"Reliability Tests of Elasticity Estimates from Alternative Specifications of the U.S. Demand for Coffee"

SUMMARY FOR EXECUTIVES. This study investigates the U.S. demand for coffee using 1957-87 annual data and the unrestrictive Box-Cox modeling methodology. The Box-Cox model has several desirable attributes, one of which is that it allows the data to speak for themselves without unnecessarily constraining them. Consequently, the results presented here are expected to approximate empirical reality better than those of the earlier studies of coffee demand which fitted restrictive functional forms to the data. Based on economic reasoning, coffee demand was here hypothesized to depend on real coffee prices, real prices of related food items such as orange juice, cola drinks, and sugar, as well as on real incomes, global warming trend, and past habitual coffee consumption. The various theoretical and statistical measures of model performance show that the Box-Cox model fitted the observed data quite well.

Following are some specific results. In the short run, a 10% increase in real coffee prices tends to reduce coffee consumption by about 1.7%. Since coffee demand is relatively insensitive to a change in its own price (partly due to strong consumption habits), producer revenues are expected to rise when coffee prices rise, all else equal. Second, consumption of sugar and cola drinks complement coffee demand while orange juice tends to displace coffee somewhat (perhaps at breakfasts, due to health trends). Demand for coffee is also expected to decline roughly 2.5% if U.S. per capita income rises by 10%, all else equal. Coffee demand may slack off at higher incomes due to saturation effects or because consumers prefer more expensive and/or healthy beverages to coffee at higher income levels. Thus, as real U.S. incomes rise producers of processed coffee and coffee substitutes need to develop more healthy coffee products which appeal to high income earners. Some coffee manufacturers recently revealed plans to follow tea manufacturers' tradition by marketing iced coffee to boost summer sales across income levels. This strategy is also a step in the right direction.

Reliability Tests of Elasticity Estimates from Alternative Specifications of the U.S. Demand for Coffee

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U.S. per capita coffee consumption peaked at 3.12 cups per person per day in 1962 and declined to 1.74 cups in 1988 (Pierog). Over the 1957-87 period, per capita coffee consumption declined 43.2 percent, real disposable personal incomes grew 246 percent, and real coffee prices more than tripled. The observed decline in U.S. coffee consumption can be attributed to rising relative prices of coffee (Timms) and the changing composition of the U.S. population[1] (*Marketing & Media Decisions*, Salathe). In spite of the observed trend, coffee remains the leading hot beverage consumed by over 60 percent of the U.S. population (Shapiro, *et al.*). Empirical elasticity estimates of coffee demand are useful for the proper delineation of economic markets for coffee and in formulating optimal product pricing policies by coffee manufacturers. Therefore, obtaining statistically efficient estimates of the demand elasticities are important.

The objectives of this paper are to: (i) provide new and improved estimates of coffee demand elasticities using 1957-1987 annual U.S. time series data; (ii) implement a hierarchical methodology for ascertaining which of the previously estimated coffee demand model specification(s) produced efficient elasticity estimators; (iii) estimate flexible functional form models and their various nested forms to test the theoretical proposition that price and income elasticities of coffee demand vary with prices and incomes; and, for the first time, (iv) investigate the long term effect of global warming (or gradual climatic change) on U.S. coffee consumption and (v) estimate the effects of the prices of sugar and orange juice on the U.S. consumption of coffee.

Determination of the efficiency of the elasticity estimates is important because past estimates diverge tremendously. Previously reported elasticity estimates have ranged as follows: own-price (-.05 to -2.78); cross-price (-.01 to .15 with respect to tea, -.16 with respect to cocoa and -.48 with respect to soft drinks); and income (-0.1 to 2.5). Table 1 summarizes specific elasticities from major U.S. coffee demand studies. The studies differ regarding functional

Table 1.
Elasticity Estimates (Computed at the Sample Means) from selected Previous Studies of U.S. Demand for Coffee

Author	Data type	Function form	Elasticities with respect to Price	Cross-price	Income	R^2
Palm and Vogelvang	Quarterly (1972-80)	Linear-log.	-.33	a	—	—
Huang, et.al.	Quarterly (1966-77)	Box-Cos				
		Regular coffee	-.18	b	.53[b]	.80[c]
		Soluble coffee	-.05	b	-.23[b]	.50
		Double-log				
		Regular coffee	-.016	.15[b] (tea)	.51[b]	.80
		Soluble coffee	-.36	-.48 (soft drink)	-.10[b]	.59
Lawrence, et al.	Annual (1946-76)	Log-linear	-.21	—	-.20[b]	a
Parikh[d]	Quarterly (1958-68) Seasonally unadjusted series	Double-log. (flow adjust-ments model)	-.22	—	—	.21
	Seasonally adjusted series	(flow adjust-ments model)	-.42	—	—	.13
Timms	Annual (1952-65)	Double-log. (Eq. lb)	-.17	—	-.51	.86
	Annual (1952-65)	Double-log. (Eq. 1a)	-.18	—	-.31	.90
	Annual (1952-65)	Double-log. (Eq. 1c)	-.14	-.10[b] (tea) -.16 (cocoa)	-.53	.93
Hughes	Annual (1920-41)	Linear	-.27	—	.32	.71
	Annual (1947-66)	Linear	-.11	—	.32	.59
Abaelu and Manderscheid	Quarterly (1953-61)	Linear				
		Milds	-1.23	f	2.5	.91
		Brazils	-4.76	f	-1.1	.93
		Robustas	-2.78	f	-.55	.92

a. Indicates not reported.
b. Reported as statistically insignificant.
c. Some studies report adjusted R^2s, other give unadjusted R^2 values.
d. U.S. Import Demand for Coffee Model.
e. Fitted price-dependent demand models; hence, reported price flexibilities are here converted to approximate lower-bound elasticities by inversion.
f. Reported that milds, brazils, and robustas are substitutes but did not report the numerical estimates of the cross-price elasticities.

forms, data, and included variables. Consequently, reconciling previous disparate elasticity estimates is a formidable task.

Twelve single-equation models were estimated using 1957-1987 U.S. annual time series data. Discrimination between models yielding minimum variance elasticity estimators and those that do not is based on the following criteria: functional form, sphericity properties of model residuals, and conformance of results with prescriptions of economic theory. The application of statistical-cum-economic procedures allows the selection of an appropriate type model (or set of models) from the general class of single-equation models. Section II of this paper presents the hierarchical tests of reliability for model elimination, section III specifies the demand for coffee models and discusses the data, section IV provides empirical results, and section V includes summary and conclusions.

Methodology for Elimination of Inappropriate Models

Single equation specifications of the demand for coffee are identified by assuming shifting supplies of coffee.[2] Therefore, empirical estimates of coffee demand elasticities are obtainable from a model of the form:

$$QCOF_d = g\,(PCOF_r, INCOM_r, OTHER), \quad (1)$$

where $QCOF_d$ measures the quantity of coffee consumption, g defines an estimable function, $PCOF_r$ is the relative price of coffee, $INCOM_r$ is real income, and OTHER is a set of other relevant determinants of coffee demand. Specification (1) is consistent with the theory of demand; however, economic theory offers little assistance in the choice of appropriate estimating functional forms in demand analyses (Bender, *et al.*). Thus, a variety of functional approximations to the general specification (1) has been fitted for coffee (see Table 1). One undesirable consequence of functional misspecification is biased (or inconsistent) elasticity estimates (Judge, *et al.*). Therefore, the choice of functional form is crucial for discriminating among contending models (Sarkar).

Search for the appropriate model (models) is (are) commonly based on *ad hoc* procedures or single conditional tests of regression specification. These include examining the signs and statistical significance of parameter estimates (*ad hoc*) and the econometric procedures such as the adjusted R^2, the Box-Cox method, and various tests of sphericity of the residuals (Thursby and Thursby). However, the simultaneous existence of multiple sources of specification errors in a model weakens the ability of single tests separately applied (Ghali and Snow). In effect, the joint tests capable of simultaneous detection of several regression specification errors are preferable. The hierarchical procedure implemented in this study is an extension of that adopted by Thursby and Thursby in their evaluation of import demand models.

The model reliability procedure implemented combines the Durbin-Watson test (or Durbin's *h* for models with lagged dependent variable) for first order residual autoregression (FAC); Ramsey's regression specifications test (RESET) capable of detecting misspecifications due to omitted variables, erroneous functional form, multicollinear regressors, and autocorrelated disturbances);[3] the correlogram test for non-first order residual autoregression (NFAC); and the Breusch-Pagan test for detecting unstable residual variances (HET).

Appropriate models are expected to yield efficient (or minimum variance) elasticity estimators. Models with conditional disturbance of mean zero ($E(\varepsilon_t \mid X_t) = 0$) produce unbiased and consistent elasticity estimators, and efficient estimators are provided by models with independent time series residuals ($E(\varepsilon_t, \varepsilon_{t-j}) = 0$; $j \neq 0$). The sequential test application procedure is as follows. First, we apply the powerful RESET procedure to determine if the elasticity estimators are unbiased and consistent. Models with significant RESET statistics are discarded as misspecified. Residuals of models surviving the RESET procedure are further tested for FAC or NFAC error processes. Models with significant FAC (and insignificant NFAC) are corrected by implementing the Cochrane-Orcutt iteration. Models with significant NFAC are reestimated subject to the "correct" error process, given the data. Models with unstable variances are detected with the Breusch-Pagan procedure and are subsequently endowed with homoscedastic behavior using the weighted least squares (WLS) method. Habit formation (HF) models with significant residual autocorrelation are first corrected before applying Ramsey's RESET.

In summary, inappropriate models are initially eliminated by RESET. Subsequent eliminations are based on the choice procedures for nested models. For example, non-habit formation (NHF) models are nested in the broader habit formation (HF) models. Statistical significance of the lagged dependent variable[4] coefficient in the HF models is the basis for discarding their NHF degenerates; otherwise, the nested model is accepted. Next, models contradicting economic theory (e.g., incorrectly signed coefficient or whose absolute values of the direct price elasticities are smaller than the cross-price effects of related commodities) are discarded. Finally, models with low adjusted R^2 ($\bar{R}^2$) are discarded. Implementing these sequential model elimination rules leaves three habit formation models as surviving the test: double-log, classic Box-Cox, and extended Box-Cox models. All statistical tests (NFAC, RESET, FAC, Nested, HET, $\bar{R}^2$) are based on a .05 significance level.

Coffee Demand Model Development and the Data

The demand for coffee is expected to be own-price inelastic for the following reasons: coffee expenditure constitutes a small fraction of the consumer budget; most related beverages are poor substitutes for coffee; and consumption of coffee is subject to habit persistence. Most previous research (except that by Abaelu and Manderscheid) reported inelastic coffee demand. Huang *et al.* and Timms found inelastic and statistically insignificant cross-effects with respect to tea (hot beverage). Soft drinks (Huang, *et al.*) and cocoa (Timms) were reported as significant complements for coffee. These findings of complementarity appear to contradict theoretical expectations, especially because soft drinks and coffee are generally available in both non-caffeinated and caffeinated forms, and cocoa and coffee are both hot beverages. Previously reported income elasticities were either zero (indicating consumption saturation at higher income levels) or significantly negative (suggesting coffee is an inferior food item).

Most of the previous research on coffee demand is limited for several reasons. First, *a priori* selection of double-log models imposes a constant elasticity of demand condition and thereby contradicts the theoretical requirement of variations of the demand elasticities as relative prices and incomes change. Second, studies incorporating income and time trend in the estimated model cursorily dismissed the very high bivariate correlation of about 0.92 between time and income, in which case the two parameter estimates are interdependent. Hence, the income elasticities so obtained are inefficient. Third, previous models (except Parikh; modeling import demand) failed to utilize the habit formation framework, whereas coffee consumption is subject to habit persistence (Houthakker and Taylor). Fourth, all previous models omitted the effects of sugar, milk, and cream, any one of which may complement coffee strongly in consumption. Fifth, an increasingly important substitute (or complement) of coffee, especially at breakfast tables (namely orange juice) is yet to be incorporated in the specification and estimation of coffee demand. In what follows, attempts are made to rectify these apparent limitations of previous studies.

In the present analysis, the extended Box-Cox (EB-C) model is sufficiently flexible to permit income and price elasticities of coffee demand to vary with income and price levels. Specifications previously estimated for coffee demand are estimated as nested forms of the EB-C model by using appropriate parametric restrictions. Past researchers estimated the following models: linear (Hughes, Abaelu and Manderscheid); linear-log (Palm and Vogelvang); log-linear (Lawrence, *et al.*); double-log (Huang, *et al.*; Parikh; Timms); and the EB-C *without* habit formation (Huang, *et al.*). The classic Box-Cox model (CB-C), not previously fitted for coffee demand, is also estimated as a special case of the

EB-C specification. More importantly, the habit formation (HF) versions of all the above specifications, never before investigated, are important for implementing the nested-form test procedure for the selection of appropriate model(s). In all, twelve models are estimated.

The EB-C demand model specification for coffee is:

$$QCOF^{(\lambda)} = \alpha_o + \alpha_1 PCOF_r^{(\lambda)} + \alpha_2 PSUG_r^{(\lambda)} + \alpha_3 PCOLA_r^{(\lambda)} + \alpha_4 PORJ_r^{(\lambda)} + \alpha_5 INCOM_r^{(\lambda)} + \alpha_6 CDD^{(\lambda)} + \alpha_7 DUM + \alpha_8 QCOF(1)^{(\lambda)} + \varepsilon, \quad (2)$$

where QCOF = per capita (U.S. population ≥16 years) consumption of coffee (green beans basis) in millions of pounds (source: coffee quantity from *USDA-Agricultural Statistics* and relevant coffee drinking population (source: *SUDOCs-Economic Report of the President*, 1989); $PCOF_r$ = retail price of coffee in cents per pound, (sources: *Agricultural Statistics; USDC/BEA - Business Statistics;* and *USDA/ERS - Consumption, Prices and Expenditures*); $PSUG_r$ = retail price of sugar in cents per pound (source: *Agricultural Statistics*); PCOLA = retail price of cola, 72-oz. carton (source: Bureau of Labor Statistics (BLS) Serials Set, House Documents for 1957-1963 data, and 1964-1987 data from *Food Consumption Prices, and Expenditures*); $PORJ_r$ = retail price of 6 oz.-can size of concentrated orange juice (source: *Food Consumption, Prices and Expenditures*); $INCOM_r$ = per capita disposable personal income (source: *Economic Report of the President*, 1989); CDD = U.S. population-weighted annual cooling degree days, with base temperature of 65°F (source: 1957-1984 data from *Historical Climatology* Series #5-2 and the 1985-1987 data were obtained via telephone from National Climatic Data Center, Ashville, NC); DUM = zero-one switching control variable, with 1 for 1958, 1963, 1969, 1972, 1975, and 1985 and 0 otherwise); QCOF(1) is one-period lagged dependent variable used for detecting the strength of habit formation in coffee consumption. Finally, the Box-Cox power transformation of a continuous variable V in specification (2) is such that:

$$V^{(\lambda)} = (V^{\lambda}-1)/\lambda, \text{ for } \lambda \neq 0, \text{ and}$$
$$V^{(\lambda)} = \log V \text{ as } \lambda \to 0 \quad (3)$$

Variables subscripted *r* indicate deflation by all-item CPI, 1982 = 100 (source: *Economic Report of the President*, 1989). Expected signs of parameter estimates are as follows: $\alpha_1 < 0$ (substitution effect of a price change exceeds income effect in absolute values); $\alpha_2 < 0$ (sugar as coffee complement); $\alpha_3 > 0$ (cola as coffee substitute); $\alpha_4 < 0$ (if orange juice is coffee complement) or $\alpha_4 > 0$ (if orange juice is coffee substitute); $\alpha_5 < 0$ (if coffee is inferior) or > 0 (if coffee is a normal commodity); $\alpha_6 < 0$ (as the long term global warming trend, which results in hotter summers and milder winters, may discourage hot coffee consumption); $\alpha_7 < 0$ (as frosts on coffee farms in Brazil during the years 1958, 1963, 1969, 1972, 1975, and 1985 reduced supplies and discouraged consumption through higher market prices); $\alpha_8 > 0$ (as current and lagged consumptions of coffee are expected to be positively correlated due to habit persistence).

Inclusion of some of the regressors in (2) deserves further treatment. First, cola could substitute for coffee as an alternative source of caffeine. Second, orange juice is a beverage which could substitute for coffee at breakfast tables due to trends toward moderating caffeine ingestion (Vanderwater) or which could complement coffee as part of a balanced breakfast. Third, coffee could be inferior, because at consumers' higher income levels, it could be displaced by consumption of substitute drinks, such as alcoholic beverages (Hughes).[5] Fourth, the climatic trend variable CDD replaces the standard time trend variable in previous studies, because the latter is highly correlated in the order of 0.95 with the $INCOM_r$ variable. Population-weighted CDD measures the number of annual cooling degree days when temperatures exceed the 65°F base. Therefore, the long term global warming trend (Herbert) could gradually reduce or moderate the frequency of coffee consumption arising from habit effects. Better still, a low bivariate correlation of about 0.35 between CDD and $INCOM_r$ indicates their independence.

In 1976 and 1986, the United States FDA examined sugar as part of its periodic review of foods. Apart from sugar's tooth decay effects, the FDA has persistently concluded that sugar does not: (i) cause obesity; (ii) cause nutrient deficiencies; (iii) have an adverse effect on human behavior; (iv) cause diabetes; or (v) contribute to cancer or heart disease. A subsequent finding of the American Council on Science and Health is that sugar is safe if consumed in amounts customary in the U.S. for the last 50 years (Pierog). The simultaneous promotion of coffee (by the coffee Development Group) and the multimillion dollar advertising and public relations campaign for promoting the FDA findings on sugar (by the Sugar Association) could be expected to increase sugar use with coffee consumption. Finally, sugar prices are a regressor in Equation (2) for several reasons. First, sugar represents a broader measure of a close complement for coffee compared with the narrowly defined low-calorie artificial sweeteners. Second, of the few potential complements for coffee, only the price of the closest complement needs to be included in the model. This is because prices of complements (or substitutes) are usually highly collinear. Thus, only one of these potential complements is included in the statistical model estimation.

Empirical Results

SHAZAM econometric software (White, *et al.*) was used in the statistical estimation of the models. Coffee demand elasticity estimates and the associated summary statistics of the models generating them are presented in Table 2 (non-habit formation models) and Table 3 (habit persistence models). Each model fitted significantly better than previous research, by capturing in excess of 95 percent (R^2) of the explained variation in the demand for coffee over the 1957-87 period. Moreover, all of the parameter estimates are appropriately signed across specifications; and only two variables ($PCOLA_r$ and CDD, each also correctly signed) are not statistically significant at customary levels across specifications. The goal of this study is to investigate models that yield efficient elasticity estimates. Thus, Appendix Table 1 contains parameter estimates of only such models.

Coffee demand is significantly own-price inelastic across specifications; a result consistent with previous findings on the demand for coffee and for individual food items in general. The estimated Box-Cox λ parameters are negative for non-habit (NHF) and positive in habit formation (HF) models but are not significantly different from zero at the .05 alpha level in the NHF EB-C and HF CB-C models. This suggests a negligible variation in own-price elasticity of demand for coffee as its relative price changes, a finding consistent with a previous NHF quarterly model result by Huang, *et al.* (p. 44) for regular coffee demand. An implication is that little error is introduced by estimating a double-log model in place of either of the Box-Cox NHF transformation models; however, the estimated λ values are significant at the .05 level in the habit formation EB-C and NHF CB-C models.

In this study, sugar is explicitly introduced in the demand for coffee model. Cross-price elasticity estimates across all specifications (Tables 2 and 3) indicate that sugar is a highly significant complement for coffee at the .05 level or better, as expected. Contrary to the study by Huang, *et al.* finding cola a significant complement for coffee, all models reveal cola to be statistically independent of coffee in consumption. The results also indicate the possibility of orange juice as a more reasonable substitute for coffee. Significant substitution (at the .20 level for the NHF models (Table 1) and at the .10 level in models integrating HF (Table 2)) of orange juice for coffee would appear to be reasonable (especially, at the breakfast table) based on a more health conscious population regarding caffeine moderation. Concluding that coffee and orange juice are now substitutes must be done cautiously because testing for taste changes (that is, structural change) is difficult when based on parametric analysis of demand (Chalfant and Alston). This is especially so when one time series is used for

Table 2.
Elasticity Estimates from Alternative Single Equation (non-habit formation, NHF) Specifications of the U.S. Demand for Coffee, 1957-87 (N=31)

Model	1NHF Strictly linear	2NHF Linear log	3NHF Log-linear	4NHF Log-log	5NHF Classic Box-Cox	6NHF Extended Box-Cox
Direct-price elasticity	-.109***	-.166***	-.139***	-.187***	-.147***	-.187***
Cross-price elasticities						
Sugar	-.159***	-.178***	-.163***	-.180***	-.164***	-.180***
Cola	-.038	-.035	-.045	-.034	-.047	-.034
Orange juice	.090*	.104*	.095	.114*	.097*	.115*
Income elasticity	-.553*	-.482***	-.445***	-.388***	-.42***	-.384***

***, and * indicate statistically significant elasticities (computed at mean levels) at the .05 or better, .10, and .20 levels, respectively.

Table 3.
Elasticity Estimates for Alternative Single Equation (Habit-Formation, HF) Specifications of the U.S. Demand for Coffee, 1958-87 (N=30)

Model	1HF Strictly linear	2HF Linear log	3HF Log-linear	4HF Log-log	5HF Classic Box-Cox	6HF Extended Box-Cox
Direct-price elasticity	-.122***	-.161***	-.151***	-.182***	-.145***	-.173***
Cross-price elasticities						
Sugar	-.130***	-.162***	-.135***	-.166***	-.135***	-.159***
Cola	-.007	-.002	-.017	-.009	-.016	-.0085
Orange juice	.104*	.126**	.113**	.138**	.113**	.129**
Income elasticity	-.287**	-.351**	-.192[b]	-.273**	-.196	-.278**
Habit formation elasticity	.384***	.234**	.341***	.176*	.343**	.230**

***, **, and * indicate statistically significant elasticities (computed at mean levels) at the .05 or better, .10, and .20 levels, respectively.
b. Indicates statistically significant RESET, Breusch-Pagan, or the Durbin-Watson test at the .05 level.

estimating the demand equation and testing for changes in tastes. This problem is investigated for red meat demand by Chalfant and Alston.

Income elasticity of demand for coffee is expected to decline with rising incomes. Therefore, the negative estimated Box-Cox λ in the NHF EB-C model suggests a declining positive or rising negative income elasticities of coffee demand. However, given the small numerical magnitude of the estimated λ (= -.03), the income elasticity of coffee demand (-.384) is expected to be fairly constant as incomes rise. These may reflect the consumption saturation effect at high income levels. The estimated λ (=0.26) for the HF EB-C model is positive and significant, indicating a falling negative or rising positive income elasticity of coffee demand of roughly -0.278. Estimated income elasticities of coffee demand are all small, negative, and are highly statistically significant for all the NHF models; however, the statistical significance is reduced (but still significant at the .10 level) for all the HF models, except in the log-linear (3HF) and classic Box-Cox (5HF) specifications with insignificant income elasticities.

Similarity of the statistical significance of specific elasticities across the specifications reported above can be very misleading, because some of these models suffer from one or more kinds of regression misspecification. In what follows, the sequential model-testing methodology discussed earlier is utilized for discriminating among these contending elasticities. The purpose is to find models that yield unbiased and consistent elasticity estimates of the U.S. demand for coffee.

Models 1NHF, 2NHF, 3NHF and 1HF, 2HF, 3HF were rejected by the RESET rule. All of the NHF models (Table 2) are nested in their corresponding HF specifications (Table 3). Contrary to the previous research by Parikh which utilized the HF framework for modelling import demand for coffee, the coefficients (and hence, the elasticities) of lagged coffee demand, QCOF(1), in the HF models are all statistically significant at the .05 level or better in this study. Rejections of all the nested models signal the importance of incorporating habit formation when modelling coffee demand.

In addition, the residuals of about 68 percent of the NHF models were significantly autocorrelated while only the linear variant of the HF models had significantly autocorrelated residuals. None of the models suffered from significant heteroscedasticity (HET), or from non-first order residual autocorrelation processes (NFAC), and only the linear NHF model was rejected based on the likelihood ratio test statistic.[6] Three models (25% of all tested specifications) survived after all test rules were applied. Each surviving model 4HF, 5HF, and 6HF has an adjusted R^2 of 0.971, comparable MSE values, and similar sample maximum log-likelihood values. However, the income elasticity of coffee demand is not significant in model 5HF and the habit effect is not as strong in model 4HF compared with models 5HF and 6HF.[7]

Table 4 classifies the various elasticities of the demand for coffee according to accepted or rejected models. The table also shows significant differences in the estimated elasticities between accepted models and each group of models rejected by RESET and nesting (habit formation rules). Differences in elasticities of the models rejected by RESET and nesting are not as pronounced, however. Table 5 contains long run estimates of the elasticities of coffee demand for each of the three accepted HF models. The results are consistent with the theoretical expectation of larger (absolute values of the) long-run elasticities of demand relative to the respective short run estimates.

Table 4.
Mean Elasticities (short-run) by Model Classification

	Accepted models	Models rejected[a] by RESET	Models rejected[a] by NESTED
Direct-price elasticity	-.168	-.146	-.158
Cross-price elasticities			
Sugar	-.153	-.113	-.120
Cola	-.011	-.059	-.068
Orange juice	.126	.067	.034
Income elasticity	-.249	-.334	-.326

a. Models with significantly autocorrelated residuals were corrected using the iterative Cochrane-Orcutt procedure. Re-estimated elasticities are used in presenting Table 5. Therefore, these elasticities represent those expected to be reported by researchers utilizing the various specifications.

Table 5.
Long Run Mean Elasticities[a] Computed for Accepted Models

Model	4HF (Double-log)	5HF (Classic Box-Cox)	6HF (Extended Box-Cox)
Direct-price elasticity	-0.221	-0.227	0.225
Cross-price elasticities			
Sugar	-0.201	-0.228	-0.206
Cola	0.011	-0.024	-0.011
Orange juice	0.167	0.172	0.166
Income elasticity	-0.331	-0.298	-0.361

a. Computed as short run elasticities divided by (1-a8), given $0 < a8 \leq 1$.

Concluding Comments

The objective of this paper was to investigate which of the commonly estimated specifications of the U.S. demand for coffee specifications yield unbiased and efficient elasticity estimates. A sequential model testing methodology was implemented with the 1957-1987 U.S. time series data, to discriminate between models yielding minimum variance elasticity estimates and those that do not.

The major findings can be summarized as follows. First, while all models had strong explanatory power (high $\bar{R}^2$s) most of the commonly fitted models were rejected as inadequate. All of the non-habit (static) models were rejected. Each surviving model incorporates the dynamic behavior in coffee consumption formalized with the habit formation framework through lagged adjustments of current coffee consumption to the desired long run equilibrium consumption level. The application of economic theory and statistical choice procedures indicates that the double-log, CB-C and E-BC models incorporating habit formation cannot be rejected when modeling the demand for coffee. Second, accepted models produced elasticity estimates which are significantly different from those rejected by RESET and nesting rules. Third, orange juice is found to be a significant substitute, and sugar a significant complement in the consumption of coffee. Fourth, the variable measuring global warming trend (long term climatic change), while appropriately signed, does not strongly affect the demand for coffee.

Several implications of the findings appear to emerge. First, coffee consumption is shown to be significantly characterized by habit formation and hence, past models of coffee demand not explicitly incorporating a measure of habit persistence are misspecified. Second, elasticity estimates of previous studies based on specifications other than the double-log or the extended Box-Cox appear to be misspecified. Third, coffee is a weakly inferior beverage. Therefore, revenues of manufacturers of coffee may be enhanced by creating new products whose consumption will increase with rising levels of income.[8] Moreover, the inelastic demand for coffee would enable producers to enhance their revenues by reducing supply, *ceteris paribus*. Equally important, as real income levels rise in the U.S. consumption of coffee may decrease, since economic theory suggests that the demand for inferior goods fall when incomes rise.

Notes

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1. Changes in the racial mix alone were expected to reduce U.S. coffee consumption by about 0.7 percent between 1980 and 1990 (Salathe, p. 1041). The complex interplay of long term factors tending to reduce coffee consumption include: lifestyle trends, product factors, and population/demographic changes.
2. This assumes relative stability of the long-run coffee demand. Historical shifts in coffee production and supplies to the U.S. arose from the impacts of: (i) stagnating world production, (ii) price speculation in the international

coffee market, (iii) removal in 1953 of the U.S. price supports for coffee, and (iv) significant frosts adversely affecting most Brazilian coffee producing areas for the 1953, 1958, 1963, 1969, 1972, 1975, and 1985 crop years. Particularly, in 1976 the extremely severe 1975 frosts in Brazil increased coffee prices to $3.40 per pound from the 80-cent level. In 1985, drought in Brazil caused low coffee bean production and price rose to $2.97 per pound. In early January of 1986, weather was the leading factor affecting coffee production and prices (Pierog, p. 55).

3. RESET has a greater power in identifying non-zero disturbance means than the FAC test, such as the Durbin-Watson.
4. Habit effects on coffee consumption can be captured in a number of ways; including use of the linear time trend, lagged consumption (flow-adjustments model), and the state adjustments model. The lagged consumption framework is chosen for this study.
5. High correlation of alcohol consumption and income precludes the inclusion of alcohol in models of coffee demand (Hughes, p. 914).
6. Ramsey's RESET is a more powerful test than the Likelihood Ratio when testing for functional form sufficiency in a regression model.
7. In model 5HF, coffee consumption is *more* sensitive to changes in the relative price of sugar, than to changes in its own relative price. This may subject model 5HF to some suspicion.
8. Celestial Seasonings recently created herbal tea. Herbal tea sales doubled in 1982 and increased another 35% in 1983 (*Marketing and Media Decisions*, p. 188). Herbal tea was created in an attempt to reverse the fastly dwindling market for traditional tea demand in the United States. Coffee producers recently announced their intention to market iced coffee in the near future.

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Appendix Table 1.
Parameter Estimates of Accepted Models of the U.S. Demand for Coffee, 1957–1987[a]

	Model		
Regressor	4HF (Double-log)	5HF (Classic Box-Cox)	6HF (Extended Box-Cox)
$PCOF_r$	-0.1817	-12.051	-1.0672
(t-value)	(-3.57)	(-3.44)***	(-3.49)***
$PSUG_r$	-0.1663	-28.345	-1.3655
(t-value)	(-3.53)***	(-3.32)***	(-3.55)***
$PCOLA_r$	-0.0098	-0.8104	-0.00463
(t-value)	(-0.188)	(-0.35)	(-0.170)
$PORJ_r$	0.1375	19.387	0.9652
(t-value)	(1.65)***	(1.64)**	(1.64)**
$INCOM_r$	-0.2735	-2.0089	-1.0038
(t-value)	(-1.94)**	(-1.22)	(-1.93)**
QCOF (1)	0.1758	0.0248	0.2287
(t-value)	(-1.29)*	(2.25)***	(1.66)**
DUM	-0.1181	-0.1043	-0.1925
(t-value)	(-1.87)**	(-1.46)*	(-1.52)*
CDD	-0.181	-0.0001	-0.0545
(t-value)	(-1.13)	(-0.91)	(-1.07)
Constant	1.853	3.0857	-1.7175
(t-value)	(1.33)	(8.27)***	(-0.54)

a. Pertinent summary statistics for each model can be reclaimed from Table 3. Statistical significance of the coefficients at the .05, .10, and .20 are indicated by ***, **, *, respectively.