Demographic and Energy Effects on the U.S. Demand for Bicycles

PETER M. KERR

The role played by demographics as well as the energy crisis in the resurgence of the demand for bicycles in the United States over the last 20 years is investigated. Although there have been several studies in this area, none presents an econometric estimation of demand. This study fills that void. The results are surprising. Demographics, and in particular the Baby Boom, have had no significant effect, whereas the energy crisis has. Less surprising is the conclusion that the resurgence of bicycle use in the early 1970s resulted from faddish preferences on the part of consumers. Some key elasticities are own price, –2.70; income, 2.77; price of gasoline, .51. For example, a 1 percent increase in the price of bicycles results in a 2.7 percent decline in their sales.

For the bicycle industry, the last 20 years have marked a resurgence of the Gay Nineties because sales per capita have exceeded the previous 1897 high in every year since 1965. According to a recent survey, the Bicycle Federation has estimated that in 1984 more than 75 million Americans rode bicycles and 1.6 million commuted by bicycle *(1)*. Periodic surveys by the National Park Service since 1960 indicate substantial increases in recreational cycling by those 12 years and over. Although there have been several studies in this area, none present an econometric estimation of demand. The current study attempts to fill this void.

Written in the midst, or at the close, of the bicycle boom of the early 1970s, the previous studies had insufficient data for econometric tests. Issues that were raised then, and since, can now be more fully evaluated. Bicycle sales seem to have taken off just when the baby boomers were coming of age; is there a significant relationship here? Did the energy crisis have any effect on bicycle sales? To what extent has the resurgence simply been a fad?

DETERMINANTS OF DEMAND

Bicycle sales for the sample period are plotted in Figure 1. The most distinguishing feature is the peak during 1972, 1973, and 1974. Earlier studies by Floyd *(2)*, Everett *(3)*, and Hirst *(4)* identified four factors that may explain the growth in bicycle sales: *(a)* the energy crisis, *(b)* greater interest in physical fitness and outdoor life, *(c)* refinement of the lightweight bicycle, and *(d)* environmental concerns. As suggested earlier, demographics may play an important role. The variables considered in this research are as follows:

Department of Economics, Southeast Missouri State University, Cape Girardeau, Mo. 63701.

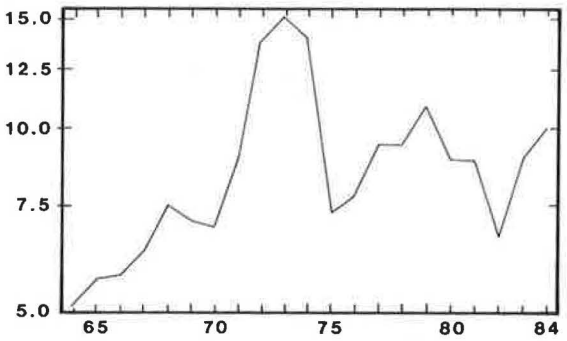

FIGURE 1 Annual bicycle sales (millions of units), 1964–1984.

SALES = total bicycle sales in the U.S. market. This figure is calculated by subtracting exports from the sum of domestic industry shipments and imports. The industry defines its product as bicycles with a wheel diameter of no less than 20 in. (Schwinn Sales, Inc., unpublished data).

STOCK = household stock of bicycles. Based on the Bicycle Manufacturers Association estimated average life span of 7 years for a bicycle, this figure is the sum of total bicycle sales for the previous 7 years.

LGWT = ratio of total lightweight sales (bicycles with wheels more than 20 in. in diameter) to total bicycle sales (Bicycle Manufacturers Association, unpublished data).

AYT = American Youth Hostels membership (American Youth Hostels, Inc., unpublished data).

BBP = total population of those aged 7 through 19. This group includes the ages of baby boomers during the boom years of bicycles sales (1972–1974). The baby boomers in this case represent both men and women who were born in those years when the number of births exceeded 4 million annually (1954 through 1964). This definition is suggested by the Population Reference Bureau for measuring the societal impact of the Baby Boom. The actual population figures are from the Bureau of Census.

MAGP = total population of those aged 7 through 44. The lower limit of this group is determined by the youngest age for which a 20-in. bicycle is recommended; the upper limit is determined by the oldest age to represent at least 10 percent of the subscribers to *Bicycling* magazine.

MAXP = total population of those aged 25 through 34. This group represents the largest 10-year cohort subscribing to *Bicycling*, which consistently makes up more than 30 percent of all subscribers.

CPIW = consumer price index (CPI) for urban wage earners and clerical workers, all items, annual average (1967 = 100). This variable is typically denoted *CPI-W* in data sources (Bureau of Labor Statistics, unpublished data).

CPIB = bicycle component of *CPI-W* (1967 = 100). Available only since 1964, this is the variable that limits the sample size.

CPIG = gasoline component of *CPI-W* (1967 = 100). This index includes both regular and premium grades.

CPIPRT = private transportation component of *CPI-W* (1967 = 100). This index includes new automobiles, used automobiles, regular and premium gasoline, premium motor oil, new tubeless tires, automobile repairs and maintenance, automobile insurance rates, automobile registration, and private and municipal parking fees.

CPIPUT = public transportation component of *CPI-W* (1967 = 100). This index includes local transit fares, taxicab fares, coach railroad fares, airplane fares (chiefly coach), and intercity bus fares.

CPIT = transportation component of *CPI-W* (1967 = 100). This index is the weighted average of the public and the private transportation components.

D1 = dummy variable that equals 1 for 1972 and 1973, zero otherwise. This variable attempts to measure a fad factor by singling out those years when sales were historically high and growing.

D2 = dummy variable that equals 1 for 1972 through 1974, zero otherwise. This variable more broadly defines the fad factor of *D1* by adding 1974. In this year, sales nearly matched the previous year and then dropped by almost half in the following year.

DG1 = dummy variable that equals 1 for 1973, 1974, 1979, and 1980; zero otherwise. This variable represents a substitute for the price of gasoline and attempts to capture the asymmetrical shock effect of the dramatic increases in the price of gasoline that occurred in those years.

DG2 = dummy variable that equals 1 for 1974 and 1979, zero otherwise. This variable more narrowly defines the shock effect for the increases in the price of gasoline.

NOMY = disposable personal income (Bureau of Economic Analysis, unpublished data).

HRS = average weekly hours per worker on private nonagricultural payrolls (Bureau of Labor Statistics, unpublished data).

Would the bulge in the population snake, that is, the Baby Boom, be a factor in the increased bicycle sales? Depending on the objective, the Baby Boom may be identified in a number of ways. With respect to measuring the societal impact, the Population Reference Bureau suggests consideration of the number of births. Bouvier (*5*, p. 7) concludes: "In looking at the number of births, then, one could say that the baby boom period was concentrated from 1954 through 1964 when over 4 million births occurred each year." Did the baby boomers come of age at the same time that the bicycle industry experienced its greatest sales, in the period from 1972 to 1974? During this time the baby boomers ranged in age from 7 to 19. Interestingly enough, the bicycle industry confines its product to those bicycles having wheels with a diameter of at least 20 in. Normally, this would exclude youngsters less than 7 years old from the market. In the preceding list, the variable *BBP* measures the size of the population in the Baby Boom age group that coincides with the bicycle boom.

Substitute demographic variables for *BBP* are also included in the preceding list. These variables are based on survey data obtained from *Bicycling* for 1978, 1980, and 1982. This magazine has long been recognized as the dominant popular publication. The variable *MAGP* broadens *BBP* to include older age groups that have a demonstrated interest in bicycling. In this instance, the ages range from 7 to 44. The upper limit is determined by the oldest age group to represent at least 10 percent of the subscribers to *Bicycling*. On the other hand, the variable *MAXP* narrows the age range to 25 through 34, the largest 10-year cohort subscribing to *Bicycling*.

Although the energy crisis may be measured in several ways, the most appropriate measure with respect to bicycles may be the price of gasoline. Everett (*3*, p. 598) points out that "car owners tend to compare only the variable (operating) cost of driving the car to the cost of riding a bicycle." In Figure 2 both the actual and the adjusted gasoline components of the CPI for urban wage earners and clerical workers (*CPI-W* or *CPIW*) are plotted. These are *CPIG* and *PGAS* (*CPIG* as a percentage of *CPI-W*), respectively. Comparison with Figure 1 shows that the peak years in bicycle sales frequently coincide with large jumps in the price of gasoline. The preceding list gives other substitute energy variables, which include the transportation, private transportation, and public transportation components of *CPI-W*.

Studies by Floyd (*2*), Hirst (*4*), Everett (*3*), and Parker (*6*) suggest a weak relationship between the energy crisis and bicycle sales. Consequently, a direct relationship between an energy-related price and bicycle demand may be difficult to discern. Nevertheless, the coincidental increases in bicycle sales and the price of gasoline are hard to ignore.

A noncontinuous relationship may exist in the sense that changes in the price of gasoline must pierce a relatively high

(or low) threshold to have an effect on the demand for bicycles. Ordinarily bicycle sales may be insensitive to changes in the price of gasoline. Nevertheless, a huge and sudden increase in the price of gasoline might spur increased use of and demand for bicycles as consumers overreact to the price hike. Such an overreaction was illustrated by the enormous premiums that many consumers were willing to pay on the few fuel-efficient cars that were available during the early energy crisis. Whether consumers would act in the opposite way with a sudden downturn in the price of gasoline is less certain; the relationship may be asymmetric.

Evidence from the Annual Housing Survey conducted by the Bureau of the Census suggests that there was an increase in bicycle commute activity in the proximity of gasoline price increases. The available survey results are as follows (*7*, p. 4):

Year	*Percentage of Households Using Bicycle or Motorcycle for Journey to Work*
1974	1.1
1975	0.8
1976	0.8
1977	0.5
1978	0.6
1979	1.3

Although it may be tempting to argue that these figures are dominated by motorcycle use, such is not the case. The 1979 figure of 1.3 percent may be broken down into the 0.6 percent of all households that commuted by bicycle and the 0.7 percent that used motorcycles (*7*, p. 2). Though not directly comparable, in 1975 0.6 percent of all workers commuted by bicycle whereas 0.4 percent used motorcycles (*8*, p. 4).

Consideration of these figures hints at the shock effect of sudden and large surges in the price of gasoline. In 1974 and 1979 when the use ratio was greater than 1 percent, there had been dramatic increases in the price of gasoline. During the first 3 months of 1974, the price of gasoline increased at a compounded annual rate of 109.6 percent. An increase of 109.7 percent was registered from the end of March to the end of June in 1979. Occurring just before and during the buying season for bicycles, these jumps are likely to have significantly affected the demand for bicycles. In an attempt to account for this shock effect the dummy variable *DG2* is created, which is equal to 1 for 1974 and 1979 and zero for all other years. Reconsideration of Figures 1 and 2 suggests that this shock effect could be broadened to include 1973 and 1980; this is done with dummy variable *DG1*.

Although the preceding discussion focuses on the bicycle's use for commuting, it should not be forgotten that the bicycle is primarily a vehicle for recreational exercise. Floyd suggested two major factors for the bicycle boom in the early 1970s (*2*, pp. 140–141):

> What factors accounted for this tremendous increase in bicycle sales? Primarily the growing interest in physical fitness and outdoor life coincided with the refinement of the lightweight bicycle to result in a rediscovery of the bicycle by the adult and young adult population. The bicycle became not only socially acceptable but even fashionable (some would say faddish).

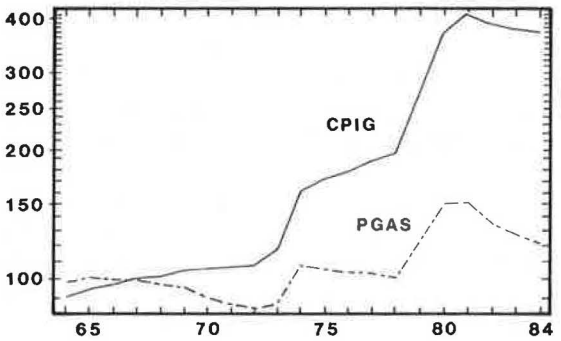

FIGURE 2 Gasoline components of *CPI-W*: actual (*CPIG*) and adjusted (*PGAS*), annual averages, 1964–1984.

Although growing bicycle sales themselves could be used as a measure of greater interest in physical fitness and outdoor life, the best available independent measure of this heightened interest may be the membership of the American Youth Hostels, Inc. (AYH). Founded 50 years ago to provide inexpensive overnight accommodations for young hikers, AYH has progressed into organized activities for virtually every outdoor activity that does not involve athletic competition, including, but not limited to, hiking, backpacking, camping, bicycling, canoeing, and ice skating. The variable *AYT* listed earlier represents the total membership of AYH. Although it purports to measure an increased interest in fitness and outdoor life, as a membership figure it may also reflect the age distribution of the population. This raises the specter of multicollinearity should *AYT* be considered together with any of the demographic variables discussed earlier.

In his study Floyd considered the composition of bicycle sales as an indicator of growing adult interest. By industry definition, lightweight bicycles are essentially those with wheel diameters of 26 or 27 ins. Consequently, lightweight bicycles are the adult-size bicycles and the ratio of lightweight sales to total sales should directly reflect adult interest in bicycling. This ratio is designated *LGWT*.

Floyd's allusion to the refinement of the lightweight bicycle is the substitution of 10-speed bicycles for the less sophisticated 1-, 3-, and 5-speed bicycles. The boom of the 1970s may have reflected more a refinement in consumer tastes than in the bicycle itself. Popularly priced 10-speeds had been available long before the boom; for instance, Schwinn, a Chicago-based manufacturer, had offered a range of 10-speed models at least as early as 1965. Although a complete time series on 10-speeds is not available, they have made up the lion's share of lightweight sales. Therefore, the sales figures for lightweight bicycles may capture the effects of both a growing adult interest and the refinement of the bicycle.

Floyd also mentions the possibility that the bicycle boom was the result of a fad. The extraordinarily high sales in the period from 1972 to 1974 may simply reflect a dramatic overshift in consumer preferences for bicycles. Two dummy variables are established to take into account or negate the effect of the fad on the other, presumably more permanent relationships. In 1972 and 1973, bicycle sales were both historically high and growing. The dummy variable *D1* is equal to 1 for both of these

years and zero for all other years. Although sales had declined from the previous year, they were still at a historically high level in 1974. The dummy variable *D2* broadens *D1* by including 1974 as a fad year. Coincidently, these variables, especially *D2*, may also negate any effect that the wage-price controls of the early 1970s may have had.

To continue with the notion that the bicycle serves in recreation, a boom in sales may reflect an increase in leisure time. To determine this effect, the average weekly hours per worker on private nonagricultural payrolls is considered as an inverse proxy for leisure. This variable is denoted as *HRS*.

A final determinant mentioned in earlier work is an increase in environmental concerns. If the advances over the control of noise and air pollution by environmental groups and agencies reflect the will of the public, it seems quite plausible that nonpolluting alternatives to recreation and transportation would experience increased interest and sales. Unfortunately, selection of a workable variable to quantify this factor has not been possible.

A final determinant is the household stock of bicycles (*STOCK*). Based on the industry estimated life span of 7 years, the stock variable is the sum of the total bicycle sales from the previous 7 years. This linear combination of the previous values of the dependent variable would lend a dynamic aspect to an otherwise static model. With such a lengthy life span, the bicycle should be considered a durable good and the stock variable should be inversely related to current sales.

ECONOMETRIC ESTIMATION TECHNIQUES

Econometric estimation can take two basic forms: single-equation estimation or simultaneous-equation estimation. The latter is theoretically preferred and among the various approaches, conditional demand analysis is particularly attractive.

Simultaneous-Equation Estimation

Although preferred, there are a number of factors that mitigate against the use of conditional demand analysis in the current study. This procedure relies solely on own price, income, and the prices of related goods for its explanatory variables and is better suited for groups of goods for which the relationships are nonchanging, such as basic commodities. In the case of bicycles as well as many other goods, sufficient information on the prices and sales of related goods is simply not available.

An additional shortcoming of the conditional demand analysis is its failure to recognize demographic factors. Ketkar and Cho concluded that (*9*, p. 16) "demographic characteristics of households are as important determinants of their expenditures as are price and income variables." Considering the previous section, age is a demographic factor that is likely to play a critical role in the demand for bicycles.

For the aforementioned reasons, conditional demand analysis is not used in this study. Reliance must be placed on the more conventional demand estimation techniques.

Single-Equation Estimation

Economic theory imposes several restrictions on any system of demand equations. Two that must be dealt with in single-equation estimation are homogeneity of degree zero and Slutsky negativity. A demand equation is homogeneous of degree zero if, when all prices and income are multiplied by the same factor, the quantity demanded does not change. Slutsky negativity merely refers to the fact that a good's own price effect is negative.

The most straightforward way to accomplish homogeneity of degree zero is to adjust all prices and income by dividing them by the index of consumer prices. More generally, real prices and income are considered instead of nominal prices and income. However, this adjustment can make it difficult to monitor Slutsky negativity. The double-logarithmic specification is the easiest way to accomplish both objectives.

The double-logarithmic form that would ensure homogeneity of degree zero is

$$\ln SALES = \alpha_0 + \alpha_1 \ln(CPIB/CPIW) + \alpha_2 \ln(NOMY/CPIW) \quad (1)$$

where

SALES = bicycle sales,
CPIW = CPI for urban wage earners and clerical workers (*CPI-W*),
CPIB = bicycle component of *CPI-W*, and
NOMY = disposable personal income.

In this instance, Slutsky negativity cannot be checked. To circumvent this problem, Equation 1 may be written in the following way:

$$\ln SALES = \alpha_0 + \alpha_1 \ln CPIB + \alpha_2 \ln NOMY + (-\alpha_1 - \alpha_2) \ln CPIW \quad (2)$$

Slutsky negativity can now be identified. A potential new problem has arisen in that under estimation Equation 2 has restricted coefficients. Fortunately, the restricted parameters are exactly identified and can be estimated by the following unrestricted model:

$$\ln SALES = \beta_0 + \beta_1 \ln CPIB + \beta_2 \ln NOMY + \beta_3 \ln CPIW \quad (3)$$

This specification would remain exactly identified with the inclusion of additional prices.

An initial estimation of Equation 3 yielded disappointing results. To improve the picture, each of the remaining explanatory variables was substituted in alternate regressions. The fad-factor dummies yielded much better results than any of the other variables, and *D2* did better than *D1*. The results of this second step are given in Table 1.

Given the tremendous jump in bicycle sales during the early 1970s, the significance of *D2* is not surprising. A characteristic of the double-logarithmic specification is that the coefficient of an independent variable is the coefficient of elasticity or, roughly, the percentage change that would occur in the dependent variable given a 1 percent change in the independent

TABLE 1 SINGLE-EQUATION ESTIMATION RESULTS: SECOND-STEP ESTIMATION

Explanatory Variable	Coefficient	*t*-Statistic	Significance of *t*-Test (two-tail)
Constant	17.5533	10.042	.0001
ln*CPIB*	–2.0809	–2.004	.0623
ln*NOMY*	2.1471	5.696	.0001
ln*CPIW*	–1.2625	–1.418	.1753
D2	0.5336	8.009	.0001

NOTE: Dependent variable, ln*SALES*; R^2 = .9382; adjusted R^2 = .9227; F = 60.72; significance of F-test = .0001; Durbin-Watson = 2.396 (reject autoregression at .01).

variable. Hence, the constant coefficients of the regression force constant coefficients of elasticity. If elasticities were ever to change, the boom of 1972 through 1974 is the most likely spot. The dummy variable for the fad factor sets this period apart, allowing the more stable long-term relationships to surface. Indeed, an operational definition of a fad might be a situation in which heretofore constant relationships are disrupted. At this point it would seem that more than anything else, the bicycle boom of the 1970s was a fad.

Reinforcing the point of the previous paragraph, Kouris *(10)* has questioned the value of assuming constant elasticities with respect to energy demand. "There are so many factors that exert an influence on energy demand that cannot be quantified; they would inevitably reflect on the elasticities of the remaining variables in the equation" (*10*, p. 68). In a footnote, he explains the first half of this statement (*10*, p. 68):

> The statistical assumptions of the least-squares technique assume that any factors not accounted for explicitly in the explanatory side of the equation will be captured by the error term. This is only partially true because the regressors are to some degree collinear with such excluded factors and therefore capture some of their effect. Hence the size of the computed elasticities does not depend exclusively on the fluctuations of the explanatory variables but also on the degree of correlation between regressors and omitted factors.

Like the second step, a third step once again considered the remaining variables in alternate regressions. Both *DG1* and *CPIG* led the others in improving the results. With respect to the coefficient of determination and the significance of the *t*-test, *DG1* outperformed *CPIG* by only the narrowest of margins and it was not enough to choose the dummy over a genuine measure. The results of this third step are reported in Table 2. This estimation represents the final estimation, because a fourth step failed to produce any additional variables with a significance level less than 40 percent.

The equation indicates that the demand for bicycles is relatively sensitive to changes in either the price of bicycles or consumer incomes or, in other words, the demand for bicycles is both price and income elastic. For instance, the price coefficient indicates that if the price of bicycles increases by 1 percent, the demand for bicycles will decline by approximately 2.7 percent. Should income rise by 1 percent, sales would increase by nearly 2.8 percent. This relatively high coefficient for income elasticity places bicycles in the category of a luxury good. These results from the United States provide an interesting comparison with the findings from a less industrialized country, India. In the only other econometric study on bicycles

TABLE 2 SINGLE-EQUATION ESTIMATION RESULTS: THIRD-STEP ESTIMATION

Explanatory Variable	Coefficient	*t*-Statistic	Significance of *t*-Test (two-tail)
Constant	19.3278	10.169	.0001
ln*CPIB*	–2.6966	–2.625	.0191
ln*NOMY*	2.7698	5.648	.0001
ln*CPIW*	–2.3837	–2.305	.0359
D2	0.5383	8.640	.0001
ln*CPIG*	0.5058	1.825	.0880

NOTE: Dependent variable, ln*SALES*; R^2 = .9494; adjusted R^2 = .9326; F = 56.31; significance of F-test = .0001; Durbin-Watson = 2.439 (inconclusive). The *t*-test on the coefficient of the lagged residual where the concurrent residual is the dependent variable was significant at .2187.

to be found, Siddharthan's *(11)* model suggests that the Indian demand for bicycles is price inelastic and that the bicycle is a necessity. These results confirm what ordinarily might be expected. In India the bicycle may be the only form of personal transportation that many households can afford, whereas in the United States the bicycle appears to be largely a recreational item.

The remaining coefficients are also as expected. The cross-price elasticity of the price of gasoline is positive and small, which indicates that bicycles are a weak substitute for motorized transportation. Furthermore, the fad dummy is directly related to bicycle sales.

Recalling that this equation represents the exactly identified and unrestricted form of the original specification clouds the interpretation of the coefficient of *CPI-W*. Nevertheless, if the bicycle is a luxury good, the sign of the coefficient would be expected. A general increase in prices would stimulate households to target initial spending cuts at luxury goods.

CONCLUSIONS

Although a system approach was not possible in this study, the tenets of the conditional demand analysis are supported inasmuch as income and prices provide much of the explanation for the resurgence in bicycle sales over the last two decades. The only variable other than prices and income to be included in the final regression was a dummy variable that presumably accounted for the disruption of normal relationships as the result of a fad or, perhaps, wage-price controls.

These results may stem, in part, from explanatory variables that were poor proxies for the characteristics that they purported to measure. Indeed, an appropriate measure for one determinant, the growing concern for the environment, was not found. However, using this excuse in the case of the demographic variables is difficult. The Baby Boom seems not to have had an effect on bicycle sales.

Although the energy crisis does have a measurable effect on the demand for bicycles, the results of this study indicate that the bicycle continues to serve primarily as a recreational good in the United States. This supports the conclusions of earlier studies, which were based, necessarily, on less data.

ACKNOWLEDGMENTS

The author appreciates the comments of the reviewers for the Transportation Research Board as well as those of earlier

reviewers: M. Ray Perryman of Baylor University and Michael P. Shields of Southern Illinois University—Carbondale. The author is also grateful for the assistance of Pauline Fox and Kang Hoon Park, both of Southeast Missouri State University, in the research process.

REFERENCES

1. Where Are They on Club Rides? *Bicycle USA*, July/Aug. 1985, p. 5.
2. C. F. Floyd. The Future of the Bicycle as a Mode of Transportation in the United States. *Traffic Quarterly*, Vol. 31, No. 1, Jan. 1977, pp. 139–153.
3. M. Everett. Commuter Demand for Bicycle Transportation in the United States. *Traffic Quarterly*, Vol. 28, No. 4, Oct. 1974, pp. 585–601.
4. E. Hirst. Bicycles, Cars, and Energy. *Traffic Quarterly*, Vol. 28, No. 4, Oct. 1974, pp. 573–584.
5. L. F. Bouvier. America's Baby Boom Generation: The Fateful Bulge. *Population Bulletin*, Vol. 35, No. 1, April 1980, pp. 3–35.
6. D. Parker. The Energy-Economics Balance. *Bicycle Forum*, No. 10. Summer 1983, pp. 30–37.
7. *The Journey to Work in the United States: 1979*. Current Population Reports, Series P-23, No. 122. Bureau of the Census, U.S. Department of Commerce, 1982.
8. *The Journey to Work in the United States: 1975*. Current Population Reports, Series P-23, No. 99. Bureau of the Census, U.S. Department of Commerce, 1979.
9. S. L. Ketkar and W. Cho. Demographic Factors and the Pattern of Household Expenditures in the United States. *Atlantic Economic Journal*, Vol. 10, No. 3, Sept. 1982, pp. 16–27.
10. G. Kouris. Elasticities—Science or Fiction? *Energy Economics*, Vol. 4, No. 2, April 1982, pp. 66–70.
11. N. S. Siddharthan. The Demand for Bicycles in India: The Relevance of Dynamic Demand Functions. *Indian Economic Journal*, Vol. 28, No. 2, Oct.-Dec. 1980, pp. 12–20.

Publication of this paper sponsored by Committee on Bicycling and Bicycle Facilities.