

## **Study on Taiwan Consumers' Cost of Living: An Application of the Additive Törnqvist Price Index Formula**

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### **ABSTRACT**

According to the estimates from the additive Törnqvist price index formula, Taiwan consumers' true cost of living grew by 29.93% with an average yearly growth rate of 1.76% during the 1991-2006 period. Nearly 85% of the total growth of cost of living derived mainly from seven commodity groups. In particular, supplementary food had made the largest contribution to the growth of cost of living over the period was because its price had increased by as high as 53.42%, and Taiwan consumers had spent around one-tenth of their total income on it. Compared with the estimates from Törnqvist price index, the Laspeyres price index had overestimated the growth of Taiwan consumers' cost of living in yearly average by 0.1 percentage points (ppts) over the sample period; the resulting substitution bias was mainly due to six commodity groups that had significant price changes. Based on our study, we would like to suggest that the Price Statistics Department in Taiwan consider compiling and publishing an alternative consumer price index (CPI) using the Törnqvist price index in Taiwan.

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*Keywords:* Törnqvist price index; Konyus cost of living index; Substitution bias; Laspeyres price index

## I. INTRODUCTION

There are very few empirical studies on Taiwan consumers' cost of living; however, the issue is becoming increasingly important in Taiwan because many economic and social welfare policies already include escalator clauses related to cost of living in order to take the impact of inflation on consumers' real purchasing power into consideration.<sup>1</sup> Normally, the escalator clauses only use the officially published Consumer Price Index (CPI) as the basis for adjustments due to changes in the cost of living in Taiwan. Since the CPI, which is computed with the Laspeyres index formula, uses consumers' base-period commodity expenditure shares as the aggregate weights and fails to consider consumer optimal choice behavior, it will over-estimate consumers' cost of living and produce a "substitution bias"<sup>2</sup> into the measurement (Braithwait, 1980; Manser & McDonald, 1988).<sup>3</sup> Hence, the current approach would not only distort the distribution of income but would consequently also aggravate economic inequality in Taiwan.

In this paper, we have utilized the Törnqvist price index, in particular, with an additively decomposed formula suggested by Reinsdorf et al. (2002) to measure the growth level of Taiwan consumers' cost of living over the period of 1991-2006. Using the Törnqvist price index to measure consumers' cost of living standards has many advantages. First and most importantly, Diewert (1976) has shown that the Törnqvist price index approximates to the second order of the underlying Konyus true cost of living index (Konyus, 1924); hence, by using the Törnqvist price index instead of the Laspeyres price index one can avoid the problem of substitution bias. Additionally, with the Törnqvist price index, the cost of living can be directly calculated using consumers' commodity expenditure shares and price ratio data without involving complicated econometric methods for estimating the related demand function parameters necessary to compute the corresponding Konyus true cost of living index (Jorgenson & Slesnick, 1999). Furthermore, unlike the econometric method, the calculations of the Törnqvist price index are not limited to broad aggregated commodity groups.

The adoption of an additively decomposed Törnqvist price index formula has two purposes. First, it allows us to identify and evaluate the contribution of each commodity group to the total growth of Taiwan consumers' cost of living over the study period. In many practical applications, we are not interested in merely knowing by how much the level of consumers' cost of living has grown; we might want to go a step further to know how much each commodity group has contributed to the total growth in the cost of living and why some commodity groups have made higher contributions than others. In this study, we found that nearly 85% of the total growth of cost of living derived mainly from seven commodity groups, these being supplementary food (5.35 ppts), medical care services (4.89 ppts), educational expense (4.31 ppts), residential rent (4.30 ppts), fruits (2.48 ppts), oil and related services (1.99 ppts) and food away from home (1.98 ppts). The above findings may provide useful information for governmental officials. For example, in order to avoid the rapid growth in Taiwan consumers' cost of living, it would be more effective for the government to try to control the price increases of the commodity groups mentioned above than the others. We went on to use the Laspeyres price index to measure Taiwan consumers' cost of living. By comparing the estimates obtained from the Laspeyres price index with those from the additively decomposed Törnqvist price index formula, we can not only estimate the level of substitution bias and evaluate the appropriateness of using the Laspeyres price index to

measure Taiwan consumers' cost of living over the sample period; we can also further investigate the composition of the substitution bias. In this study, we found that substitution behavior occurred to most commodity groups over the study period. In particular, strong substitution effects appeared in six commodity groups whose prices had experienced significant changes, these being supplementary food, fruits, educational expense, communication fees, personal care services, and main food.

In the following section, we explain why the Törnqvist price index would approximate to the true economic cost of living index, and then derive its corresponding additive decomposition formula following the approach of Reinsdorf et al. (2002). In Section III, we first describe the data used for computing Taiwan consumers' cost of living over the period of 1991-2006, and then analyze our empirical results. Our analysis focuses on explaining the growing sources or contributing factors of Taiwan consumers' cost of living over the period of 1991-2006. In addition, we also use the Laspeyres price index to measure Taiwan consumers' cost of living and investigate the level and composition of substitution bias over this period through comparison with the estimates from the Törnqvist price index. In Section IV, we summarize our major empirical findings and suggest that the Price Statistics Department in Taiwan start to compile and publish an alternative consumer price index using the Törnqvist price index.

## II. TÖRNQVIST PRICE INDEX AND CORRESPONDING ADDITIVE DECOMPOSITION FORMULA

Tremendous progress has been made in the field of economic price index number theory<sup>4</sup> in the last few decades (Samuelson & Swamy, 1974; Diewert, 1981). In particular, since Diewert (1976, 1978) developed the "superlative index number theory," it has become popular for economists to use superlative price indexes to measure and analyze consumers' cost of living standards<sup>5</sup> (Manser & McDonald, 1989; Aizcorbe & Jackman, 1993; Sharpiro & Wilcox, 1996; Cage & Jackman, 1997; Blow & Crawford, 2001).<sup>6</sup> Diewert (1976) defined a price index as superlative if it is exact for a "flexible" (unit) expenditure function  $c$ , where a "flexible" (unit) expenditure function  $c$  means that it is capable of providing a second-order approximation to an arbitrary twice differential (unit) expenditure function at any point in its domain.

Diewert (1976, p.122) showed that if the reference utility level is chosen to be  $u^* = (u^0 * u^1)^{1/2}$ , the geometric mean of period 0 and period 1 utility levels, then the following Törnqvist price index  $P^T(P^1, P^0, Q^1, Q^0)$ ,

$$P^T(P^1, P^0, Q^1, Q^0) \equiv \prod_i \left( \frac{p_i^1}{p_i^0} \right)^{(s_i^0 + s_i^1)/2} \quad (1)$$

which is a geometric average mean of price ratios with weights equal to  $(s_i^0 + s_i^1)/2$ , where  $s_i^t$  represents the expenditure ratio for commodity  $i$  at period  $t$ ,  $t=0&1$ , is a superlative index number formula. Because it is exactly equal to Konyus true cost of living index (Konyus, 1924), i.e.,

$$P^T(P^1, P^0, Q^1, Q^0) = P^K(P^1, P^0, u^*) = \frac{c(p^1, u^*)}{c(p^0, u^*)}, \quad (2)$$

where the  $c(P, u)$  has the “flexible” general translog functional form,

$$\ln c(P, u) = \alpha_0 + \sum \alpha_i \ln p_i + (1/2) \left( \sum_i \sum_j \alpha_{ij} \ln p_i \ln p_j \right) + \beta_0 \ln u + \sum_i \beta_i \ln p_i \ln u + (1/2) \beta_{00} (\ln u)^2;$$

where  $\ln$  is the natural logarithm function and the parameter  $\alpha_i$ ,  $\alpha_{ij}$ , and  $\beta_i$  satisfying the following restrictions:

$$\sum_i \alpha_i = 1; \alpha_{ij} = \alpha_{ji}, \forall i, j; \sum_j \alpha_{ij} = 0; \sum_i \beta_i = 0.$$

Furthermore, it can be shown that  $c(P, u)$  can provide a second-order Taylor series approximation to an arbitrary cost function.<sup>7</sup>

However, when using the geometric Törnqvist price index formula (see Eq. (1)) to estimate consumers’ cost of living, one is unable to directly identify the exact contribution of each individual commodity group to the total growth of the consumer’s cost of living due to its non-additive index formula. Reinsdorf et al. (2002, p.55) have recently proved that any geometric mean index of price ratio  $P^{\sigma_i}(P^1, P^0, Q^1, Q^0)$  can be rewritten as the following additive formula:<sup>8</sup>

$$P^{\sigma_i}(P^1, P^0, Q^1, Q^0) = \Pi_i \left( \frac{P_i^1}{P_i^0} \right)^{\sigma_i} = \Sigma_i \frac{P_i^1 \sigma_i / m(P_i^1, P^{\sigma_i} P_i^0)}{\Sigma_j P_j^0 \sigma_j / m(P_j^1, P^{\sigma_j} P_j^0)} = \Sigma_i s_i \sigma_i \left( \frac{P_i^1}{P_i^0} \right) \quad (3)$$

where  $P^t$  and  $Q^t$  are the corresponding price and quantity vectors; the logarithmic mean function,  $m(a, b)$  is defined for positive  $a$  and  $b$  as  $(a-b)/(\log a - \log b)$ , or as  $a$  if  $a = b$ ; and where the additive weight

$$s_i \sigma_i = \frac{P_i^0 \sigma_i / m(P_i^1, P^{\sigma_i} P_i^0)}{\Sigma_j P_j^0 \sigma_j / m(P_j^1, P^{\sigma_j} P_j^0)}, \quad i = 1, 2, \dots, n.$$

Then, if we let  $\sigma_i = (s_i^0 + s_i^1)/2$ , the above Törnqvist price index formula (Eq. (1)) can be expressed alternatively as follows:

$$P^T(P^1, P^0, Q^1, Q^0) = \Pi_i \left( \frac{P_i^1}{P_i^0} \right)^{(s_i^0 + s_i^1)/2} = \Sigma_i \frac{P_i^1 \left( (s_i^0 + s_i^1)/2 \right) / m(P_i^1, P^T P_i^0)}{\Sigma_j P_j^0 \left( (s_j^0 + s_j^1)/2 \right) / m(P_j^1, P^T P_j^0)} = \Sigma_i s_i^T \left( \frac{P_i^1}{P_i^0} \right), \quad (4)$$

where the additive weight

$$s_i^T \equiv \frac{\left(\frac{s_i^0 + s_i^1}{2}\right) / m(p_i^1, P^T p_i^0)}{\sum_j \left(\frac{s_j^0 + s_j^1}{2}\right) / m(p_j^1, P^T p_j^0)}, i = 1, 2, \dots, n.$$

According to Eq. (4), the contribution of individual commodity group  $i$  to the level of the consumers' cost of living is determined by its corresponding aggregate weight  $s_i^T$  which is stated in terms determined by the average expenditure share that consumers have spent on it between the base and the current period together with price ratio ( $P_i^1/P_i^0$ ). Therefore, a commodity group would contribute more to the total growth in the cost of living if it had a larger increase in its price level and consumers had spent more of their income on it. In the next section, our empirical analysis is based on the above transformed additive form of the Törnqvist price index formula.

We will also use the following Laspeyres price index formula to measure Taiwan consumers' cost of living over this period.<sup>9</sup> By comparing these results with the estimated results from the transformed Törnqvist price index, we will be able to evaluate the appropriateness of using the Laspeyres price index to measure Taiwan consumers' cost of living.

$$P^L(P^1, P^0, Q^1, Q^0) = \frac{\sum_i P_i^1 q_i^0}{\sum_i P_i^0 q_i^0} = \sum_i s_i^0 \left( \frac{P_i^1}{P_i^0} \right), \quad (5)$$

where the additive weight

$$s_i^0 \equiv \frac{P_i^0 q_i^0}{\sum_i P_i^0 q_i^0}.$$

### III. EMPIRICAL RESULTS AND ANALYSIS

To calculate both the Törnqvist and Laspeyres price indexes used in the following empirical analysis, data on both Taiwan consumers' expenditure shares and prices are required. Data on commodity expenditure shares are taken from "The Survey of Family Income and Expenditure in Taiwan Area of the Republic of China, 1991 through 2006." The survey data, which includes expenditure data for more than 50 commodity groups, is on magnetic tape available from the Directorate-General of Budget, Accounting and Statistics (DGBAS), Executive Yuan, the Republic of China. For a detailed explanation about the number of sample household units and commodity groups contained in each survey year, please see APPENDIX 1. Data for  $P_{it}$  are from "The Monthly Commodity-Price Statistics in Taiwan Area of the Republic of China, 1991-2006 (1996=100), which includes price data for 42 commodity groups. This bulletin is also published by the DGBAS. Because of the somewhat different classifications of commodity groups in these two separate sets of data, we had to reclassify the data into 29 commodity groups in order to come up with a corresponding match for expenditure shares and commodity prices.

**Table 1**  
Consumer price indexes for 29 commodity groups in Taiwan area, 1992-2006  
(1991 = 100)

Commodity groups	1992	1996	2001	2006	Growth rate (%) (1991-2006)
1.Main food	100.94	116.86	122.19	131.62	31.62
2.Supplementary food	111.10	134.30	133.28	153.42	53.42
3.Fruits	125.90	173.28	178.43	204.66	104.66
4.Dairy	101.17	105.34	114.73	120.58	20.58
5.Alcoholic	99.59	104.30	114.72	174.13	74.13
6.Non-alcoholic	102.31	105.70	102.85	112.35	12.35
7.Food away from home	103.11	117.23	126.80	129.76	29.76
8.Garments	101.60	102.63	96.34	97.29	-2.71
9.Footwear	100.83	99.98	87.74	88.72	-11.28
10.Apparel services and accessories	98.57	110.79	104.29	112.84	12.84
11.Residential rent	104.30	120.55	124.51	121.50	21.50
12.Maintenance and repairs	103.67	126.66	120.53	128.34	28.34
13.Household appliances	100.11	108.47	102.28	97.54	-2.46
14.Household keeping services	104.70	132.05	152.36	150.38	50.38
15.Water, electricity and gas supply	102.01	107.71	114.47	122.44	22.44
16.Transportation equipment	97.86	100.90	96.12	88.14	-11.86
17.Oil, parts and related services	99.07	102.54	116.91	138.79	38.79
18.Transportation fees	100.33	121.98	137.14	140.05	40.05
19.Communication fees	100.77	97.08	85.63	78.79	-21.21
20.Medical care services	107.04	114.77	137.51	166.11	66.11
21.Medicines and health food	103.08	109.64	113.76	120.31	20.31
22.Medical supplies and appliances	99.19	100.40	86.10	79.46	-20.54
23.Educational expense	107.12	143.27	172.94	173.44	73.44
24.Entertainment expense	101.42	106.77	106.77	101.40	1.40
25.Tobacco	100.09	104.38	106.78	145.94	45.94
26.Cosmetic items	99.34	102.21	102.28	99.61	-0.39
27.Personal care services	106.52	137.93	153.86	155.81	55.81
28.Wedding and funeral expense	101.23	112.02	124.15	122.05	22.05
29.Others	102.63	109.30	114.20	112.91	12.91
Average	104.46	119.62	124.47	129.55	29.55

Note: In the table we have only reported consumer price indexes for 29 commodity groups of every-five year over the study period. The consumer price indexes of all years are available from the authors upon request.  
Data source : Commodity-Price Statistics Monthly in Taiwan Area of the Republic of China

As seen in Table 1, the price levels of 22 out of 29 commodity groups in Taiwan over the period of 1991-2006 show increasing trends. Among them, price levels of seven commodity groups have increased more than 50% over the study period, these being the fruits (increased by 104.66%), the alcoholic (74.13%), the educational expense (73.44%), the medical care services (66.11%), the personal care services (55.81%), the supplementary food (53.42%), and the household keeping services (50.38%); next, except for four commodity groups i.e. the tobacco (increased by 45.94%), the transportation fees (40.05%), the oil and related services (38.79%) and the main food (31.62%), the price levels of all other commodity groups had increased less than 30% over the study period, ranging from 29.76% (for the food away from home) to 1.40% (for the entertainment expense). In general, the price levels of the service groups grew faster than those of the goods groups in Taiwan over this period. In addition, price levels of both the alcoholic and the tobacco had increased significantly mainly because of the change of tax systems imposed on them in 2002. At the same time, there are seven commodity groups whose price levels showed a declining trend over this period, four of which had price levels decreased by more than 10%. In particular, price levels of both the communication fees and the medical supplies and appliances had decreased more than 20%, -21.21% and -20.54%, respectively. Price levels of both the transportation equipment and the footwear had decreased by around 11%. The reduction of import tariff is one of the main causes for the reduction of price levels of most of the manufacturing commodity groups, e.g. the medical supplies and appliances and the transportation equipment. Furthermore, the deregulation of the telecommunications industry during this period accounted for the significant decline in price level of communication fees in Taiwan.

First, according to the Törnqvist price index computed by the additive Eq. (4), Taiwan consumers' cost of living had increased 29.93% with a yearly (compound average) growth rate of 1.76% over the period of 1991-2006 (1991=100), (see Table 2). If the Laspeyres price index were used instead, it would show that the level of Taiwan consumers' cost of living had increased by 31.89% with a yearly growth rate of 1.86% over the period of 1991-2006 (see Table 2). Comparison with the estimates from the Törnqvist price index shows that the Laspeyres price index had overestimated the total growth of Taiwan consumers' cost of living by 1.96 percentage points (or ppts), or by a yearly average by 0.1 ppts over the same period. This level of overestimated substitution bias obtained using the Laspeyres price index is consistent with previous studies in the literature. Recently, Reinsdorf and Triplett (2004) reviewed the BLS research on substitution bias against the Laspeyres price index and concluded that "... these studies show that a COLI (Cost of Living Index) computed from an approximation to the true utility function suggests a small amount of substitution bias, on the order of 0.1 – 0.2 points per year." (See Reinsdorf & Triplett, 2004, pp. 24-27; Moulton, 1996)

**Table 2**  
Estimates of Taiwan consumers' cost of living based on  $P^T$  and  $P^L$ , 1991-2006

Year	Törnqvist price index ( $P^T$ )		Laspeyres price index ( $P^L$ )	
	Index (1991=100)	Yearly growth rate (%)	Index (1991=100)	Yearly growth rate (%)
1991	100	-	100	-
1992	104.59	4.59	104.76	4.76
1993	107.49	2.77	107.82	2.92
1994	111.49	3.72	112.30	4.15
1995	115.40	3.51	116.48	3.73
1996	118.70	2.85	119.99	3.01
1997	119.89	1.00	121.03	0.87
1998	122.06	1.81	123.76	2.25
1999	122.32	0.22	123.82	0.05
2000	123.98	1.36	125.42	1.28
2001	124.04	0.05	125.32	-0.07
2002	123.26	-0.63	124.42	-0.72
2003	123.35	0.07	124.18	-0.20
2004	125.58	1.81	126.99	2.26
2005	128.91	2.65	131.25	3.36
2006	129.93	0.79	131.89	0.49
Annual compound growth rate (%)		1.76%		1.86%

We move on now to analyze the contribution of each commodity group to the total growth of Taiwan consumers' cost of living over the study period. From the additive decomposition results listed in Table 3, we find that according to the estimates computed by the Törnqvist price index there are seven commodity groups whose contributions to the estimated total growth of Taiwan consumers' cost of living over this period (1991-2006) are all greater than 1.9 ppts. These are supplementary food (5.35 ppts), medical care services (4.89 ppts), educational expense (4.31 ppts), residential rent (4.30 ppts), fruits (2.48 ppts), oil and related services (1.99 ppts) and food away from home (1.98 ppts). Together their contributions to the estimated total growth of Taiwan consumers' cost of living amount to 25.30 ppts or around 85% of the total growth level. The individual contributions of the remaining 22 commodity groups to the estimated total growth of the cost of living over this period are all much smaller in comparison with the above seven commodity groups, ranging from 0.85 ppts (for water, electricity and gas supply) to -0.57 ppts (for communication fees).

**Table 3**  
The additive decomposition of total growth rate of Taiwan consumers' cost of living  
(1991-2006) based on  $P^T$  and  $P^L$

Commodity groups	Price growth rate (1991-2006)	Törnqvist price index ( $P^T$ )		Laspeyres price index ( $P^L$ )		Substitution Bias	
		$S_i^T$	components (3)=(1)*(2)	$S_i^0$	components (5)=(1)*(4)	$S_i^0 - S_i^T$ (6)=(4) - (2)	components (7)=(5) -(3)
1.Main food	31.62	2.47	0.78	3.38	1.07	0.91	0.29
2.Supplementary food	53.42	10.02	5.35	13.54	7.23	3.52	1.88
3.Fruits	104.66	2.37	2.48	3.62	3.79	1.25	1.31
4.Dairy	20.58	1.12	0.23	1.16	0.24	0.04	0.01
5.Alcoholic	74.13	0.46	0.34	0.6	0.44	0.14	0.10
6.Non-alcoholic	12.35	1.57	0.19	1.58	0.20	0.01	0.00
7.Food away from home	29.76	6.66	1.98	5.87	1.75	-0.79	-0.23
8.Garments	-2.71	4.20	-0.11	4.98	-0.13	0.78	-0.02
9.Footwear	-11.28	1.15	-0.13	0.97	-0.11	-0.18	0.02
10.Apparel services and accessories	12.84	0.74	0.09	0.89	0.11	0.15	0.02
11.Residential rent	21.50	20.00	4.30	20.04	4.31	0.04	0.01
12.Maintenance and repairs	28.34	1.16	0.33	1.3	0.37	0.14	0.04
13.Household appliances	-2.46	3.09	-0.08	3.15	-0.08	0.06	-0.00
14.Household keeping services	50.38	1.10	0.55	1.19	0.60	0.09	0.05
15.Water, electricity and gas supply	22.44	3.77	0.85	4.04	0.91	0.27	0.06
16.Transportation equipment	-11.86	2.29	-0.27	2.46	-0.29	0.17	-0.02
17.Oil, parts and related services	38.79	5.12	1.99	3.94	1.53	-1.18	-0.46
18.Transportation fees	40.05	1.31	0.53	1.61	0.64	0.30	0.12
19.Communication fees	-21.21	2.67	-0.57	1.03	-0.22	-1.64	0.35
20.Medical care services	66.11	7.39	4.89	4.24	2.80	-3.15	-2.08
21.Medicines and health food	20.31	1.14	0.23	0.99	0.20	-0.15	-0.03

**Table 3 (continued)**

22. Medical supplies and appliances	-20.54	0.35	-0.07	0.24	-0.05	-0.11	0.02
23. Educational expense	73.44	5.87	4.31	6.37	4.68	0.50	0.36
24. Entertainment expense	1.40	6.77	0.09	6.45	0.09	-0.32	-0.00
25. Tobacco	45.94	1.01	0.47	1.27	0.58	0.26	0.12
26. Cosmetic items	-0.39	1.94	-0.01	1.6	-0.01	-0.34	0.00
27. Personal care services	55.81	1.32	0.74	1.67	0.93	0.35	0.19
28. Wedding and funeral expense	22.05	0.72	0.16	0.76	0.17	0.04	0.01
29. Others	12.91	2.21	0.29	1.05	0.14	-1.16	-0.15
Total growth rate, 1991-2006			29.93		31.89		1.96

According to Eq.(4), the amount which a commodity group contributes to growth in the cost of living will be determined together by how much its price has increased over the period, and its aggregate weight, which depends on the consumers' average expenditure shares on that commodity group between the base and the current periods. By examining the price increases and the corresponding aggregate weights (and the average expenditure shares) of all commodity groups, we notice that both the price increases and the corresponding aggregate weights of the above seven commodity groups were in general all much larger than the averages of all commodity groups. In particular, we find that the reason supplementary food made the largest contribution to the growth of cost of living over the period was because its price had increased by as high as 53.42%, and Taiwan consumers had spent around one-tenth of their total income on it. Similarly, both the medical care services and the educational expense had made the second and third largest contributions to the growth of cost of living for the same reason. The prices of the medical care services and the educational expense had increased by 66.11% and 73.44%, respectively; and Taiwan consumers had also spent a lot of their income on them, the aggregate weights for the medical care services and the educational expense were 7.39% and 5.87%, respectively. The price of the fruits had increased by 104.66%, the highest among all the commodities and was nearly twice of that of the supplementary food, however since its aggregate weight was about one-fourth of the latter, its contribution to the growth of the cost of living was only 2.48 ppts, about half of the contribution made by the supplementary food. The prices of the alcoholic, the personal care services and the household keeping services had all increased more than 50%, higher than that of most of commodity groups over the period, but their corresponding aggregate weights were all less than 1%. In other words, Taiwan consumers had spent relatively much less of their income on them, hence, their contributions to the overall growth in the cost of living were all less than 1 ppts, ranging from 0.74 ppts (for the personal care services ) to 0.34 ppts (for the alcoholic)

(see also tobacco and transportation fees).

On the other hand, although the price of the residential rent had only increased by 21.5%, its contribution to the growth in the cost of living was 4.3 ppts and was almost as large as that of the educational expense, mainly because Taiwan consumers had spent more than one-fifth of their total income on it over the study period. Similar to the residential rent, the prices of the oil and related services and the food away from home had increased moderately by 38.79% and 29.76%, however both had also made significant contributions to the growth of cost of living due to that Taiwan consumers had also spent relatively more of their income on them, and the aggregate weights for the oil and related services and the food away from home were 5.12% and 6.66%. Although the aggregate weight for the entertainment expense is 6.77%, which was even higher than that of the food away from home, however its price level had only increased by 1.4%, hence its contribution to the total growth of cost of living was only 0.09 ppts over the study period.

We further examine the composition of substitution bias through comparison of the contribution of each commodity group to the overall growth in the cost of living estimated from both the Laspeyres price index and the additive Törnqvist price index formulas. In general, we find that the substitution behavior did occur to most commodity groups with significant price changes over the study period (see Table 3, column (8)). In particular, strong substitution effects appeared in the following six commodity groups: supplementary food, fruits, educational expense, communication fees, main food, and, personal care services. Five of them had prices increased significantly above the average (29.55%, see Table 1), these five being fruits (price increased by 104.66%), educational expense (73.44%), personal care services (55.81%), supplementary food (53.42%), and main food (31.62%); the price for communication fees had decreased the most, by -21.21%. Without having taken the substitution effects caused by the above six commodity groups into consideration, Taiwan consumers' cost of living would have been overestimated by 4.38 ppts according to the Laspeyres price index over the study period. In particular, the contributions of supplementary food and fruits to the growth of Taiwan consumers' cost of living had been overestimated by the Laspeyres index by 1.88 ppts and 1.31 ppts, respectively.

On the other hand, the prices of medical care services and oil and related services had increased more than the average level over the sample period; nevertheless, Taiwan consumers had increased, rather than decreased, their shares of expenditure on them. As a result, according to the Laspeyres price index, these two commodity groups together had underestimated Taiwan consumers' cost of living by 2.54 ppts in comparison with estimates made by the Törnqvist price index; in particular, medical care services alone had underestimated Taiwan consumers' cost of living by 2.08 ppts over the sample period. One possible explanation might be that Taiwan consumers' preference on these commodity groups may have changed over the study period.

#### IV. CONCLUSIONS

In this paper we have utilized the additive Törnqvist price index formula to analyze the growth of Taiwan consumers' cost of living and its contributing factors over the period of 1991-2006. In addition, we have also evaluated the appropriateness of using the Laspeyres price index to measure Taiwan consumers' cost of living over this period. We

have reached the following important conclusions.

First of all, according to the estimates from the Törnqvist price index, Taiwan consumers' true cost of living had grown 29.93% over the period of 1991-2006 (1991=100) with an average yearly growth rate of 1.76%. Furthermore, we found that nearly 85% of the total growth of cost of living derived mainly from seven commodity groups, these being supplementary food (5.35 ppts), medical care services (4.89 ppts), educational expense (4.31 ppts), residential rent (4.30 ppts), fruits (2.48 ppts), oil and related services (1.99 ppts) and food away from home (1.98 ppts). The main reason was that both the price increases and the corresponding aggregate weights of the above seven commodity groups were in general all much larger in comparison with the average of all commodity groups over this period. In particular, supplementary food had made the largest contribution to the growth of cost of living over the period because its price had increased by as high as 53.42%, and Taiwan consumers had spent around one-tenth of their total income on it. Similarly, both the medical care services and the educational expense had made the second and third largest contributions to the growth of cost of living for the same reason. The price of the fruits had increased by 104.66%, the highest among all the commodities, and was nearly twice of that of the supplementary food, however since its aggregate weight was about one-fourth of the latter, its contribution to the growth of the cost of living was only 2.48 ppts, about half of the contribution made by the supplementary food. The individual contributions of the remaining 22 commodity groups to the estimated total growth of the cost of living over this period are all much smaller in comparison with the above seven commodity groups, ranging from 0.85 ppts (for water, electricity and gas supply) to -0.57 ppts (for communication fees).

Next, a comparison of the Törnqvist and Laspeyres price index estimates suggests that the Laspeyres price index had overestimated the growth of Taiwan consumers' cost of living by 1.96 ppts or in yearly average by 0.1 ppts over the sample period. The above finding is consistent with previous studies in the literature (see Reinsdorf & Triplett, 2004; Moulton, 1996). Without having taken the substitution effect caused by the price changes into consideration, six commodity groups, whose prices had changed significantly over the period, had together overestimated Taiwan consumers' cost of living by 4.38 ppts, according to the Laspeyres price index; in particular, in the supplementary food and fruits, the Laspeyres price index had overestimated Taiwan consumers' cost of living by 1.88 ppts and 1.31 ppts, respectively. On the other hand, the prices of medical care services and oil and related services had increased more than the average level over the study period; nevertheless, Taiwan consumers had increased, rather than decreased, their shares of expenditure on them. As a result, according to the Laspeyres price index, these two commodity groups together had underestimated Taiwan consumers' cost of living by 2.54 ppts in comparison with estimates made by the Törnqvist price index; in particular, medical care services alone had underestimated Taiwan consumers' cost of living by 2.08 ppts over the sample period. One possible explanation might be that Taiwan consumers' preference on these commodity groups may have changed over the study period.

Following the suggestion of the well-known Boskin Commission Report (1996, p. iii), which had recommended "that the CPI (Consumer Price Index) should move toward a COLI (Cost Of Living Index) concept by adopting a "superlative" index formula to account for the changing market baskets,"<sup>10</sup> in August of 2002, the U.S.

Bureau of Labor Statistics started to officially publish another new consumer price index, called Chained Consumer Price Index for All Urban Consumers or C-CPI-U, which is basically computed using the Törnqvist superlative price index formula. The new measure is designed to be a closer approximation to a cost of living index than the existing BLS measure (see Cage, Greenlees and Jackman (2003)). Recently, Triplett (2001, F331) had strongly contended that “the theory of the cost-of-living index does provide the underlying conceptual rationale for constructing a practical CPI.” Furthermore, using the Laspeyres price index (or other fix-basket price indexes) in constructing a CPI will cause substitution bias in measurement. More importantly, Triplett (2003) argued that the Laspeyres price index (or any other fix-basket price index) fails to provide an underlying conceptual framework for resolving measurement issues within CPI detailed component indexes. Based on our empirical study, we would also like to suggest to the Price Statistics Department in Taiwan that it is about time for them to consider compiling and publishing an alternative consumer price index (CPI) using the Törnqvist price index in Taiwan.

#### ENDNOTES

1. To name just a few of such public policies: income tax exemptions and tax bracket adjustments; inheritance and gift tax exemptions and tax bracket adjustments; land price adjustments for land value increment tax; and adjustments of the basic (minimum) wage.
2. Conceptually “substitution bias” can be divided into the “upper level substitution bias” and “lower level substitution bias.” The “substitution bias” discussed in this paper is referred to the “upper level substitution bias,” that occurs among basic commodity groups of the index (in the following analysis we have considered 29 commodity groups). In contrast to the former, the “lower level substitution bias” occurs between the detailed items and varieties within a specific commodity group.
3. In fact, the bias caused by using the CPI to estimate consumer’s true cost of living is not limited to substitution bias only, other biases such as outlet substitution bias, new product and quality change bias would also occur. According to the Boskin Commission’s Report (See Boskin et al., 1996), the U.S. CPI in 1995-96 was upward biased by 1.1 percentage points per year, and 0.15 percentage points was contributed by the upper-substitution bias. (See Boskin, et al., (1996)). Recently Lebow & Rudd (2003) have updated the study about the upward bias regard to U.S. CPI and concluded “that the CPI likely overstates the rate of increase in the “true” cost of living by about 0.9 percentage points per year.” (See Lebow & Rudd (2003, p.192)) Furthermore, their study also indicated that the total bias in CPI contributed by the “upper level substitution bias” and the “lower level substitution bias” were 0.3 and 0.05 percentage points, respectively, and the rest was contributed by the outlet substitution bias, new product and quality change bias (Also see Gordon (2006)).
4. The economic price index number formula theory began with Byushgens (1925) and Konyus & Byushgens (1926) (See Diewert (1997, p.130)).
5. Two most widely used superlative price indexes, as strongly recommended by Diewert (1976, 1997) are the Törnqvist price index and the Fisher ideal price index (Also see Hill (2006)).

6. Beginning from 2002 (August), the U.S. Bureau of Labor Statistics started to officially publish another brand new consumer price index, called Chained Consumer Price Index for All Urban Consumers or C-CPI-U, which is basically computed using the Törnqvist superlative price index formula (see Cage, Greenlees & Jackman (2003)).
7. In addition, it can be shown if all of the  $\beta_i = 0$ , and  $\beta_{00} = 0$ , then  $C(p,u) = u \cdot c(p)$  becomes a unit cost or expenditure function, and we have homothetic preferences. Diewert (1976, p.121) has shown that the Törnqvist price index is also exact for a Translog unit cost function  $c(p)$ . Diewert (1976, p.123) first pointed out the possibility that “the same price index  $P^j$  is exact for more than one functional form (and reference utility level) for the true cost of living.”
8. Other alternative additive decomposition approaches for the Törnqvist and Fisher indexes had been proposed and compared in the literature. (See Hallerbach (2005); Balk (2004); and Dumagan (2002)).
9. Alternatively, Laspeyres price index can be treated as an exact price index by assuming that consumer has fixed coefficient Leontief-type preference structure.
10. The Boskin Commission’s Report (See Boskin et al., 1996, p. iii) had recommended “that the CPI (Consumer Price Index) should move toward a COLI (Cost Of Living Index) concept by adopting a “superlative” index formula to account for the changing market baskets.” This recommendation has recently been reaffirmed by the National of Sciences on Conceptualizing and Measuring Cost-of-Living and Price Indexes (known as the CNSTA) report that “The BLS should publish, contemporaneous with the real-time CPI, an advance estimate of the superlative index, utilizing either a constant - elasticity - of - substitution method or some other method.” (See National Research Council, 2002, p.6).

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**APPENDIX 1**

Sample units and detailed commodity groups included in “The Survey of Family Income and Expenditure in Taiwan Area of the Republic of China, 1991 through 2006.”

Year	Sample units (Households)	Detailed commodity groups
1991	16,434	61
1992	16,434	61
1993	16,434	65
1994	16,434	50
1995	14,706	50
1996	13,702	51
1997	13,701	51
1998	14,031	51
1999	13,801	51
2000	13,801	51
2001	13,601	51
2002	13,681	51
2003	13,681	51
2004	13,681	51
2005	13,681	51
2006	13,776	51