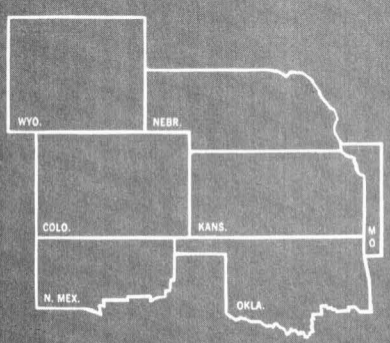

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Synthetics and Substitutes: Challenge To Agriculture

By Gene L. Swackhamer

FROM THE beginning of history, man has struggled to develop food production capacity to sustain world population. In much of the Western world the job has been done well, with human nutritional needs being more than satisfied. However, in many of the developing nations, maintaining nutritional levels adequate for survival remains a major undertaking. By the year 2000, world population is expected to increase to 6 billion—double the current level. Obviously, demographers expect these people to be fed—that is implied in the population projection—but diets may be barely adequate for many.

The *challenge* to traditional agriculture is immense. The next generation must duplicate the food production record achieved since the dawn of history. Consider the magnitude of this demand. Can it be done?

Making an adequate nutritional diet available to an expanding world population is a *challenge* to man's ingenuity; meeting human diet and living needs with synthetic products that substitute for natural agricultural products is a *challenge* to traditional farming. These two challenges are opposites—one is a promise, the other is a threat; both are not generally well understood. The purpose of this article is to condense relevant economic and research information on synthetics and substitutes. A diverse assortment of literature was reviewed in an attempt to enumerate as accurately as possible the major markets in which synthetics are found and to discuss the economic impact of synthetic substitutes in these markets.

In a literal sense, synthetics are artificial replacements for natural-form products. Substitutes are replacements, too—automobiles and tractors substituted for horses, plastic buttons substitute for pearl buttons, and rayon and nylon are substitutes for cotton and wool and for each other and other synthetics. If left at this point, a description of the mix of synthetics and substitutes and the raw material and end-use product markets affected would be hopelessly intertwined. Therefore, to better describe the nature of competition from synthetics and to assess their competitive impact, further delineation is made.

In this article, synthetics are defined as raw or semiprocessed materials, derived only from nonagricultural sources. Substitutes are materials which partly or totally replace a natural-form component in resource combinations and

end-use products. A substitute may originate from either agricultural or nonagricultural sources, but synthetics will be limited to nonagricultural sources. Thus, a synthetic substitute is a product derived from nonagricultural sources that substitutes for an agricultural product.

Consider the following illustrations: nylon, saccharin, urea, artificial flowers, and synthetic leather[1] are typical *synthetic substitutes*. Each is derived from nonagricultural raw materials and competes with agricultural products. Coffee whiteners, meat analogs, rayon, glycerin, and filled milk are *agricultural substitutes*. These products are either wholly derived from agricultural raw materials (soybeans, vegetable oils, regenerated cellulose, etc.) or may represent a combination of synthetic and natural-form materials. *Resource substitutes* represent a third classification, including such substitutions as mechanical and electrical power for manual labor, tractors and trucks for horses, inorganic commercial fertilizers for organic fertilizers, commercially prepared animal feeds for grasses and legumes, and agricultural chemicals for traditional field culture. Although these types of displacements have been dynamic and are still continuing, only occasional reference will be made to them.

THE MARKET IMPACT OF SYNTHETIC SUBSTITUTES

Measuring ersatz competition for the whole array of resource and product markets would be a major effort beyond the purpose and scope of this research, yet the need for some estimates of current market share, value of product, and potential developments is very great. The proliferation of synthetic substitutes in our economy during the past two decades has been astounding. Many markets have been affected. Both farm and urban families have benefited from the technology of our age, but adjustments have been necessary as production and market environments change. In a study of 12 agricultural markets, it was estimated that synthetics had captured 10 per cent of the value of the current market for agricultural products.[2]

Some estimates of market share illustrate the competition faced by crop and livestock products. Of more than 600 million pairs of shoes manufactured annually, 75 per cent have nonleather soles and 20 per cent have nonleather uppers. Synthetic fruit flavors and products account for more than 5 per cent of fruit beverage sales; substitutes account for an additional 25 per cent. Artificial sweeteners, riding a soft drink boom, have continued to gain a larger share of the sweetener market and now represent an annual sugar equivalent of about 800,000 tons, compared with about 3 million tons of annual beet sugar output. Wool and cotton continue to lose markets to synthetic and cellulosic substitutes, which claim about 64 per cent of the dollar volume spent by the textile industry and over 40 per cent of the pound volume. Urea competes with natural-protein supplement animal feeds; the forestry products industry finds the furniture, housing, and paper markets challenged by chemically derived plastics—even Christmas trees, mistletoe, and holly are not immune to the permeation of science. The food industries have been less influenced by synthetic substitutes, but face potential competition from agriculturally derived product substitutes and other new foods. Because current experiments with protein and energy sources have such awesome implications, a later section is devoted entirely to food.

[1]In an attempt to generalize this review of synthetics, a preference was given to generic and scientific names over trade names. Occasional use of a trade name is not an endorsement of one product over another, but an effort to avoid unnecessary technicality.

[2]William S. Hoofnagle and Ray S. Corkern, "Information Needed for Decision Making," *Synthetics and Substitutes for Agricultural Products* (Institute of Food and Agricultural Sciences, University of Florida, Publication No. 1, May 1966), pp. 89-95.

Table 1

ANNUAL GROWTH RATE IN CONSUMPTION AND MARKET SHARE OF NATURAL-FORM AND SYNTHETIC SUBSTITUTES

Markets	Growth Rates		Market Share			
	Year	Rates (Per Cent)	Year	Share (Per Cent)	Year	Share (Per Cent)
All Fibers	1949-65	2.8	1949	100.0	1965	100.0
Cellulosic		.4		97.2		67.2
Noncellulosic		19.0		2.8		32.8
Soaps and Detergents	1945-65	3.4	1945	100.0	1965	100.0
Agricultural sources		—5.9		96.3		19.3
Nonagricultural		17.0		3.7		80.7
Ethyl Alcohol	1946-65	4.0	1946	100.0	1965	100.0
Agricultural sources		—6.2		61.3		16.2
Nonagricultural		8.4		38.7		83.8
Sweetener	1958-65	1.9	1958	100.0	1965	100.0
Agricultural sources		1.6		96.3		93.8
Nonagricultural		9.3		3.7		6.2
Oilseed Protein Feeds	1955-64	6.3	1955	100.0	1964	100.0
Oilseed meal		5.8		91.3		87.8
Urea		10.4		8.7		12.2
Glycerin	1945-65	3.1	1945	100.0	1965	100.0
Natural		—1.5		89.7		42.8
Synthetic		13.0		10.3		57.2

SOURCE: Compiled from Ray S. Corkern, "Synthetic Substitutes in Agricultural Markets," **Marketing and Transportation Situation, No. 166** (Washington: U. S. Department of Agriculture, August 1967), pp. 21-28.

A summary of estimated market shares and growth rates for selected markets is presented in Table 1. These data show the directions and magnitudes of change for synthetic and natural-form products. Agriculturally derived products show a declining annual rate of growth in the soap and detergent, ethyl alcohol, and glycerin markets and a declining share of total volume in all six markets. Further analysis will be made of the factors influencing competition between synthetics and agricultural products in individual markets.

Fibers

The label "fibers" encompasses numerous textile, apparel, carpet, and fabric markets subclassified as cotton, wool, cellulosic (rayon and some acetates) and noncellulosic (nylon, polyester, acrylic, spandex, textile glass, etc.) synthetic substitutes. On a per capita consumption basis, their relative share of the total U. S. fiber market is estimated to be: cotton, 47 per cent; wool, 6 per cent; cellulosics, 15 per cent; and noncellulosics, 32 per cent. In individual markets, of course, these estimates will vary considerably. Wool's share of the $28 billion textile apparel market may rise to 10-11 per cent, while nylon's share of the carpet market approaches 50 per cent.

Synthetic substitutes are fabricated to fill voids in agricultural markets that result from supply shortages, volatile price fluctuations, inconsistent qualities, and lack of variety. Most fiber substitutes have been tailored for specific markets requiring certain attributes not found in natural fibers, yet few synthetics are perfect substitutes. Natural products often have unique advantages that encourage the use of synthetic-natural blends such as the polyester-cotton, wrinkle-resistant, permanent-press fabrics.

The 19 per cent average annual rate of growth for noncellulosic fibers between 1949-65 (Table 1) understates the current rate, estimated at 24 per cent since 1960. Further encroachment by synthetic substitutes into fiber markets can be expected. A steady stream of research and development expenditures by major chemical firms continues to yield new products ("spunbonded" nonwoven materials, olefins, etc.) with market potential.

Fats and Oils

The role of animal fats and vegetable fats and oils in soaps, detergents, and paints has steadily declined. The use of petroleum-derived alcohols, lignin sulfonates, phosphates, and latex emulsions and alkyds (paints) has rapidly increased. Although the gains made by synthetic substitutes such as organic detergents have been impressive, nonfood markets for agricultural fats and oils will continue to be extensive because of a multiplicity of end-product uses. In many cases, lost agricultural markets have been recovered or replaced. Inedible tallow—

used in soap—peaked at 1.5 billion pounds in the early 1940's, compared with .7 billion pounds in the 1960's; however, the loss has been more than offset by use of tallow in animal feeds and fatty acids. In other cases, export market growth has compensated for loss of domestic market shares.

Alcohol, Glycerin, and Adhesives

Ethyl alcohol can be produced from agricultural carbohydrates (corn and barley grains) and from ethylene gas—a synthetic substitute. On the basis of 372 bushels of corn and 83 bushels of barley malt yielding 1,000 gallons of ethyl alcohol it is estimated that synthetics now account for over 85 per cent of the market (Table 1). Glycerin, a byproduct of animal and vegetable fat processing in soap and industrial product manufacture, has been increasingly synthesized from petroleum sources. The 13 per cent annual rate of growth for synthetic glycerin probably indicates further decline in natural glycerin production.

The lumpiness of home-made, flour-and-water paste is long remembered. Starch, dextrin, casine, and other agricultural materials have long been used to make adhesives. Increased use of laminations and pressure bindings of heterogeneous substances, however, has resulted in the development of synthetic adhesives that substitute for agriculturally derived products.

Forestry Products

In an increasing number of markets, there are products that look like wood. They have a natural-looking color and grain, the "carvings" are precise, and they sound authentic to the rap of a knuckle, but they are plastic. Shrink-proof, heat-resistant plastic furniture that is impervious to moisture and scratches and will not warp is a reality. Plastic consumption by the furniture industry—estimated at $85 million in 1968—will probably double in the next few years.

A growing market for disposable products has encouraged pulpwood production, technology, and a search for new raw material sources—such as Kenaf, a promising annual paper pulp crop—but plastics are likely to dominate the field. Low-cost production of polystyrene (coffee cups, egg cartons) substitutes for cardboard and polyurethane (high-temperature insulation and crush-resistant packaging) replaces other paper products.

Of all wood used, lumber comprises 60 per cent; paper, 30 per cent; and other products, 10 per cent. Increased economic activity, a growing population, and improved timber technology have helped expand the use of forest products in the aggregate, though per capita use of many individual products is declining. Use of pulpwood for paper and paper products has shown a strong upward trend approaching 480 pounds per capita per year—triple 1920 usage. Plywood, particle boards, and paneling likewise have an upward trend, although per capita consumption of lumber and many wood products continues to decline.

Oilseed Protein Feeds and Roughages

Even though urea (an organic chemical of 45 per cent nitrogen at feed grade) is limited to use by ruminants and has technical limits in mixed feeds, over 400,000 tons were used in feeds last year. Total urea production was 2.8 million tons—one-half of which was used as fertilizer. Because of cost advantages and favorable results from feeding trials, continued substitution of urea for high-protein agricultural sources is expected. Assuming a maximum technical limit of one-third of the protein in ruminant rations, urea consumption may soon double.

The replacement of field-grown roughage in ruminant rations by oyster shell, granite, sawdust, sand, plastic pellets, and other substances has produced a controversy. Regardless of the ultimate resolution by nutritionists, the likelihood of further feeding of low-roughage or "no"

roughage rations seems assured. New knowledge about toxicity, vitamin supplementation, and utilization of cellulases will undoubtedly lead to development and use of new synthetic animal feeds.

Leather Products

Synthetics have made a big dent into the $400 million U. S. shoe-upper market. Only about 71 per cent of the nonrubber footwear manufactured this year will contain all or part leather. Acceptance of poromeric materials, even without leather's porosity, has resulted primarily because of customer appreciation of easy maintenance and long life and the footwear industry's desire for raw material of uniform thickness and greater price stability. Other new materials such as polyvinyl chloride, featuring low cost, easy fabrication, simulated leather designs, extrusion injected soles and uppers, and dielectric heat bonding instead of stitching are challenging traditional materials. Polyvinyl chloride use has increased at an impressive 50 per cent average annual rate since 1962.

Prior to 1953, the United States was a net importer of all types of hides and skins. Since then, the Nation has become a net exporter of more than $100 million of bovine hides and skins annually. The turnaround could not have come at a better time. Rapid growth in the use of poromerics, vinyls, and fabrics as substitutes for leather in shoe manufacture and rapid expansion of livestock production would have led to a hide surplus had the United States not exported an annual amount about equal to the domestic market loss to synthetic substitutes. Even so, the outlook is uncertain.

THE FOODS WE EAT

The Malthusian thesis that population will outdistance world food production has received renewed interest in recent years. But there are some impressive arguments to the effect that just as Malthus overlooked the impact of technology on food production, current famine alarmists are making the same error. For example, consider the following developments: Food production in the Western world adequately supports the producers, their families, and many others. Utilizing current technology, the Western world has the potential to continue to support its population growth. In the United States, continued production advances will occur on fewer acres and with less labor. The developing nations also continue to register food production achievements as their store of knowledge improves. Availability of fertilizers, new hybrid grains, and technical assistance is elevating several to self-sufficiency. Our export market weakness since 1966 has reflected to a considerable extent the production advancements of foreign nations.

Food developments that will have great influence on man's future are materializing. These biological and chemical advancements are a threat to traditional agriculture but a promise to human well-being. Aside from the scientific knowhow that has generated food from petroleum (single-cell protein—SCP), algae, and bacteria, new food concepts are evolving.

To most people, food is meat, eggs, and potatoes. To the physical scientist, food is energy (calories), and to the nutritionist, food is protein, carbohydrates, lipids, and vitamins. For many scientists unassociated with modern agriculture, our Nation's food output per input unit—envied by world agriculturists—is not impressive. Why? Because they think in terms of energy-conversion efficiency. On this score, the grain and livestock industries, as protein producers, come in second-best to microorganisms. Too, there is the roundabout way in which agriculture uses sunshine (energy) and water and photosynthesis to produce an annual energy equivalent per acre equal to the energy of just one day of sunshine on that same acre. Irrelevant? Yes, perhaps so, but the development of SCP and other synthetics described in this section is a step in the direction of poten-

tially producing food substitutes much more efficiently than by use of many of the traditional methods.

Protein Sources

Proteins, carbohydrates, and fats are the fuels of our bodies. All three supply energy, but proteins are essential building blocks for growth because of the amino acids they supply. Although carbohydrates and fats are also important foods, they are generally abundant throughout the world in wheat, rice, potatoes, and native foods, whereas protein-rich foods (red meat, milk, fish) are not. Finding new sources of inexpensive protein for developing nations has high priority and assuring an adequate food supply for future generations is equally important. Because of the critical role proteins play in human nutrition, most current research is focused on this food, although other considerations are also encouraging the development of new foods. (1) Special markets such as for vegetarians, allergic adults and infants, regular baby foods, low-cost nutritive diets for the aged, developing nations, drive-in restaurants, and institutional feeding represent large potential sales. (2) The natural advantage of soybeans with a better amino acid balance than other major vegetable sources and twice the protein of beef[3] has encouraged intensive use research. (3) Not the least of these factors is the unending search for a more efficient, less costly method of food production.

Soybeans. Soybeans, an excellent protein food source, have contributed substantially to agricultural substitutes. Soy flour and grits used in baking, soup mixes, cereals, baby foods, and processed meats already account for a 300-million-pound, $20 million annual industry. Soy protein concentrate is used in breads and ground meats. Protein isolates, which contain about 90 per cent protein, promise the greatest potential, with sales exceeding 10 million pounds annually. Available in powder, spun, or extruded form, protein isolates are used to make whipped toppings, frostings, soy milks, synthetic meats, binders and emulsifiers; coffee whiteners, and other foods. Soy protein supplement is added to high-starch diets in developing nations and is distributed by UNICEF at approximately 12 cents per pound versus 41 cents for milk-protein equivalent. About 28 million tons of soybean oil are produced annually in the United States for use as cooking oils, food ingredients, and industrial products. Other soybean-derived protein forms include enzyme-modified soy isolate (soy flakes and artificial egg albumin) and enzyme-active meal (white bread bleaching agent).

Although soy proteins are agricultural substitutes rather than synthetics, their impact on traditional animal and vegetable protein sources is substantial. With use expanding at a 20-28 per cent annual rate during the past four years, and more firms investing in new product development, the prospect for continued market penetration is good. In addition, new food forms—sufu (soybean cheese), meat analogs, entree supplements, etc.—with unique characteristics of their own will challenge traditional foodstuffs not only as substitutes and imitations but as original alternatives.

Synthetic Foods. Two significant developments are accelerating the research of synthetic foods. First, the demands of population on food supply are expected to intensify in many areas. Second, the changing concepts of foods and nutrition have provided nonagriculturally related firms an opening into a dynamic new field. Foremost among the discoveries of these efforts has been SCP—single-cell protein.

Man has used single-cell agents—yeasts and bacteria—beneficially for years, but these micro-organisms never attained the status of acceptable complete foods. However, because of

[3] *Proceedings of International Conference on Soybean Protein Foods* (Washington: Agricultural Research Service, No. 71-35, U. S. Department of Agriculture, May 1967), p. 24.

the numerous SCP advantages—high-grade protein, high productivity, low cost, simplicity of processing, packaging and shipping, freedom from seasonality and natural growing constraints, and multiple uses—a dedicated effort now is being made to manufacture and sell SCP.

The production potential of single-cell proteins is fantastic. Production increases exponentially so that a one-pound seeded culture would multiply to two tons of edible food (half protein, half carbohydrates and fats) in 24 hours.[4] The raw materials for SCP include an organic carbon source (sulfite waste liquor from paper pulp manufacture, molasses, or petroleum and natural gas hydrocarbons), nitrogen, phosphorus, sulfate, water, oxygen, and certain trace elements. The SCP yield from 1,000 pounds of petroleum is approximately 1,000 pounds of edible product which compares with 500 pounds of catfish, 250 pounds of dressed poultry, and 75 pounds of dressed beef per 1,000 pounds of feed![5]

Sea Foods. The sea has great potential as a source of food. Although oceans comprise much of the earth's surface and are known to be rich with many resources, knowledge of ocean farming is just at the threshold. We have just begun to realize the importance of ocean research.

Algae are 20-40 times more efficient in converting solar energy into food than are field crops.[6] These prolific plants have shown production potentials of from 20-60 tons dry-weight per acre per year, with proteins about equal to yeasts in value and superior in vitamin levels. It is estimated that the per ton cost of algae protein would be comparable to soybean protein but could become cheaper with advanced production techniques.

The harvesting of plankton has been suggested as a possible source of human food. These lower-order forms of life live on nutrients in the shallow ocean above the continental shelf. They are a source of food to shellfish and smaller fin fish. The greatest economy would seem to lie in cultivating and harvesting the shell and fin fish that consume the plankton, rather than in trying to harvest plankton direct. These fish use plankton more efficiently than the human body would, and even those species undesirable as fresh foods can yield a valuable supply of protein in the form of fish protein concentrate (FPC). Such protein sources have already gained acceptance as supplements to high-starch and carbohydrate diets in protein deficient nations.

The cultivation of freshwater fish on a commercial basis has attracted new interest. Catfish farming has proved successful in landlocked Plains states because of improved technology in raising fingerlings, in achieving excellent growth rates, and in simplifying harvesting. Catfish have been found to be very efficient nutrient converters with the capability of producing about a pound of growth for each pound of feed.

Although nutritious, many of the synthetic foods and protein supplements are not appealing in concentrated forms. To enhance their organoleptic acceptability and palatability, most are used as supplements to native foods. Current research with synthetic proteins in animal rations with synthetic flavors, and on extruding simulated food textures shows promise of producing acceptable foods products.

Fruit Beverage Market

In 1955, synthetics and substitutes in the fruit beverage market were virtually unknown. Now they account for more than 30 per cent of a billion dollar industry. Gaining market share with each citrus freeze and consumer acceptance with product improvement and extensive promotion, synthetic fruit beverages are a for-

[4]"Food from Petroleum," *SPAN,* Standard Oil Company (Indiana), Vol. VIII, No. 3 (Fall 1968), pp. 6-9.
[5]*Ibid.*
[6]Kermit Bird, "Foods of the Future," *Food Product Development,* December 1968-January 1969, pp. 26-32.

midable market force. Like many farm products, citrus suffers from weather irregularities that cause abrupt supply changes, price fluctuations, and inconsistent qualities. The challenge to citrus producers is to regain competitive advantage through a superior natural product. In the words of researchers for the Florida Citrus Commission, ". . . competition from synthetics will not be permanently lessened by antisynthetic legislation, regulation, advertising, and legal and/or antitrust harassment. New product development utilizing natural fruit solids offers the best means for combating competition from synthetics."[7]

Dairy Products

The most dramatic episode of substitute versus natural products took place between butter and oleomargarine. The stage was set early for this incongruous struggle. Even Gilbert and Sullivan in *H.M.S. Pinafore* wrote a lyrical prelude —"Things are seldom what they seem, skim milk masquerades as cream." The parade of state "Dairy Laws" began in 1885, followed by oleo color mixing and a succession of court cases. One state required margarine to be colored pink. A 10 per cent Federal tax on colored margarine was voted in 1902. Federal legislation remained in force until 1950 and interstate shipments of filled fluid milks are still regulated.

The thrust of legislation was protectionist—to keep "imitation" products from claiming dairy association. The ramifications of this historic legal confrontation are many and go far beyond this one industry. Consider the word "imitation." Courts have ruled that imitation implies inferiority, which may not be a correct product description. Many synthetics and substitutes have attributes superior to natural products, such as longer shelf life, adaptability to freezing, or economy. Additionally, true synthetics may have individual characteristics placing them beyond a substitute classification.

Other ramifications apply in reverse. Sometimes the industry seeking protection became so rigidly defined that innovative development was stymied. The dairy industry did this with butter—which is narrowly defined by grade and standard and act of Congress. The result was to assure market voids reflecting changing consumer preferences and to invite more competition. No one can doubt the delaying effectiveness of such legislation, though consumers may resent it. In the case of margarine, per capita consumption rose from 2 pounds in the 1920's to over 10 pounds in the 1960's, while butter declined one-half to about 6 pounds.

Most dairy product substitutes are not true synthetics. Margarine has a vegetable oil base. Coffee whiteners are 5 to 10 per cent vegetable fats. Synthetic whipping creams contain vegetable oils, as do filled evaporated milks and mellorine frozen desserts.

Substitutes for fluid milk are of two general types: those with one or more milk components and those with none. Neither are true synthetics. Milk substitutes, with some milk ingredients, come under the regulatory jurisdiction of the 1923 Federal Filled Milk Act, whereas the latter group does not. To date, with the exception of Hawaii and Arizona, market penetration by substitute milks has been limited, even though they are lower-priced and nearly equal nutritionally.

Dairy industry representatives have estimated that one-fourth of their total market has been lost to substitutes during the past 25 years. Coffee whiteners claim 35 per cent of the coffee cream market, substitutes from 65 to 80 per cent of the whipping cream market, and mellorine 5 per cent of the frozen dessert market.

Sweeteners, Flavors, and Vitamins

Of an approximately 10-million-tons annual

[7]W. E. Black and Leo Polopolus, "Synthetics and Substitutes and the Florida Citrus Industry," *Synthetics and Substitutes for Agricultural Commodities,* Institute of Food and Agricultural Sciences (Gainesville, Fla., University of Florida, May 1966), pp. 2-11.

sugar market, nearly 40 per cent is imported from foreign countries and 60 per cent is domestically produced—3 million tons coming from sugar beets. On a sugar-equivalent basis, synthetic sweetener production (saccharin and cyclamates) is estimated at 800,000 tons. The growth of synthetic sweeteners has risen rapidly during the past decade, as a weight-conscious public seeks low-calorie foods. Synthetics provide no caloric value. One pound of 90 per cent cyclamate-10 per cent saccharin is equivalent in sweetness to 57 pounds of sugar.

Some of the sugar market has been lost to low-calorie synthetics, especially in soft drinks —the largest single sugar outlet—but the impact has been less than imagined because much of the "low calorie" growth has been new business.

Synthetic flavors and vitamins present an intriguing challenge to chemists but not an especially great threat to farmers. Enriched products have wide consumer acceptance. But the success of synthetic substitutes depends greatly on their resemblance to natural products.

SUMMARY OF AGRICULTURAL MARKET LOSSES

A commendable effort to measure the loss of agricultural markets to *synthetic* and *agricultural substitutes* was made by Corkern and Poats.[8] In Table 2, a summary of their study, the loss in 1967 alone was estimated at $895 million—over 10 per cent of the total for the markets analyzed.

Technology plays an important role in the development of synthetic products. Sometimes synthetics result from hours of painstaking experiments, but laboratory accidents produce new ideas and products almost as often. Frequently, a process exists long before a useful product is merchandised, and quite often a myriad of products flows from one discovery.

Football on synthetic grass, leonardite (nonfuel part of low-rank lignite coal) as a fertilizer, freeze-dried and irradiated foods, plastic flowers, bamboo as a fiber crop, and propylene glycol (high-energy) space foods are but samples of new product markets not covered. However, other issues need attention because ersatz competition causes problems.

Displacement of any product by another is painful, but in a market-oriented economy, consumers make the final decisions—not the producers. Consumers are assumed to behave rationally, but their alternatives may be limited by product selection and information availability. Yet, regardless of imperfections, no amount of protection will save a product once consumer tastes and preferences change. This is the cold impersonal side of economics. But agriculture has several advantages that assure continued vitality. Food habits change very slowly.

Table 2
ESTIMATED LOSS OF TRADITIONAL AGRICULTURAL MARKETS TO SYNTHETICS AND AGRICULTURAL SUBSTITUTES IN SELECTED AGRICULTURAL MARKETS, 1967

Agricultural Product or Market	Unit	Market Loss		Estimated Total Market
		Quantity	Value	
			(Millions)	(Millions)
Cotton	Mil. lb.	1,780	$456	$1,124
Wool	Mil. lb.	235	176	385
Cane and beet sugar	Thou. dol.	370	76	1,954
Oilseed meal	Thou. dol.	358	30	537
Fats and oils for soap	Mil. lb.	460	31	53
Drying oils for paints	Mil. lb.	248	32	64
Glycerin	Mil. lb.	46	7	25
Starch for dextrin for adhesives	Mil. lb.	54	4	43
Soy meal and casein for adhesives	Mil. lb.	76	6	24
Leather for shoe uppers	Mil. sq. ft.	51	31	491
Citrus	Mil. gal.	52	45	334
Fluid milk	Mil. lb.	12	1	3,162
Total	—	—	$895	$8,196

SOURCE: **Marketing and Transportation Situation,** No. 171 (Washington: ERS, U. S. Department of Agriculture, November 1968), p. 26. For a description of the estimating procedure, refer to Corkern and Poats footnote 7.

[8]Ray S. Corkern and Frederick J. Poats, "Synthetics and Agricultural Substitutes in Food and Nonfood Markets," *Marketing and Transportation Situation,* No. 171 (Washington: U. S. Department of Agriculture, November 1968), pp. 25-28.

Many synthetics serve new markets rather than replacing agricultural products. With technological and managerial innovation, agriculture has remained an efficient competitor. And, assuming synthetic *food* consumption increases at a 10 per cent compound annual rate through 1975, synthetic substitutes still would account for no more than 1 per cent of the total. Furthermore, some synthetic products are complementary rather than competitive with food production.

Competition from synthetics and substitutes will not lessen with time, nor will price advantage alone hold an agricultural market. Agriculture's production orientation is both a strength and a weakness. Failure to expand and adequately fund marketing and research hinders agriculture's ability to compete, yet the rewards for innovation are great. A willingness to blend the best of natural and synthetic components may have saved cotton, and product development breathed new life into the potato. Adaptability is of prime importance in meeting competition. Only willingness to discover new and better techniques of production and products will keep the industry competitive.

Part I

The Quality of Mortgage Credit

By Robert E. Knight

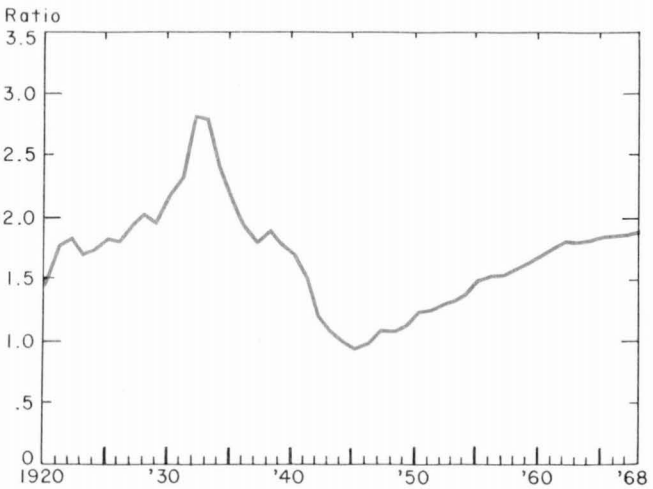
A SIGNIFICANT and contributing characteristic of the postwar economic expansion has been the very rapid growth of private debt. In 1945, government indebtedness was nearly double private debt, but today private debt of over $1.1 trillion is 2½ times greater than government debt. Although credit would normally be expected to grow with the economy, it has risen more rapidly than income throughout the postwar period. As a result, the debt-income ratio shown in Chart 1 has begun to approach the historically high levels for periods of prosperity attained during the late 1920's. These developments have prompted some observers to conclude not only that debtors are becoming overextended but also that a decline in the quality of credit has occurred.

The major components of private debt are corporate, mortgage, and consumer credit. This article will examine some of the economic factors which influence the quality of mortgage credit. Nonfarm mortgage debt has increased more than tenfold since 1945 and currently represents the most important element in household indebtedness. Although the growth rate of mortgage credit has been less than that of consumer credit, household mortgage debt is practically three times the volume of total consumer credit and is only slightly less than one-third of all private debt.

Consumer credit, which includes instalment loans, charge accounts, single payment loans, and service credit, is the other major component of household debt. Consumer credit has recorded the most rapid gains, but it still represents only about 10 per cent of total private debt. Its rapid growth rate is attributable partly to the very small amount outstanding at the end of the war. Corporate borrowings, on the other hand, account for nearly half of total private debt. However, corporate indebtedness has grown less rapidly than both types of household credit, despite an increase of practically 700 per cent since 1945.

Chart 1

RATIO OF NET PRIVATE DEBT TO DISPOSABLE INCOME



Source: **1969 Economic Report of the President.**

Household mortgage credit has also been increasing more rapidly than income. (See Chart 2.) Many developments have contributed to this growth. The shortage of housing after World War II forced many families temporarily to double up and created an unsatisfied demand. Since then the demand for new housing has been further stimulated by an increase in the number of families, by the net movement of families to rapidly growing suburbs, and by rising incomes which have permitted families to acquire higher quality homes. The cost of housing has also increased greatly. Estimates indicate that the cost of constructing a residential nonfarm home has more than doubled since 1950 while the cost of a typical building site has increased nearly four times.

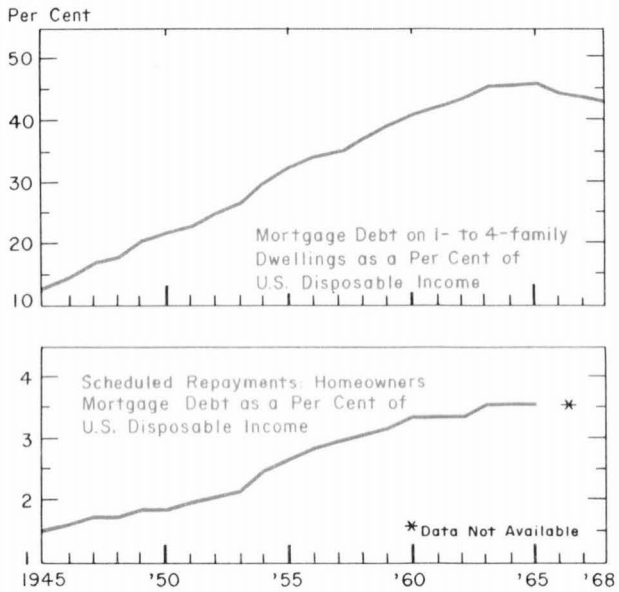
The progressive easing of mortgage terms has also facilitated the growth of mortgage debt. Smaller down payments and higher loan-value ratios not only make more families able to qualify for mortgage credit, but also increase the average debt they are likely to have. The lengthening of the average maturity of mortgages has reduced the repayment rate, tending to increase mortgage debt outstanding.

Although the ratio of mortgage debt to income has grown rapidly throughout the post-war period, deepening of mortgage credit has been limited.[1] In 1950, about 11 million nonfarm families owned mortgaged homes. By 1966, over 21 million homeowning families had mortgages. If a typical family in 1966 had the same ratio of mortgage debt to income that a similar family had in 1950, the increase in homeowners with mortgages and the rise in income combined would explain over 82 per cent of the growth in nonfarm mortgage debt. Deepening would account for an increase relative to income of about $1,500 on a typical mortgage. Although there has been a tendency for some deepening to occur since 1950, the amount has not been great.

Despite the slight deepening in mortgage debt, the debt repayment burden for a typical

Chart 2

RATIO OF HOMEOWNER MORTGAGE DEBT TO DISPOSABLE INCOME



Sources: **1969 Economic Report of the President,** National Industrial Conference Board.

Table 1

NET PUBLIC AND PRIVATE DEBT

(In billions of dollars)

		1945	1968[e]
Public		265.9	443.6
	Federal Government and Agency	252.5	292.5
	Federal Financial Agency		21.6
	State and Local Governments	13.4	129.5
Private		140.0	1,103.8
	Corporate	85.3	586.0
	Farm	7.3	50.0
	Mortgage*	27.0	283.5
	Commercial and Financial*	14.7	71.5
	Consumer*	5.7	112.8
Total		405.9	1,547.4

*Nonfarm
[e]Estimated
Source: **1969 Economic Report of the President.**

[1]Deepening of credit refers to an increase in the average debt per borrower relative to income.

family does not appear to have increased since 1950. Scheduled repayments of homeowner mortgage debt for all families in 1950 accounted for an estimated 1.9 per cent of total United States disposable income. By 1965, the figure had risen to about 3.5 per cent of disposable income. The increase in the number of families with mortgage debt could account for the entire rise in the ratio. It would appear that the progressive lengthening of the average maturity date of a typical mortgage has largely offset any tendency for family mortgage repayments to rise relative to income.

However, a word of caution is in order. Although indicative of trends, these figures which relate to averages cannot be taken as accurate guides to the total distribution of debt or the repayment burden. Ideally, one would wish to examine the debt ratio and repayment streams for those in various income classes, but satisfactory data covering the entire postwar period is not readily available. Limited evidence suggests that, relative to income, the lower income families have a higher ratio of mortgage debt and a higher repayment rate. If the weight of mortgage debt on lower income families has grown over time, the burden of the total debt could increase without being reflected in the overall averages. Nevertheless, there is little reason to believe the aggregate statistics present a misleading picture of the postwar trends.

DETERMINANTS OF THE QUALITY OF CREDIT

The quality of credit may be analyzed from several viewpoints. The ultimate indicator of credit quality is whether the loan is repaid according to the initial terms of the contract. Rising delinquency, default, or foreclosure rates would signify that a decline in credit quality had occurred. To loan officers attempting to evaluate an application for a loan, on the other hand, the likelihood of repayment is a paramount consideration and the officer often must make many specific assumptions in reaching his decision. If these should prove incorrect or if unforeseen circumstances should develop, a loan which initially looked excellent may become questionable. Consequently, the quality of a loan may change over its lifetime and the ultimate repayment or foreclosure may not be an accurate indication of probability of repayment at the time it was granted. Few loan officers will make loans they expect to turn sour.

Judgment about the quality of credit, moreover, may differ with the relationship of the viewer. One of the many aims of Congress in instituting the Federal Housing Administration, and later the Veterans Administration, was to promote home ownership by increasing the availability of private mortgage credit to those who would normally have difficulty in meeting lender qualifications. By insuring lenders against default, these programs have been able not only to provide financing on liberal terms, but have also largely removed the risk to the lender. From the standpoint of a lender, therefore, an FHA-insured or VA-guaranteed mortgage may be of higher quality than a conventional mortgage, but the overall likelihood of default is also often decidedly higher.

Numerous factors interact to determine the quality of a loan. On the aggregate level, the future course of income, employment, and asset values directly affect the probability of repayment. Many loans that would be repaid in periods of high employment will be defaulted if income is falling and unemployment is rising. To use an analogy from a different financial field, if the stock market rises to an unsustainably high level, loans to purchase stocks may be of low quality regardless of the immediate financial position of the borrower.

The specific terms of the loan and the financial characteristics of the borrower affect both his willingness and ability to repay. If debt repayments, for example, represent such a large proportion of the borrower's income that there is little margin for unexpected expenses, the

possibility of default increases. Other factors which may contribute significantly to the probability of eventual foreclosure are the age and occupation of the borrower, his responsibility for financial obligations, possible marital difficulties, and the marketability of the collateral. The death of the borrower will often result in a mortgage being defaulted.

In recent years most discussion of the quality of credit has focused on the progressive liberalization of terms. While knowledge of the effect of loan terms is vital to the individual lender, aggregate developments are likely to be more instrumental in determining the quality of credit from the standpoint of the entire economy. During periods of rising income and asset values, many loans with very easy terms will prove successful.

Several of the more important general determinants of the quality of credit are discussed in the following sections. Since repayment of a debt also depends on numerous circumstances affecting only the individual borrower, the list is not complete.

Acquired Equity

The borrower's equity in an asset is the difference between the value of the asset and outstanding debt plus interest due. Since there are generally costs associated with selling a home, these are sometimes subtracted in calculating the mortgagor's equity. Since the borrower's equity represents his net investment in an asset, it also represents his financial loss in event of foreclosure. Whenever the borrower's equity is small, the possible financial loss from defaulting on a loan is also small. Once considerable equity has been acquired, however, this potential loss increases and, apart from other considerations, the borrower has a greater incentive to maintain debt repayments. If it should become impossible for him to continue the payments, the debtor will often sell the property, pay off the balance on his loan, and realize his equity. The higher the borrower's equity, therefore, the less likely is the chance of his defaulting and the better is the quality of credit.

Prior to the great depression of the 1930's, few long-term loans were fully amortized. While the borrower was normally expected to make periodic repayments of interest on the principal, the great bulk of single family mortgages were written so that the entire principal was due on the maturity date, which was commonly five years from the time the loan was granted. If the mortgagor was unable to accumulate a sum to repay the entire principal, he would repay what he could and a new mortgage would generally be written for the balance. Under these arrangements, assuming no speculative increases in the values of existing assets, the value of the home would depreciate over time while the loan balance would remain unchanged. Although the loan-value ratios on first mortgages were conservative in the 1920's compared to those offered today, second and third mortgages were much more common. If the combined loan-value ratio were high or the rate of depreciation rapid, the mortgagor could accumulate a sizeable negative equity in his home.

Most mortgage loans today are amortized so that the mortgagor makes periodic repayments not only of interest but also of principal. The rate at which a borrower acquires equity is a function of the depreciation or appreciation on the asset and the terms of the loan: initial down payment, the interest rate charged, and the years to maturity. The borrower will accumulate equity more rapidly the slower the rate of depreciation, the larger the down payment, the lower the interest rate charged, and the shorter the maturity.

Although practically all mortgage loans are now fully amortized, the loan-value ratio has increased greatly throughout the postwar period. As a consequence, loans made on very liberal terms accumulate little or no borrower equity in early years. The Federal Housing Ad-

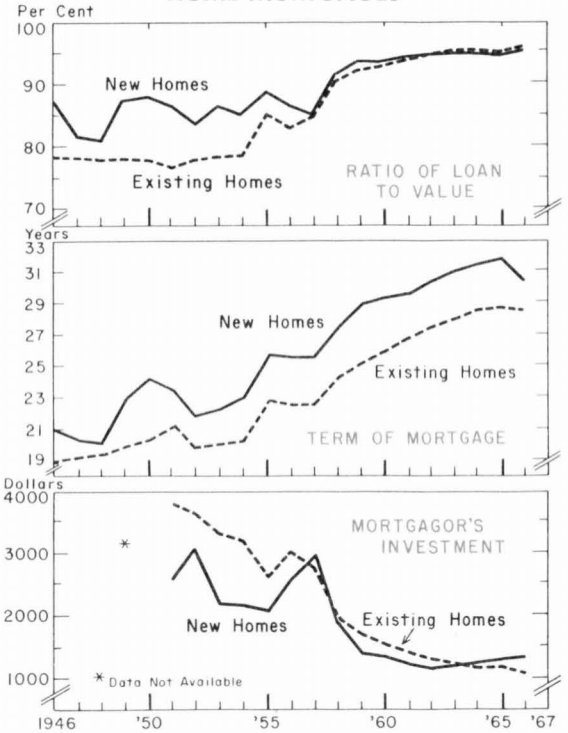
ministration, for example, will insure a loan of $14,500 on a new home costing $15,000. Until the recent rise in interest rates, the loan could be made for a period of 35 years at an interest rate of 5¼ per cent. If straight line depreciation of 2 per cent per year and a sales commission of 5 per cent are assumed, the borrower's equity is negative for the first 25 years of the mortgage. Since the mortgagor will accumulate equity less rapidly with lower down payments and lengthening of the maturity of the loan, these factors tend to be associated with a lowering of credit standards.

Guttentag's studies of the postwar mortgage market suggest that changes in the minimum required down payment are the most important short-run determinant of the demand for mortgage credit.[2] If a small reduction in down payments permits mortgages to be obtained by many borrowers who otherwise could not qualify under the relatively liberal terms offered by the FHA or VA, the quality of these loans is likely to be low. The effect on quality of a longer maturity, however, is unclear. Although a longer term tends to reduce the build-up of equity, it also reduces the required repayments relative to the borrower's income. If payments require a smaller fraction of the mortgagor's income, he is less likely to encounter difficulty in meeting the payments.

Chart 3 shows the easing of terms on FHA-insured home mortgages which has occurred throughout the postwar period. In 1946 the average period to maturity of mortgages insured for new homes was 21 years, but by 1967 this had risen to about 30 years. Briefly during the early 1960's the average term to maturity exceeded 30 years. Loan-value ratios similarly have trended steadily upward, increasing from 87 per cent in 1946 to 95 per cent in 1966. Despite a tripling in the median

Chart 3

CHARACTERISTICS OF FHA-INSURED HOME MORTGAGES



Source: Federal Housing Administration.

mortgage debt, the average mortgagor's initial investment, which consists primarily of the down payment and closing costs, has fallen by nearly 50 per cent. In recent years, however, a slight reversal of direction has occurred. As shown in the chart, the terms on FHA-insured mortgages for existing homes have experienced an equally dramatic easing. Each of these postwar trends could be interpreted as a relaxation in the quality of credit.[3]

[2]Jack M. Guttentag, "Some Studies of the Post World War II Residential Construction and Mortgage Markets." (Unpublished Ph.D. dissertation, Columbia University, 1958).

[3]Emphasis on FHA mortgage characteristics is based both on the ready availability of continuous series and on the fact that the statistical model developed in Part II of this article utilizes FHA data. Statistics for VA-guaranteed and conventional mortgages suggest that similar developments have occurred for these types of mortgages also. GI mortgages since 1949 evidence an even sharper decline in average down payments. Conventional mortgages, of course, are seldom made on such liberal terms, but the terms exhibit a similar trend toward relaxation.

Borrowers will also acquire equity rapidly if asset prices are rising. The United States emerged from World War II with an acute housing shortage. The sharply rising demand and limited increases in the supply produced significant increases in the prices of homes. Until the late 1950's, it was often possible for a person to sell a home purchased only a year earlier for 10 to 20 per cent more than he had paid. Under such circumstances, a mortgagor in financial difficulty would often sell his home, repay the mortgage, and realize his increased equity rather than risk its possible loss through foreclosure. With a rising demand, selling a home could often be accomplished quickly and with relatively little difficulty. Although home prices were comparatively stable during the late 1950's and early 1960's, they have again begun to rise in recent years. The increased rate of family formation, continuing movement to the suburbs, sharply increased costs of constructing new homes, and the belief that real estate investment represents a good hedge against inflation have all been contributing factors. A degree of speculation has also been present.

Just as rising asset prices tend to reduce default and foreclosure rates, falling real estate values can remove acquired equity very rapidly and increase the rates. Estimates suggest that the average price of owner occupied homes declined by about 25 per cent between 1929 and 1934. In addition to falling income, the forced sale of foreclosed homes which accompanied the general scramble for liquidity, the overbuilding of suburban areas, and the failure of population to grow as rapidly as had been predicted were partly responsible for declining real estate prices. Under such circumstances, it becomes almost impossible to sell homes at a profit, partly removing the incentive for the mortgagor to sell rather than permit foreclosure. With little equity, individuals may not even have sufficient resources to cover sales expenses. If a mortgagor did have such resources, he could usually bring his loan current and avoid threatened foreclosure. While perhaps not the most important single factor, falling real estate prices contributed greatly to the increased foreclosure rates which occurred during the depression. If a settling in real estate prices should occur in the future, an increase in default and foreclosure rates is very likely to occur.

Regional and National Economic Conditions

Although default rates indicate a slight sensitivity to fluctuations in national income, throughout the postwar period foreclosure rates show little relationship. However, both rates appear to react quite sharply to changes in local economic conditions.[1] The failure of population to grow as rapidly as had been projected in Florida during the early 1960's produced a marked increase in home mortgage foreclosures. Foreclosure rates in areas which rely heavily on a single industry are also likely to react strongly to economic setbacks. In Kansas during the late 1950's, for example, the curtailment of aircraft employment at Wichita and the deactivation of a Navy installation at Hutchinson moved the state FHA foreclosure ratio to one of the highest in the nation. Default and foreclosure rates in Detroit are quite sensitive to the level of automobile sales and to changes in production and income.

Despite the fact that default and foreclosure rates evidence little cyclical movement over business cycles, aggregate business conditions are clearly an important determinant of the quality of credit. Since most mortgagors expect to repay borrowing from current income, their ability to meet payments is highly dependent on income and employment expected in the future. If a man incurs a debt during a period of prosperity and later becomes unemployed

[1]For supporting evidence see the studies in *FHA Mortgage Foreclosures*. Hearings before a subcommittee of the Committee on Banking and Currency, United States Senate, 88th Congress, 2nd Session, 1964.

in a recession, the likelihood of his being able to meet each payment on schedule is greatly reduced.

Since debt repayments, on the other hand, tend over time to become a relatively small drain on income, many low quality loans will prove successful during periods of strongly rising incomes. Most workers expect their incomes to rise annually. If borrowers expect to meet debt repayments in part from the anticipated growth in income, lack of growth or the curtailment of income can produce losses. As long as income remains high and growing, serious problems with the quality of credit are not likely to be encountered.

Financial Characteristics of Mortgagor

For the economy as a whole, debt will impose a real burden if repayments become so great that debtors are forced to curtail spending on current output. Aggregate figures, however, suggest this is not an immediate concern for mortgage debt. Despite the fact that mortgage debt has been rising much more rapidly than disposable income, the progressive lengthening in mortgage maturities has offset the tendency for the ratio of scheduled mortgage repayments to disposable income to rise greatly. Scheduled mortgage repayments currently account for less than 4 per cent of U. S. disposable income.

The ability of borrowers to maintain debt repayments in times of economic hardship is partly dependent on the debtor's net worth and holdings of liquid assets. If the borrower's income declines he may continue to repay his debt by drawing on holdings of liquid assets. In the long run he may also dispose of some nonliquid assets. Total liquid assets of consumers have grown very rapidly throughout the postwar period, and this has occasionally been cited as evidence that the increases in private debt need not warrant concern. Nevertheless those applying for mortgage loans do not appear to have shared in the rise in liquid asset holdings. Despite significant increases in scheduled mortgage repayments, liquid asset holdings for purchasers of homes with VA-guaranteed prior approval loans have shown almost no increase since 1954. (See Table 2.) This also could be interpreted as a decline in the quality of mortgage credit.

Table 2

AVERAGE LIQUID ASSETS OF PURCHASERS WITH VA PRIOR APPROVAL HOME LOANS

Year	Amount
1954	$1,996
1955	1,777
1956	1,970
1957	2,215
1958	2,020
1959	1,720
1960	1,725
1961	1,530
1962	1,665
1963	1,845
1964	2,040
1965	2,350
1966	2,085

Source: **1966 Statistical Yearbook**, Department of Housing and Urban Development.

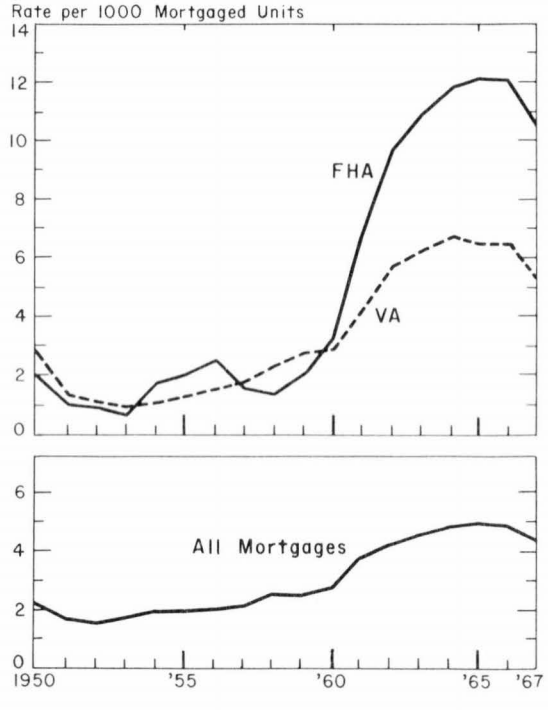
THE RECORD

The foreclosure rate on nonfarm real estate since 1950 is shown in Chart 4. The foreclosure rate per 1,000 mortgaged structures was 2.17 in 1950, but under the economic impact of the Korean War, it declined to 1.55 in 1952. Thereafter the foreclosure rate rose for six years, reaching a rate of 2.46 in the recession year of 1958. After a brief pause in 1959, the upward climb resumed. By 1965 the foreclosure rate at 4.93 was more than double the very low rate of 1950 and practically triple the rate of 1951. Since 1966 the rate has declined slightly, but it remains high by early postwar standards.

FHA-insured and VA-guaranteed home mortgage foreclosures have shown even more pronounced upward trends. Since 1951 the FHA foreclosure rate has increased over 10 times and the VA rate over four times. While

Chart 4

NONFARM MORTGAGE FORECLOSURES



Source: Federal Housing Administration, Veterans Administration, Federal Home Loan Bank Board.

rising foreclosure rates are a cause for concern during times of rising income, the postwar rates are not particularly high when viewed over a longer period. It has been estimated, for example, that the foreclosure rate in 1926 was over twice that of the peak postwar figure in 1965.

Since the three series in the chart have been constructed from different sources they are not directly comparable. Nevertheless, the figures tend to show that FHA-insured and VA-guaranteed mortgages have a much higher incidence of foreclosure than do conventional mortgages. This supports the argument that mortgages granted with very liberal financing terms evidence higher rates of foreclosure. The relationship, however, is not perfect. Many FHA and VA mortgages appear to have been made with no down payments, yet the foreclosure rate on FHA mortgages is much higher than on VA mortgages.

An interesting feature of the chart is that foreclosures show little sensitivity to changes in aggregate business conditions. Although the foreclosure rate rose in the recession years of 1954, 1958, and 1960, even sharper increases in foreclosures were recorded in periods of relatively high employment. This is due partly to the relatively mild business cycles of the postwar period. Some studies, on the other hand, have concluded that such noneconomic reasons as death, illness, marital difficulties, excessive use of credit, improper regard for obligations, and dissatisfaction with the home explain as many foreclosures as do changes in income and employment.[5]

Also contributing to the poor relationship is the fact that a long and variable lag may be encountered between initial delinquency and foreclosure. Some lending institutions will initiate foreclosure proceedings on delinquent loans more rapidly than others. If the mortgagee should grant forebearance, many months may pass before foreclosure is finally begun. State laws also differ greatly on the length of time required to foreclose.

While the initial postwar level was extremely low, the foreclosure rate has risen steadily and significantly through most of the postwar period. By this standard, the figures leave little doubt that some decline in the quality of credit did occur.

[5]For example, see the studies cited in footnote 4.