Consumer Demand and the True Cost-of-Living Index*

Hak-Kil Pyo
Seoul National University

I. Introduction

Since Stone (1954) proposed the linear expenditure system, empirical studies on consumer demand have taken two directions. One was the effort to apply more flexible functional forms and the other was the extension of the linear expenditure system in the dynamic form. Studies by Theil (1965), Barten (1967), Christensen, Jorgenson, and Lau (1975), and Deaton and Muellbauer (1980a) belong to the first category while Stone and Rowe (1958), Pollak and Wales (1969), and Phlips (1972) belong to the latter. The flexible-form approaches have provided us with a less restrictive set of demand functions so that homogeneity and symmetry could be tested explicitly instead of having them as part of the maintained hypotheses. However, the rejection of these hypotheses and the violation of the negativity condition, as have been often the case in studies such as Christensen, Jorgenson, and Lau (1975) and Deaton and Muellbauer (1980a) make it difficult to go beyond testing the theory of demand. For this reason, applied welfare analysis, including areas such as the calculation of cost-of-living index and optimal taxation, has used Stone's system predominantly, despite its restrictive features. This paper follows the latter approach and applies both static and dynamic versions of the linear expenditure system to Korean data (1953-84).

The main purpose of this paper is to provide empirical results of ap-

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plying the linear expenditure system to a developing economy's expenditure data. Most of the empirical demand studies have been confined to advanced countries: Stone (1954) and Deaton and Muellbauer (1980a) for Great Britain, Yoshihara (1969) for Japan, Theil (1965) and Barten (1967) for the Netherlands, Pollak and Wales (1969) and Christensen, Jorgenson, and Lau (1975) for the United States, and Berndt, Darrough, and Diewert (1977) for Canada to cite a few of the numerous studies. However, in recent years there have been increasing number of empirical studies for developing countries: Lluch, Powell, and Williams (1977) for the application of the linear expenditure system in many developing countries, Pollak and Wales (1987) for pooling international consumption data including developing countries, and Ahn, Singh, and Squire (1981) and Kim (1986) for Korea in particular.

Unlike the production sector, in which data such as capital stock is not readily available in most developing countries, consumer-expenditure data is more reliable and is available over a longer period of time so that an empirical study using a developing economy's data is fully warranted and fully possible. In addition, we often find that the magnitudes of both absolute and relative price changes in developing countries are greater than those in advanced countries. For example, according to the data appended in Berndt, Darrough, and Diewert (1977), the price of nondurables in Canada during 1961 and 1971 increased by 28 per cent while the price of Primary (food and beverages) and Secondary (tobacco, clothing, health, and recreation expense) goods in Korea during the same period increased by 4 and 5.6 times respectively. On the other hand, the relative price of Services with respect to Nondurables increased by 25.2 per cent in Canada while it declined by 30 per cent in Korea during the same period. We suspect that the predominant rejection of homogeneity and symmetry in empirical studies using the data of advanced countries could be due to this lack of sufficient variability in relative prices.

After estimating one static version and three dynamic versions of the linear expenditure system, we found that the dynamic versions with varying tastes in committed expenditure satisfy the negativity condition.

Therefore, in a developing economy like Korea where the relative prices and the demand pattern change rather rapidly, the static linear expenditure system derived from the assumption of a time-invariant Stone-Geary utility function may not be a suitable specification for the demand system. Based on estimates of the dynamic versions, Pigou's Law is examined and the true cost-of-living index is generated.

Section 2 summarizes the alternative versions of the linear expenditure system; from this the formula for examining Pigou's Law and the true cost-of-living index are restated. Section 3 presents the estimation results of alternative linear expenditure models. Section 4 examines the implication for Pigou's Law and generates the true cost-of-living index. The last section contains concluding remarks.

II. The Linear Expenditure System: Alternative Versions

The system of demand functions proposed by Stone (1954) takes the following form:

$$p_i x_i = p_i c_i + b_i (y - \sum_{j=1}^{n} p_j c_j) \quad (i=1,\ldots,n) \tag{1}$$

where p_i and x_i are price and quantity of the i^{th} good consumed and y is the total expenditure.

Stone (1954) considered an expenditure function that is linear in prices and income and algebraically imposed the theoretical restrictions of adding up, homogeneity, and symmetry to construct the above demand system. Therefore, these restrictions are not testable in a linear expenditure system that limits the flexibility of the model in testing the theory of demand. It is well known that the direct and the indirect utility function and the expenditure function corresponding to the linear expenditure system are respectively:

$$u(x) = \Pi (x_i - c_i)^{bi} \tag{2}$$

$$v(p,y) = (y - \Sigma p_j c_j) / \Pi p_j^{bj} \tag{3}$$

and

$$e(p,u) = \Sigma p_j c_j + u \Pi p_j^{bj} \tag{4}$$

with the restriction $\sum_{i=1}^{n} b_i = 1$.

As noted in Deaton and Muellbauer (1980b), the concavity of the expenditure function is ensured if the following restrictions hold:

$$b_i \geqslant 0 \text{ and } x_i \geqslant c_i \text{ for all } i \tag{5}$$

which says the total quantity demanded for the i th good must be greater than or equal to the committed quantity of demand. The demand functions derived from constrained utility maximization must satisfy the four fundamental properties: adding up, homogeneity, symmetry, and negativity. Since the linear expenditure system expressed in eq. (1) has already imposed the first three properties, it needs to satisfy only restriction (5) to ensure the negativity property of the Slutsky matrix.

The dynamic extension of the linear expenditure system relaxes the assumption of the time-invariant form of the utility function and changes it into the following form:

$$u^t(x_t) = \Pi (x_{it} - c_{it})^{bit} \tag{6}$$

which implies that the utility function of the representative consumer may change over time. The dynamic version of the linear expenditure system can be derived by resetting parameters b_i and c_i in the static version as follow:

$$b_{it} = b_{oi} + b_i^* T \tag{7}$$

$$c_{it} = c_{oi} + c_i^* T \tag{8}$$

$$b_{it} = b_{oi} + b_i^* T \text{ and } c_{it} = c_{oi} + c_i^* T \tag{9}$$

where T denotes a time index and the restrictions $\sum_{i=1}^{n} b_{oi} = 1$ and $\sum_{i=1}^{n} b_i^* = 0$ must be maintained.

Substituting (7), (8), and (9) into (1) yields the following dynamic version of the linear expenditure system:

$$p_i x_i = p_i c_i + b_{oi} (y - \Sigma p_j c_j) + b_i^* (y - \Sigma p_j c_j) T \tag{10}$$

$$p_i x_i = p_i c_{oi} + b_i (y - \Sigma p_j c_{oj}) + (p_i c_i^* - b_j \Sigma p_j c_j^*) T \tag{11}$$

and

$$p_i x_i = p_i c_{oi} + b_{oi} (y - \Sigma p_j c_{oj}) + b_i^* (y - \Sigma p_j c_{oj}) T + p_i c_i^* - b_{oi} \Sigma p_j c_j^* T + b_i^* \Sigma p_j c_j^* T^2 \tag{12}$$

with the restrictions $\sum_{i=1}^{n} b_{oi} = 1$ and $\sum_{i=1}^{n} b_i^* = 0$.

The basic properties of the linear expenditure system can be examined by deriving the following elasticities from (1):

$$e_{ii} = (1 - b_i) c_i / x_i - 1 \tag{13}$$

$$e_{ij} = -b_i p_j c_j / p_i x_i \quad (i \neq j) \tag{14}$$

$$e_i = b_i / w_i \quad (w_i = p_i x_i / y) \tag{15}$$

which are the own-price elasticity, the cross-price elasticity, and the income elasticity for the i^{th} good respectively. Those formulae need to be changed for the dynamic reformulation of the linear expenditure system by substituting $b_i = b_{io} + b_i^* T$ and/or $c_i = c_{io} + c_i^* T$ into the above formulae. From (13) we can see that if condition (5) is met, the own-price elasticity must be negative ($e_{ii} < 0$). Looking at (14) and (15), we ensure that the possibility of having gross-substitutes ($e_{ij} > 0$) and inferior goods ($e_i < 0$) is ruled out in the linear expenditure system, provided that c_j's are non-negative. However, if c_j is negative, good j is a price-elastic good ($| e_{jj} | > 1$) and good i and good j are gross-substitutes ($e_{ij} > 0$). Phlips (1972) reports negative estimates of c_j for some commodity groups and interprets such goods as the goods for which the committed expenditure does not occur until the total expenditure reaches a certain level.

From the identity between the ordinary and the compensated price elasticities, e_{ij} and e_{ij}^* (Deaton and Muellbauer 1980b, p. 62):

$$e_{ij}^* = e_{ij} + e_i w_j$$

we also derive the following results:

$$e_{ii}^{*} = (1-b_i)(c_i - x_i)/x_i \leqslant 0$$
$$e_{ij}^{*} = -b_j p_j (c_j - x_j)/p_i x_i \geqslant 0$$

provided that condition (5) ($x_i \geqslant c_i$) is satisfied. Therefore, in the linear expenditure system no good can be a Giffen good and two goods are always "net-substitutes".

These are the basic properties of the linear expenditure system that reflect its restrictive feature. However, as Brown and Heien (1972) and Pollak and Wales (1969) point out, if a commodity is disaggregated appropriately and the subcommodity groups are formed properly, then we could overcome these restrictive features and utilize the linear expenditure system in a variety of different ways. Combining equations (13) and (14) together forms the following formula:

$$e_{ij} = \delta_{ij} \phi e_i - e_i w_j - e_i b_j \phi \tag{16}$$

where $\phi = -(y - \Sigma p_j c_j)/y$ and $\delta_{ij} = 0$ for $i \neq j$ and $\delta_{ij} = 1$ for $i = j$. Rewriting (16), the following can be derived:

$$\begin{aligned} e_{ii} &= \phi e_i - e_i w_i - e_i b_i \phi \\ &= \phi e_i - e_i w_i + e_i b_i (y - \Sigma p_j c_j)/y \\ &= \phi e_i - e_i w_i + e_i (p_i x_i - p_i c_i)/y \\ &= \phi e_i - e_i p_i c_i / y \\ &= \phi e_i \text{ (as } w_i \text{ approaches to zero)} \end{aligned} \tag{17}$$

That is, if we ensure enough disaggregation so that w_i, and therefore $p_i c_i / y$ becomes smaller, then a proportionality exists between the own-price elasticity and the income elasticity which the literature refers to as Pigou's Law (Frisch 1959; Deaton 1974). In addition, we can see that if this happens, the cross-price elasticity vanishes as follows:

$$\begin{aligned} e_{ij} &= -e_i w_j - e_i b_j \phi \\ &= -e_i w_j + e_i b_j (y - \Sigma p_j c_j)/y \\ &= -e_i w_j + e_i (p_j x_j - p_j c_j)/y \\ &= -e_i w_j + e_i w_j - e_i p_j c_j / y \\ &= 0 \text{ (as } w_j \text{ approaches to zero)} \end{aligned} \tag{18}$$

It should be noted that as long as the share of committed expenditure of the j^{th} commodity in total expenditure (not necessarily w_j) is negligible, the above results hold. As noted in Deaton (1974) and Deaton and Muellbauer (1980b), these features are due to the additive preferences implied in the Stone-Geary utility function (2) from which the linear expenditure system was derived.

The estimation of a system of demand equations like the linear expenditure system enables us to generate true (i.e. constant utility) cost-of-living indices that permit consumers to substitute in response to relative price changes. Following Muellbauer (1974), a true cost-of-living index that compares prices p_t and p_o is given by:

$$CLI(t) = \frac{e(p_t,\ u)}{e(p_o,\ u)} = \frac{\Sigma c_j p_{jo}}{y_o} \frac{\Sigma c_j p_{jt}}{\Sigma c_j p_{jo}} + \left(1 - \frac{\Sigma c_j p_{jo}}{y_o}\right) \frac{\Pi \left(\frac{p_{it}}{b_i}\right)^{bi}}{\Pi \left(\frac{p_{io}}{b_i}\right)^{bi}} \tag{19}$$

The true cost-of-living index is a weighted average of an arithmetic price index, $\Sigma c_j p_{jt}/\Sigma c_j p_{jo}$, using "committed purchases" as weights and a geometric index, $\Pi(p_{it}/b_i)^{bi}/\Pi(p_{io}/b_{io})^{bi}$, using marginal propensities to consume as weights. The former gives high weights to "necessities" and the latter gives high weights to "luxuries" as noted by Muellbauer (1974). When a dynamic version of the linear expenditure system is estimated, the above formula needs to be modified by substituting $b_i = b_{io} + b_i^* T$ and/or $c_i = c_{io} + c_i^* T$.

III. Estimation Results

We estimated four alternative versions (one static and three dynamic) of the linear expenditure system by using the data on per-capita private consumption expenditure in Korea during the period of 1953-84. The sources of data are National Income Accounts (The Bank of Korea, 1984) and the Economic Statistics Yearbook (The Bank of Korea, 1985). The price index for each commodity group was generated by weighting price deflators of each sub-group by the respective expenditure share. We chose to disaggregate private consumption expenditure by the following five commodity groups:

(1) Primary: Food and Beverages

(2) Secondary: Tobacco, Clothing and other personal effects, Personal care and health expenses, and Recreation and entertainment

(3) Utilities: Fuel and light

(4) Services: Transportation and communication and Miscellaneous services

(5) Dwellings: Furniture, furnishings, and household equipment, Rent and water charges and Household operation expenses

Yoshihara (1969) applied a similar disaggregation. However, he seemed to have defined "primary" in a much narrower sense, probably including only basic food instead of Food total since the actual expenditure share of Primary (0.23) in 1938 shown in his Figure 2 is only half of the actual expenditure share of Food total (0.49) in the same year (Long-term Economic Statistics). He must have put the non-basic food into Secondary since the actual expenditure share of Secondary (0.48) in the same year read from his Figure 3 is unusually large.

The expenditure shares have changed significantly over the sample period, reflecting a rapid structural change in consumer demand in Korea. For example, the share of Primary decreased from 0.55 to 0.37 over the 32 years, while that of Secondary increased from 0.18 to 0.28. Significant price changes also occurred, both in absolute and relative terms. During the period of 1970-84, the prices of most goods and service went up by about seven times. In particular, the relative price rise of Services and Utilities outpaced those of other goods.

The static version of the linear expenditure system (1) was first estimated without restricting coefficients by two-step ordinary least squares estimation methods as done by Stone (1954) and Yoshihara (1969): estimating b_i at the first-step and then estimating c_i at the second-step by

TABLE 1
LINEAR EXPENDITURE SYSTEM: STATIC MODEL
UNRESTRICTED OLS ESTIMATES AND RESTRICTED MLE ESTIMATES

	b_i	c_1	c_2	c_3	c_4	c_5	R^2	b_i	c_i	R^2
Primary	0.242	20.258	−4.840	12.801	0.033	15.549	0.99	0.272	28.575	0.99
	(14.06)	(12.87)	(−0.66)	(4.16)	(0.01)	(2.46)		(28.98)	(47.44)	
Secondary	0.294	2.302	9.399	9.173	12.146	1.888	0.99	0.290	21.737	0.99
	(21.38)	(0.71)	(4.70)	(4.54)	(5.91)	(0.45)		(29.56)	(34.06)	
Utilities	0.049	−9.055	62.460	2.095	−14.243	10.054	0.99	0.058	3.438	0.99
	(8.27)	(−1.08)	(5.04)	(7.73)	(−2.68)	(0.93)		(19.29)	(30.00)	
Services	0.222	38.815	20.756	−14.741	10.527	6.725	0.99	0.218	13.985	0.99
	(15.89)	(8.91)	(3.21)	(−5.42)	(13.39)	(1.20)		(24.66)	(33.10)	
Dwellings	0.193	33.81	0.671	−2.805	27.574	7.815	0.99	0.162	9.524	0.99
	(17.91)	(8.75)	(0.12)	(−1.16)	(11.25)	(6.61)		(36.94)	(26.57)	

Note: The figures in parentheses are t-values.

using the estimates of b_i. As pointed out by Zellner (1962), the resulting estimates are identical to the estimates by the generalized least squares. Table 1 presents these unrestricted estimates. Some estimates of c_i are negative (Yoshihara (1969) also reported a negative c_i), while $\Sigma b_i = 1$ is automatically satisfied as expected.

To impose the constraints that the same parameters in different equations must be the same and that the sum of b_i must be equal to one, we need to estimate the linear expenditure system by either the Zellner method or by maximum likelihood estimation. Following Parks (1971), the maximum likelihood estimation method was applied to each of four versions of linear expenditure system (1), (10), (11), and (12) using a TSP package on the Seoul National University computer. The estimates are presented in Table 1 and 2 which show that the individual equations fit very well with R^2 in excess of 0.99 and that no negative c_i is estimated. However, when we checked condition (5), both the static model and the dynamic model (1) failed to meet the condition that committed demand be smaller than or equal to total demand for every commodity ($c_i \leqslant x_i$). For example, the former failed in almost all observations and the latter failed in pre-1972 years for the Primary equation. Therefore, we base subsequent analysis on the estimates of dynamic model (2) and (3), which satisfied the negativity condition for all commodities throughout the

TABLE 2
LINEAR EXPENDITURE SYSTEM. DYNAMIC MODELS: RESTRICTED MLE ESTIMATES

Model (1)	b_{io}	b_i^*	c_i	R^2	d.w.
Primary	0.313	−0.0044	200,091	0.99	1.81
	(18.99)	(−5.07)	(28.54)		
Secondary	0.374	−0.0076	122,120	0.99	1.39
	(19.71)	(−6.58)	(15.19)		
Utilities	0.053	0.00054	15,303	0.99	1.07
	(5.99)	(1.06)	(10.32)		
Services	0.122	0.0010	59,528	0.99	1.09
	(4.03)	(7.36)	(10.49)		
Dwellings	0.138	0.0011	41,041	0.99	1.09
	(7.86)	(1.13)	(10.70)		

Model (2)	b_i	c_{io}	c_i^*	R^2	d.w.
Primary	0.265	5,857	17,119	0.99	1.79
	(8.68)	(5.29)	(13.16)		
Secondary	0.373	6,300	9,186	0.99	1.59
	(12.08)	(4.03)	(5.26)		
Utilities	0.040	1,316	1,001	0.99	0.95
	(3.55)	(8.67)	(5.28)		
Services	0.85	6,269	3,207	0.99	1.28
	(4.28)	(17.4)	(6.28)		
Dwellings	0.237	3,743	1,848	0.99	0.75
	(9.91)	(3.79)	(1.49)		

Model (3)	b_{io}	b_i^*	c_{io}	c_i^*	R^2	d.w.
Primary	0.313	−0.0049	169,522	4,392	0.99	1.76
	(8.10)	(−1.72)	(28.85)	(9.94)		
Secondary	0.456	−0.0090	86,435	4,428	0.99	2.07
	(13.07)	(−3.33)	(11.82)	(9.87)		
Utilities	0.035	−0.0006	9,721	1,213	0.99	0.86
	(2.49)	(−0.52)	(6.99)	(8.95)		
Services	0.041	0.0024	34,447	5,659	0.99	1.30
	(1.14)	(0.76)	(7.99)	(13.84)		
Dwellings	0.155	0.0142	30,981	258	0.99	1.45
	(8.41)	(8.97)	(11.38)	(1.12)		

Note: The figures in parentheses are t-values.

entire period. The violation of the negativity condition as a result of estimating the linear expenditure system was also found in Pollak and Wales (1969) for the United States data (1948-65) and Theil (1965) for the British data (1900-38). These results suggest that the time-invariant utility function implied in a static linear expenditure system is not a suitable preference representation for a dynamic economy like Korea and that the appropriate dynamic extension can be made by incorporating the changes in tastes, that is, by taking into account the trend in comitted expenditures.

IV. Pigou's Law and the True Cost-of-Living Index

Table 3 presents estimates of own-price elasticities and income elasticities from dynamic model (2) and (3) evaluated at the average expenditure share. It also checks Pigou's Law. Primary has lower own-price elasticities than Secondary in both models. In terms of income elasticities, Primary and Services are categorized as necessities and Secondary and Dwellings as luxuries. Similar results can be obtained from Stone (1954) which used British data from 1920-38. According to the calculations by Deaton and Muellbauer (1980b), the estimated own-price elasticity for Food (meat, fish and dairy, fruit, and vegetable) was −0.4 while that for household operation was −0.6. The estimated income elasticities ranged from 0.7 for meat, fish, and dairy to 1.3 for durable goods and transport. Yoshihara (1969) did not report elasticity estimates, but our approximate calculation of income elasticities at mid point (1930) based on his estimates of b_i ranges from 0.46 for Primary to 1.50 for Secondary and 1.60 for Utilities.

The approximate proportionality between own-price elasticities and income elasticities can be checked by comparing the last two columns in Table 3. It exists for Utilities, Services, and Dwellings while it does not show up for Primary and Secondary. Therefore, we can verify the assertion that Pigou's Law applies to the commodities with smaller expenditure weights; in other words it applies when a more detailed commodity breakdown is made in the linear expenditure system.

Finally we attempted to generate the true (constant utility) cost-of-living indices (CLI) from estimates of dynamic model (2) using formula (19). They are reported in Table 4 together with the Consumer Price Index (CPI), which is often used as a cost-of-living index. It is noted that CPI

TABLE 3
ESTIMATES OF ELASTICITIES AND PIGOU'S LAW

	e_i 1)	e_{ii} 1)	$\phi = e_{ii}/e_i$ 2)	$\phi = (e_{ii} + e_i p_i c_i / y)/e_i$ 3)
Dynamic Model (2)				
Primary	0.55	−0.33	−0.60	−0.16
Secondary	1.41	−0.48	−0.34	−0.12
Utilities	1.02	−0.35	−0.34	−0.32
Services	0.84	−0.44	−0.52	−0.46
Dwellings	2.14	−0.66	−0.31	−0.26
Dynamic Model (3)				
Primary	0.64	−0.38	−0.59	−0.16
Secondary	1.70	−0.57	−0.34	−0.13
Utilities	0.88	−0.36	−0.41	−0.38
Services	0.42	−0.38	−0.90	−0.84
Dwellings	1.47	−0.42	−0.29	−0.21

Notes: 1) Estimates of elasticities evaluated at average expenditures
2) Estimated by using the fourth equation in eq. (17)
3) Estimated by using the last equality in eq. (17)

TABLE 4
THE TRUE COST-OF-LIVING INDEX (CLI) AND CPI

	(1)	(2)	(3)	(4)
year	$\frac{\Sigma c_j p_{jt}}{\Sigma c_j p_{jo}}$	$\Pi \left(\frac{p_{it}}{p_{io}}\right)^{b_i}$	CLI	CPI
1960	0.007	0.033	0.009	n.a
1965	0.034	0.077	0.038	n.a
1970	0.087	0.134	0.091	0.222
1975	0.321	0.396	0.327	0.452
1980	1.000	1.000	1.000	1.000
1984	1.540	1.318	1.522	1.376

Notes: 1) (3) CLI are computed by weighting (1) with the weight .92, which is the share of committed expenditure in the base year (1980) and by weighting (2) with the remainder .08.
2) CPI is from Report on Monthly Labor Survey (Ministry of Labor, 1985/1)

consistently underestimates the true cost of living throughout the entire period. As can be seen from the first two columns,the arithmetic price index ($\Sigma c_i p_{it} / \Sigma c_i p_{io}$) which gives "necessities" higher weights is higher than the geometric price index ($\Pi(p_{it}/p_{io})^{b_i}$) which gives "luxuries" higher weights. Since the weight ($\Sigma c_j p_{jo}/y_O$) for the former in base year 1980 was 0.92, which is much higher than the weight ($1-\Sigma c_j p_{io}/y_o = 0.08$) for the latter, the true cost-of-living index (CLI) reflects heavily the price increase in "necessities" as it should.

V. Concluding Remarks

In this paper, we applied four alternative models of the linear expenditure system to estimate consumer expenditure patterns in Korea during the period of 1953-84. We noted that both the expenditure shares and the price indices of various commodities have changed more significantly during the period than those observed in many advanced countries. These significant changes allowed dynamic versions of the linear expenditure system which accounted for the change in tastes, particularly in committed expenditures, to perform better than its static version.

The estimated own-price and income elasticities are similar to those estimated from advanced countries, and Pigou's Law seems to apply to commodity groups with smaller expenditure weights. We also estimated the true cost-of-living index by utilizing estimates from a dynamic version of linear expenditure system. When compared to Consumer Price Index (CPI), we found that the CPI would consistently underestimate the true cost of living throughout the period.

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