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Merrill J. Bateman

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SANTA MONICA • CALIFORNIA

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This study is presented as a competent treatment of the subject, worthy of publication. The Rand Corporation vouches for the quality of the research, without necessarily endorsing the opinions and conclusions of the authors.

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One of the most important policy problems facing the Colombian government is the coffee surplus.

Although the coffee sector's share of national income has been declining, the coffee industry still accounts for 8 to 9 percent of the nation's income. Moreover, coffee is the most important source of foreign exchange. The problem is that Colombian production has exceeded the demand for Colombian coffee, given the price levels that the International Coffee Organization (ICO) has tried to maintain. Since 1957, total marketing possibilities, domestic sales, and exports have averaged only about 90 percent of production, and the burden of financing purchase of the surplus (and obtaining agreement on the distribution of the costs of the support program) has limited the success of the government's development policy. Given the government's desire to maintain its membership in the ICO and the limitation on export quotas that membership entails, production will continue to exceed marketing possibilities unless there is a change in the government support policy.

To help reveal the relationship between changes in prices received by producers and quantitative changes in coffee production, Bateman formulates an econometric model on the premise that a coffee farmer maximizes profits by adjusting his stock of trees to match his expectations concerning future prices. Adjustment equations of the Nerlovian genre are used. That is, it is assumed that movements in actual producer prices shape expectations concerning future prices and that the actual stock of trees is adjusted in proportion to the difference between the desired long-run stock and the actual stock. Another input is information about the agronomic production lag (3-6 years) and biennial yield fluctuation of Colombian coffee.

With the model, three different price elasticities are distinguished: (1) output response to current price; (2) output response to past prices, allowing for a change in the stock of trees (but without a Nerlovian adjustment); and (3) output response to past prices, allowing for both a change in the stock of trees and a Nerlovian adjustment. (Because of inconsistencies in the coefficients estimated for the lagged dependent variables, it was not possible to obtain elasticity estimates of the latter type.)

Empirical results obtained from the model suggest that (1) changes in price do not affect the intensity of harvesting; (2) there are lags of 5 years between price changes and lags of 7 years between production changes; and (3) the elasticity of coffee supply with respect to price is about 0.5. These findings imply that a 20 percent reduction in producer prices would lead to a 10 percent reduction in coffee production, but only after 7 years. Previous estimates of the elasticity of the Colombian coffee supply have been substantially lower, but the models used to obtain them are flawed by improper assumptions about the time lag between changes in price and changes in output and about the yield-age relationship for newly planted coffee trees.

* * *

This is the final publication of a broad study of the Colombian economy undertaken at The Rand Corporation. The primary emphasis has been on the macropolicy options of the Colombian government with respect to the development of the industrial sector.

CD

PREFACE

This Memorandum is the final publication of a multifaceted study of the Colombian economy undertaken at The RAND Corporation under the sponsorship of the Agency for International Development, with supplementary funds provided by the Corporation. The primary emphasis has been on the macropolicy options of the Colombian government with respect to the development of the industrial sector. This phase of the analysis was summarized in Colombian Development Policy, R-461-AID/RC, by Richard R. Nelson, Robert L. Slighton, and T. Paul Schultz, August 1969. It was initially hoped that a similarly comprehensive study of policy options toward the agricultural sector could be undertaken. The first and critical stage in such a study was to have been an analysis of supply response to price change for the major cash crops in Colombia. The available data were not sufficient to permit such a study, however, and the decision was made to restrict this phase of the study to the supply characteristics of the coffee sector. The present Memorandum summarizes that research.

The author is indebted to Richard R. Nelson and George R. Hall of The RAND Corporation, Mark Nerlove of Yale University, and Paul Johnson of North Carolina State University for many helpful suggestions during the course of this study. Any errors that remain are, of course, the sole responsibility of the author.

The author is a member of the Department of Economics at Brigham Young University, Provo, Utah, and a Consultant to the Economics Department of The RAND Corporation.

SUMMARY

One of the most important policy problems facing the Colombian government is the coffee surplus. Since 1967 total marketing possibilities, domestic sales, and exports have averaged only about 90 percent of production, and the burden of financing purchase of the surplus (and obtaining agreement on the distribution of the costs of the support program) has served as an important constraint on the success of the government's development policy. Given the Colombian government's desire to maintain its membership in the International Coffee Organization and the limitation on export quotas that such membership entails, production may exceed marketing possibilities in the future if there are not adjustments made promptly in the government support policy. In these circumstances it is highly important to understand the nature of the relationship between changes in prices received by producers and changes in the quantity of coffee production. The quantitative study of this relationship is the focus of this Memorandum.

To this end an econometric model is formulated on the hypothesis that a coffee farmer maximizes profits by adjusting his stock of trees to match his expectations of future prices. Adjustment equations of the Nerlovian genre are employed. That is, it is assumed that movements in actual producer prices shape expectations concerning future prices and that the actual stock of trees is adjusted in proportion to the difference between the desired long-run stock and the actual stock. Information as to the agronomic production lag (3-6 years) and biennial yield fluctuation of Colombian coffee is utilized. Several alternative forms of the basic estimating equation are examined.

With this model three different price elasticities can be distinguished: output response to current price; output response to past prices, allowing for a change in the stock of trees, but not taking into account an adjustment process of the Nerlovian type; and output response to past prices allowing for both a change in the

stock of trees and the Nerlovian adjustment process. Because of inconsistencies in the coefficients estimated for the lagged dependent variables, it was not possible to obtain elasticity estimates of the latter type, however.

The empirical results obtained from this model suggest, first, that changes in prices do not affect the intensity of harvesting (at least over the price range observed since 1945); second, that there are lags between changes in prices of five years and in changes of production of seven years; and third, that the elasticity of coffee supply with respect to price is about 0.5. These findings imply that a 20 percent reduction in producer prices would lead to a 10 percent reduction of coffee production, but that it would take at least seven years for this effect to be brought about. Previous estimates of the elasticity of coffee supply in Colombia have been substantially lower, but the models used to obtain these estimates are flawed by inappropriate assumptions as to the time lag between changes in price and changes in output and as to the yield-age relationship for newly planted coffee trees.

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I. COFFEE AND THE COLOMBIAN ECONOMY

The major purpose of this Memorandum is to formulate an econometric model for the supply of Colombian coffee and to estimate the output response of the coffee industry to price incentives. In addition to the model, the role of coffee in the Colombian economy is analyzed to provide a framework for understanding the implications of the model's results.

The study is organized as follows: Section I examines the coffee industry with attention given to production and price movements, coffee as a source of income, and coffee exports as a source of foreign exchange; Section II outlines the physical environment of Colombian coffee; Section III formulates a supply model for Colombian coffee; and Section IV presents the empirical results of the model.

The period under review begins in 1947 and ends in 1965. Colombian coffee has a much longer history and has played a dominant role in the Colombian economy for a number of decades, but data for the last 20 years are readily available even though their accuracy leaves something to be desired.

During the past twenty years Colombian coffee exports have varied between 270,000 and 400,000 metric tons with Colombia's export volume representing anywhere from 14 to 25 percent of the world total. Colombia's share of the world export market reached its peak of 24.8 percent in 1954 and then began to decline, averaging approximately 15 percent during the first half of the 1960s. The decline has been largely due to the rapid expansion of coffee in other areas, particularly Africa.

The importance of coffee in the Colombian economy is illustrated in Table 1. Beginning in 1950, coffee exports were valued at 600 million pesos, represented almost one-tenth of the nation's income, and earned four-fifths of the country's foreign exchange. The next seven years (1951-1957) found the coffee industry at its zenith in terms of its contribution to the economy of the country. During

Table 1

COLOMBIAN NATIONAL INCOME, VALUE OF EXPORTS,
AND COFFEE PRICES, 1950-1965

Year	National Income (billions of pesos)	Exports (billions of pesos)		Coffee Exports as a Percent of		Coffee Prices	
		Total	Coffee	National Income	Total Exports	U.S. Spot Price for Manizales (¢/lb)	Export Price of Colombian Coffee (U.S. $; 1958 = 100)
1950	6.84	.77	.60	8.8	77.8	53.2	102
1951	7.66	.99	.74	9.7	75.2	58.7	112
1952	8.28	1.08	.85	10.3	78.5	57.0	109
1953	9.21	1.41	1.15	12.5	81.6	60.2	114
1954	10.94	1.58	1.31	12.0	83.1	80.0	153
1955	11.25	1.46	1.23	10.9	83.7	64.6	123
1956	12.66	1.66	1.35	10.7	81.2	74.0	141
1957	14.80	1.85	1.42	9.6	76.9	63.9	122
1958	16.46	2.32	1.74	10.6	74.8	52.3	100
1959	19.08	2.45	1.79	9.4	73.0	45.2	86
1960	21.82	2.60	1.77	8.1	68.3	44.9	86
1961	25.10	2.60	1.78	7.1	68.3	43.6	83
1962	28.15	3.03	2.13	7.6	70.3	40.8	78
1963	35.53	3.36	2.14	6.0	63.6	39.6	76
1964	44.23	4.38	2.89	6.5	65.8	48.8	93
1965	48.78	5.00	2.70	5.5	54.0	48.5	93

Sources:
1948-1964, International Financial Statistics, Supplement to 1965-1966 Issues, pp. 54-59.
1965-1966, International Financial Statistics, June 1967, pp. 84-87.

this period coffee exports, as a percentage of total exports, increased from 75 percent in 1951 to a high of 84 percent in 1954 and were still above 75 percent in 1957. In the peak year, 1954, coffee exports were valued at 1.31 billion pesos; total exports were 1.58 billion. With regard to the entire economy, coffee exports averaged almost 11 percent of national income between 1951 and 1957. If one also adds the income earned in the domestic coffee manufacturing sector, approximately 3.5 percent can be added to the coffee export percentage, illustrating more clearly the significant contribution of the coffee sector to the national economy.[1]

The major reason for coffee's increased contribution to the Colombian economy during the mid-1950s was the rise in world coffee prices. Prices began increasing in 1946 when the United States ended price controls. From a low of 21 cents per pound in 1946 the U.S. spot price for Colombian coffee (Manizales) advanced to a high of 80 cents in 1954. During this period a rapidly increasing demand was only partially offset by moderate increases in supply. Two extraordinary events led to significant price jumps. In 1950, Brazil's surplus stocks were exhausted for the first time in two decades. As a result, all coffee prices increased markedly and, in particular, the price of Manizales jumped from 37 to 50 cents between 1949 and 1950. The second event began in late 1953 with reports of frost damage to the Brazilian crop. Although the reports exaggerated the extent of the damage, the scramble in the market pushed the price of Colombian coffee to 80 cents per pound.

The value of Colombian coffee exports continued to increase, in peso terms, after 1954. In the ten-year period beginning in 1956 the peso value doubled as coffee exports advanced from 1.35 billion to 2.70 billion. The numerous devaluations in the dollar value of

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[1] U.N. Food and Agriculture Organization, Coffee in Latin America: Colombia and El Salvador, 1958, p. 12.

the Colombian peso were mainly responsible for the increase. In dollar terms, the amount of foreign exchange earned by coffee exports in 1965 was less than in 1956 and considerably less than the zenith year of 1954. The respective U.S. dollar earnings for 1954, 1956, and 1965 were $550 million, $413 million, and $350 million.

The loss of foreign exchange occurred in spite of increased production and exports. Volume increases in Colombian coffee exports during the 1956-1965 period were more than offset by decreases in the dollar price of coffee. The country's coffee exports increased approximately 25,000 metric tons between 1953-1957 and 1960-1965 -- an 8 percent increase (see Table 2). On the other hand, Table 1 shows a considerable drop in the U.S. dollar export price of Colombian coffee -- the price level for the 1960-1965 period was approximately 35 percent lower than the 1953-1957 level.

The impact of declining prices also appears in the percentage that coffee exports are of national income and total exports. From a high of 12.5 percent of national income in 1954, coffee exports fell to 5.5 percent in 1965. From more than 80 percent of total exports, coffee declined to just over 50 percent. Other sectors of the Colombian economy were advancing rapidly during this period and overshadow the contribution of coffee. One should remember, though, that many of those sectors were able to grow because of the foreign exchange base provided by the coffee sector.

The information on Table 2 is closely associated with the data on Table 1; however, the second table allows one to examine a different set of relationships.. In particular, annual production data and real producer prices form a basis for examining producer responses to price incentives.

Two different series of production figures are presented in Table 2 with each one coming from a different source.[1] The first

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[1]Appendix A provides additional information about the production and price series that appear in Table 2.

Table 2

COLOMBIAN COFFEE PRODUCTION
EXPORTS, AND PRICES
(1934-1965)

Year	Production (1,000 metric tons)		Exportable Production (1,000 metric tons)	Exports[c] (1,000 metric tons)	Price				
	FAO[a]	Berry (National Accounts)[b]			Purchase Price of Coffee Paid by the Federation[d]	Consumer Price Index for Colombia (1953 = 100)	Real Producer Price		
							#1[e]	#2[f]	#3[g]
1934							163.1		
1935		309.4					157.5		
1936		325.0					152.4		
1937		331.5					121.3		
1938	267.6	348.4		255.7			107.8	122.6	
1939	265.0	344.5		226.4			110.9	123.4	
1940	267.0	347.1		267.4			84.9	83.2	
1941	285.6	371.8		174.7			125.3	140.1	
1942	329.3	427.7		258.5			121.6	137.6	
1943	317.0	412.1		315.1			113.4	126.8	132.7
1944	332.0	431.6		295.4			121.7	109.9	142.4
1945	328.7	429.0		308.9			117.3	107.5	137.2
1946	345.7	436.8		339.7			140.7	145.6	164.6
1947	369.5	465.4		320.3			154.1	146.0	180.3
1948	346.5	478.4		335.3		68	131.7	150.0	154.1
1949	368.9	453.7		324.6		73	155.1	147.6	181.5
1950	337.8	412.0		268.3		88	186.3	209.0	218.0
1951	302.3	452.0		287.6		95	212.0	235.8	248.0
1952	402.7	504.0		301.9	260.0	93	237.0	224.0	279.6
1953	384.3	507.0		397.9	260.0	100	234.3	217.6	260.0
1954	403.1	498.0		345.2	347.5	109	282.1	270.8	318.8
1955	377.1	454.0		352.0	345.0	109	249.9	229.9	316.5
1956	335.1	493.0		304.2	305.0	116	319.6	298.3	262.9
1957	365.2	584.0		289.4	423.0	133	303.0	254.4	318.0
1958	468.4	589.0	420.0	326.5	526.0	153	255.5	201.2	343.8
1959	462.0	620.0	414.0	384.8	415.0	164	191.8	153.6	253.0
1960	480.0	563.0	420.0	356.3	407.3	170	197.0	144.8	239.6
1961	462.0	619.0	420.0	339.1	451.0	186	191.7	148.4	242.5
1962	468.0	587.0	408.0	393.7	476.7	190	178.8	135.9	250.9
1963	492.0	588.0	390.0	368.0	510.0	252	173.6	142.2	202.4
1964	450.6	629.0	432.0	384.7	657.7	295	181.5	136.0	222.9
1965	480.0	594.0	300.0	339.1	732.5	306	178.3	126.2	239.4

Notes:

[a]Crop year.

[b]Calendar year.

[c]Export figures published by Banco de la Republica.

[d]Average crop-year price in pesos per 125 kilos fixed by the Federation for its stores and agencies (Tipo Pergamino corriente).

[e]Producer price of coffee deflated by the cost of living index for Manizales.

[f]Producer price deflated by a price index of "alternative" crops.

[g]Federation producer price deflated by a cost of living index for Colombia (1952-1965). Pre-1952 data equal 117.0. Real producer price #1.

Sources:

FAO Production, 1938-1960, Production Yearbook, Selected Volumes.
FAO Production, 1961-1965, Production Yearbook, Vol. 20, 1966.
Berry Production, personal correspondence with Edmar Bacha, January 28, 1968.
Exportable Production, Pan American Coffee Bureau, Annual Coffee Statistics, 1965.
Exports Data, 1938-1946, personal correspondence with Edmar Bacha, January 28, 1968.
Exports Data, 1947-1965, Pan American Coffee Bureau, Annual Coffee Statistics, 1965. Initial source for export figures was Banco de la Republica.
Federation Price, Federacion Nacional de Cafeteros, Boletin de Informacion Estadistica Sobre Cafe, 1966.
Consumer Price Index, IMF, International Financial Statistics, Selected Volumes.
Real Producer Price #1 and #2, personal correspondence with Edmar Bacha, January 28, 1968.

column is taken from FAO reports and the time reference is the crop year (July-June). The second column consists of data compiled by A. Berry of Yale University. For most of the data, his sources were figures obtained from the IBRD and the Colombian national accounts. The time frame for the Berry data is the calendar year.

A comparison of the production data in the first two columns of Table 2 reveals some differences. The Berry data are consistently larger than the FAO production figures. The absolute difference is in the neighborhood of 100,000 tons for most of the period with the difference rising to as much as 220,000 tons in 1957. If one plots the first two columns, a very interesting pattern appears. Beginning in 1950, which is the first year Berry used the national accounts as a source, movements in the Berry data foreshadow movements in the FAO series with a one-year lead. For example, the year 1950 was a poor production year from the standpoint of the Berry data, but the FAO series suggests that a low was reached in the 1950-1951 crop year. Other trough years in the Berry series are 1955 and 1960 with the low points in the FAO data coming in 1955-1956 and 1960-1961. Production increases in the Berry data occur in 1951, 1952, and 1957. On the other hand, increases in the FAO data occur in 1952 and 1958. The reason for the lead in the Berry data is obvious. Approximately 80 percent of the coffee crop is harvested in October and November.[1] Thus, when a substantial increase or decrease occurred, it was recorded in the calendar year "n" and in the crop year "n/n+1".

The difference between the figures for "Exportable Production" and "Exports" for any particular year is an approximation of the surplus coffee stocks the Colombian government has been forced to store. On the basis of the information in Table 2, the accumulated surplus stocks for the 1958-1965 period totaled 400,000 tons. This

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[1] Personal correspondence received from Dr. Hernan Uribe Arango, Executive Director of the Fondo de Desarrollo y Diversificacion de Zonas Cafeteras, Colombia, March 12, 1968.

represents an average surplus of 50,000 tons per year or 8 to 10 percent of the crop (the percentage depends on which production series is used -- FAO or Berry). The annual surpluses are due to the export quotas assigned Colombia by the International Coffee Organization (ICO).

The final three columns in Table 2 provide estimates of the real producer price of coffee. For the most part, the movements in the three series correspond and follow the movements of the world price described earlier. After World War II, the real producer price increased from 120 pesos per 125 kilos (the average price for 1941-1945) to an average of 145 pesos for the 1946-1949 period.[1] This 21 percent increase in the real producer price was considerably lower than the 92 percent rise in the world price because of the cost of living increase in Colombia. The consumer price index increased 77 percent between 1941-1945 and 1946-1949. Just as the world price increased markedly following the depletion of Brazilian stocks in 1949, so did producer prices in Colombia. The real producer price averaged 217 pesos between 1950 and 1953, a 50 percent increase over the preceding four years. This was just the beginning, however, as the producer price continued to climb during the middle of the decade, reaching a high of 320 pesos per load of 125 kilos in 1956.

The price increases of the late 1940s and early 1950s stimulated coffee planting throughout the world. Coffee production began to increase during the mid-1950s and by the end of the decade supply exceeded demand at the high world prices prevailing between 1954 and 1956. The consequent decline in the world price of Colombian coffee during the late 1950s brought a decrease in the Colombian producer price. The real producer price fell from 303 pesos in 1957 to 255 pesos in 1958 and again to 192 pesos in 1959. With the advent of the

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[1] Real producer price #1 is used for discussion purposes. The correlation between the first and second series is very high. On the other hand, the exact timing of upward and downward movements between the first and third price series is not as close as it is between the first two. All three series are tested in the econometric model.

coffee alliance in 1957-1958 and its expansion in the succeeding years, the export quota system arrested the decline in world prices and Colombian officials have tried to stabilize the real producer price. Between 1959 and 1965, the real price received by the farmer fluctuated between 178 and 197 pesos -- a fairly narrow range considering the previous 15 years.

An examination of the production data in relation to movements in the real producer price suggests a production response approximately 5 to 7 years after price changes occur. For example, the price increases in 1946 and 1947 led to increases in production in 1952. The marked increases in the producer price, beginning in 1950, resulted in a production response first noticed in 1957. These lags are somewhat longer than the actual time required by the coffee tree to mature and achieve a significant production level. On the other hand, if one allows a year or so to elapse before the farmer can fully respond to price changes, the 5 to 7 year time-lag between changes in prices and output is not unreasonable. More attention will be given to the lag structure later.

Given the importance of coffee to Colombia, an understanding of the supply and demand mechanisms for coffee is important. Future developments in the demand for coffee and their subsequent effects on world prices will partially determine the volume of foreign exchange that Colombia will have at her disposal. On the other hand, the response of Colombian coffee farmers to economic variables and government policies that affect those variables will determine: (1) the surplus coffee Colombia will be forced to carry as inventories (given her membership in the International Coffee Organization), (2) the prices that the Colombian government will be able to pay the producers and, therefore, the per capita income of said producers, (3) the total cost of transporting coffee internally from the local buying stations to the ports or places of storage, and (4) the opportunity costs of forgoing the use of coffee inputs in other pursuits.

This study does not examine the very complex problem of the costs and returns of membership in the ICO. It is assumed here that Colombia

will remain a member of the organization. In this case Colombia will desire to reduce production, and an obvious way to do this is to reduce the real producer price of coffee. A knowledge of the elasticity of supply is valuable in predicting the output results of any proposed price changes. As stated above, the focus of this study concerns the supply relationships. With this in mind, I examine the physical environment of coffee before formulating an econometric model.

II. THE PHYSICAL ENVIRONMENT OF COLOMBIAN COFFEE

During the 1955-1956 crop year the Economic Commission of Latin America (ECLA) and the Food and Agriculture Organization of the United Nations (FAO) conducted a study of the coffee industry of Colombia in conjunction with similar studies for El Salvador and Brazil. Most of the information that appears in this section is taken from that study, as it is the only major effort to analyze Colombian coffee.[1]

Currently, coffee is the main agricultural commodity in twelve departments. These regions cover the spurs of the three cordilleras that cross Colombia from south to north and the Sierra Nevada de Santa Marta in the north. The coffee zones lie within a belt whose altitude varies between 800 and 2,000 meters above sea-level. Coffee is most intensively cultivated on the western slope of the central cordillera.

Four agricultural regions in Colombia account for three-fourths of total coffee production. For the three crop years 1956-1957 to 1958-1959, the department of Caldas produced 30 percent of the total crop. Antioquia, whose capital is Medellin, produced 16 percent, and the other two departments, Tolima and Valle, averaged 16 and 13 percent respectively.

FARM SIZE

The ECLA/FAO study established four categories for analyzing farms according to size. Table 3 is taken from the ECLA/FAO report and relates to adult coffee only; however, adult coffee constituted 89 percent of the coffee area.

Farms under one hectare represented 36 percent of the total number of coffee farms. However, these small farms represented only 6 percent of the hectarage devoted to coffee and 5 percent of the

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[1] As mentioned above, another study is just being completed. A draft of the study should be available soon.

Table 3

COLOMBIA: PRODUCTION, AREA YIELDS AND NUMBER OF COFFEE FARMS, BY SIZE OF ADULT COFFEE-PLANTING[a], 1955-1956

Size of Adult Coffee-Planting	Number of Farms		Area		Production		Yield	Production per Farm	Area per Farm
	Number	Percent	Hectare	Percent	Tons	Percent	Kilogrammes/ Hectare	Kilogrammes	Hectares
Up to 1.0 hectare	77,245	36.3	39,573	5.8	19,129	5.3	483	248	0.5
1.1 to 10.0 hectares	123,719	58.1	388,923	56.7	207,639	57.9	534	1,678	3.1
10.1 to 50.0 hectares	11,429	5.4	198,947	29.0	108,637	30.3	546	9,505	17.4
50.1 to 100.0 hectares	447	0.2	27,120	3.9	13,734	3.9	506	30,725	60.7
100.1 to 200.0 hectares	79	--	9,649	1.4	4,426	1.2	459	56,025	122.1
over 200.0 hectares	51	--	22,028	3.2	4,996	1.4	227	97,961	431.9
Total[b]	212,970	100.0	686,240	100.0	358,561	100.0	523	1,684	3.2

Notes:

-- Indicates negligible.

[a]In this table, production area and number of farms only refer to adult coffee plantings; therefore national totals are somewhat smaller than in previous tables.

[b]Excluding "other areas."

Sources:

ECLA/FAO coffee survey.

industry's output. The heart of the industry was and is the farms between one and ten hectares and large farms with ten to fifty hectares. Together these two categories accounted for 86 percent of the area devoted to coffee and 88 percent of the country's production. Few farms were larger than 50 hectares, and these represented 8 percent of the area and contributed less than 7 percent of the country's output. Although one can almost disregard the large farms on the grounds that they are few and contribute only a small proportion of total production, one cannot overlook the very small farms even though they produce a small proportion of the total output. The large number of individuals involved requires that this category be given attention by those in authority.

COFFEE YIELDS

In developing an econometric model to estimate the price elasticity of supply, one must know the yield cycle of the tree when planting information is not available. More specifically, three different price elasticities can be distinguished. The first is the output response to current price. This response occurs over a period too short for new plantings to come into bearing. The second is the response of output to past prices, allowing for a change in the stock of trees but not taking into account an adjustment process of the Nerlovian genre. The third elasticity allows for changes in the stock of trees and adjustment lags.

Two different approaches exist for measuring the last two responses. One relates changes in the stock of trees to price movements. This provides a direct measure of the farmer's planting response; and if one assumes a constant relationship between the stock of trees and output, this method also provides an indirect estimate of the relationship between output and prices.

The second approach substitutes output data for information on tree stocks and attempts to estimate the output elasticity directly.

In order to use this method effectively, one must have information about the yield cycle of the tree so that the output-price lag structure can be properly identified.

Colombian data on changes in the stock of trees including new trees planted and old trees removed do not exist on an annual basis. On the other hand, output data, producer prices, and yield data are available. The only approach available is the second one which relates output to prices. Thus, it becomes necessary to examine the yield cycle of Colombian coffee trees.

The ECLA/FAO survey of 1955-1956 attempted to measure the relationship between yields and tree age. Table 4 summarizes the information the survey obtained.

Essentially no production is achieved during the first two years of the tree's life. According to the survey, yields reached approximately one-third their maximum during the third year and between the fourth and ninth years a tree passes from an immature to an adult stage. From the tenth through the fifteenth year, tree yield is at a maximum. Somewhere between the fifteenth and twentieth years, tree yields begin to decline and generally by the twenty-fifth year the coffee tree is no longer considered to be a valuable asset. In other words, the economic life of a coffee tree in Colombia is accepted as approximately twenty-five years.

Personal correspondence with Dr. Hernan Uribe Arango, Executive Director of the Fondo de Desarrollo y Diversificacion de Zonas Cafeteras, spells out even more clearly the yield pattern of Colombian coffee trees during the maturation period:

> The coffee flowers appear on the nodes of one-year-old branches, and from flowering to the ripe fruit there is a lapse of 7 to 9 months. In Colombia's central zone, where most of Colombia's coffee is grown, the first crop is gathered between the 18th and 21st months after the coffee tree is planted. From there on until the fifth year, the annual production increases; the fifth year, due to the extinguishing of the production area on the branches, there is a decline in production. During this

Table 4

COLOMBIA: DISTRIBUTION OF AREA, PRODUCTION, AND YIELDS OF COFFEE PLANTINGS BY AGE, 1955-1956[a]

Age of Plantings (years)	Area of Plantings		Production of Green Coffee		Yield (kilogrammes/ hectare)
	Hectares	Percent	Tons	Percent	
More than 15	430,995	56.1	221,338	60.5	514
13-15	65,998	8.6	35,799	9.8	542
10-12	76,484	9.9	44,385	12.1	580
7-9	51,825	6.7	28,810	7.9	556
4-6	60,938	7.9	28,229	7.7	463
3	34,361	4.5	6,434	1.8	187
2	26,603	3.5	818	0.2	31
1	21,601	2.8	0	0	0
Totals[a]	768,805	100.0	365,813	100.0	476

Notes:

In private correspondence, Marc Nerlove points out that age and location as well as size of holding may be related. This raises problems in using the data in the table since the age variable will then carry the effects of the other variables on yield and perhaps produce misleading results.

[a]Excluding area and production in other areas outside the 12 main producing departments.

Source:

ECLA/FAO coffee survey.

> fifth year, since there is little fruit production, the tree is in a condition to form more of the productive branches on which the following year's production will increase. The tree production varies from then on, with high yields one year and low yields the next.[1]

In summary, the tree begins to produce in the second year and production increases through the fourth, the fifth year brings a decrease in production and, finally, peak production is achieved in the sixth year with biennial yield fluctuations occurring thereafter. The biennial yield fluctuations are the result of internal competition within the tree. The branch development of a tree competes with the fruit development so that "the branch that enjoys a good production one year will have a poor one the next."[2]

The dominant factor determining the biennial yield fluctuations is the weather. During periods of dry weather physiological processes take place within the nodes and other parts of the tree responsible for the later development of the leaves, buds, and so on. The external activity (formation of leaves, buds, and fruit) occurs during rainy periods. The internal transformations have been labeled the "preparatory phase" and the external growth is known as the "constructive phase." According to Trojer "both the preparatory and constructive phases can be correlated with different weather characteristics."[3]

Very little is known about tree productivity during the late stages of tree life. The data gathered by the ECLA/FAO study suggest that the yield decline is not severe. The results of the ECLA/FAO data are generally dismissed, however, on the grounds that the diseased and poor-yielding trees have been replaced thus biasing the result.

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[1] Personal correspondence with Dr. Hernan Uribe Arango, March 12, 1968.

[2] Ibid.

[3] Hans Trojer, "Agroclimatologia," lecture notes provided by Dr. Hernan Uribe Arango.

Also, it is difficult to establish the age of the older coffee trees as farmers do not always remember the year in which a given tree was planted.

With the above information in mind, I shall analyze models already developed by Marcelle Arak and Edmar Bacha. Further, I shall use my model to estimate the output-price relationships in Colombia, and compare the results with those obtained by Arak and Bacha.

III. ECONOMETRIC MODELS FOR COFFEE

During the past three years a considerable amount of attention has been given to the construction of econometric models to explain the supply of coffee. The first major work was the Ph.D. thesis of Marcelle Arak, entitled "The Supply of Brazilian Coffee," M.I.T., 1967. Arak used the first approach of relating the change in the stock of trees to price movements. The second person to take up the cause of measuring supply elasticities for coffee was Edmar Bacha, a graduate student at Yale University. He recently completed a doctoral thesis that includes demand and supply models for world coffee. Bacha's supply models relate output to prices.

ARAK MODELS

Brazilian coffee information is the best collection for perennials anywhere in the world. The number of trees and the age distribution are available for a number of states and for a number of years. The availability of such data allowed Arak to perform a number of tests. In particular, her thesis examined the determinants of coffee supply within the farmer's control: the stock and age distribution of the coffee trees. Given that the total number of coffee trees and the number in each age group depend on the planting and abandonment or removal decisions of coffee farmers, her study analyzed those decisions and attempted to estimate the farmer response to price changes for each type of decision.

Because of the differences in growing conditions from region to region, Arak experimented with a number of different models. The period of analysis was 1930 to 1955 for Sao Paulo, 1927 to 1955 for Espirito Santo and Minas Gerais, and 1945 to 1962 for Parana. For the Sao Paulo area, one of the models applied assumed that planting in year "t" was a function of the farmer's price expectations in that year, the availability of suitable coffee land, and the age composition of the tree stock. Another model, similar to the first, assumed that

the rate of planting, as opposed to the level of planting, was a function of the same set of variables. The models tried were:

$$N_t = a_o + a_1 P_t^* - (T_o + \sum_{i=1}^{t} N_i) + a_2 T_{A_t} \quad (1)$$

$$\frac{N_t}{T_{t-1}} = a_o + a_1 P_t^* - (T_o + \sum_{i=1}^{t} N_i) + a_2 T_{A_t} \quad (2)$$

where

N_t = plantings in year "t".

T_{t-1} = stock of trees in year "t-1".

P_t^* = price expectations in year "t".

T_o = stock of trees in year zero.

N_i = plantings in year "i".

T_{A_t} = percent of tree stock age ten years and over in year "t".

The planting response (unadjusted for lags) of farmers to a change in expected coffee prices as measured by the models, was relatively high. The elasticity of annual planting with respect to coffee prices was 2.0 in the first model and 2.3 in the second. The two models did not provide an estimate of the adjustment coefficient so that adjusted price elasticities were not identifiable.

For the states of Minas Gerais and Espirito Santo, Arak employed a set of hypotheses different from those for Sao Paulo. Instead of outlining the specific set of postulates employed by Arak for these regions, I shall outline a generalized model which will form a basis for explaining her work and the Bacha model which will be described later.

The general model is as follows:

$$T_t^* = a + bP_t^* \quad ; b>o \tag{3a}$$

$$N_t = \gamma_1(T_t^* - T_{t-1}); \quad o<\gamma_1 <1; \; T_t^* > T_{t-1} \tag{3b}$$

$$N_t = 0 \quad ; \quad ; \; T_t^* \leq T_{t-1} \tag{3c}$$

$$R_t = E_t \quad ; \quad ; \; T_t^* \geq T_{t-1} \tag{3d}$$

$$R_t = 0 \quad ; \quad ; \; T_t^* < T_{t-1} \tag{3e}$$

$$E_t = \gamma_2(T_t^* - T_{t-1}); \; -1<\gamma_2<o \; ; \; T_t^* < T_{t-1} \tag{3f}$$

Equation (3a) states that the farmer's desired stock of trees is a function of his real expected price stream for coffee. Equations (3b) and (3c) state that new planting will be proportional to the difference between the desired stock and the actual stock when the former exceeds the latter, and that new planting will equal zero when the actual stock equals or exceeds that desired by the farmer. Equations (3d) and (3e) indicate that replantings, R_t, will equal eradications, E_t, when the desired tree stock equals or exceeds the actual, but will equal zero when the opposite holds. The last equation states that eradications are proportional to the difference between the desired and actual stocks and take place when the actual stock exceeds the farmer's desired level.[1]

The above model outlines the essential features of the formulation used by Arak for Minas Gerais and Espirito Santo. In addition, she

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[1]It should be recognized at this point that the farmer has another option in addition to planting, replanting, and eradication. That option is abandonment and is implicitly included in eradications.

assumed a direct correspondence between the total stock of trees and the adult stock where the latter was assumed to include trees four years and older.[1] Consequently, her dependent variable was the change in the adult stock of trees and her model attempted to estimate the effects of planting and eradication on this variable. Arak accepted the parameter estimates for the planting portion of the model but was not satisfied with the results for the eradication section. The planting-price estimates suggested long-run (that is, allowing for lagged adjustments) elasticities of .54 and .28 for Minas Gerais and Espirito Santo, respectively.

For the state of Paraná, Arak worked with a third set of hypotheses different from those outlined above. This region was opened up after World War II and has experienced phenomenal growth since then. The allocation ratio, $\Delta A_t/\Delta C_t$, was made a function of relative prices of coffee and other agricultural goods. ΔA_t is the change in the area of adult coffee trees and ΔC_t is the change in the total agricultural area of the state. The results indicated a long-run price elasticity equal to .955.

Arak also ran a number of other models, but the main results are those summarized above.

BACHA MODEL

Edmar Bacha recently completed a doctoral thesis at Yale University (1968) which includes a demand and supply model for world coffee.[2] He used two different models to estimate the world supply. The first model is applied to Africa, Colombia, and a group of countries

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[1] Brazilian trees bear earlier than Colombian trees. Available data suggested a maturation period of approximately four years for coffee trees in Brazil.

[2] The following information is taken from a preliminary summary of his work entitled "The Supply of World Coffee," November 1967.

categorized as "other Spanish-American Countries." The second model was used to estimate the output-price response for Sao Paulo.

The first Bacha model is identical to the general model outlined above. In order to simplify his task, Bacha makes the following additional assumptions: (1) Coffee price expectations were never low enough during the observation period (1940-1960) to cause the actual tree stock to exceed the desired one; (2) the "representative" farmer is assumed to foresee at t-n (where "n" is the length of the maturation period) the number of trees he is going to eradicate at t and to "replant" at t-n the same number of trees that he will eradicate n years later; and (3) the volume of coffee produced equals a constant times the stock of adult trees. With these assumptions, his model takes the following form:

$$T^*_{t-n} = a + bP^*_{t-n} \tag{4a}$$

$$N_{t-n} = \gamma_1 \left(T^*_{t-n} - T_{t-n-1}\right) \tag{4b}$$

$$A_t = T_{t-n} \tag{4c}$$

$$Q_t = \sigma A_t \tag{4d}$$

$$Q_t = \sigma\gamma_1 a + \sigma\gamma_1 bP^*_{t-n} + (1-\gamma_1)\, Q_{t-1} \tag{4e}$$

The first two equations are the same as eqs. (3a) and (3b) in the earlier model and represent the same assumptions. Equation (4c) states that the adult stock of trees in period t is the same as the total stock n years ago. This is made possible by the second assumption listed above in which the farmer foresees his eradications and plants enough trees in t-n to offset the trees removed in t. Equation (4d) fulfills the assumption that output is proportional to the stock of adult trees. The final equation is derived from the first three and is the one Bacha estimates.

Series for total coffee production and for deflated domestic producer prices were obtained for Colombia. Export volume figures and dollar prices in the international market were used for Africa and the other Spanish-American countries. Bacha further assumed that a three-year average of observed real prices (centered in t-4) represented the level of price expectations at time "t-4."

Table 5 lists the unadjusted and adjusted elasticities obtained by Bacha and Arak. In general Bacha's elasticities for Colombia appear low. Two of his assumptions may account for this. The first assumption is that age is an important determinant of yield only in the fourth year of the tree's life. This leads to the conclusion that the non-negative change in output is a function of new plantings made in one year only. The Uribe information cited earlier suggests that young trees continue to increase through the sixth year. In fact, one of the largest increases in output takes place between the fifth and sixth years. This leads to Bacha's second crucial assumption. He assumes that a reasonable lag between planting and mature bearing is four years. This lag is used for Africa, Colombia, the other Spanish-American countries, and Brazil. Even if this were a reasonable assumption for areas other than Colombia, four years is too short of a lag for Colombian coffee.[1] Thus, Bacha's use of just one price variable centered on t-4 does not capture a significant portion of the output response to price changes.

With the above models in mind, I shall now attempt to construct an econometric supply model for Colombia. The model relaxes the rigid Bacha assumption that yield is independent of the age of trees (except in the fourth year) and is based on the author's previous work.[2]

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[1] Bacha's use of prices lagged four years for Colombia and the other countries is apparently the result of carrying over the biological information concerning Brazilian coffee trees.

[2] See Clifton R. Wharton, Jr. (ed.), Subsistence Agriculture and Economic Development, Chapter 8, Aldine Publishing Co., 1969.

Table 5

ARAK-BACHA PRICE ELASTICITIES FOR COFFEE

Country	Period	Dependent Variable	Price Elasticities: Unadjusted for Lags	Price Elasticities: Long-Run (Adjusted for Lagged Response)	Source
Brazil					
Sao Paulo	1930-1955	N_t	2.02		Arak
Sao Paulo	1930-1955	N_t/T_{t-1}	2.28		Arak
Espirito Santa	1927-1955	ΔA_t	.08	.54	Arak
Minas Gerais	1927-1955	ΔA_t	.20	.28	Arak
Parana	1945-1962	$\Delta A_t/\Delta C_t$		.96	Arak
Colombia	1939-1964	Q_t	.07	.45	Bacha
Other Spanish-American	1943-1960	Q_t	.26	.51	Bacha
Africa	1943-1960	Q_t	.16	.42	Bacha

Note:

The symbols for the dependent variable are defined as follows:

N_t = number of newly planted trees in year t.

T_t = total stock of trees in year t.

A_t = stock of adult trees or area devoted to adult trees in year t.

C_t = total agricultural area of a region in year t.

COLOMBIAN COFFEE MODEL

It is assumed that the "representative" farmer attempts to maximize profits by adjusting his stock of trees to match his expectation of future prices. Further, there are obstacles hampering the farmer in equating his actual stock of trees with his "desired" tree level. Those obstacles relate to the elasticities of supply of different inputs. Thus the farmer attempts to adjust his actual stock to meet his long-run equilibrium stock of trees. The model is:

$$T_t^* = a_0 + a_1\bar{P}_t = u_t \tag{5}$$

where

T_t^* = desired or long-run equilibrium tree level.

$\bar{P}_t = \sum_{i=0}^{n} (P_{t-i}^*)/(n+1)$

P_{t-i}^* = the expected real producer price of coffee in year t+i.

u_t = the random disturbance term.

Equation (5) states that the desired tree level is a function of the mean value of the expected price stream over the life time of the trees.

Adjustment equations of the Nerlovian genre are employed:

$$\bar{P}_t - \bar{P}_{t-1} = B(\bar{P}_t - P_{t-1}) \tag{6}$$

$$T_t - T_{t-1} = \gamma(T_t^* - T_{t-1}) \tag{7}$$

The price expectation model assumes that movements in actual producer prices shape the farmer's expectations concerning the future. The distributed lag function is common in the literature.

The stock adjustment equation assumes that the actual stock of trees is adjusted in proportion to the difference between the long-run stock and the actual.

The adjustment coefficients are B and γ with the expected value of each falling somewhere between 0 and 1. The size of γ, the acreage adjustment coefficient, depends on the nature of the constraints facing the farmer.

When eqs. (5), (6), and (7) are combined in order to eliminate the desired stock and expected price variables, the result is

$$T_t = a_0 B\gamma + a_1 B\gamma P_t + \left[(1-B) + (1-\gamma)\right] T_{t-1} - \left[(1-B)(1-\gamma)\right] T_{t-2} + \tilde{u}_t \tag{8}$$

where

$$\tilde{u}_t = \gamma\left[u_t - (1-B)\, u_{t-1}\right]$$

The last equation suggests that the actual stock of trees is a function of the current price and the tree stock of the previous two periods. An identification problem exists with respect to the coefficients B and γ. It is not possible to determine separately the coefficients for price expectations and stock adjustment without *a priori* information regarding one or the other.[1]

If data were available for the number of trees on an annual basis, it would be possible to estimate the parameters of eq. (8). This is a close approximation to the equation estimated by Arak for Minas Gerais and Espirito Santo except that she tried to separate the

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[1] If an additional nonexpectational variable were included in the model, the adjustment coefficients would be identifiable without the *a priori* data.

effects of planting and eradication. Given the lacunae that exist in tree stock data, attention is now given to the relationship between output and the number of trees.

There are a number of alternatives facing the farmer in adjusting his actual tree stock to meet his desired stock. Suppose the desired stock exceeds the actual, the farmer can eliminate the deficit by new plantings alone or by new plantings combined with the replacement of old trees. On the other hand, when the actual level exceeds the desired, the adjustment can be made by letting trees go out of production, by eradicating trees without replacing them or by abandoning coffee trees. A modified approach to the latter problem could also take the form of leaving part of the tree crop unharvested.

It is known that the levels of replantings during the 1950s was very low even in the period of high prices, 1953-1955. In those three years, for example, the FAO study revealed that the total number of trees replaced approximated 4.4 percent of all adult trees, or about 1.5 percent annually.[1] Also, producer prices during the 1950s were relatively high compared with producer costs during that period and with producer prices of previous periods. From the evidence one could conclude that little or no eradication took place during the period under review (1947-1965). The most logical adjustment to the stock of trees would have included new plantings and letting old trees go out of production.

In light of the above, the output-tree stock relationship can be formulated as follows:

$$\tilde{Q}_t = \sum_{i=0}^{\infty} b_i \Delta T_{t-i} \qquad (9)$$

where

$\tilde{Q}_t$ = the potential harvest in year "t".

b_i = the yield per acre for trees planted in year "t-i".

ΔT_{t-i} = plantings in year "t-i".

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[1] FAO, p. 26.

Given the information of an earlier section on the relationship between yields and the age of trees, most of the terms in the above equation can be eliminated by performing a first-difference operation. This leads to eq. (10):

$$\Delta\tilde{Q}_t = \sum_{i=k}^{m} \Delta b_i \Delta T_{t-i} + \sum_{i=s}^{t} \Delta b_i \Delta T_{t-i} \qquad (10)$$

where

$\Delta b_i = b_i - b_{i-1}$

k = the first year in which the tree produces significant output.

m = the year in which trees attain their maximum output.

s = the year in which the tree yield begins to decline significantly.

t = the terminal year in which the trees are no longer economic.

The first set of terms on the right hand side of (10) refers to the changes in output which result from new trees coming into bearing. The second set of terms refers to the decline in yield as trees leave the bearing stage. The data gathered by the ECLA/FAO Study Group which appear in Table 4 suggest that the decline in yields is spread out over a long period of time and is not severe. Yield information gathered for Brazilian coffee trees also suggests that trees at 70-80 years of age can produce almost as much as trees in their prime (10-15 years of age).[1] On the other hand, one wonders if the decline is not more severe than that suggested by the data. There is some evidence that diseased and poor-yielding trees are eliminated and replaced by new ones. Still the FAO evidence indicates that replantings were almost insignificant in relation to the number of adult trees. Because of the uncertainty about the effect of declining yield in older trees and because the number of observations are limited and therefore the degrees of freedom are at a premium, it will be assumed for the purposes

[1] Marcelle Arak, "The Supply of Brazilian Coffee" (unpublished Ph.D. thesis), Massachusetts Institute of Technology, 1967, pp. 23-24.

of this paper that the last set of terms in eq. (10) is zero. More specifically, it is assumed that Δb_i in periods "s" through "t" approach zero.

It is now possible to combine (10) with (8) provided that (8) is also first-differenced. The result is reported in the following equation:

$$\Delta\tilde{Q}_t = K_1 \left[\sum_{i=k}^{m} \Delta b_i \Delta P_{t-i} \right] + K_2 \left[\sum_{i=k}^{m} \Delta b_i \Delta T_{t-i-1} \right] - K_3 \left[\sum_{i=k}^{m} \Delta b_i \Delta T_{t-i-2} \right] + \sum_{i=k}^{m} \Delta b_i \Delta\tilde{u}_{t-i} \tag{11}$$

where

$K_1 = a_1 B\gamma$

$K_2 = (1-B) + (1-\gamma)$

$K_3 = (1-B)(1-\gamma)$

In eq. (11) the terms in brackets involving the change in tree stock for periods "t-i-1" and "t-i-2" are equal to the change in potential output lagged one and two years. Therefore, (11) can be re-written in the following form:

$$\Delta\tilde{Q}_t = \left[\sum_{i=k}^{m} \Delta b_i \Delta P_{t-i} \right] + K_2 \Delta\tilde{Q}_{t-1} - K_3 \Delta\tilde{Q}_{t-2} + v_t \tag{12}$$

where

v_t = the random disturbance term in eq. (11).

Obviously, the potential harvest variable is not observed but is modified by weather, the impact of current price on harvesting, and the biennial yield effect which is characteristic of coffee production. If one assumes that these relationships are additive, the following equation relates actual production to the potential harvest.

$$Q_t = \tilde{Q}_t + c\Delta Q_{t-1} + dP_t + w_t \tag{13}$$

where

Q_t = actual production of coffee in year "t".

c = the biennial yield coefficient. This coefficient is assumed to be less than zero.

w_t = the impact of weather on output plus other omitted variables which may affect output. Weather data have not been gathered; and even though the omitted variables may have systematic effects, w_t is assumed to be random.

Combining eqs. (12) and (13) provides the following:

$$\Delta Q_t = K_1 \left[\sum_{i=k}^{m} \Delta b_i \Delta P_{t-i} \right] + d\Delta P_t + c\Delta^2 Q_{t-1} \tag{14}$$

$$+ K_2 \left(\Delta Q_{t-1} - c\Delta^2 Q_{t-2} - d\Delta P_{t-1} \right)$$

$$- K_3 \left(\Delta Q_{t-2} - c\Delta^2 Q_{t-3} - d\Delta P_{t-2} \right) + \tilde{v}_t$$

where

$\tilde{v}_t$ = the random disturbance term including weather.

The final equation relates the change in actual output to changes in lagged prices (those which induce planting), the change in current prices (the harvesting response), the dependent variable lagged one

and two years (the Nerlovian adjustment mechanism), and the second-order change in output lagged one, two, and three years (the biennial yield effect).

Before proceeding it should be noted that $\Delta^2 Q_{t-1}$ is an exact linear combination of ΔQ_{t-1} and ΔQ_{t-2}. For this reason it is impossible to enter all three variables at the same time. On the other hand, if one omits $\Delta^2 Q_{t-1}$, the coefficient for ΔQ_{t-1} becomes $(K_2 + c)$ and the coefficent for ΔQ_{t-2} becomes $-(K_3 + c)$.

From an examination of eqs. (13) and (14) one can make some quantitative judgments about the relative size of the coefficients for the lagged dependent variables. If $\Delta^2 Q_{t-1}$ is omitted, the sum of the ΔQ_{t-1} and ΔQ_{t-2} coefficients equals $K_2 - K_3$ which, in turn, equals $1-B\gamma$. Since the original hypotheses assume that B and γ fall between zero and one, $K_2 - K_3$ should be greater than zero. Further, if the absolute value of the biennial yield coefficient, c, is greater than K_2, the coefficient for ΔQ_{t-1} will be less than zero and the corresponding coefficient for ΔQ_{t-2} will be greater than zero. On the other hand, if the absolute value of c is less than K_2 but greater than K_3, the coefficient for both lagged dependent variables will be greater than zero. Finally, if both K_2 and K_3 are greater than the absolute value of c, the coefficient for ΔQ_{t-1} will be greater than zero and the coefficient for ΔQ_{t-2} will be negative.

The coefficients for $\Delta^2 Q_{t-2}$ and $\Delta^2 Q_{t-3}$ are $-K_2c$ and K_3c respectively. This suggests that the first coefficient should be positive and the second negative given that c is negative. Furthermore, K_2 should be larger than K_3 and therefore the absolute value of K_2c should be greater than the absolute value of K_3c.

An examination of eq. (13) provides some information about the absolute size of c. If potential output were stagnant and if current price and weather were treated as random factors, the value of c should be in the neighborhood of -1; however, if potential output is increasing over time, the absolute value of c should be greater than one. In the latter case, the coefficient, c, overstates the biennial yield effect.

An alternative formulation for the biennial yield variable which eliminates the bias of a secular trend is the percentage change in output lagged one period. Equations (13a) and (14a) incorporate this expression.

$$Q_t = \tilde{Q}_t + f\left(\frac{\Delta Q_{t-1}}{Q_{t-1}}\right) + dP_t + w_t \tag{13a}$$

$$\begin{aligned}\Delta Q_t = {} & K_1 \sum_{i=k}^{m} \Delta b_i \Delta P_{t-i} + d\Delta P_t + f\Delta\left(\frac{\Delta Q_{t-1}}{Q_{t-1}}\right) \\ & + K_2\left(\Delta Q_{t-1} - f\Delta\left(\frac{\Delta Q_{t-2}}{Q_{t-2}}\right) - d\Delta P_{t-1}\right) \\ & - K_3\left(\Delta Q_{t-2} - f\Delta\left(\frac{\Delta Q_{t-3}}{Q_{t-3}}\right) - d\Delta P_{t-2}\right) + \tilde{v}_t\end{aligned} \tag{14a}$$

Equations (14) and (14a) are identical except that the second-order absolute change variables in the first are replaced by variables representing a change in the percentage change in (14a). This modification has eliminated the exact linear relation which existed in (14) but some multicollinearity may exist.

The next section examines the empirical results obtained from applying (14) and (14a) to the Colombian data.

IV. EMPIRICAL RESULTS

As pointed out earlier, two production series exist. They are the FAO coffee production estimates and the Colombian National Accounts series. Each was tried in different regressions. The three price series appearing in Table 2 were also used in the regression analysis. The first price series represents farmer prices deflated by a cost of living index for Manizales. The second series represents the producer price deflated by a weighted average of farmer prices for alternative products. The third series is the producer price guaranteed by the Federation deflated by a cost of living index for Colombia.[1]

Each output series was tried with the various price series. The most successful combinations were the National Accounts production with the first and second price series and the FAO data with the Federation price series. The regression results for these production and price combinations are reported in Tables 6 and 7. The results in Table 6 represent the application of eq. (14) and Table 7 records the results obtained from eq. (14a).

Each table is divided into two parts. The first section treats the data as if no structural shifts occurred during the period. The regression results in the second section were derived after providing special treatment for 1950, 1955, and 1960. According to Bacha, weather played an important role in determining output in the three years mentioned.[2] In both 1950 and 1955, production declined by more than 40,000 tons when compared with the previous year. Between 1959 and 1960, production fell 57,000 tons. If, in fact, the decline in

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[1] See the Appendix for additional information.

[2] Edmar Bacha, "The Supply of World Coffee," p. 19.

Table 6

REGRESSION COEFFICIENTS FOR THE SUPPLY OF COLOMBIAN COFFEE

MODEL I--EQUATION (14)

1947-1965

(Numbers in parentheses are standard errors of the coefficients; numbers in brackets are t-statistics)

Part 1

Type of Data and Time Period	Constant	ΔP_t	ΔP_{t-1}	ΔP_{t-2}	ΔP_{t-k}	ΔP_{t-m}	ΔQ_{t-1}	ΔQ_{t-2}	$\Delta^2 Q_{t-2}$	$\Delta^2 Q_{t-3}$	R^2	S_e	d.f.
(1) National Accounts Production Price #1 (1947-1965)	30.00	-.14 (.25) [-.57]	-.32[f] (.25) [-1.30]	-.39 (.28) [-1.38]	.80[a] (.23) [3.55]	.80[b] (.26) [3.09]	-.34[e] (.25) [-1.38]	-1.33[b*] (.33) [-4.00]	.24[f] (.22) [1.09]	.88[a] (.22) [-3.97]	.83	23.57	9
(2) National Accounts Production Price #1 (1947-1965)	18.31				.62[a] (.20) [3.10]	.82[a] (.26) [3.21]	-.26[e] (.19) [-1.42]	-1.10[b*] (.32) [-3.42]	.32[e] (.22) [1.42]	.64[a] (.19) [-3.37]	.76	24.51	12
(3) National Accounts Production Price #2 (1947-1965)	42.09	-.25 (.30) [-.83]	-.65[d] (.29) [-2.23]	-.43 (.29) [-1.48]	.69[c] (.25) [2.73]	47[d] (.22) [2.18]	-66 (.30) [-2.15]	-1.40[c*] (.44) [-3.15]	.13[g] (.29) [.45]	-.95[a] (.24) [-4.02]	.78	26.70	9
(4) National Accounts Production Price #2 (1947-1965)	26.53				.50[d] (.24) 2.09]	.46[d] (.24) [1.92]	.38[e] (.23) [-1.68]	-.95[d*] (.41) [-2.32]	-.26[g] (.29) [-.89]	-.67[b] (.24) [-2.81]	.61	30.97	12
(5) FAO Production Federation Price (1952-1965)	12.64	.13 (.37) [.35]	.15 (.35) [.44]	-.29 (.37) [-.79]	.54[e] (.29) [1.85]	.75[e] (.45) [1.66]	-.42[f] .33 [-1.27]	-.13 (.48) [-.28]	-.17 (.33) [-.54]	-.34[f] (.28) [-1.22]	.80	36.75	4
(6) FAO Production Federation Price (1952-1965)	11.50				.43[d] (.22) [1.96]	.88[c] (.33) [2.67]	.44[d] (.20) [-2.18]	-.49[d*] (.20) [-2.44]		-.35[d] (.16) [-2.13]	.73	30.06	8

Table 6 (Cont.)

Part 2

(adjusted for 1950, 1955, and 1960)

Type of Data and Time Period	Constant	ΔP_{t-5}	ΔP_{t-7}	ΔQ_{t-1}	ΔQ_{t-2}	$\Delta^2 Q_{t-2}$	$\Delta^2 Q_{t-3}$	Δ_{50}	Δ_{55}	Δ_{60}	R^2	S_e	d.f.
(7) National Accounts Production Price #1 (1947-1965)	25.85	.70[c] (.35) [2.80]	.61[d] (.27) [2.23]	-.45[e] (.25) [-1.79]	-1.06[b*] (.31) [-3.42]	.28[f] (.22) [1.25]	-.74[c] (.31) [-2.42]	-41.23[e] (25.99) [-1.59]	-25.65[g] (30.10) [-.85]	31.10 (54.33) [.57]	.83	23.36	9

Notes:

d.f. indicates degrees of freedom.

Significance Levels:

a = .005
b = .01
c = .025
d = .05
e = .10
f = .15
g = .25
* = two-tailed test

The symbols "k" and "m" refer to the years in which tree yields increase significantly. For the regressions using National Accounts data, "k" and "m" are 5 and 7, respectively. When FAO data are used k = 6 and m = 8.

Table 7

REGRESSION COEFFICIENTS FOR THE SUPPLY OF COLOMBIAN COFFEE

MODEL 2--EQUATION (14a)

1947-1965

(Numbers in parentheses are standard errors of the coefficients; numbers in brackets are t-statistics)

Part 1

Type of Data and Time Period	Constant	ΔP_t	ΔP_{t-1}	ΔP_{t-2}	ΔP_{t-k}	ΔP_{t-m}	ΔQ_{t-1}	ΔQ_{t-2}	$\Delta\left(\frac{\Delta Q_{t-1}}{Q_{t-1}}\right)^h$	$\Delta\left(\frac{\Delta Q_{t-2}}{Q_{t-2}}\right)^h$	$\Delta\left(\frac{\Delta Q_{t-3}}{Q_{t-3}}\right)^h$	R^2	S_e	d.f.
(1) National Accounts Production Price #1 (1947-1965)	34.54	-.26 (.25) [-1.05]	-.39[e] (.25) [-1.53]	-.14 (.25) [-.54]	.73[b] (.23) [3.21]	.62[d] (.28) [2.24]	-1.86[e*] (.90) [-2.07]	-1.06 (1.08) [-.98]	7.18[f*] (4.51) [1.59]	7.01[b] (2.12) [3.31]	4.03[b*] (1.10) [3.67]	.85	23.44	8
(2) National Accounts Production Price #1 (1947-1965	17.32				.64[b] (.21) [3.03]	.90[a] (.27) [3.34]	-.27[f*] (.20) [-1.35]	-1.71[a] (.41) [-4.17]		4.59[b] (1.63) [2.81]	3.12[b*] (1.01) [3.08]	.73	25.66	12
(3) National Accounts Production Price #2 (1947-1965)	38.57	-.20 (.32) [-.62]	-.59[d] (.29) [-2.04]	-.26 (.29) [-.90]	.66[c] (.25) [2.58]	.35[e] (.24) [1.43]	-2.61[d*] (.94) [-2.78]	-.63 (1.18) [-.54]	10.59[e*] (5.21) [2.03]	7.56[a] (2.14) [3.53]	4.24[b*] (1.23) [3.45]	.80	27.20	8
(4) National Accounts Production Price #2 (1947-1965)	25.47				.52[d] (.26) [2.00]	.52[d] (.26) [2.00]	-.40[f*] (.25) [-1.58]	-1.68[a] (.53) [-3.19]		5.02[c] (2.01) [2.50]	3.25[d*] (1.32) [2.46]	.56	32.93	12
(5) FAO Production Federation Price (1952-1965)	9.28	.16 (.41) [.40]	.27 (.43) [.63]	-.33 (.45) [-.75]	.62[f] (.42) [1.48]	.78[e] (.49) [1.59]	-.37 (.38) [-1.00]	-.99[f] (.81) [-1.23]		3.19[f] (2.48) [1.28]	1.06 (1.31) [.81]	.73	42.30	4
(6) FAO Production Federation Price (1952-1965)	10.63				.37[f] (.30) [1.23]	.88[d] (.40) [2.18]	-.39[f*] (.25) [-1.58]	-1.13[d] (.56) [-2.02]		2.58[e] (1.66) [1.55]	1.15 (1.02) [1.12]	.64	36.67	7

Table 7 (Cont.)

REGRESSION COEFFICIENTS FOR THE SUPPLY OF COLOMBIAN COFFEE

MODEL 2--EQUATION (14a)

1947-1965

Part 2

Type of Data and Time Period	Constant	ΔP_{t-k}	ΔP_{t-m}	ΔQ_{t-1}	ΔQ_{t-2}	$\Delta\left(\frac{\Delta Q_{t-2}}{Q_{t-2}}\right)^{h}$	$\Delta\left(\frac{\Delta Q_{t-3}}{Q_{t-3}}\right)^{h}$	Δ_{50}	Δ_{55}	Δ_{60}	R^2	S_e	d.f.
(7) National Accounts Production Price #1 (1947-1965)	13.13	.46[d] (.32) [1.44]	.82[c] (.30) [2.72]	-.11 (.30) [-.38]	-1.30[d] (.63) [-2.07]	3.13[f] (2.50) [1.25]	2.61[e*] (1.25) [2.09]	24.41 (21.77) [1.12]	38.13 (23.37) [1.63]	33.63 (35.47) [.94]	.76	27.83	9
(8) National Accounts Production Price #2 (1947-1965)	15.65	.37[f] (.30) [1.24]	.58[c] (.24) [2.46]	-.07 (.28) [-.23]	-1.02 (.59) [-1.71]	2.38[f] (2.31) [1.03]	2.65[e*] (1.26) [2.11]	-1.77 (22.86) [-.08]	-27.10[f] (23.69) [-1.14]	-4.10 (33.05) [-.12]	.73	29.50	9

Notes:

d.f. indicates degrees of freedom.

Significance Levels:

a = .005
b = .01
c = .025
d = .05
e = .10
f = .15
g = .25
* = two-tailed test

[h] These variables have been multiplied by 100.

The symbols "k" and "m" refer to the years in which tree yields increase significantly. For the regressions using National Accounts data, "k" and "m" are 5 and 7, respectively. When FAO data are used k = 6 and m = 8.

output in these three years was due to unusual climatic phenomena, the years should be excluded from the analysis or dummy variables should be introduced for each year.

A comparison of output and prices lagged five and seven years reveals that the 1950, 1955, and 1960 declines in output coincide with price decreases five and seven years earlier. For this reason, the decision was made to introduce the dummy variables, Δ_{50}, Δ_{55}, Δ_{60} in a special regression to test whether climatic phenomena or price or both were responsible for the decreases in production.[1] The dummy variables have a value of one in the particular year they represent, a minus one in the following year and zero in all other years.

In Tables 6 and 7, the first two regressions employ National Accounts output and the first price series; the second price series is then substituted for the first in the next two regressions; and regressions five and six utilize the FAO-Federation combination. The final regression in Table 6 and the last two regressions in Table 7 incorporate the dummy variables mentioned above in an attempt to adjust for bad weather.

One of the first items of importance is the specific lag structure suggested by the computer results. Previously it was noted that coffee trees in Colombia produce fruit as early as the second year after planting and that yields continue to increase until the sixth year. The one exception to this pattern is the fifth year after planting in which tree yields decline. Given this information, the dependent variable, ΔQ_t, was regressed on the variables that appear in eqs. (14) and (14a), including producer prices lagged three through eight years. When the National Accounts output data were used, the

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[1] If one believes that the production decreases were partially determined by earlier price declines, then the statements made earlier about little or no eradication are not valid. On the other hand, eradication can be accommodated in the model outlined above if eradications and new plantings are treated symmetrically.

only significant price variables were ΔP_{t-5} and ΔP_{t-7}. The coefficient for price lagged six years was negative but not significant. When the FAO output series was used, the best results were obtained with a lag structure of six and eight years.

One might ask the question, why is the output-price lag structure five and seven years for the National Accounts data and six and eight years for the FAO series? The answer is apparent when one remembers that the FAO data are on a crop year basis and the National Accounts estimates correspond to calendar years. Output harvested in the 1960-1961 crop year was recorded in 1961 by the FAO. However, most of this output was harvested in October, November, and December and appeared in 1960 in the Colombian National Accounts series. Thus, if one makes allowance for the calendar-crop year difference, the lag structures are identical.

A second question concerns the discrepancy between the regression results and the information provided by Uribe. The regression results suggest that significant increases in output occur five and seven years after price changes whereas Uribe's information points out that significant increases in output occur somewhere between the third and sixth years after planting. The reason for this could be that an economic as well as an agronomic lag exists. The economic lag is the elapsed time between the price change and the actual planting of a tree. The agronomic lag is the period of time it takes the tree to reach maturity after it has been planted. The agronomic lag described by Uribe is approximately six years. If one adds to this an economic lag of one year or a substantial portion of a year, the lag structure suggested by the regression results agrees with the lag structure suggested by Uribe.

When the first price series is used with the National Accounts data, the coefficient for prices lagged five and seven years are highly significant -- generally at the .01 level or better (see regressions 1-2 in Tables 6 and 7). When the National Accounts production and the second price series are combined, the coefficients

for lagged prices are not as significant as the estimates generated by the first combination; however, the significance levels are satisfactory (see regressions 3 and 4 in each table.) The coefficients for prices lagged six and eight years in the FAO-Federation Price combination are acceptable but statistically less significant than the estimates generated by the other two combinations (regressions 5 and 6).

Regardless of the output-price data used, the coefficients for current prices and prices lagged one and two years were not significant and in most cases the signs attached to the coefficients were "wrong."[1] This suggests that current prices did not affect harvesting during the period of observation. This is not surprising given the relatively high producer price that prevailed throughout the 1950s and 1960s. For instance, the real price received by the producer during the 1961-1965 period averaged almost 25 percent more than the 1946-1949 farmer price although it was 17 percent less than the average price of the 1950-1953 period.

All but one of the four coefficients for the lagged dependent variables have the expected sign in Table 6. The one exception is the coefficient for ΔQ_{t-2}. It was stated earlier that if the coefficient for ΔQ_{t-1} had a negative sign, then the coefficient for ΔQ_{t-2} should have a positive sign. Instead, the actual results show a negative sign for both. In fact, the t statistic for ΔQ_{t-2} suggests that its coefficient is more significant than the ΔQ_{t-1} coefficient.[2]

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[1]The negative sign for the ΔP_t coefficient could be the result of an identification problem. If the current producer price is correlated with the world price, the inclusion of the former produces a "mongrel" equation. The evidence suggests that the producer price was high enough during the period that harvesting was not affected by it. If this is the case, exclusion of the current price term eliminates the identification problem as the supply function is identifiable.

[2]This is particularly true of the regressions using the National Accounts and Price #1 data where the significance level of the ΔQ_{t-2} coefficient was .01 using a two-tailed test.

It was stated earlier that the biennial yield effect might be weak, that is, the "c" coefficient would be insignificant. If this were the case, the coefficient for ΔQ_{t-2} should be negative; however, the coefficient for ΔQ_{t-1} should be positive when the ΔQ_{t-2} coefficient is negative. An examination of the results contradicts this, as both coefficients are less than zero.

It was also noted earlier that the coefficient for $\Delta^2 Q_{t-2}$ should be greater in absolute size than the coefficient for $\Delta^2 Q_{t-3}$. The opposite case exists in every regression.

An examination of the results for eq. (14a) in Table 7 indicates that the coefficients for the price variables are quite similar to those reported in Table 6. On the other hand, the signs of the coefficients for the lagged dependent variables do not meet with the original hypotheses in most cases. For example, the coefficient for ΔQ_{t-1} is always negative, and the coefficients for the first and third percentage change variables are always positive.

A problem encountered in the second formulation was one of multicollinearity between ΔQ_{t-1} and $\Delta\left(\frac{\Delta Q_{t-1}}{Q_{t-1}}\right)$. When the latter variable was excluded from the regression, the coefficient for ΔQ_{t-1} changed from a large negative value to one close to zero. Further, some multicollinearity exists between ΔQ_{t-2} and $\Delta\left(\frac{\Delta Q_{t-2}}{Q_{t-2}}\right)$. Consequently, the coefficients for these variables are suspect.

Because of the inconsistencies in the coefficients for the lagged dependent variables, it is not possible to obtain reasonable estimates of K_2 and K_3. This means that it is not possible to recover the long-run price coefficients $a_1\Delta b_5$ and $a_1\Delta b_7$. On the other hand, it is possible to obtain the unadjusted price elasticities from the lagged price estimates. The elasticities appear in Table 8.

The second part of Tables 6 and 7 differ from the first section in that the dummy variables for 1950, 1955, and 1960 are included. The signs for the dummy variable coefficients are mixed (although

mostly negative) and the coefficients are not generally significant at an acceptable level (.10). The introduction of the weather variables decreases the size of the P_{t-5} and P_{t-7} coefficients -- particularly the former. This shows up in the elasticity estimates in Table 8.

The elasticities in Table 8 for the FAO-Federation data are quite high relative to the elasticities generated by the other data. The larger elasticities obtained from the FAO-Federation combination are inherent in the data. The FAO production series moves from a low of 302,300 tons in 1951 to a high of 492,000 in 1963 -- an increase of 63 percent. The National Accounts series increases from a low of 436,800 in 1946 to 629,000 tons in 1964 -- a 44 percent change. A glance at the price information in Table 2 reveals that the Federation price starts at a low of 132.7 and rises to a high of 343.8 in 1958 -- slightly less than a 60 percent increase -- and the first price series shows a 276 percent increase between the 1940 low of 84.9 and the 1956 high of 319.6. Thus, the range in the FAO production series is larger than the National Accounts data and the Federation price movements are more stable than the first price series. Therefore, these relationships account for the different estimates and remind the reader that the validity of the estimates hinges on the accuracy of the data as well as the accuracy of the model.

When one compares the elasticities in Table 8 with the corresponding Bacha elasticity for Colombia in Table 5, the former are always higher. Two reasons for Bacha's low estimate are: (1) his lag structure was too short (he used a three year moving average of prices centered on t-4), and (2) his formulation assumed that yield is not a function of age during the maturation period. Equations (14) and (14a) allow for yield changes and the lag structure was lengthened over that assumed by Bacha.

In summary, the best data combination (judged by significance tests) is the National Accounts data combined with the first price series. All of the lagged price coefficients were statistically

Table 8

PRICE ELASTICITIES FOR COLOMBIAN COFFEE[a]

Type of Data[b]	Model No. 1 (Eq. 14)			Model No. 2 (Eq. 14a)		
	P_{t-k}	P_{t-m}	Total	P_{t-k}	P_{t-m}	Total
National Accounts Production Price #1						
(Regression No. 2)	.23	.29	.52	.23	.31	.54
(Regression No. 7)	.26	.21	.47	.17	.28	.45
National Accounts Production Price #2						
(Regression No. 4)	.17	.16	.33	.18	.18	.36
(Regression No. 8)	--	--	--	.13	.20	.33
FAO Production Price #3						
(Regression No. 6)	.25	.46	.71	.21	.46	.67

Notes:

[a]The elasticities have been calculated at the sample means. They represent output responses to prices unadjusted for lags as the adjusted responses were not identifiable.

[b]The symbols "k" and "m" refer to the years in which tree yields increase significantly. For the regressions using National Accounts data, "k" and "m" are 5 and 7, respectively. For FAO data, K=6 and m=8.

acceptable and these models generated much higher unadjusted elasticities than Bacha's Colombian estimate. Perhaps most important of all is the lag structure suggested by the results, that is, changes in output occur five and seven years after price adjustments. As far as the two different models are concerned, the results for the lagged dependent variables are rather disappointing. Very little empirical basis was established for preferring one model over the other, although the second formulation is preferable on theoretical grounds.

V. SUMMARY AND CONCLUSIONS

The major objective of this Memorandum has been to obtain an estimate of the output-price relationship for Colombian coffee. The importance of this product to the Colombian economy is indicated by the fact that although the coffee sector's share of national income has been declining, the coffee industry still accounts for 8 to 9 percent of the nation's income. Furthermore, coffee is the most important earner of foreign exchange and will be for some time.

It was also noted that Colombian production has exceeded world demand for Colombian coffee given the price levels the ICO has tried to maintain. Colombian surpluses totaled approximately 50,000 tons per annum for 10 years, 1957 to 1967. Given Colombia's desire to remain a member of the ICO and the ICO's objective of reducing production, an important question arose, "To what extent do Colombian coffee farmers respond to producer prices?"

The study then proceeded to outline the economic models of Arak and Bacha to provide a framework for the model derived in this Memorandum. Since planting data are not available in Colombia, it was not possible to use the formulations developed by Arak; and although the basic Bacha model formed a foundation for the theoretical structure outlined here, some adjustments were made so that the yield-age relationships could be taken into account.

The empirical results obtained from eqs. (14) and (14a) suggested a lag structure of five to seven years, which seemed plausible in light of the four to six year agronomic structure suggested by Uribe. Finally, the unadjusted elasticities generated by the model were in the neighborhood of .5. This suggests that if the Colombians are interested in reducing production, one alternative open to them would be to reduce the real price received by the coffee farmer. If a 10 percent reduction in output is desired, a 20 percent reduction in the real producer price would accomplish this end. On the other hand, the Colombians should understand that the total output response would take at least seven years.

There are still a number of refinements that can be made. For example, the formulation for the biennial yield variable did not produce satisfactory results. More information is needed, however, before this relationship can be derived. Also, if enough data were available, one could separate the years in which prices increased from the years in which they decreased. This would allow one to test the hypothesis that the response differs depending on the direction of the price change. Still, the above formulation does provide an indication of the output response to prices and may prove useful to the interested parties.

Appendix

PRODUCTION AND PRICE DATA

The data in Table 2 in the text are crucial to the analysis. The purpose of this appendix is to provide relevant information for each series as well as its source.

The first column is taken from FAO reports and the time reference is the crop year (July-June). The second column was compiled by A. Berry of Yale University. His figures are on a calendar year basis and represent total production of parchment coffee in thousands of metric tons. The data for the years 1935-1937 were derived from export figures, multiplied by 1.053. The data for 1938-1948 were taken from the data published by the IBRD. The figure for 1949 was interpolated, and the information for 1950-1965 was taken from the Colombian National Accounts.

The third and fourth columns present figures for "Exportable Production" and "Exports." The U.S. Department of Agriculture estimates Colombian consumption of coffee, which figure is then subtracted from production figures to obtain the volume available for export. The export data are compiled by the Colombian Coffee Federation and published by the Banco de la Republica.

With regard to the price data of Table 2, the "Purchase Price of Coffee Paid by the Federation" is a crop-year average of the prices fixed by the Colombian Coffee Federation for its buying agents. This price acts as a floor for coffee that meets the standards of the Federation. The first two columns under "Real Producer Price" were compiled by Berry. The first is the farmer price of coffee deflated by a cost of living index for Manizales (a city in the center of Colombia's coffee area) and the second column is the same farmer price deflated by a weighted average of farmers' prices for alternative products. The last column was obtained by (1) dividing the Federation price by the Colombian cost of living index for the years 1952 through 1965; (2) taking an average ratio of the 1952-1955 figures in the

third price column to the data in the first price column and then using this ratio to extend the third column back to 1943 using the first column as a base. The third column was extended backward in time so that the Federation price could be tested in the econometric model along with the other series.

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