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CONTENTS

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Food and Population: A Long View

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WITH the sharp increase in food prices in 1973 and 1974, the world food-population ratio began to receive increasing attention. Writers in both professional journals and more widely read magazines have pointed to the prospect of rising world food costs and starvation in the years ahead.[1]

The recent predictions, that per capita food production will decline, are consistent with the basic classical argument of the early 1800's that the growth rate of the world population tends to exceed that of food production. These views are founded on presumptions of major constraints to increasing crop yields and a continuing high rate of world population growth.[2] The alleged constraints to food production growth, however, give little recognition to the diversity of the food-population problems among different economies of the world, let alone take account of the economic factors which affect the incentive to reduce food production costs.

This article postulates that the United States and the other more developed nations (MDCs) will not experience rising real food costs over the longer run despite some increase in the early 1970s and the numerous reports which point to world famine. It hypothesizes that the food-population ratio in the various nations of the world is largely a function of the size and composition of per capita wealth, and that per capita wealth remains near the subsistence level for most of the less developed nations (LDCs). Consequently, they are still subject to periodic famines. However, famines in the LDCs will not spill over into the MDCs which have gradually increased per capita wealth and been free from famines for more than a century.

Early Food – Population Views

Predictions of rising food scarcity and limits to productivity growth are not of recent origin. Such allegations can be traced back several centuries. They became widely accepted following the writings of the classical economists in the late 1700s and early 1800s. Giovanni Botero in 1589 postulated that population tends to increase to the limits imposed by the means of subsistence.[3] Adam Smith contended that the means of subsistence limits the multiplication of humans and all other species of animals.[4] He and

[1]Writings which represent these views include: Paul R. Ehrlich, *The Population Bomb* (New York: Ballantine Books, 1968); Lawrence A. Mayer, "We Can't Take Food for Granted Anymore," *Fortune* (February 1974), pp. 85-89 and 132-36; Gene Karetz, "The Global Food Shortage," *Business Week*, June 8, 1974, p. 63; "The Fat Years and the Lean," *The Economist*, (November 2, 1974), p. 19; "Formula for World Famine?", *U.S. News and World Report*, January 28, 1974, pp. 50-52; Wayne Bartholomew and George A. Wing, "Profiles of the Future, Arab Petroleum = American Food," *Business Horizons* (Indiana University Graduate School of Business, Vol. XVII, Number 6, December 1974), pp. 5-14; "In the End, Even U.S. May Not Be Able to Feed the World," *U.S. News and World Report*, May 27, 1974, pp. 57-58; Lester R. Brown and Erik P. Eckholm, "Food and Hunger: The Balance Sheet," *Challenge* (September-October 1974), pp. 12-24; Willard W. Cochrane, "Food, Agriculture, and Rural Welfare: Domestic Policies in an Uncertain World," *American Journal of Agricultural Economics*, Volume 56, Number 5 (December 1974), pp. 989-997; and "U.S. Food Power: Ultimate Weapon in World Politics," *Business Week*, December 15, 1975, pp. 54-60.

[2]Ehrlich, *Population Bomb,* pp. 44 and 46-47; Brown and Eckholm, "Food and Hunger," pp. 12-24; and Cochrane, "Food Agriculture and Rural Welfare," pp. 989-91.

[3]Joseph A. Schumpeter, *History of Economic Analysis* (New York: Oxford University Press, 1954), pp. 254-55.

[4]Adam Smith, *The Wealth of Nations* (New York: The Modern Library, 1937), pp. 79, 81.

other classical economists viewed the food producing qualities of land as being highly inelastic with respect to other inputs. They believed that any gains in yields resulting from new technology would be quickly offset by population growth.[5]

David Ricardo, a leading proponent of the classical view on returns to land, reasoned that (1) rent arises because of differences in soil fertility; (2) the value of production on the unit of least fertile land in use will only be sufficient to cover costs of nonland inputs thus yielding no rent; (3) labor values are determined by returns to labor on the less fertile acres; and (4) marginal productivity of labor will decline over time as the population increases and additional marginal acres are brought under cultivation.

The proponents of this view held that the total volume of real wages is relatively fixed, being limited to a worker's output on the least fertile land times the total number of workers. Consequently, as population increases, per capita real wages were expected to decline, and starvation among the marginal nonlanded classes was expected to become widespread. On the other hand, returns to the landed classes would tend to rise since the difference in yield between the more fertile and the marginal acres would be greater and rents higher.[6]

Thomas Malthus, the leading proponent of the classical starvation view, contended that there is no limit to the prolific reproduction of people except when imbalances resulting from their crowding interfere with each other's means of subsistence. He postulated that under favorable conditions the means of subsistence might increase in an arithmetic ratio, whereas population tends to increase in a geometric ratio, doubling each twenty-five years.[7]

James Mill and other early 19th century writers further developed the subsistence argument into a wages-fund theory. Mill substituted all forms of capital for land in the Malthusian model and argued that a decrease in the ratio of capital to population over time will cause (real) wages to decline, implying a reduction in per capita output of all goods and services including food. Like Malthus he believed that population tended to increase at a faster rate than capital, and was held in check by the limits on real wages, i.e. the means of subsistence.[8]

Table I

MAJOR FAMINES IN WESTERN EUROPE

Date	Place	Estimated Deaths
310 A.D.	England	40,000
436	Rome	N.A.
1005	England	N.A.
1016	Europe	N.A.
1069	England	N.A.
1235	England	20,000 (in London)
1315-17	Central and Western Europe	10% of population over wide area
1347-48	Italy	N.A.
1693	France	N.A.
1769	France	5% of population
1816-17	Ireland	737,000
1846-47	Ireland	1,000,000

N.A. — not available.
Source: *Encyclopedia Britannica*, 1970 ed., s.v. "Famine". *Encyclopedia Americana*, 1970 ed., s.v. "Famine".

Early Views Consistent with Evidence

The classical food supply views appear to explain population growth throughout most of recorded history. Prior to the industrial revolution in the 1800s, per capita wealth and production was relatively low throughout the world and famines occurred frequently even in the more developed areas. Some periods of major famine reported in Western Europe are listed in Table I. The great Irish famine of 1846-47 following the failure of the Irish potato crop was the last major famine to occur during peacetime in either Western Europe or the United States. The population of Ireland declined more than two million, or about 25 percent as a result of the famine, related deaths, and migrations.

Threat of Famine Continues for Most People

World food production per capita has trended up in recent decades, but the overall improvement has been relatively modest. Food production per capita rose one percent per year during the decade 1954-64 and about 0.8 of a percent per year during the decade 1964-74 (Table II). Total food production rose at rates of 3.0 and 2.7 percent, respectively, in the two decades. However, population growth was maintained at a 1.9 percent rate throughout both decades, offsetting much of the increase in food production.

[5]Smith, *The Wealth of Nations,* pp. 94-95; David Ricardo, *The Principles of Political Economy and Taxation* (London: J. M. Dent and Sons, Ltd., 1948), p. 279-80, and Thomas Robert Malthus, *On Population,* ed. Gertrude Himmelfarb (New York: Random House, 1960), pp. 151-57.

[6]Ricardo, *Principles,* pp. 273-92.

[7]Malthus, *On Population,* pp. 154, 156.

[8]James Mill, *Elements of Political Economy,* Reprints of Economic Classics (New York: August M. Kelley, Bookseller, 1963), pp. 40-50.

Table II

GROWTH OF WORLD POPULATION AND FOOD PRODUCTION

(Average Annual Rate of Change)

	1954-64			1964-74		
		Food Production			Food Production	
	Population	Total	Per Capita	Population***	Total	Per Capita
More Developed Countries*	+1.3%	+3.0%	+1.7%	+1.0%	+2.7%	+1.8%
Less Developed Countries**	+2.4	+3.1	+0.6	+2.6	+2.6	0
World	+1.9	+3.0	+1.0	+1.9	+2.7	+0.8

*Western Europe, North America, Oceania, Eastern Europe, and the U.S.S.R.
**Africa, Far East, Latin America, Near East, and the Asian Centrally Planned Countries.
***1964-73.
Source: U.S.D.A., *The World Food Situation and Prospects to 1985*, Foreign Agricultural Economic Report No. 98, December 1974.

Furthermore, the rate of increase in food production per person varied widely among the world economies. During the decade ending in 1974 all the per capita increase occurred in the MDCs. The rate of increase in total food production in the LDCs declined from 3.1 to 2.6 percent per year from the decade ending in 1964 to the decade ending in 1974, about the same as that in the MDCs. However, the population growth rate in the LDCs rose from 2.4 percent in the decade ending in 1964 to 2.6 percent in the latter decade, whereas the population growth rate in the MDCs declined from 1.3 to 1.0 percent (Table II). The rise in population during the latter decade in the LDCs exactly offset the increase in total food output while food production per capita continued up in the MDCs at about the same rate as in the earlier decade. Furthermore, more than a third of the LDCs experienced a decline in per capita food production during the 20 years ending in 1972.

Many people in the LDCs, which include Latin America, and most of Asia and Africa, probably remain near the Malthusian level of subsistence. These nations have relatively high rates of population growth and low rates of capital accumulation and productivity per capita both on their farms and in other industries. They add about 61 million to the world's population each year and account for 86 percent of the world's annual population increase.[9] More recent comparisons indicate a leveling off in the population growth rates of these regions; however, there is still little tendency for their rates of population growth to decline.

Reflecting the low productivity levels in the LDCs, their diets generally remain near the subsistence level. In 1970 per capita calorie and protein consumption in these nations averaged only 69 and 60 percent, respectively, of such consumption in North America. Furthermore, the proportion of food obtained from animal products was only about one-fifth of that in the U.S.[10]

If the LDCs produced a large quantity of non-food products, they could, as Japan has done, achieve higher dietary standards by exchanging such products for food produced by the MDCs. But, total production of all goods per person in the LDCs is relatively low and consists largely of subsistence type products used domestically. In 1972, for example, national income totaled only $55 billion in India, $54 billion in Brazil, $16 billion in Turkey, $7 billion in Colombia, and $2 billion in Ethiopia. National income totaled $1,041 billion in the United States.[11] A few of the LDCs produce sizable quantities of crops and other commodities for export such as coffee and soybeans in Brazil, sugar in the Philippines, palm oil in Malaysia, feed grains in Argentina, and petroleum in the Organization of Petroleum Exporting Countries (OPEC), but as a general rule their low rate of production does not provide a sufficient quantity of foreign exchange to trade for large quantities of additional food.

Saving and investment in capital goods are apparently increasing in the LDCs at a higher rate than population growth, indicating some gains in the per capita stock of capital. The Commission on International Development found that savings and gross investment in these nations totaled 15 and 17.8 percent,

[9]United States Department of Agriculture, *The World Food Situation and Prospects to 1985,* FAE Report No. 98, 1974, pp. 12-14 and 75.

[10]Food and Agricultural Organization of the United Nations, *Monthly Bulletin of Agricultural Economics and Statistics* (September 1974), pp. 3-6; and USDA, *World Agricultural Situation* (December 1973), p. 51.

[11]United Nations, *Monthly Bulletin of Statistics* (February 1976).

respectively, of Gross National Product (GNP) during the period 1960-67. However, saving and investment relative to GNP is still very low in the LDCs, averaging well below that of the MDCs.[12]

Foreign aid has been a source of new capital in many of the LDCs. Such aid has been evident in providing machinery and equipment for industry, for building roads and railways, ports, fertilizer plants, and irrigation facilities. Some of the LDCs, especially the more advanced, have received sizable amounts of private capital. However, few LDCs present a favorable climate for private investment, either from foreign or local sources. As pointed out by the Commission on International Development, "too few of these countries recognize the tremendous contribution which private investment can make to economic development and in an environment unsympathetic to all private entrepreneurship it is hardly surprising that foreign investors sense danger."[13] As indicated by D. Gale Johnson a strong case can be made that the major barriers to growth in the LDCs are political in nature. He contends that the barriers to rising per capita food supplies are neither primarily economic nor scientific. However, he suggests that conditions for significant increases in food production include: a major expansion of agricultural research in the developing countries themselves, an adequate supply of modern inputs required to increase yields, the improvement and expansion of the irrigated area, incentives to farmers to make the required changes (including the expansion of the cultivated area), and improvements in transportation, marketing, and processing institutions and facilities. In addition, increased investment in human capital and improved communications is desirable, not only because of its contribution to increased agricultural output but also because of the need to assist farm people in the long-run adjustments they must make to economic growth.[14]

The relatively low level of capital formation in the LDCs carries over into their investment in knowledge related to food production. In 1965 expenditures on agricultural research and extension services in the LDCs relative to farm production was only about one-half of that in the MDCs.[15]

The LDCs have achieved some growth in recent years increasing their real GNP at an estimated average rate of 4.8 percent from 1950 to 1967, or considerably faster than that of the MDCs during their early stage of development.[16] However, because of the accelerating rate of population growth, per capita income growth has been relatively modest, and many of the LDCs have realized very little, if any, per capita income gains.

Individual nations formerly in the LDC group have managed to move into the MDC group over time. Occasionally a less developed country begins to make progress. Once a significant amount of progress is made and the political climate for private investment is improved, imported private funds along with enhanced private domestic savings become major sources of development capital. Then the LDCs tend to move into the more developed category of nations. Notable examples of such movements in recent decades have been Japan, Israel, and Greece. Furthermore, once substantial progress has been made few nations have dropped back into the low-productivity class. As long as low production persists, however, the food supply-population situation in most of these nations will not have a major impact on food prices in the MDCs.

Food Still Limits Population Growth in Some Areas . . .

Classical theories that population is limited by the means of subsistence are consistent with the experience in many of the LDCs. People still exist near the subsistence level in many of these nations, and a year or two of below-average crop yields can result in famine, severe malnutrition, and a slower growth or decline in population. India, for example, has experienced a number of major famines since 1800. Eleven major famines were reported in some parts of the nation since then, as shown in Table III. The longest interval between the major famines listed in these sources was from 1900 to 1943 and other sources list a number of famines even during this interval.[17]

The preponderance of evidence indicates that low per capita production has reduced the rate of popu-

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[12]Commission on International Development, *Partners in Development* (New York: Praeger Publishers, 1969), p. 31.

[13]Ibid, p. 105.

[14]D. Gale Johnson, *World Food Problems and Prospects* (Washington, D.C.: American Enterprise Institute for Public Policy Research, June 1975), pp. 77 and 79.

[15]Robert E. Evenson and Yoav Kisler, "Investment in Agricultural Research and Extension: A Survey of International Data," *Economic Development and Cultural Change* (April 1975), p. 510.

[16]Commission on International Development, *Partners in Development*, p. 27.

[17]See, for example, Rajpat Rai, *England's Debt to India* (New York: B. W. Huebsch), 1917, p. 267; and Dr. M. Arokiaswami and T. M. Royappa, *The Modern Economic History of India* (Madras-2, India: Newman Book House, 1959), p. 335.

Table III

FAMINES IN INDIA SINCE 1800

Date	Place	Estimated Deaths
1803-4	Western India	Thousands
1837-38	Northwest India	800,000
1861	India	N.A.
1866	India, Bengal and Orissa	1,500,000
1868-70	India, Rajputana, Northwest and Central India, Punjab and Bombay	33% of total population in Rajputana
1874	India	N.A.
1876-78	India	5,000,000
1896-97	India	5,000,000
1899-1900	India	1,250,000
1943-44	India, Bengal	1,500,000
1964	India	N.A.

N.A. — not available.

Source: *Encyclopedia Britannica*, ed., s.v. "Famine". *Encyclopedia Americana*, ed., s.v. "Famine".

lation growth in India during the past century from what it would have otherwise been. Ansley Coale and Edgar Hoover, using census data, show a small decline in the nation's population from 1891 to 1901, and growth of less than one-sixth of one percent per year from 1891 to 1921. They found a fairly constant birth rate, but fluctuating death rates in response to major epidemics and famines.[18] Rajpat Rai estimated that if the famines had not occurred, the population of India would have been about 40 million greater that it was in 1901.[19]

The acceleration of India's population growth rate in recent decades is also consistent with the classical population-subsistence thesis. For example, during the forty years from 1891 to 1931, the population remained relatively stable, rising only 0.2 of a percent per year. Available production data for this period indicate little change in per capita wealth and income. Colin Clark calculated that output of all goods and services per breadwinner remained unchanged from 1909-13 to 1935-38. On the basis of NBER estimates GNP per person in the United States during this period grew at an average rate of .9 percent per year.[20] Coale and Hoover found that since 1931 both population and food production in India have increased rapidly compared to the earlier period. Population has increased at a 1.8 percent annual rate and food production at a 1.6 percent rate.[21]

The somewhat faster rate of population growth relative to food production in India in recent decades can be attributable to a larger volume of food imports, improved internal transportation which facilitated food movements among the various provinces, and improved health practices which limit the deaths caused by diseases associated with malnutrition. Since the late 1940s imports of food have averaged about 5 percent of total usage, whereas previously the nation was largely self-sufficient. A large percentage of the food imports have been financed by the MDCs under various government aid programs. Farm commodity imports from the U.S., financed largely through Government aid programs, averaged almost $300 million per year during the last two decades.[22] Subsidized food shipments by the United States to India began in 1935-36, but were relatively small until the 1950s. Then food shipments began to increase sharply under the authority granted in Public Law 480 which provided for the exchange of food for nonconvertible Indian currency.

India has been able to increase yields and production of cereal grains but the gains were not sufficient to offset expanding consumption. From 1960-62 to 1969-71 average yields in India rose at an annual rate of 2 percent and population rose at a rate of 2.6 percent. Production of grains rose at a 3 percent rate, as the acreage planted to grains was increased, but grain consumption rose at a 3.4 percent rate.[23]

While food export subsidy programs of the U.S. and other MDCs have prevented major famines in recent years, the basic causes of malnutrition in India and some other LDCs have not been eliminated. Professor Theodore W. Schultz, who has studied the effects of aid, concluded that such shipments of food products cannot solve the basic malnutrition problem.[24] In a similar view Harry Walters reported increasing food deficits and a growing dependence on food imports in the traditional agricultural econo-

[18]Ansley J. Coale and Edgar M. Hoover, *Population Growth and Economic Development in Low-Income Countries* (Princeton: Princeton University Press, 1958), pp. 30-31.

[19]Rajpat Rai, *England's Debt*, p. 266.

[20]Colin Clark, *The Economics of 1960* (London: Macmillan and Company, Ltd., 1944), chart under back cover, and U.S. Department of Commerce, *Long-Term Economic Growth 1860-1965.*

[21]Coale and Hoover, *Population Growth*, p. 30; *UN Statistical Yearbook;* and *World Almanac*, 1974 ed., S.V. "India".

[22]*USDA Foreign Agricultural Trade of the United States*, (May 1974), p. 24.

[23]U.S.D.A., *The World Food Situation and Prospects to 1985*, p. 18.

[24]Theodore W. Schultz, *Economic Crises in World Agriculture* (Ann Arbor: The University of Michigan Press, 1965), p. 3, 19.

Table IV

AVERAGE YIELDS PER ACRE
U.S.
(Bushels)

	1866-69	1928-31	1971-74
Wheat	12.6	14.7	31.4
Rye	11.3	11.4	25.5
Corn	24.3	24.2	86.9
Oats	28.0	30.5	50.3
Barley	23.0	22.1	41.7

Source: U.S.D.A., *Agricultural Statistics*, annual issues; *Barley: Acreage, Yield, Production, Price, Value by States 1866-1953*, Statistical Bulletin No. 421; *Corn: Acreage, Yield, and Production of —*, June 1954; *Farm Production, Farm Disposition, and Value of Oats 1909-1941*, July 1944; *Flaxseed and Rye: Acreage, Yield, Production, Price, Value by States 1866-1953*, Statistical Bulletin No. 254; *Wheat: Acreage, Yield, and Production*, Statistical Bulletin No. 158, February 1955; *Crop Production*, various issues.

mies such as India.[25] Thus, the age-old problem of starvation and famine has not disappeared for many people.

Technical assistance programs designed to enhance food output in the LDCs likewise have not significantly altered their food-population relationships. Schultz concluded that in Latin America little real per capita gain has resulted from our contribution of $44 million to such programs from 1943 to 1955. Nine Latin American countries lost ground on a per capita basis, two of which had no programs; and eleven countries gained, one of which received no assistance. On average Latin America's agricultural production increased no faster than the rate of population growth. Hence, very little association existed between such programs and the well-being of the people.[26]

. . . But Many Nations Are No Longer Subject to Famines

In contrast to the continued threat of famine in many nations, for more than a century no famines have occurred in most of the MDCs. These nations, including the United States, Canada, Western Europe, the U.S.S.R., Australia, and New Zealand, have had relatively low rates of population growth and high rates of capital formation and production. Their populations grew at an average rate of 1.3 percent per year from 1952 to 1962 and at a 1.0 percent rate from 1962 to 1972 (Table II). They produced three-fourths of the world's food output in 1973 and consumed 50 percent more food per capita than the LDCs. While accounting for only one-fourth of the increase in world population since the mid-1950s they accounted for three-fourths of the increase in world food output.[27]

Those MDCs such as Japan which are not self sufficient in food production produce large quantities of other goods in which they have greater relative efficiency, and exchange such goods with other nations that can produce food more cheaply. Hence, even though they possess few food producing resources, they do not have a serious food-population problem.

Return to Famines Unlikely in the U.S.

Despite the sharp increase in world food costs in recent years there is little evidence that the MDCs are returning to the economic status of the LDCs.[28] Real food costs over the long run reflect basic farm product supply and demand conditions, and evidence does not support the view that these conditions have changed toward a reduction in the real food supply in the United States and other MDCs. The long-run food supply factors after adjustment for inflation have moved sharply counter to the classical predictions of universal famines for more than half a century. In contrast to the classical view that crop yields are relatively fixed, and that real returns to land will rise with population growth, the evidence in recent decades supports the opposite view. The importance of the original properties of the soils has declined relative to that of other investments in determining crop yields.

Crop yields in the U.S. were relatively stable from the 1860s, when yield data were first recorded, until the early 1930s, tending to confirm the classical views. Corn yields averaged 24.3 bushels per acre in the four years 1866-1869, inclusive, and 24.2 bushels per acre in 1928-31 (Table IV). Rye yields were likewise relatively stable during this period. Wheat and oat yields rose somewhat but barley declined. In contrast to the stability of yields prior to the early 1930s, however, yields since then have increased sharply. Corn yields have more than tripled, wheat and rye have more than doubled, and oats and barley have almost doubled.

[25]Harry Walters, *The World Food Situation* (Report to the Committee on Agriculture and Forestry for the 1975 U.S. Agricultural Outlook, December 23, 1974), pp. 20-29.

[26]Schultz, *Economic Crises*, p. 55.

[27]U.S.D.A., *The World Food Situation and Prospects to 1985*, pp. 14-16.

[28]For an opposite view, see Ehrlich, *Population Bomb*, pp. 44 and 46-47; Brown and Eckholm, "Food and Hunger," pp. 12-24; and Cochrane, "Food Agriculture and Rural Welfare," pp. 989-91.

Rising yields since the 1930s largely reflect the increasing application to land of capital investments in man-made productive factors. The quantity of such yield increasing investments is determined by relative prices and the incentive for invention and discovery. Inventions and discoveries have contributed to more viable seed, heartier and more productive plants, shorter growing season requirements, lower-cost fertilizers, a more balanced supply of plant nutrients, improved weed, disease, and insect controls, crop rotations, soil management, and improved planting, cultivating and harvesting procedures. More efficient machinery and equipment, has led to efficiencies in planting, tillage, harvesting, irrigation, and drainage.

Real wages in the U.S. have also failed to follow the predictions of Mill and other proponents of the classical thesis who contended that population would rise faster than capital formation and reduce wages to the subsistence level. Instead of remaining near the subsistence level real wages in manufacturing have increased in each 20-year period during the last 60 years (Table V). Real wages rose at an average rate of two percent per year during the 60-year period. Hence, in contrast to the food-population subsistence theories espoused by the classical economists, major gains in per capita wealth, production, and income, have occurred in the United States. The classical theories of relatively fixed soil productivity, rising rents, and slow rate of capital formation did not envision the extent of man's ability to increase production in the MDCs. Their population theories overestimated man's incentive to multiply and underestimated his wealth accumulations and productive capacity in these nations. As a consequence, the supply of food and other real goods has expanded at a faster rate than population growth.

Table V

EARNINGS — PRODUCTION WORKERS IN MANUFACTURING, UNITED STATES

Date	Nominal Weekly Wage Rate	Wages Adjusted for Changes in Consumer Prices	Annual Rate of Change from Previous Date (real wages)
1914	$ 10.92	$ 36.28	
1934	18.20	45.39	+1.1%
1954	70.49	87.57	+3.3
1974	176.00	119.16	+1.6
1914-74			+2.0

Source: U.S. Department of Labor, *Employment and Earnings Statistics for the United States 1909-1972*, pp. 35; *Employment and Earnings*, September 1975, p. 73; and Bureau of Labor Statistics releases for price index data.

Recent Food Price Disturbances Do Not Reflect a Change in Trend

While real food costs in the United States rose sharply in 1973 and 1974, evidence points to short-run explanations for much of the increase. A number of short-run factors have had a stimulative effect on food prices. Government food subsidies to lower income groups have increased sharply, tending to enhance total food demand since 1969. The total value of Federal distributions under the Food Stamps, Food Distribution, and Child Nutrition programs of the U.S. Department of Agriculture rose from $1.2 billion in 1969 to $5.5 billion in 1974, and to $6.8 billion in 1975. While these programs may be permanent, the momentum of their upward pressure on food prices should decline if fewer families are hereafter added to the food aid lists.

Demand for food for export was enhanced by relatively unfavorable weather over part of the world. The much publicized Russian wheat sales and the larger grain sales to Western Europe in 1972 reflected poor crop growing conditions and a sharp increase in production of livestock products in these areas. A sharp cutback in Peruvian fish meal production in late 1972 and 1973, a source of protein for animal feed, also contributed to higher demand for U.S. livestock feed.

A number of factors on the supply side of the domestic market also contributed to the food price increases. Wage-price controls, environmental regulations, relatively poor domestic weather conditions, a sharp increase in fuel costs as a result of the OPEC petroleum monopoly, and changes in the international terms of trade all tended to reduce domestic food supplies from what they would otherwise be.

Domestic wage and price controls in effect during the early 1970s were especially harmful to the food industry. They held the prices of some inputs, such as fertilizer, below long-run equilibrium levels, which reduced the incentive to expand output. Consequently, fertilizer "shortages" developed and, once the controls were lifted, fertilizer prices rose above long-run equilibrium levels. Both the "shortages" and the higher input prices, which followed the lifting of the controls, tended to increase food costs. The freeze on meat prices in the summer of 1973 was also harmful. It reduced the incentive for farmers to produce, thus delaying increases in livestock production.

Environmental and safety programs imposed on a wide scale have tended to reduce the supply of all goods and services including food. Controls on chemicals for crops and on growth additives for livestock feed have both tended to increase farm production costs and reduce food supplies. The OPEC oil cartel which quadrupled the export price of oil has been an important cost-increasing factor since late 1973. Energy costs quickly permeate throughout the economy and affect costs of producing all goods and services.

The depreciation of the dollar relative to other nation's currencies in 1971 was likewise a short-run cost increasing factor. It changed the relative prices of internationally traded goods. Prices of domestic goods to foreign purchasers were reduced and prices of foreign goods to U.S. purchasers were increased. Consequently exports of U.S. agricultural products rose and imports of goods declined resulting in fewer goods for domestic use including food.

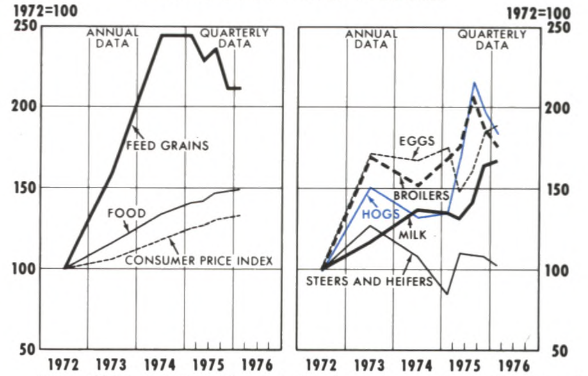
None of the above factors appear to be the type that will alter trend movements. Some, such as the environmental protection measures and the oil cartel, will cause only a once-and-for-all reduction in the food supply (reduced quantity supplied at any given price) unless further restrictive measures are taken. On the other hand, per capita wealth is likely to continue upward and the flow of cost-reducing technologies into the food industry is likely to be maintained causing the supply of food to continue to increase.

The turnaround in food production and price prospects for food this year relative to other prices is evidence that food prices rose above longer-run equilibrium levels following the short-run disturbances in 1972 and 1973. The disturbances largely affected the prices of grain and other livestock feed. Average feed prices increased sharply leading to reduced output and higher prices for animal food products. But, following the large crop harvested last fall, grain prices declined sharply and all food prices began to level off. Consequently, the spread between food and all consumer prices, that had developed since 1972, began to close (see chart). During the period of sharply increasing food prices, the percent of U.S. disposable personal income spent on food at home rose, increasing from 12.5 percent in 1972 to 13.1 percent in 1975. With the turnaround in food prices relative to other consumer goods, the percent of personal income spent on food may resume its downward trend in 1976.

Summary and Conclusion

Fear of famines is not of recent origin. The tendency for population growth to exceed that of food production has been recognized as critical to the well-being

Price Changes for Food and Selected Farm Products



Source: U.S.D.A. Agricultural Prices, Dairy Situation, Poultry and Egg Situation, Livestock and Meat Situation, and U.S. Department of Labor.

Latest data plotted: 1st quarter 1976 based on estimates of latest data available

of man throughout history. From time to time some analysts propose that the solution to this imbalance should receive top priority. Others, however, view it as a continuous age-old problem associated with wealth accumulation and economic growth. To the latter group the food shortages and starvation in the LDCs is another episode in the classical model of economic development and a problem not subject to solution by "crash" programs.

The threat of famine is not worldwide. Essentially two worlds exist in terms of per capita food supplies — one, the LDCs, in which growth of population tends to approach that of capital accumulation and productivity, and to be limited by the means of subsistence, and another, the MDCs, in which capital and real per capita income growth is at relatively high rates and population growth is at a relatively low rate.

Famines in the LDCs during the past two decades have been inhibited by food aid programs of the more developed nations. This aid, however, has not improved their per capita productivity. In contrast it may have worsened their food-population relationship.

The success of technical assistance programs for the LDCs has likewise been questioned. Some have suggested that a large portion of future aid be channeled toward a major expansion of research in the LDCs themselves. It is also apparent that progress toward increasing total output could be quickened by providing a more favorable political climate for saving and capital investment in the LDCs. With a more favorable climate for capital investment, technicians which accompany such investment serve to hasten the technical training of the local work force, an important factor in achieving rapid gains in production.

While starvation will likely remain a major problem in the LDCs until a sizable increase is achieved in per capita wealth and production, a downtrend in the food supply is not likely to occur elsewhere. Supply and demand conditions in most of the LDCs do not have a major impact on food supplies and prices in the more affluent economies. Although they receive gifts from the MDCs, and some export sizable quantities of goods, most of the LDCs have a relatively small impact on world food prices.

Consequently there is little danger that starvation and famines in the LDCs will spill over into the more developed nations. The MDCs have in recent years experienced some short-run reversals in real food cost but the basic trend in food costs continues downward. The growth of capital, technology, and knowledge in these nations has continued. These factors increase man's ability to produce goods and services. Moreover, there has been no tendency in recent years for their populations to increase at a faster rate than heretofore. Instead of accelerating, their population growth rate has declined. Consequently, instead of a change toward scarcity and famine, once the short-run disturbances are past, the downtrend in real food costs is likely to be resumed.

If the LDCs increase their wealth and develop the capacity to expand output of nonfood goods sufficiently to trade for major quantities of food, such trade would not be detrimental to the well-being of the MDCs. By trading food freely with such nations the MDCs would be able to get more goods and services from their scarce resources than if they produced solely for their own consumption. Consequently, the MDCs have nothing to fear from the possibility of rising productivity and rising food demand in the LDCs.

Preferred Habitat vs. Efficient Market: A Test of Alternative Hypotheses

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THE standard Keynesian view is that actions taken by monetary authorities affect aggregate demand by altering interest rates. Since investment and consumption presumably depend primarily on intermediate and long-term rates and central banks operate primarily in short-term markets, a transmission mechanism is needed to explain how monetary policy affects aggregate demand. Expressing long-term rates as a distributed lag of short-term rates provides one such link.

The Preferred Habitat hypothesis of interest rate determination, as developed by Modigliani and Sutch, has received rather wide acceptance in econometric model building. The hypothesis of Modigliani and Sutch implies that long-term interest rates depend on a 16 quarter distributed lag of short-term interest rates.[1] The particular form of dependence implied by the Modigliani-Sutch hypothesis is widely recognized as the dominant lag structure and this lag structure has been incorporated into several large econometric models.[2]

There is, however, an impressive body of empirical evidence indicating that interest rates follow a random walk; that is, movement in a given period is independent of movements in previous periods.[3] This evidence is consistent with the hypothesis that capital markets are efficient in the sense that prices fully reflect all available information.[4] If capital markets are efficient and both long-term and short-term interest rates essentially perform a random walk, then long-term rates are not determined by a long distributed lag of short-term rates. If long-term interest rates do not depend on a distributed lag of short-term rates, then some important econometric models contain a potentially serious misspecification.

This conclusion would be particularly relevant for the FRB-MIT-Penn model. In this model, the transmission mechanism is essentially from monetary actions to short-term interest rates, to long-term interest rates, to aggregate expenditures, output and employment.[5] Since the effect of short-term rates on long-term rates is distributed over 16 quarters, the effects

*We would like to thank Robert Rasche and Michael Hamburger for their helpful comments and suggestions.

[1]Franco Modigliani and Richard Sutch, "Innovations in Interest Rate Policy," *American Economic Review* (May 1966), and "Debt Management and the Term Structure of Interest Rates: An Empirical Analysis of Recent Experience," *Journal of Political Economy,* Supplement (August 1967).

[2]See, for example, the Federal Reserve-MIT-Penn model and RDX2 developed by the Bank of Canada.

[3]See for example, G.O. Bierwag and M.A. Grove, "A Model of the Structure of Prices of Marketable U.S. Treasury Securities," *Journal of Money, Credit and Banking* (August 1971); C.W.J. Granger and H.J.B. Rees, "Spectral Analysis of the Term Structure of Interest Rates," *Review of Economic Studies* (January 1968); John Pippenger, "A Time Series Analysis of Post-Accord Interest Rates: Comment," *Journal of Finance* (September 1974); and Richard Roll, *The Behavior of Interest Rates* (New York: Basic Books, 1970). For some conflicting evidence, see Stanley Diller, *The Seasonal Variation of Interest Rates,* NBER Occasional Paper No. 80, 1969.

[4]For an excellent survey of the evidence bearing on and supporting the Efficient Market hypothesis, see Eugene Fama, "Efficient Capital Markets: A Review of Theory and Empirical Work," *Journal of Finance* (May 1970).

[5]". . . the structure of our model implies that the money supply can affect consumption, as well as every other component of demand, only through its effect on the short-term rate . . ." Franco Modigliani, "Monetary Policy and Consumption: Linkages via Interest Rate and Wealth Effects in the FMP Model," *Consumer Spending and Monetary Policy: The Linkages,* F. Modigliani et al. (Federal Reserve Bank of Boston, 1971, pp. 61-62).

of monetary actions tend to be spread over a very long period of time.[6]

The long distributed lag from short-term to long-term interest rates in the FRB-MIT-Penn model may at least partially explain why that model yields substantially different estimates from that indicated from St. Louis Federal Reserve Bank research concerning how rapidly nominal income responds to monetary policy. For example, the original Andersen-Jordan results suggest that the response of nominal income to a change in the monetary base is completed within about only four quarters. On the other hand, Modigliani describes the response of nominal income in the FRB-MIT-Penn model to a change in unborrowed reserves as follows: "The response is clearly rather slow, as the money supply responds but gradually to the increase in reserves and in turn GNP responds gradually to the change in M. Still, by the end of the third year, the GNP multiplier seems to be close to its limiting value."[7]

The results of our tests lead us to reject the Modigliani-Sutch Preferred Habitat hypothesis in favor of the Efficient Market hypothesis. This conclusion indicates that the FRB-MIT-Penn model embodies a misspecification of the transmission mechanism for monetary policy. In particular, our results suggest that the FRB-MIT-Penn model and other econometric models using a similar distributed lag relationship between long-term and short-term interest rates are likely to overstate the length of the lag from monetary policy to employment, income, and prices.

ALTERNATIVE HYPOTHESES

Modigliani-Sutch Preferred Habitat Hypothesis

As developed by Modigliani and Sutch, the Prefered Habitat model (hereafter referred to simply as M&S and PH, respectively) is a combination of three logically independent hypotheses. One is that market participants have a preferred habitat, that is, they tend to match the term structure of their assets and liabilities. The second is that long-term rates depend on expected future short-term rates. The third is that market expectations about future short-term rates contain both regressive and extrapolative elements.[8]

According to Modigliani and Sutch, the long-term rate L(t) depends on current and past short-term rates S(t) and a risk premium F(t) that reflects the difference between the premium on long-term and short-term bonds generated by the Preferred Habitat.

$$(1)\ L(t) = \alpha + \beta_0 S(t) + \sum_{i=1}^{16} \beta_i S(t-i) + F(t) + \eta(t)$$

The β_i's first rise and then fall as a result of extrapolative and regressive expectations.[9]

Since various proxies for F(t) have yielded at best only weak results, this term has been omitted in practice. The operational version of the Preferred Habitat hypothesis therefore is

$$(2)\ L(t) = \alpha' + \beta_0 S(t) + \sum_{i=1}^{16} \beta_i S(t-i) + \eta'(t)$$

where F(t) is now absorbed into the constant α' and error term $\eta'(t)$.

Efficient Market Hypothesis

The essence of the Efficient Market hypothesis is that current interest rates fully reflect *all* available information. This hypothesis is in conflict with the Modigliani-Sutch postulate that market expectations contain both regressive and extrapolative elements. If capital markets are efficient and interest rates essentially perform a random walk, then market expectations contain neither regressive nor extrapolative elements.[10]

[6]In models which incorporate monetary channels of influence other than, or in addition to, the cost of capital channel, the shortening of the lags between the changes in money and the long-term interest rate would not necessarily shorten the lags between changes in money and output, prices, and employment.

[7]Franco Modigliani, "Monetary Policy and Consumption," p. 54.

[8]Although the second and third hypotheses are logically separate, they are not independent empirically. As long as we do not have any direct measure of expected future short-term rates, the hypothesis that current long-term rates depend on expected future short-term rates is empirically empty without a theory of how those expectations are formed.

[9]Modigliani and Sutch, "Innovations in Interest Rate Policy," p. 188.

[10]In a later paper, Franco Modigliani and Robert J. Shiller attempt to demonstrate that a similar model is consistent with the concept of Rational Expectations developed by J. F. Muth. Although the concepts of Rational Expectations and Efficient Markets seem to have much in common, the two approaches have developed almost entirely independently, and the relationship between them is not at all clear. See Franco Modigliani and Robert J. Shiller, "Inflation, Rational Expectations and the Term Structure of Interest Rates," *Economica* (February 1973). For some apparently conflicting results, see Thomas J. Sargent, "Rational Expectations and the Term Structure of Interest Rates," *Journal of Money, Credit and Banking* (February 1972), as well as Michael J. Hamburger and Elliott Platt, "The Expectations Hypothesis and the Efficiency of the Treasury Bill Market," *Review of Economics and Statistics* (May 1975).

A large amount of empirical evidence indicates that there is essentially no exploitable regularity in the movement of interest rates. If that is correct, and capital markets are efficient, then current interest rates fully reflect all available information, and there should be no systematic relation between current long-term rates and lagged short-term rates. In other words, if past short-term rates contain information about future long-term rates that is not fully reflected in current long-term rates, as is the case in the PH model, then current long-term rates do not fully reflect all available information, and in this sense long-term capital markets are not efficient.

In order to provide an explicit hypothesis against which we can test the PH hypothesis of M&S, we develop a simplified Efficient Market hypothesis (hereafter referred to as SEM).[11] For simplicity, the impact of new information on capital markets is arbitrarily divided into three components: the impact of new information that is relevant primarily to the determination of short-term rates x(t), the impact of new information that is relevant primarily to long-term rates y(t), and the impact of new information that is relevant to both rates z(t).

Under these assumptions, current long-term and short-term interest rates can be described as follows:

$$(3)\ L(t) = L(t-1) + \lambda z(t) + y(t)$$

$$(4)\ S(t) = S(t-1) + z(t) + x(t)$$

where x(t), y(t) and z(t) are independent of each other and each is distributed independently over time.

This approach is based on the idea that both long-term and short-term rates essentially perform a random walk and that they are related to each other to the extent that both respond to the same information z(t). This suggests we can express the relation between long-term and short-term rates as follows:

$$(5)\ L(t) = L(t-1) + \lambda \Delta S(t) + u(t)$$

where u(t) is a nonserially correlated random variable. However, since $\Delta S(t)$ is only a proxy for z(t), and u(t) [which equals $y(t) - \lambda x(t)$] is not independent of $\Delta S(t)$, OLS estimates of λ are biased.

The interpretation of equation (5) is that capital markets are efficient and that both long-term and short-term rates are influenced by a common body of information. It would be more realistic to permit x(t), y(t), and z(t) to have some structure or to postulate a whole spectrum of information and to develop a model explaining the response of both long-term and short-term interest rates to each segment in that spectrum. But simplicity is a virtue, and we believe that, given the present state of knowledge, equation (5) represents a useful model for our purpose, which is to test the Preferred Habitat hypothesis of Modigliani-Sutch against the Efficient Market hypothesis.[12]

Levels Versus Differences

Over the years the results of several studies, which have used a variety of techniques, have cast doubt on the reliability of the lag structure estimated by M&S.[13] One of the most important of these is the study by Michael Hamburger and Cynthia Latta, who used a model originally suggested by John Wood.[14]

According to Wood, as a reasonable approximation, we can express the relation between long-term and short-term rates as follows:

$$(6)\ L(t) = a + bS(t) + v(t)$$

First-differencing this equation, which is the form in which Wood tested it, yields an equation that is apparently similar to equation (5), but differs in that the error term v(t) in the Wood model is implicitly assumed to be independent of the short-term interest rate.

M. Hamburger and C. Latta compared the PH and Wood models in differences. Their paper, which anticipates much of the empirical work presented here, yields results that lead them to reject the PH model.

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[11]This and other discussions of the Efficient Market hypothesis in this paper ignore the important role of transaction costs.

[12]It should be clear, however, that such a model is not the best possible alternative. A model that explicitly identified the events reflected in x(t), y(t), and z(t) and related them to long-term and short-term rates would yield a more useful explanation. The model developed by M. Feldstein and G. Chamberlain in "Multimarket Expectations and the Rate of Interest," *Journal of Money, Credit, and Banking* (November 1973), is one example of such an attempt.

[13]See, for example, R. Dobell and T. Sargent, "The Term Structure of Interest Rates in Canada," *Canadian Journal of Economics* (February 1969); T. Cargill and R. Meyer, "A Spectral Approach to Estimating the Distributed Lag Relationship between Long and Short Term Interest Rates," *International Economic Review* (June 1972), and "Estimating Term Structure Phenomena from Data Aggregated over Time," *Journal of Money, Credit and Banking* (November 1974); V. Chetty, "Estimation of Solow's Distributed Lag Models," *Econometrica* (January 1971); G. Pierson, "Effect of Economic Policy on the Term Structure of Interest Rates," *Review of Economics and Statistics* (February 1970); and especially M. Hamburger and C. Latta, "The Term Structure of Interest Rates," *Journal of Money, Credit and Banking* (February 1969). For a reply to Hamburger and Latta, see Franco Modigliani and Richard Sutch, "The Term Structure of Interest Rates: A Re-examination of the Evidence," *Journal of Money, Credit and Banking* (February 1969).

[14]Hamburger and Latta, "The Term Structure of Interest Rates." John H. Wood, "The Expectations Hypothesis, the Yield Curve, and Monetary Policy," *Quarterly Journal of Economics* (August 1964).

However, as pointed out by M&S, when the PH and Wood models are compared in levels, the PH model has greater explanatory power.[15]

The superiority of the PH model over the levels version of Wood's model, however, cannot be used to discriminate between the SEM and PH models. If the SEM model is essentially correct, then we would expect a distributed lag model such as the PH model to yield better results than the levels version of Wood's model. This point is demonstrated in the Appendix.

Replication of Modigliani-Sutch Evidence

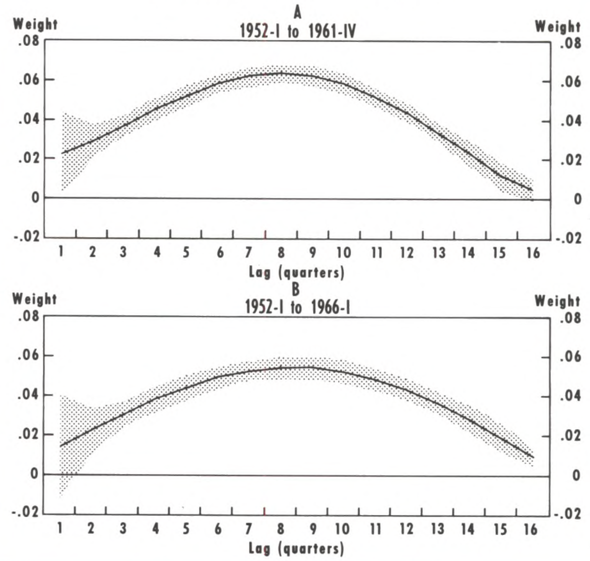
Before proceeding further, we replicate the Modigliani-Sutch evidence supporting their version of the Preferred Habitat hypothesis. They estimate their equation for two overlapping periods running from the first quarter of 1952 (I/1952) to the fourth quarter of 1961 (IV/1961) and from I/1952 to I/1966. In both periods, they use quarterly data, estimate the current short-term rate separately, and use a fourth degree Almon lag, with the 17th lag constrained to zero, to estimate the lag structure. Although they use the yield on taxable long-term government bonds to measure long-term rates in both periods, they use the yield on three-month Treasury bills calculated on a discount basis as a measure of short-term rates in the shorter period and the same rate calculated on a bond yield basis in the longer period. In the results presented here we use their measure of long-term rates and their bond yield measure of short-term rates.[16]

When we reestimate their model using equation (2) for the period running from I/1952 to I/1966, we get the same results. When we reestimate their model for the period I/1952 to IV/1961 using the bond yield measure of the short-term rate rather than the yield on a discount basis, we obtain essentially the same results. Table I shows our estimates (labeled P&P) for both periods as well as the estimates reported by M&S for the period I/1952 to IV/1961. Our estimates of the coefficients for lagged short-term rates with a band of plus or minus one standard error are shown in Figure I.

[15]Modigliani and Sutch, "The Term Structure of Interest Rates: A Re-examination of the Evidence."

[16]Except for the long-term rate from I/1952 to I/1953, the data are taken from Sutch's dissertation, pp. 216-17. For the period I/1952 to I/1953, we use quarterly averages of the long-term Treasury bond yield reported in the *Treasury Bulletin* on a monthly basis. Sutch apparently dropped these five quarters from his later work because the maturity of the long-term bonds used to calculate the yield changed twice during this period.

Figure I
Distributed Lag Coefficients



TESTING ALTERNATIVE HYPOTHESES

The widespread acceptance and use of the Modigliani-Sutch version of the Preferred Habitat hypothesis in econometric model building is based essentially on the results shown in Table I and Figure I. As compared only to the alternative hypothesis that there is no relation between long-term rates and current as well as lagged short-term rates, this evidence would lead one to accept their hypothesis.

But the null hypothesis of no relation is a straw man. In order to determine whether or not their hypothesis is the best available explanation of the determination of long-term interest rates, it should be tested against a strong alternative hypothesis. Given the very impressive amount of evidence supporting the hypothesis that organized capital markets are efficient and that both long-term and short-term interest rates essentially perform a random walk, the SEM model developed above provides a strong alternative hypothesis.

The fundamental difference between the two hypotheses is the way capital markets respond to new information. In the SEM model formalized in equation (5), long-term and short-term rates respond fully and simultaneously to a common body of new information. As a result, all relevant information contained in past short-term rates is *fully* reflected in the lagged long-term rate, and the current change in the short-term rate can be viewed as a proxy for the new information that affects both rates.

In the PH model, new information influences long-term rates slowly and indirectly. There the implicit hypothesis is that new information alters current short-term rates and the change in the current short-term rates then continues to alter long-term rates over several quarters as expected future short-term rates respond over time to the new information.

Suppose, for example, that there is an unanticipated open market sale of short-term government securities. The SEM hypothesis says that both long-term and short-term rates respond fully and simultaneously to this event when it happens. The PH hypothesis however implies that the open market operation first affects essentially only current short-term rates. Then, in response to extrapolative and regressive expectations about future short-term rates, the long-term rate responds over time to the open market operation and the initial rise in short-term rates.

These two ways of viewing the relation between long-term and short-term interest rates are fundamentally different, and the essence of the difference concerns the nature of the information contained in lagged short-term interest rates.

Table I

PREFERRED HABITAT PARAMETER ESTIMATES
Obtained from Equation (2)

	I/1952 to IV/1961				I/1952 to I/1966	
	M&S		P&P		P&P	
i	β_i	t value	β_i	t value	β_i	t value
0	0.316	(10.53)	0.3076	(10.37)	0.2607	(7.15)
1	0.0229	(1.06)	0.0223	(1.06)	0.0142	(0.53)
2	0.0293	(3.21)	0.0286	(3.22)	0.0225	(1.92)
3	0.0373	(6.90)	0.0366	(6.98)	0.0305	(4.66)
4	0.0458	(7.63)	0.0449	(7.73)	0.0380	(5.46)
5	0.0536	(9.24)	0.0525	(9.37)	0.0444	(6.49)
6	0.0599	(12.47)	0.0586	(12.42)	0.0494	(8.50)
7	0.0641	(14.56)	0.0626	(14.56)	0.0529	(10.44)
8	0.0656	(13.38)	0.0640	(13.44)	0.0547	(10.81)
9	0.0644	(11.70)	0.0626	(11.68)	0.0546	(9.18)
10	0.0603	(10.76)	0.0586	(10.66)	0.0526	(8.71)
11	0.0537	(10.13)	0.0520	(10.05)	0.0488	(8.67)
12	0.0449	(8.80)	0.0434	(8.64)	0.0433	(8.25)
13	0.0347	(5.98)	0.0334	(5.84)	0.0363	(6.30)
14	0.0239	(3.41)	0.0228	(3.32)	0.0281	(4.04)
15	0.0136	(1.83)	0.0128	(1.77)	0.0190	(2.54)
16	0.0051	(0.91)	0.0047	(0.86)	0.0095	(1.66)
Constant	1.239	(44.25)	1.251	(21.55)	1.474	(23.45)
R^2	0.975		(Adj.) 0.971		(Adj.) 0.955	
D-W	1.42		1.39		0.579	
Standard Error	0.093		0.093		0.127	

The next logical step is to formulate a test that will permit us to discriminate between these two models. In order to be effective, such a test must not be prejudiced and should cast light on the essential difference between the two approaches.

One possibility, and the one M&S insisted upon in their exchange with Hamburger and Latta, is to compare equations (2) and (6)

$$(2)\ L(t) = \alpha' + \beta_0 S(t) + \sum_{i=1}^{16} \beta_i S(t-i) + \eta'(t)$$

$$(6)\ L(t) = a + bS(t) + v(t)$$

to see whether the 16 lagged short-term rates have any significant explanatory power.

Such a test does get at the heart of the issue. But, as we point out above and demonstrate in the Appendix, if the SEM model is essentially correct, then this test is likely to be prejudiced in favor of the PH model.

Another alternative is to compare equation (2) and the SEM model as described by equation (5).

$$(5)\ L(t) = L(t-1) + \lambda \Delta S(t) + u(t)$$

But there are two reasons for not doing this. First, the SEM model contains a lagged long-term interest rate and this could prejudice the result in favor of the SEM model. Second, such an approach does not provide a direct test of the essential difference between the two models. That is whether or not there is information in lagged short-term rates that is not fully captured by L(t-1).

A third alternative, and the one we choose, is, in effect, to difference the PH model as expressed by equation (2) and to rewrite the differenced version as follows:

$$(7)\ L(t) = L(t-1) + \beta_0\, \Delta S(t) + \sum_{i=1}^{16} \beta_i\, \Delta S(t-i) + \Delta\eta'(t)$$

This puts the SEM and PH models on exactly the same footing and permits us to get at the essence of the difference between the two models. In addition, this approach does not appear to involve any prejudice against the PH model. For the shorter period, equation (2) yields a slightly higher adjusted R^2 than equation (7) (0.975 versus 0.962), but for the longer period the results are reversed (0.955 versus 0.974).[17]

We believe equations (5) and (7) provide the basis for a fair and direct test of what is the essence of the difference between the PH and SEM models. If the market for long-term government securities is essentially efficient, the error term obtained from estimating equation (5) should be free of autocorrelation and adding lagged changes in the short-term rate should not reduce significantly the mean-squared-error. If the market is not efficient and expectations contain both regressive and extrapolative elements, then we would expect equation (7) to yield a better explanation of the long-term rate, in terms of a statistically significant smaller mean-squared-error, than equation (5).

The results from estimating equation (5) for the two overlapping periods chosen by Modigliani and Sutch are as follows:

I/1952 to IV/1961

$$L(t) = \underset{(0.447)}{0.0453} + \underset{(32.506)}{0.9949}L(t-1) + \underset{(6.146)}{0.2218}\,\Delta S(t)$$

$$\bar{R}^2 = 0.964 \qquad SE = 0.1047$$

I/1952 to I/1966

$$L(t) = \underset{(0.922)}{0.0696} + \underset{(46.415)}{0.9861}L(t-1) + \underset{(7.1346)}{0.2246}\,\Delta S(t)$$

$$\bar{R}^2 = 0.975 \qquad SE = 0.0949$$

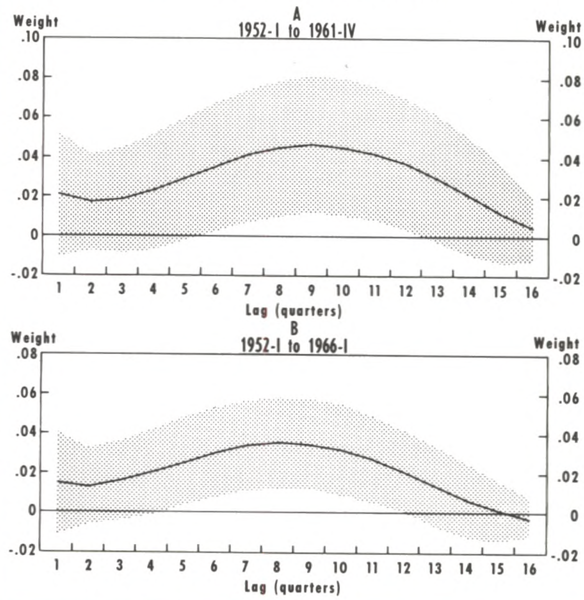
where t values are shown in parentheses.

Since the regressions contain a lagged dependent variable, the Durbin-Watson statistic is biased toward 2.0 and a more appropriate measure for serial correlation in the residuals is the h-statistic which has a standard normal distribution.[18] The h-statistic is - 0.199 for the shorter period and - 0.002 for the longer period. As implied by the SEM model, there is no indication of any first order serial correlation in the residuals.

The estimated parameters of equation (7) are shown in Table II and the estimates of the coefficients for lagged changes in short-term interest rates are shown in Figure II with a band of plus or minus one standard error. Following Modigliani and Sutch we estimated the lag structure using a fourth degree Almon lag with the 17th lag constrained to zero.

Figure II

Distributed Lag Coefficients



In both periods, with the exception of the first coefficient, the lag structure retains the inverted U shape, but now none of the lagged coefficients are statistically significant at the five percent level. An F test indicates that lagged short-term interest rates contain no information that is not already captured by the lagged long-term interest rate. For the shorter period, adding $\sum_{i=1}^{16} \beta_i \, \Delta S(t-i)$ to equation (5) does not increase significantly the explained variance (an F-statistic of 0.506). For the longer period the same comparison yields the same result (an F-statistic of 0.77).[19] This evidence does not support the claim that expectations contain regressive and extrapolative elements and that, therefore, lagged short-term interest rates contain additional information not captured by the lagged long-term interest rate.

Although there is no evidence that lagged short-term interest rates contain any significant information, the tendency for the inverted U shape to persist suggests that there might be at least some information in

[17]Since $\Delta S(t)$ and $u(t)$ are correlated in equation (5), the estimate of λ is biased downward. This errors in variables problem can be corrected using an instrumental variables technique to estimate equations (5) and (7). Estimating equations (5) and (7) using an instrumental variables technique suggested by Durbin does not alter the conclusions drawn from the OLS estimates presented below that there is no information in the lagged $\Delta S(t)$'s. J. Johnston, *Econometric Methods* (New York: McGraw-Hill, 1972), p. 284.

[18]See Johnston, *Econometric Methods,* pp. 312-13.

[19]In order to be significant at the 5 percent level, the F statistic would have to exceed 2.66 for the shorter period and 2.56 for the longer period. There is the possibility that estimating the PH model as equation (7) introduces spurious autocorrelation into the residuals, thus possibly tending to bias the F tests against the PH model. The insignificant h-statistic for the estimates of both the SEM and PH models, however, suggests this is not a serious problem.

Table II

PREFERRED HABITAT PARAMETER ESTIMATES
Obtained from Equation (7)

	I/1952 to IV/1961		I/1952 to I/1966	
i	β_i	t	β_i	t
0	0.2338	(5.348)	0.2385	(6.604)
1	0.0209	(0.663)	0.0150	(0.576)
2	0.0170	(0.689)	0.0136	(0.692)
3	0.0183	(0.681)	0.0160	(0.775)
4	0.0228	(0.769)	0.0204	(0.923)
5	0.0289	(0.919)	0.0256	(1.122)
6	0.0354	(1.077)	0.0304	(1.320)
7	0.0410	(1.206)	0.0338	(1.463)
8	0.0449	(1.290)	0.0354	(1.523)
9	0.0466	(1.326)	0.0349	(1.499)
10	0.0458	(1.311)	0.0321	(1.398)
11	0.0424	(1.238)	0.0272	(1.221)
12	0.0367	(1.099)	0.0208	(0.966)
13	0.0292	(0.902)	0.0135	(0.656)
14	0.0206	(0.678)	0.0064	(0.333)
15	0.0119	(0.461)	0.0007	(0.045)
16	0.0046	(0.273)	−0.0019	(0.184)
L(t − 1)	0.9873	(30.494)	0.9819	(44.229)
Constant	0.0497	(0.473)	0.0705	(0.911)
$\bar{R}^2$	0.962		0.974	
h	−0.666		−0.558	
Standard Error	0.1076		0.0957	
DF	33		50	

models is based primarily on three factors. They are as follows. First is the ability of the model to explain the behavior of long-term interest rates over the sample period in the sense of a high R^2. Second is the significance of the lag structure. Many of the t-statistics are over 5. Third, the estimated lag coefficients take the form of a smooth inverted U, which Modigliani and Sutch interpret as being consistent with extrapolative and regressive expectations.

With respect to the smooth inverted U, our results suggest that this is due to the Almon technique, which forces the estimates to fit a smooth curve, rather than the result of extrapolative and regressive expectations.

As for the significance of the lagged short-term rates that M&S found in their PH formulation given by equation (2), the SEM model proposed here suggests that such statistical significance need not be interpreted as evidence of extrapolative and regressive expectations. The SEM model, as presented in the text and amplified in the Appendix, explains how adding lagged short-term rates can improve the fit obtained from the distributed lag. Alternatively, the smooth inverted U may be the result of using a low degree Almon polynomial rather than the result of extrapolative and regressive expectations.

In order to obtain some evidence on this point, we estimate the lag structure in equation (7) using ordinary least squares. Since changes in Treasury bill rates essentially are uncorrelated, multicollinearity is not a problem and, under the assumptions of the PH model, OLS regression provides an unbiased estimate of the parameters. Regression results using ordinary least squares are shown in Table III. Figure III shows the estimates of the coefficients for lagged changes in short-term rates with a band of plus or minus one standard error. In neither period is there a smooth inverted U. This result suggests that the smooth inverted U is the result of using the Almon lag.

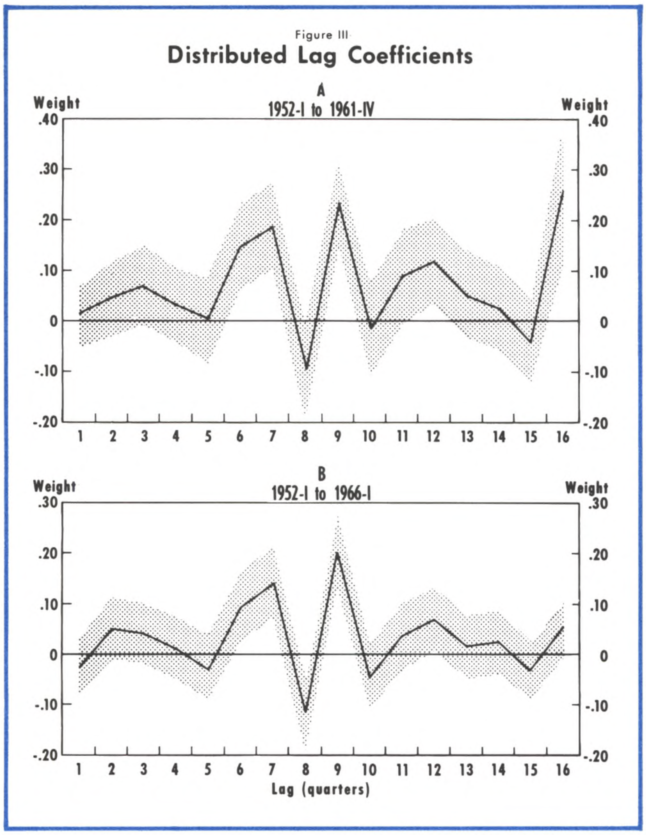
Table III

PREFERRED HABITAT PARAMETER ESTIMATES
Obtained from Equation (7) Using OLS

	I/1952 to IV/1961		I/1952 to I/1966	
i	β_i	t	β_i	t
0	0.2750	(4.706)	0.2940	(6.301)
1	0.0119	(0.177)	−0.0260	(0.468)
2	0.0435	(0.589)	0.0511	(0.831)
3	0.0719	(0.928)	0.0413	(0.668)
4	0.0316	(0.422)	0.0119	(0.188)
5	0.0030	(0.035)	−0.0291	(0.419)
6	0.1477	(1.685)	0.0931	(1.331)
7	0.1886	(2.172)	0.1431	(2.008)
8	−0.0960	(1.028)	−0.1197	(1.655)
9	0.2348	(2.666)	0.2035	(2.821)
10	−0.0148	(0.157)	−0.0470	(0.671)
11	0.0882	(0.944)	0.0355	(0.503)
12	0.1193	(1.420)	0.0687	(1.075)
13	0.0525	(0.596)	0.0144	(0.226)
14	0.0257	(0.304)	0.0232	(0.365)
15	−0.0424	(0.503)	−0.0320	(0.562)
16	0.2498	(1.741)	0.0585	(1.197)
L(t − 1)	0.9679	(28.424)	0.9856	(48.046)
Constant	0.0778	(0.755)	0.0482	(0.674)
$\bar{R}^2$	0.969		0.978	
h	0.574		−0.444	
Standard Error	0.0969		0.0882	
DF	21		38	

CONCLUSION

The acceptance of the Preferred Habitat model and its widespread use in econometric



regressing the current long-term rate on the current short-term rate even though long-term rates do not depend on lagged short-term rates.

With respect to the high R^2 obtained by M&S, we find that in order to explain the current long-term interest rate, it is sufficient to use the long-term rate lagged one quarter and the current change in the short-term rate. The addition of lagged changes in short-term rates does not add significantly to the explanation of the current long-term rate. This finding is consistent with the SEM model, but inconsistent with the PH model as specified by M&S. This result, which is part of a large and growing body of evidence that conflicts with the term structure model suggested by Modigliani and Sutch, leads us to reject the Preferred Habitat model in favor of the Simplified Efficient Market hypothesis.

Although a comparison of the two models leads us to reject the PH model, we recognize that the SEM model is a naive hypothesis that can and should be improved upon. We are trying to extend the SEM model and we hope that in the process we will be able to contribute to a better understanding of the relation between short-term and long-term interest rates.

APPENDIX

We can demonstrate as follows why we would expect the PH model to yield better results than the levels version of the Wood's model. Equations (3) and (4) can be solved as follows to express L(t) and S(t) in levels.

$$\text{(I)}\ L(t) = \lambda \sum_{i=0}^{\infty} z(t-i) + \sum_{i=0}^{\infty} y(t-i)$$

$$\text{(II)}\ S(t) = \sum_{i=0}^{\infty} z(t-i) + \sum_{i=0}^{\infty} x(t-i)$$

Using equations (I) and (II) to express the relation between the long-term and short-term rate in levels yields the following.

$$\text{(III)}\ L(t) = \lambda S(t) + \sum_{i=0}^{\infty} [y(t-i) - \lambda x(t-i)]$$

Comparing equations (III) and (6) we see that if the SEM model is correct, the error term v(t) in the Wood model is a random walk, i.e., a sum over time of uncorrelated random variables and, therefore, highly autocorrelated. As a result, we would expect that the estimation of the Wood model, i.e., equation (6), using ordinary least squares would not do as well as alternative specifications which use proxies to explain some of the structure in the error term v(t). One proxy, of course, is lagged S(t), which like v(t), has strong positive autocorrelation.

In addition we note from equation (4) that S(t) depends on x(t). Since v(t) is composed partly of lagged x(t)'s, the addition to equation (6) of a distributed lag on S(t) should do better than the Wood model described by equation (6). That is,

$$\text{(IV)}\ L(t) = a + bS(t) + \sum_{i=1}^{n} b_i S(t\text{-}i) + v'(t)$$

should "explain" some of the residual variance in the Wood model.

Under these conditions, however, such an improvement does not imply that current changes in L(t) depend in any way on the past behavior of S(t). In other words, the SEM model explains why a distributed lag on S(t) could contribute to the explanation of L(t) even though changes in long-term and short-term rates are only contempraneously correlated.

If the SEM model is essentially correct, then the relation between S(t) and L(t) is symmetric. We can derive equation (V) from equations (I) and (II)

$$\text{(V)}\ S(t) = a' + b'L(t) + w(t)$$

where

$$w(t) = \sum_{i=0}^{\infty} [x(t\text{-}i) - \frac{1}{\lambda}\ y(t\text{-}i)]$$

and w(t), therefore, has the same properties as v(t) in equation (6). That is, w(t) should be roughly a random walk and w(t) should not be independent of L(t). If our argument about the effect of adding lagged short-term rates to equation (6) is correct, then we should obtain similar results by adding lagged long-term rates to equation (V). That is,

$$\text{(VI)}\ S(t) = a' + b'L(t) + \sum_{i=1}^{n} b_i' L(t\text{-}i) + w'(t)$$

should "explain" some of the residual variance in equation (V).

When we estimate equation (V) for the two periods used by M&S, we get the following results:

1952-I to 1961-IV

$$S(t) = -1.5934 + 1.1798L(t)$$
$$(2.92) \qquad (7.24)$$

$R^2 = 0.579$ DW = 0.4300 SE = 0.5654

1952-I to 1966-I

$$S(t) = -2.1021 + 1.3451L(t)$$
$$(5.07) \qquad (11.66)$$

$R^2 = 0.7121$ DW = 0.3572 SE = 0.5195

where t values are shown in parentheses.

If we follow M&S and use a fourth degree polynomial with a tail constraint to estimate equation (VI) where n equals 17, we obtain the results shown in Table IV. As expected, the lagged long-term rates appear to add significantly to the explanation of the current short-term rate.

It should be pointed out that we did not search to obtain an optimum fit. We simply reversed the roles of long-term and short-term rates and then followed exactly the procedure used by M&S. The results shown in Table IV strongly support our claim that the significant lag structure obtained by M&S is not the result of extrapolative and regressive expectations.

Table IV

PARAMETER ESTIMATES
From Equation (VI)

	I/1952 to IV/1961		I/1952 to I/1966	
i	β_i	t	β_i	t
0	2.0275	7.68	2.2544	8.85
1	0.2814	1.41	0.1755	0.91
2	0.0178	0.20	−0.0051	0.05
3	−0.1813	3.04	−0.1565	2.68
4	−0.3172	4.89	−0.2714	4.47
5	−0.3929	6.45	−0.3452	6.04
6	−0.4128	8.13	−0.3762	7.85
7	−0.3833	8.38	−0.3649	8.66
8	−0.3126	6.30	−0.3149	7.14
9	−0.2103	3.83	−0.2323	4.82
10	−0.0880	1.59	−0.1257	2.63
11	0.0410	0.79	−0.0065	0.15
12	0.1619	3.27	0.1111	3.40
13	0.2579	4.51	0.2106	6.54
14	0.3107	4.46	0.2725	6.47
15	0.3002	4.05	0.2750	5.60
16	0.2045	3.64	0.1932	4.90
Constant	−1.8271	4.95	−1.8918	7.54
$\bar{R}^2$	0.889		0.903	
DW	1.2344		0.8094	
Standard Error	0.2901		0.3095	

But equation (IV) is not the only possible modification of the Wood model which would account for some of the variance in the error term v(t). Equation (4) of the SEM model implies that ΔS(t) and x(t) are correlated. Thus a distributed lag on ΔS(t) should explain some of the variance in the error term v(t) in equation (6). That is,

$$\text{(VII)}\ L(t) = a + bS(t) + \sum_{i=1}^{n} b_i \Delta S(t\text{-}i) + v''(t)$$

also should do better than the Wood model.

The SEM model, however, implies that the best way to capture the error variance in Wood's model is not to restrict the proxies for $\sum_{i=0}^{\infty} x(t-i)$ and the structure in v(t) to S(t) or ΔS(t), but to use L(t-1) and S(t-1).

From equation (III) we see that the error v(t) in the Wood model can be expressed as follows:

$$\text{(VIII)}\ v(t) = \sum_{i=0}^{\infty} y(t\text{-}i) - \lambda \sum_{i=0}^{\infty} x(t\text{-}i) = L(t) - \lambda S(t)$$

But equation (VIII) implies that

$$\text{(IX)}\ L(t\text{-}1) - \lambda S(t\text{-}1) = \sum_{i=1}^{\infty} y(t\text{-}i) - \lambda \sum_{i=1}^{\infty} x(t\text{-}i)$$

As a result, we can use (L(t-1) − λS(t-1)) to capture all of v(t) except for the two terms y(t) and λx(t). When we do this by combining equations (III) and (IX), we return full circle to equation (5) where the error term is orthogonal.