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Optimization Analysis of the U.S. Aggregate Consumption: A Goodness-of-Fit Approach

Bahram Adrangi
University of Portland, adrangi@up.edu

Kambiz Raffiee

OPTIMIZATION ANALYSIS OF THE U.S. AGGREGATE CONSUMPTION: A GOODNESS-OF-FIT APPROACH

by Bahram Adrangi* and Kambiz Raffiee**

Abstract

This paper examines the hypothesis of optimizing behavior of the U S. consumers using quarterly and seasonally adjusted series on real consumer expenditures on eight commodity groups. clothing, durable goods, energy, food, housing, medical care, transportation, and others for the period of 1947 I through 1993 I. Following the Weak Axiom of Revealed Preference (WARP), a money-metric utility function is derived to calculate an efficiency index to determine the percentage difference between the observed cost of consumption and the optimum cost of consumption in each period of the sample The empirical results provide evidence that the allocative efficiency in the U S has improved only slightly due to the wave of deregulations in the early 1980s. Our results are consistent with the predictions of the general theory of second best in showing that gains in the allocative efficiency may be minimal as long as many sectors of the economy remain partially or totally regulated

I. Introduction

The U.S economy has undergone a dramatic transformation from consisting of a large number of small firms during the 18th and 19th centuries to being increasingly dominated by giant corporations in the 20th century. The growth of big business led to concentration of economic power in the hands of few firms while increasing productivity and standard of living. Increasing corporate power precipitated the government regulation of industries [Peltzman, 1977]. For example, most trucking, railroad rates and routes, and waterway shipping were regulated under the Interstate Commerce Commission established in 1887. Despite some successes, the outcomes of government regulatory efforts have been mixed at best In many cases a clear economic case for regulation, i.e., a lack of well-defined property rights, deficient information in the market, and existence of natural monopolies, does not exist. Therefore, in the last few decades government policies toward business have attracted interest among politicians, economists, and the public at large. The discussions have often centered on the issue of competition in the market place and ways to enhance the degree of competition in the economy The consensus among policy makers and economists alike seems to be that more competition in the market place may improve productive and allocative efficiencies in the economy.

These discussions and concerns resulted in the partial or total deregulation of industries such as airlines, banking, and trucking in the late 1970s and early 1980s. Even partial deregulation of any sector is lauded by economists as a means of improvement in allocative and productive efficiencies. However. the general theory of second best maintains that the benefits of piece-meal policies of deregulation may be overstated. According to this theory, as long as regulatory constraints are imposed on some sectors of the economy, even the restoration of pareto optimality conditions in other sectors may not produce the desired optimum productive and allocative efficiencies [Peltzman, 1976; Schmalensee, 1979; Stigler, 1971; Weiss; 1981].

Many researchers, particularly in the past two decades, have measured or analyzed economic efficiency in the newly deregulated industries. For example, Adrangi et al. [1995], Moore [1986], Winston et al. [1990], Daughty and Nelson [1988], and Ying [1990a, 1990b], among others. study the deregulation of the U.S. trucking industry and its effects on the productivity and technical efficiency of the trucking industry. Almost all of these studies conclude that the deregulation of this industry resulted in

* School of Business Administration, The University of Portland, 5000 North Willamette Blvd., Portland, Oregon 97203.
**Department of Economics, University of Nevada, Reno, Reno, Nevada, 89557.

rate reductions and improvements in technical efficiency. Winston et al. (1990) find that shippers and ultimately consumers and the society benefited from the deregulation of the trucking industry by approximately $11 billion (in 1977 dollars) annually.

Other researchers, Bailey et al. [1985], Bailey and Williams [1988], Borenstein [1989, 1990], Graham et al. [1983], and Morrison and Winston [1993], among others, show that the deregulation and structural transition in the U.S. airline industry have drastically improved airline efficiency and reduced air fares.

Similarly, the last two decades have witnessed a serious increase in critical scrutiny of public policy toward the banking industry. Longstanding restrictions on various aspects of the industry due to regulation, e.g., limits on pricing, on asset management, and on geographic expansion, have been reduced or eliminated in recent years. Deregulation has also changed conditions of entry, type of products that financial intermediaries may legally offer, and degree of competition in banking markets. The conditions of stability, efficiency, and resource allocations of the banking industry are all improved under deregulation [Gilbert, 1984; Kane, 1981; Rose, 1987].

Despite the aforementioned moves in the U.S. economy toward a "freer market" with less regulations and controls by the government, government agencies such as Federal Aviation Agency (FAA), Interstate Commerce Commission (ICC), and Federal Communications Commission (FCC) still regulate diverse sectors of the economy such as trucking, banking, airlines, railroads, barges, pipelines, and telecommunications.[1] Complete deregulation of the economy may never occur, perhaps due to externalities, public goods, and natural monopolies. Restrictive regulation in the absence of "market failure" may also stem from a lack of concrete evidence that increased competition in the economy leads to enhanced allocative and productive efficiencies.

The past research on economic gains from competitive markets and reduced deregulation has focused on the supply-side of the economy and gains in technical and productive efficiencies. In contrast to the supply-side issues and technical efficiency, the demand-side of the market has received very little attention. The question of whether consumers are maximizing utility subject to budget constraint, i.e., exact optimizing behavior, is assumed but generally not critically tested and evaluated in the academic literature. This issue is important because efficiency on the production and supply-side is not sufficient to guarantee the efficiency in the entire economy unless the consumer behavior also satisfies the conditions of utility maximization under constraint.

The examination of consumer behavior is not unrelated to the deregulation of various sectors of the economy. The deregulation provides consumers an opportunity to benefit from choices that the competitive market offers. Do consumers actually take advantage of the freer market and strive to allocate their resources most efficiently as professed by the neoclassical theory of consumer behavior? If on the demand-side consumers are not allocating their scarce resources in accordance with the utility maximization paradigm, then the economy may not achieve maximum efficiency despite gains in productive efficiency.

This paper presents new empirical evidence on the nature of optimizing behavior of the U.S. consumers using quarterly and seasonally adjusted series in 1987 dollars, taken from the Citibase, on real consumer expenditures on eight commodity categories: clothing, durable goods, energy, food, housing, medical care, transportation, and others for the period of 1947:I through 1993:I. Following the Weak Axiom of Revealed Preference (WARP) developed by Varian [1990], a money-metric utility function is derived and an efficiency index is calculated to determine the percentage difference between the observed cost of consumption and the optimum cost of consumption for each period of the sample.

The empirical results provide evidence that the allocative efficiency in consumption in the U.S. has improved only slightly in the aftermath of the wave of deregulations in the early 1980s. Our findings seem to be consistent with the predictions of the general theory of second best in showing that gains in the allocative efficiency may be minimal as long as many sectors remain partially or totally regulated.

The outline of this paper is as follows. Section II presents the theoretical framework for deriving the efficiency index following the

WARP. The application of the WARP to the analysis of the hypothesis of optimizing behavior of the U.S. consumers and the empirical findings are discussed in Section III. The conclusion of this study is summarized in the final section.

II. Methodology

Consider a consumption process by a consumer that generates an observed set of data (P^i, X^i) for $i = 1, \ldots, n$, where P^i is a vector of good prices and X^i is a vector of good demands. Let the revealed preference relation of the consumer be presented by the notation $>$. If these data were generated by the utility-maximizing behavior of the consumer, it must satisfy the following condition:

$$X^i > X^j \qquad \text{if } E(P^i, X^i) \leq E(P^i, X^j) \quad (1)$$

where $E(P^i, X^i) = P^i X^i$ is the cost of the observed consumption choice, and $E(P^i, X^j) = P^i X^j$ is the cost of any other consumption choice. This criterion is known as the WARP. This condition is both necessary and sufficient for utility-maximizing behavior. If a data set satisfies the WARP, then it is possible to construct an expenditure function that would generate the observed decisions as utility-maximizing decisions. Discussion on consistency with utility maximization based on the WARP can be found in Afriat [1972], Akerlof and Yellen [1985], Diewert and Parkan [1985], and Varian [1985, 1990], among others.

In the empirical analysis of consistency with utility minimization, one has to make the distinction between the conventional tests and the goodness-of-fit tests. The major criticism of the conventional tests is that they are based on exact optimizing behavior. Hence the conventional tests are exact tests in the sense that either the data pass the test exactly, or they don't. If the data fail the test, the optimizing hypothesis is rejected and the magnitude of the deviation between observed and optimum choices cannot be determined. On the other hand, nearly optimizing behavior is just as good as exact optimizing behavior in the sense that one only has to define a reasonable deviation between optimum and observed choices to accept the hypothesis of nearly optimizing behavior [Akerlof and Yellen, 1985; Cochrane, 1989, Varian, 1984, 1985, 1990]. The notion of nearly optimizing behavior is the basis for the application of the goodness-of-fit tests as opposed to the conventional tests to investigate the characteristics of exact optimizing behavior.

An index of efficiency developed by Afriat [1972] and described in Varian [1990] is used to derive a goodness-of-fit measure to examine utility-maximizing behavior. If there is a violation of the WARP, then $E(P^i, X^i) > C(P^i, X^j)$ for all $X^j \geq X^i$. The relative measure of departure from utility maximization is given by the efficiency index, e^i, defined as

$$e^i = 1 - E(P^i, X^j)/E(P^i, X^i) \qquad (2)$$

The efficiency index is the percentage difference between the cost of the observed consumption choice and the cost of any other consumption choice. This index is a relative measure of how much the consumer could have saved if X^j rather than X^i was purchased at price P^i. If the value of the efficiency index is small, then it would be reasonable to consider the consumer as being a nearly utility maximizer. A reduction in the value of the index is also an indication of an improvement in the optimizing behavior of the consumer.

The first step in applying the goodness-of-fit measure is estimating the total cost of consumption that would have been incurred by the consumer, $E(P^i, X^j)$, had X^j rather than X^i been chosen based on meaningful optimizing principles. $E(P^i, X^j)$ could then be compared with observed expenditure data, $E(P^i, X^i)$, to calculate the efficiency index given in equation (2). As a procedure to estimate $E(P^i, X^j)$, consider the following generalized Cobb-Douglas utility function of a consumer.

$$U = \prod_{i=1}^{n} x_i^{a_i}; \; i = 1, \ldots, n \qquad (3)$$

where x_i is the quantity consumption of good i and a_i is the expenditure share of good i. The demand functions consistent with the conditions of the WARP in equation (1) and the utility function in equation (3) are

$$x_i = a_i E(P^i, X^j)/p_i; \; i = 1, \ldots \ldots, n \quad (4)$$

where p_i is the market price of good i To make the system of equations of good demands in equation (4) consistent, i.e., $E(P^i, X^j) = \Sigma p_i x_i$, the restriction is imposed so that $\Sigma a_i = 1$

To derive the explicit expression for the expenditure function $E(P^i, X^j)$, the good demands in equation (4) are substituted into equation (3) and solved for $E(P^i, X^j)$. The resulting equation is:

$$E(P^i, X^j) = \prod_{i=1}^{n} a_i^{-a_i} \prod_{i=1}^{n} (p_i x_i)^{a_i} \quad (5)$$

Taking the natural logarithm of both sides of equation (5), one gets.

$$LnE(P^i, X^j) = -\sum_{i=1}^{n} a_i Lna_i + \sum_{i=1}^{n} a_i Ln(p_i^i x_i) \quad (6)$$

Equation (6) is the explicit functional form of the expenditure function consistent with the necessary and sufficient conditions of utility-maximizing behavior implied by the WARP. It is also noted that the natural logarithm of the actual expenditures by a consumer on all goods, $LnE(P^i, X^i)$, is equal to the natural logarithm of the expenditure-minimizing amount, $LnE(P^i, X^j)$, plus an error term, u, representing the optimization error. Using equation (6), one obtains:

$$LnE(P^i, X^i) = LnE(P^i, X^j) + u \quad (7)$$

or

$$LnE(P^i, X^i) = -\sum_{i=1}^{n} a_i Lna_i + \sum_{i=1}^{n} a_i Ln(p_i x_i) + u \quad (8)$$

To develop the goodness-of-fit test to examine consistency with utility-maximization, the parameters in equation (8) are estimated subject to the restriction that $\Sigma a_i = 1$. Once these estimates are obtained, one can determine the expenditure of the consumption choice implied by the WARP, $E(P^i, X^j)$, in equation (6), and then calculate the efficiency index, e^i, in equation (2) to examine the optimizing behavior of consumers. The empirical results of the test of optimizing behavior of aggregate consumption expenditures in the U.S. are presented in the sequel.

III. Empirical Results

In this section, the empirical results of the test of the hypothesis of optimizing behavior of the U.S. consumers are discussed. First, the overall aggregate consumption behavior in the U.S. is examined by estimating equation (8) using quarterly and seasonally adjusted series in 1987 dollars, taken from the Citibase, on real consumer expenditures on eight commodity categories: clothing, durable goods, energy, food, housing, medical care, transportation, and others for the period of 1947:I through 1993:I. Additionally, the estimation results are checked for both first-order and fourth-order autocorrelation. Second, the sequential Chow test is performed to test for the occurrence of structural change in the aggregate consumption during the period of the study. Finally, the efficiency index is calculated for each period by estimating equation (8) and using equations (2) and (6) to determine the magnitude of the departure from cost-minimizing behavior in consumption.

Descriptive statistics and definition of the variables used in the study are listed in Table 1. The OLS estimate of equation (8) subject to the restriction that $\Sigma a_i = 1$ is shown in Table 2.[2] It is noted that each of the coefficient estimates has the expected sign and is significant at the 5 percent level. The estimated regression explains over 99 percent of the variation in the total consumption expenditures as is indicated by the adjusted R^2 The estimated Durbin-Watson (DW) statistic of 0.413 indicates the presence of the positive first-order autocorrelation at any reasonable level of significance.

Equation (8) is reestimated using the maximum-likelihood (ML) estimation technique for correction of the first-order autocorrelation. The results are reported in Table 3.[3] The results on the coefficient estimates have the expected sign and are significant at the 5 percent level. The estimated DW statistic is 2 03, confirming the

TABLE 1
Descriptive Statistics for the Expenditure Function Variables, U.S Economy, 1947 I to 1993.I[a]

Variables	Mean	S D
Total Consumption Expenditures	1886.16	803 98
Clothing	98.03	46 87
Durables	216 58	118 05
Energy	74 41	18.72
Food	378 34	93.29
Housing	277 28	132.00
Medical Care	206 55	126 64
Transportation	73 19	28.19
Others	560.77	246 78

[a] All the figures on the mean are in billions of dollars

removal of the first-order autocorrelation from the estimated regression

Given the sample period of 1947:I to 1993:I, one would expect some structural instability in the model coefficients. In order to examine the stability of the model, a formal test for the structural stability of the model is performed based on the sequential Chow test [Green, 1993]. The F-value for the Chow test is 11.36 obtained at the period of the first quarter of 1985. The calculated statistic is statistically significant at the 5 percent level, suggesting that there indeed is a structural change in 1985.[4] Consequently, equation (8) is reestimated for each of the two sub-periods of 1947:I to 1984:IV and 1985:I to 1993:I using the ML estimation technique for correction of the first-order autocorrelation subject to the restriction that $\Sigma a_i = 1$. The results are reported in Table 4, and are used to calculate the efficiency index to examine the hypothesis of optimizing behavior of the U.S. consumers in each of the sub-periods as described below.

The last step is to empirically examine the fundamental question of whether the consumption behavior in the U S. over the period of the study is consistent with the WARP explained in Section II. The basis for this analysis is the estimation result of the expenditure function in equation (8), reported in Table 4, and the calculation of the efficiency index in equation (2)

Using the parameter estimates of the expendi-

TABLE 2
Estimated Consumption Expenditure Function Under the WARP; U S Economy, 1947 I to 1993.I

Variable	Coefficient	Standard Error
Clothing	0 160181	0.006477
Durables	0 084585	0.002604
Energy	0.013448	0 005252
Food	0 237149	0.010012
Housing	0.074260	0 005306
Medical Care	0 116747	0.006339
Transportation	0.044930	0 002968
Others	0.257279	0 007654
Intercept	1.897710	0 024134
Adjusted R^2	0.99	
D.W	0 413	

TABLE 3
Maximum-Likelihood (ML) Estimate of the Expenditure Function with Correction for the First-Order Autocorrelation Under the WARP, U S Economy; 1947.I to 1993.I

Variable	Coefficient	Standard Error
Clothing	0 150744	0 007954
Durables	0 095698	0 003216
Energy	0 032985	0 004445
Food	0 220987	0 007175
Housing	0 098104	0.008731
Medical Care	0 075228	0 005603
Transportation	0.040740	0.005346
Others	0 276072	0.009110
Intercept	1 000402	0 000136
Adjusted R^2	0 99	
D W.	2 03	

TABLE 4
Maximum-Likehood (ML) Estimate of the Expenditure Function with Correction for the First-Order Autocorrelation Under the WARP; U S. Economy; Sub-periods of 1947:I to 1984:IV and 1985:I to 1993:I

Variable	Coefficient (1947:I to 1984·IV)	Standard Error (1947:I to 1984·IV)	Coefficient (1985.I to 1993·I)	Standard Error (1985.I to 1993·I)
Clothing	0.156677	0.008192	0.166100	0.006569
Durables	0.088219	0.003381	0.118729	0.002776
Energy	0.031145	0 004530	0.014947	0 003083
Food	0 222969	0.006885	0.141736	0.004301
Housing	0 104837	0 009221	0 125985	0.009235
Medical Care	0.070845	0.005228	0.111851	0.006096
Transportation	0 036254	0.005148	0 022484	0 004486
Others	0.275872	0.008651	0 282888	0 004081
Intercept	0.000213	0.000157	$8\ 11 \times 10^{-5}$	6.27×10^{-5}
Adjusted R^2	0.99		0.99	
D.W.	1.78		2.14	

ture function in equation (8) in each sub-period of the study, reported in Table 4, and the result in equation (6), the cost-minimizing level of expenditures for consumption, $E(P^i, X^j)$, is estimated. From these estimations and the observed consumption expenditure figures, $E(P^i, X^i)$, the efficiency index, e^i, in equation (2) is calculated.

It should be emphasized that the calculated values of the efficiency index are positive for each time period because the actual cost of consumption, $E(P^i, X^i)$, to purchase a given commodity basket must always be greater than the optimum cost of consumption, $E(P^i, X^j)$, for purchasing the same commodity basket if there is a violation of the WARP.

The calculated efficiency index for the first quarter of selected years in each of the sub-periods of the study is reported in Table 5. According to these indices, U.S. consumers are fairly efficient for all years under study. For example, in 1947.I the value of this index is 0.10 indicating that the actual consumption expenditures on all goods and services consumed are fairly close to their optimal levels. The value of the coefficient rises to 0.28 in 1984.I, indicating that the inefficiency in consumer expenditures triples over the three decades. This could be a result of the introduction of more regulations and price and wage controls. However, the value of the index dips slightly in 1985.I to 0.25 and remains constant at 0.27 from there on. This shows some minor gain in efficiency in consumer expenditures in the post 1985 era as opposed to the years prior to 1985.

It may be argued that the deregulation movements of the early 1980s in the trucking, airline, and banking industries, among others, were coming to fruition by 1985. Therefore, freer markets are expected to reduce the cost of transportation of goods and services as well as financial services. The benefits of the deregulation are reputed to be contagious across various

TABLE 5
Selected Estimated Efficiency Index for Measurement of Departure from Expenditure Minimization in Consumption Under the WARP, U S. Economy, Sub-periods of 1947:I to 1984:IV and 1985·I to 1993 I

Sub-period of 1947.I to 1984:IV:								
1947 I	1950 I	1955 I	1960 I	1965 I	1970.I	1975.I	1980 I	1984.IV
0 10	0.25	0.26	0.26	0.27	0.28	0 28	0.28	0.28
Sub-period of 1985:I to 1993:I·								
1985.I	1990 I to 1993:I·							
0 25	0.27	0.27						

sectors and throughout the economy by reducing the cost-push inflation. As proponents of deregulation have argued, in the end, consumers benefit from the lower costs of good sand services and are able to allocate their resources more efficiently, thus, improving their welfare.

IV. Conclusion

The deregulation of various sectors of the economy certainly provides consumers an opportunity to benefit from choices that the competitive market offers. The relevant issue is whether consumers actually take advantage of the deregulation process, and strive to allocate their resources most efficiently. If on the demand-side consumers are not allocating their scarce resources in accordance with the utility maximization paradigm, then the economy may not achieve maximum efficiency despite gains in productive efficiency.

This paper analyzes the U.S. consumers' optimizing behavior hypothesis for the period of 1947.I through 1993.I. The estimation results indicate that the U.S consumers are fairly efficient for all years under study. For the period of 1947.I to 1984.IV, the estimate of the consumption efficiency index, measuring the percentage difference between the cost of the observed consumption choice and the cost of the optimum consumption choice under WARP, ranges from 0.10 in 1947.I to 0.28 in 1984.IV. This finding indicates that the consumers were almost three times below their optimum consumption expenditure in 1984 as compared to 1947. This could be a result of the introduction of more regulations, e.g., transportation and banking, and price and wage controls. However, the value of the index declines slightly in 1985.I to 0.25 and remains constant at 0.27 for the remaining years till 1993. This slight improvement in the consumers' efficiency after 1984.I may mark the beginning of the beneficiary effect of less regulation by the government.

It may be argued that the potential deregulation movements benefits of the early 1980s in a number of key industries, e.g., the trucking, airlines, and banking industries, among others, were starting to materialize by 1985, resulting into reduced costs of transportation of goods and financial services. As proponents of deregulation have argued, in the end, consumers benefit from the lower costs of more available baskets of goods and services and are able to allocate their resources more efficiently, thus, improving efficiency in consumption and their welfare.

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Notes

1. It is noted that under a current proposal by the Clinton Administration the Congress is considering the elimination of the Interstate Commerce Commission.
2. Since its constant term is non-linear, equation (8) is estimated nonlinearly subject to the requirement that $\Sigma a_i = 1$. The results are, again, similar to those reported in Table 2
3. The use of quarterly data in this paper warrants a concern over the fourth-order serial correlation in the disturbance term of equation (8). This possibility is investigated using the Lagrange Multiplier (LM) test due to Breusch (1978) and Godfrey (1978). The calculated chi-square statistic is 8 43. Based on the critical value of the chi-square statistic with 4 degrees of freedom at the 5 percent level of significance of 9.49, the maintained hypothesis of no fourth-order serial correlation in the disturbance term of equation (8) is accepted.
4. The finding of the structural change in the residuals of the estimation results reported in Table 3 is also checked using a cusum square (CUSUMS) test of the residuals. With a 95 percent confidence bond, the CUSUMS test of the residuals confirms the finding that there is a structural change in the period of the study at the first quarter of 1985.