-tail test). The discrepancy between the value for "$a_0$" in equation (3) and the value in equation (6) is largely due to the omission of the two observations, $t = 12$ (1958/59) and $t = 13$ (1959/60), in the calculation using IBC registrations. For both of these observations there is a very large increase in production over the preceding year. The values for "$a_1$" vary considerably. The coefficients are largest for São Paulo and Espírito Santo, where the reversal to be expected from one year to the next is roughly nine-tenths the increase or decrease of the previous year. In São Paulo there was little change in the level of production throughout the period studied, so that different yearly increases and decreases in productive capacity would obscure only in a limited way observation of the two-year cycle. The inclusion of a time trend variable in the equation for Espírito Santo probably enabled better account to be taken of changes in productive capacity in that state than elsewhere. The widely varying changes in productive capacity in Paraná, and possibly in Minas Gerais, may have obscured the two-year cycle. "On-off" variations in the component states of the group of "other states" may have offset one another.

The difference between realized and expected values $(Q_t - \hat{Q}_t)$ is considered as an estimate of production change *net* of the effects of the two-year cycle and the effects of part of the change in productive capacity. This difference is called "residual I." An attempt is made to relate changes in the size of "residual I" to reported changes in weather, insect, and plant disease conditions during the flowering, maturing, and harvesting seasons for coffee, to reported changes in the rate of increase or decrease in productive capacity, and to any other factors mentioned as affecting the size of coffee production in a particular area in a specific year. Most of the qualitative information for this part of the analysis was obtained from periodic USDA crop reports currently presented in the Foreign Agriculture Circular series for coffee, designated FCOF (*18*; *19*). Use is made also of a second residual, "residual II." This residual is the difference between the final and first production estimates published by USDA for each year's crop, that is, $(Q_t - Q_t^{1st})$. The size of this residual gives a rough indication of the predictability of the results of certain causes of production change.

Chart 1 summarizes the results of the analysis of changes in coffee production for Brazil. Adverse conditions were reported in Brazil by USDA for most of the years in which a shortfall of realized production below expected production is shown. Drought was reported in the early flowering season for the 1950/51 crop (*19*, November 14, 1949, pp. 496–97). Although the situation is less clear for 1951/52, rain damage appears to have been of some importance (*19*, May 7, 1951, p. 538). The information available does not provide an explanation which would account for the shortfall in 1952/53. However, this shortfall was relatively small. Frost injured both the 1954/55 and the 1956/57 crops in Paraná (*18*, FCB 3–54, p. 5; FCOF 11–55, pp. 2–3). In 1960/61 drought hit the crop in São Paulo and Paraná so that production fell more than would have been anticipated in the wake of the bumper 1959/60 crop (*18*, FCOF 4–59, p. 5). Frost damaged the 1963/64 crop in Paraná (*18*, FCOF 4–62, p. 4). Weather conditions were most unfavorable for the 1964/65 crop with frost damage to Paraná trees for the second consecutive year and severe drought centered in São Paulo (*18*, FCOF 3–63; FCOF 1–64, p. 4).

It is less easy to explain increases in production greater than would have been expected on the basis of equation (3). Very favorable weather conditions and

CHART 1.—BRAZIL: THREE ESTIMATES OF COFFEE PRODUCTION, 1945/46 to 1966/67*




* USDA data from sources cited for Appendix Table I; expected production calculated using equation 3 from Table 3.

large increases in productive capacity are probably the principal causes. It is difficult to pinpoint the years when large increases in productive capacity manifested themselves. Wickizer reports renewed plantings beginning in 1943 particularly in northern Paraná (22, p. 143). These plantings may have contributed to the large 1948/49 crop. Production rose substantially in 1955/56 and each year from 1957/58 through 1959/60. King, in his study of Brazil's coffee industry, records sharp increases in acreages of producing coffee trees in Paraná in each of these years (*14*, p. 6). In addition, Coste includes in his study a table from the September 1955 issue of *Revista Cafetera Colombia* showing that almost two-thirds of the coffee trees in Paraná at that time were less than five years of age (*8*, p. 549). These increases resulted from plantings induced by the sharp rise in the price of coffee in 1949 and the continued high level ending in a second rise in 1954 together with favorable conditions for expansion of coffee production in Paraná. Little change occurred in other states in Brazil at this time. There is no ready explanation for the large crop in 1965/66 or the fact that the crop in 1966/67 exceeded the expected value despite reports of frost and broca damage (*18*, FCOF 5-65, p. 4; FCOF 4-66, p. 4).

The sum of the squared observations for residual I is more than three times the sum of the squared observations for residual II. Thus the first estimate published by USDA for Brazilian coffee production provides a better forecast of the final estimate published by USDA than the estimate derived from equation (3).[8] This result is as expected because first estimates published by USDA can take into consideration such factors as frost damage, drought, rain damage, broca damage, and varying rates of change in productive capacity.

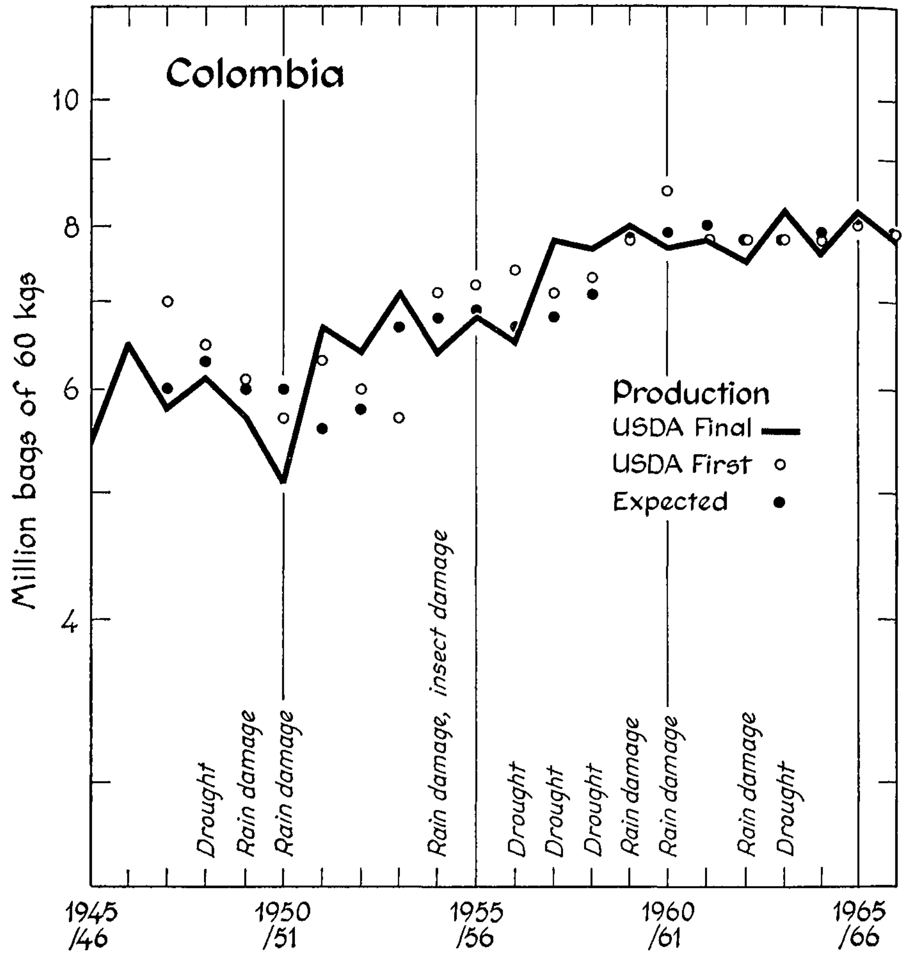
Colombian coffee production as shown in Chart 2 appears much more stable than that shown in Chart 1 for Brazil. Unfortunately, USDA reports on Colombia give a much less clear indication of the relative importance of the various causes of production change than do the reports for Brazil. Heavy rains from January through April 1950 reportedly damaged the year-end crop for the 1949/50 season and destroyed many of the blossoms for the 1950/51 crop (*19*, June 26, 1950, p. 673). The 1954/55 crop was also adversely affected by heavy rains and by damage as well from amaga ants and other insects (*18*, FCB 19-54, p. 1; FCOF 11-55, pp. 4-5). No reports of adverse conditions are available to explain the shortfall for either 1962/63 or 1964/65.

A USDA report refers to three "exceptionally good crops in succession"—for the years 1951/52, 1952/53, and 1953/54 (*18*, FCB 8-54, p. 2). The same report states that a survey carried out in mid-1952 indicated that slightly over 10 per cent of all coffee trees in Colombia were not yet in production. This percentage seems low, in view of the increase in plantings which might have been expected to follow the sharp price rise in world coffee markets in 1949. It would appear, therefore, that the large crops in 1951/52, 1952/53, and 1953/54 were more the result of favorable conditions and perhaps better care of plantations than the result of increased plantings. Production from new trees may have contributed more to the large crops in 1957/58 and 1958/59. Plantings made at the time of the very high prices in the early 1950s, especially in 1953/54, could be expected to enter production about this time. However, reports also mention both increased use of fertilizer and favorable weather (*18*, FCOF 4-58, p. 5; FCOF 1-59, p. 5). No explanation is available for the large 1963/64 crop.

In contrast to the situation for Brazil, the sum of the squared observations for residual I is lower than the sum of the squared observations for residual II. Thus equation (4) provides a better basis for prediction of the final estimate of production than does the first estimate published by USDA. As the equation does not take into account such factors as rain or drought damage, the record of the USDA in forecasting the coffee crop in Colombia would seem rather poor. However, it should be emphasized that the diversity of production conditions in different parts of Colombia makes forecasting of coffee production a rather difficult task.

[8] The significance of this comparison depends upon the accuracy of the final estimate published by USDA. If no revisions were made in the estimates, the first estimate would be a perfect forecast of the final estimate!

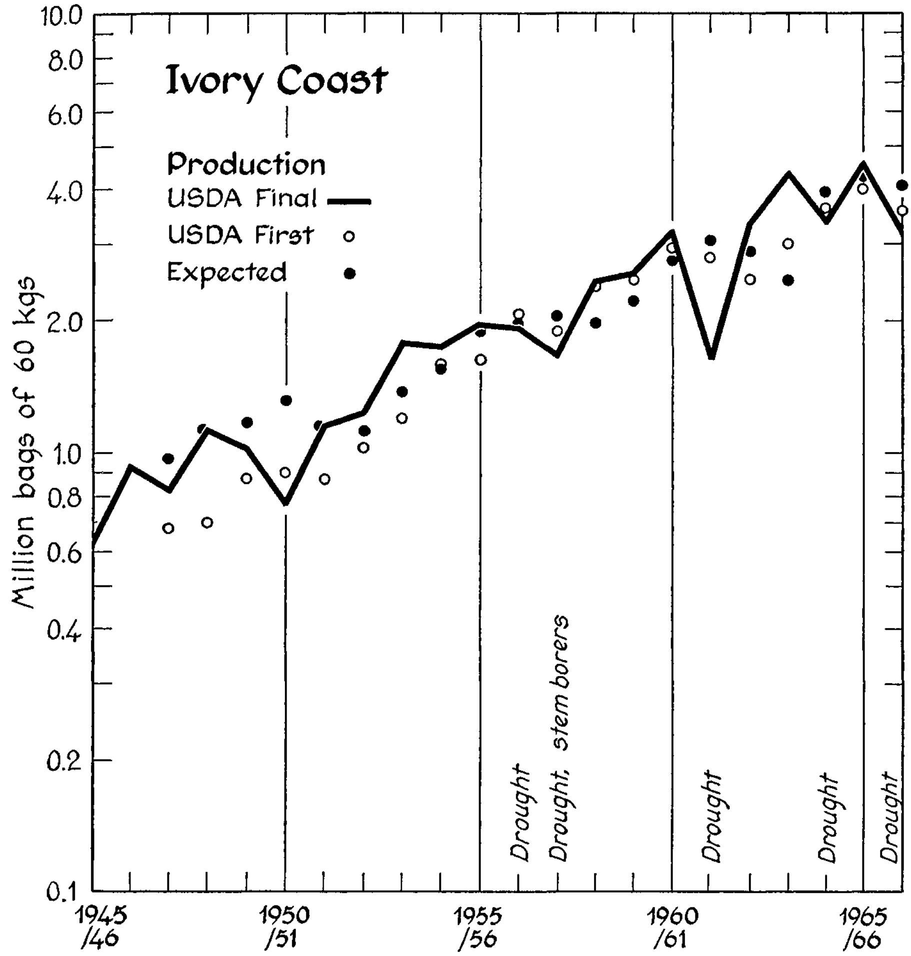
CHART 2.—COLOMBIA: THREE ESTIMATES OF COFFEE PRODUCTION, 1945/46 to 1966/67*




* USDA data from sources cited for Appendix Table I; expected production calculated using equation 4 from Table 3.

Chart 3 illustrates the upward thrust of coffee production in Ivory Coast which may be contrasted with the slower rates of growth illustrated in Charts 1 and 2. No reports were discovered concerning production conditions in Ivory Coast during the first three years when shortfalls of $Q_t$ below $\hat{Q}_t$ are recorded: 1947/48, 1949/50, and 1950/51. All of the other shortfalls are coincident with reports of drought (*18*, FCOF 3–57, p. 3; FCOF 1–58, p. 7; FCOF 4–61, p. 5; FCOF 3–66, p.4; *3*, p. 159). Unfortunately, the reports do not make clear the timing of the drought damage. In 1957/58 stem borer damage was reported as well (*18*, FCOF 8–57, p. 6). $Q_t$ exceeded $\hat{Q}_t$ by large amounts each year from 1958/59 to 1963/64, excluding 1961/62 when prolonged drought was reported. The very large increase in 1963/64 was in part the result of "excellent growing conditions" (*18*, FCOF

CHART 3.—IVORY COAST: THREE ESTIMATES OF COFFEE PRODUCTION, 1945/46 to 1966/67*




* USDA data from sources cited for Appendix Table I; expected production calculated using equation 5 from Table 3.

4–63, p. 6). However, a large part of the differences in this period seem attributable to increases in productive capacity at a rate greater than the secular trend. As in the case for Brazil, the sum of the squared observations for residual I exceeds the sum of the squared observations for residual II, although the difference here is not great.

## FORECASTING THE COFFEE CROP FOR BRAZIL, COLOMBIA, AND IVORY COAST

### *Brazil*

A rough ranking of the causes of change in annual production of coffee in Brazil can now be made. Probably of greatest importance over the period under study is the change in productive capacity, which in turn is related both to world coffee prices and to Brazilian government policy concerning coffee production and trade. Explicit consideration of the effects of changes in world prices and in government policy on productive capacity in Brazil is considered as outside the scope of this study. The production increases have been greatest in Paraná where registered production accounted for only 10 per cent of total Brazilian registrations during the five-year period 1945/46 through 1949/50 and nearly 50 per cent of total registrations during the period 1960/61 through 1964/65. As indicated above, the increase in productive capacity in Paraná has not been at a steady rate. The productive capacity in São Paulo and Minas Gerais at the end of the twenty-year period under study was probably little different from that at the beginning. Increases in the late 1950s appear to have been matched by decreases in the 1960s. In Espírito Santo, decreases in the 1960s probably exceeded any increases in productive capacity that may have been achieved in the late 1950s.

The two-year cycle might be considered second as a cause of annual production change in Brazil. Analysis of registration data coupled with the description of other potential causes of production change provides additional evidence of the importance of the two-year cycle. Analysis of registration data for smaller geographic units than the states might prove useful.

The presence or absence of frost damage is of great importance in determining the size of the larger changes in Brazil's coffee production from one year to the next. This factor is given its due weight in the price reactions of international coffee markets. The relative importance of frost damage as a cause of production change is increasing as the center of coffee production in Brazil shifts more and more to Paraná, the coffee-producing state most susceptible to frost damage.

Most of the coffee-producing states have suffered drought damage. If drought and frost damage happen to coincide, as they did in 1964/65, a very small crop may result. Paraná seems less frequently hit by drought, so that the shift of production to this state may lessen somewhat the importance of drought damage.

The pattern of rainfall during harvest time affects both the current crop and the succeeding crop. The positive effect on the size of the succeeding crop is probably of greater importance than the negative effect upon the quality and, to a lesser extent, upon the quantity of the current crop.

Broca damage appears to have been more important during the early part of the period under study than in the later part. However, the importance of varying amounts of damage from the coffee-bean borer must not be too heavily discounted, as evidenced by the reports of serious damage during 1966. Nevertheless, the removal of older trees as part of the diversification program, especially in Espírito Santo, should help to lessen the importance of this pest.

The important causes of annual production change in Brazil may be observed many months before the actual harvest is made. Indeed, new plantings must be made four or five years before any production is obtained. The effects of abandonments and of diversification programs may be assessed, at least partially, in advance. The two-year cycle occurs with considerable regularity. This cycle is more evident the more the production data are disaggregated by geographic regions of production. Frost damage occurs about nine months or so before harvesting begins. The presence or absence of rains before, during, and immediately after the blossoming period (roughly nine months before harvesting) is important.

Useful estimates of production for Brazil could be made in October or November, just after the flowering season is ended, when it is known whether there has been frost damage and whether the rain conditions in the important early stages in the development of the coffee cherries have been favorable. In addition, if possible, the estimates should be disaggregated for the major coffee-producing states, so that developments as the crop matures in different parts of the country can be followed with greater ease by those interested.[9]

*Colombia*

From the information at hand one may conclude at least tentatively that the two-year cycle is the most important factor in explaining year-to-year variation in coffee production in Colombia. The rain or drought conditions are the next most important considerations. Changes in productive capacity have played a role as well but have not been as important as in most other producing countries. The upward trend of production has been at a slow and fairly steady rate. Damage from insects such as *hormigas de amaga* is mentioned only occasionally. Frost damage is not reported for Colombia. Problems in crop forecasting for Colombia arise from the diversity of conditions in the coffee-growing regions. It seems unlikely that worthwhile production forecasts can be made for Colombia many months before the actual harvest is made without considerable cost—except insofar as the two-year cycle equation might be utilized.

*Ivory Coast*

The relative variability of year-to-year change in coffee production in Ivory Coast is high in comparison with that in Colombia. This factor, coupled with the greater degree of differentiation of the market for robustas than the market for milds from the rest of the coffee market, suggests the value of an early forecast of coffee production in Ivory Coast. Because the two-year cycle is less pronounced for robusta production than for arabica production, the two-year cycle equation is less effective as a guide than the corresponding equation for Colombia. Changes in productive capacity and the presence or absence of drought are the other important causes of production change in Ivory Coast. The little information found concerning the timing of drought damage suggests that it occurs relatively late in the maturation period, thus casting further doubt on the possibility of obtaining good early forecasts of Ivory Coast coffee crops.

## IMPLICATIONS FOR FURTHER COMMODITY RESEARCH

While research on a particular agricultural commodity must give due attention to the characteristics peculiar to that commodity, it is hoped that at least some

[9] At present the first production estimate published for Brazil by USDA does not appear until June for the harvest then well under way. George Gordon Paton and Company publish in *Coffee Intelligence* estimates of Brazilian production attributed to "one of the country's leading coffee firms" (6). This series covers the major coffee-producing states individually and is designed to tie in with the registrations data published later by the IBC. The first crop forecast in this series usually appears in September immediately following or even during the flowering season—nine months prior to the first estimates published by USDA. Unfortunately, no adequate test of the reliability of the estimates published in *Coffee Intelligence* could be made because they have been published with regularity only in the 1960s.

of the steps in this study on coffee might be applied to short-range forecasting of production of other agricultural commodities. Probably more important is the possibility of stimulating commodity research of a similar type. At present a gap appears to exist between the work of the economist concerned with commodity problems who works at an academic institution and the work of the commodity analyst working for private concerns, governments, and national and international agencies. The former has been concerned with such problems as the construction of buffer stock models and the econometric analysis of supply response to price changes. The latter has been concerned primarily with the detailed assessment of current developments in commodity markets. This study fits somewhere between these extremes. Studies of this type would seem important if consideration is to be given either to international planning of commodity trade through such measures as international commodity agreements or to aggressive national policies concerning production or marketing of particular commodities, particularly those entering international trade. (The writer is not arguing here for or against either.) It must be admitted that to a certain extent such work is already being done by government agencies and the private trade. However, studies by persons so employed are rarely made public. Hence it is believed that the economist in an academic institution can make a contribution by pursuing such studies because his work can be made subject to the critical assessment of a wider audience.

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APPENDIX TABLE I.—COFFEE PRODUCTION, 1945/46 TO 1966/67*

*(Thousand bags of 60 kgs.)*

| Year | Brazil | Columbia | El Salvador | Mexico | Guatemala | Ivory Coast | Angola | Uganda | Other countries | World total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1945/46 | 15,800 | 5,500 | 850 | 950 | 1,000 | 625[a] | 425 | 525 | 5,800 | 31,500 |
| 1946/47 | 17,100 | 6,500 | 1,100 | 925 | 1,125 | 925[a] | 825 | 350 | 6,600 | 35,500 |
| 1947/48 | 16,900 | 5,800 | 1,075 | 875 | 1,050 | 800[a] | 775 | 550 | 6,800 | 34,600 |
| 1948/49 | 20,600 | 6,100 | 1,325 | 1,100 | 1,150 | 1,125[a] | 625 | 525 | 6,700 | 39,300 |
| 1949/50 | 19,200 | 5,700 | 1,250 | 1,000 | 1,050 | 1,000[a] | 600 | 475 | 7,300 | 37,600 |
| 1950/51 | 19,900 | 5,100 | 1,200 | 1,100 | 950 | 725[a] | 850 | 650 | 7,800 | 38,300 |
| 1951/52 | 18,100 | 6,700 | 1,075 | 1,175 | 1,300 | 1,125[a] | 925 | 725 | 8,000 | 39,200 |
| 1952/53 | 19,200 | 6,400 | 1,375 | 1,450 | 1,150 | 1,125[a] | 950 | 575 | 9,200 | 41,500 |
| 1953/54 | 19,700 | 7,100 | 1,075 | 1,425 | 1,150 | 1,675[a] | 1,275 | 625 | 10,000 | 44,000 |
| 1954/55 | 18,100 | 6,400 | 1,325 | 1,600 | 1,075 | 1,625[a] | 950 | 1,175 | 9,900 | 42,200 |
| 1955/56 | 23,500 | 6,800 | 1,250 | 1,450 | 1,125 | 1,825 | 1,325 | 1,300 | 11,700 | 50,300 |
| 1956/57 | 18,000 | 6,500 | 1,500 | 1,600 | 1,250 | 1,750 | 1,350 | 1,350 | 12,000 | 45,400 |
| 1957/58 | 25,000 | 7,800 | 1,375 | 1,900 | 1,425 | 1,625 | 1,275 | 1,425 | 13,100 | 55,000 |
| 1958/59 | 31,000 | 7,700 | 1,475 | 1,600 | 1,400 | 2,475 | 1,475 | 1,525 | 13,000 | 61,700 |
| 1959/60 | 44,000 | 8,000 | 1,575 | 2,050 | 1,600 | 2,575 | 1,800 | 1,950 | 15,400 | 78,900 |
| 1960/61 | 29,000 | 7,700 | 1,450 | 2,100 | 1,500 | 3,200 | 2,750 | 1,900 | 16,100 | 65,800 |
| 1961/62 | 35,000 | 7,800 | 1,900 | 2,350 | 1,700 | 1,650 | 2,800 | 1,950 | 16,800 | 72,000 |
| 1962/63 | 27,000 | 7,500 | 1,650 | 2,200 | 1,900 | 3,350 | 3,100 | 2,950 | 17,700 | 67,400 |
| 1963/64 | 28,200 | 8,200 | 2,000 | 2,850 | 1,800 | 4,350 | 2,800 | 2,900 | 17,800 | 71,000 |
| 1964/65 | 10,000 | 7,600 | 2,050 | 2,650 | 1,625 | 3,375 | 3,100 | 2,450 | 18,500 | 51,300 |
| 1965/66 | 37,400 | 8,200 | 1,800 | 3,000 | 2,025 | 4,550 | 2,800 | 2,600 | 18,700 | 81,100 |
| 1966/67 | 21,000 | 7,800 | 2,100 | 2,900 | 1,800 | 3,175 | 3,400 | 2,700 | 19,200 | 64,100 |

* Data from United States Department of Agriculture (USDA), Foreign Agricultural Service, *Foreign Agriculture Circular*, FCB and FCOF, various issues from May 21, 1954, through January 1967; and United States Department of State, Foreign Service, *Brazilian Coffee: Production and World Trade* (1953), Table II. Data for Brazil, Colombia, other countries, and world total rounded to nearest 100,000 bags. Other data rounded to nearest 25,000 bags.

[a] Estimates for 1945/46 through 1954/55 published by USDA refer to French West Africa including the coffee-producing territories of Ivory Coast, Guinea, and Dahomey. USDA estimates for French West Africa allocated between Ivory Coast and Guinea on basis of ratio for each year as calculated from data provided in FAO, *World Coffee Economy*, Commodity Bulletin Series No. 33, 1961, p. 46, Table 1A. Production for Dahomey considered below 25,000 bags and hence ignored.

APPENDIX TABLE II.—IBC REGISTRATIONS, 1945/46 TO 1966/67*

*(Thousand bags of 60 kgs.)*

| Year | São Paulo | Paraná | Minas Gerais | Espírito Santo | Other states | Brazil total |
|---|---|---|---|---|---|---|
| 1945/46 | 6,100 | 670 | 2,870 | 1,990 | 1,060 | 12,700 |
| 1946/47 | 8,870 | 1,140 | 2,180 | 1,210 | 620 | 14,020 |
| 1947/48 | 6,520 | 1,550 | 2,760 | 2,040 | 700 | 13,570 |
| 1948/49 | 11,170 | 1,890 | 2,410 | 1,030 | 450 | 16,950 |
| 1949/50 | 7,390 | 2,320 | 3,210 | 2,540 | 840 | 16,300 |
| 1950/51 | 8,120 | 4,030 | 2,750 | 1,390 | 470 | 16,750 |
| 1951/52 | 6,260 | 2,840 | 3,370 | 2,040 | 500 | 15,020 |
| 1952/53 | 7,190 | 5,050 | 1,840 | 1,530 | 490 | 16,100 |
| 1953/54 | 6,160 | 3,200 | 3,370 | 1,830 | 590 | 15,100 |
| 1954/55 | 7,330 | 1,340 | 3,170 | 1,850 | 820 | 14,510 |
| 1955/56 | 9,270 | 6,310 | 3,740 | 2,050 | 700 | 22,060 |
| 1956/57 | 6,020 | 2,180 | 1,930 | 1,560 | 850 | 12,540 |
| 1957/58 | 9,540 | 4,730 | 3,700 | 2,500 | 1,160 | 21,630 |
| 1958/59 | 10,700 | 8,590 | 4,240 | 2,570 | 710 | 26,810 |
| 1959/60 | 15,620 | 20,410 | 4,490 | 1,910 | 1,400 | 43,820 |
| 1960/61 | 8,240 | 14,320 | 3,480 | 3,100 | 710 | 29,850 |
| 1961/62 | 11,560 | 17,940 | 3,600 | 1,800 | 960 | 35,860 |
| 1962/63 | 5,000 | 17,980 | 2,500 | 2,410 | 780 | 28,660 |
| 1963/64 | 9,580 | 9,160 | 2,160 | 1,580 | 680 | 23,150 |
| 1964/65 | 6,820 | 7,150 | 1,800 | 1,700 | 600 | 18,060 |
| 1965/66 | 11,820 | 21,000 | 2,940 | 1,350 | 540 | 37,630 |
| 1966/67 | 4,780 | 9,550 | 2,210 | 1,530 | 620 | 18,690 |

* Data from Instituto Brasileiro do Café (IBC), *Anuário Estatístico do Café, 1965*, p. 1, for years 1945/46 through 1964/65, and from *Coffee Intelligence*, January 5, 1967, for 1965/66 and 1966/67. Coverage of registrations changes in 1958/59 (see text, footnote 3). Data rounded to nearest 10,000 bags.