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Estimating Upward Bias in the Japanese CPI Using Engel's Law

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Abstract

The Japanese Consumer Price Index (CPI) is considered to be upwardly biased. This paper estimates the Engel curve based on National Survey of Family Income and Expenditure data to measure the bias. The estimated annual bias for the period 1989 to 2004 is 0.5 percentage points. Correcting the bias leads to a lower inflation rate of 0.14 percent per year, against the official inflation rate of 0.65 percent during the period. A demographic analysis shows that a household with a pre-school child faces a smaller bias suggesting that the opportunity cost of shopping determines the size of the bias.

Keywords: consumer price index bias; Engel's Law

JEL Classification Numbers: C10 E30 D12

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1 Introduction

The general consumer price index (CPI) represents the cost of living and general inflation, and many policies are index-linked to the CPI. However, the CPI has been criticized for overstating the cost of living and, therefore, as being upwardly biased. Because of CPI bias, welfare policies become ineffective if the beneficiaries are overcompensated. This leads to excess government spending.

Several studies have estimated the bias of the Japanese CPI. Shiratsuka (1999) estimated that the size of the overall bias is 0.9 percentage points per year. Ariga and Matsui (2003) concluded that the CPI is upwardly biased by at least 0.5 percentage points per year. Measuring the bias of the Japanese CPI based on the calculation methodology and bias estimates of the US CPI, Broda and Weinstein (2007) concluded that the Japanese CPI overstates the cost of living by around 1.8 percentage points per year.

This paper, following a different approach from previous studies, applies the Engel curve method suggested by Hamilton (2001) and Costa (2001) to estimate bias in the Japanese CPI. The Engel curve method exploits the fact that the change of food expenditure share represents the change of real income after accounting for the change of relative food price. Then, if the CPI correctly represents the cost of living and household preference is stable, the CPI-deflated Engel curve should be stable across different periods after the relative price change in food and household characteristics are controlled for. In this approach, a shift of the Engel curve from one year to another indicates CPI bias. Several previous studies rely on this method (Beatty and Larsen, 2005; Barrett and Brzozowski, 2010; Chung et al., 2010). In contrast to previous studies in which the CPI bias is analyzed in terms of its causes, this approach estimates the overall CPI bias.

In addition, this paper analyzes the cause of bias from the point of the opportunity cost of shopping. Aguiar and Hurst (2007) and Abe and Shiotani (2012) analyzed the relationship between prices that households face and the frequency of shopping. Both studies suggested that households, such as the elderly, who have enough time to find lower prices for commodities face a lower inflation. Based on the same idea, therefore, This paper estimates bias between the households with and without pre-school children. A household with enough time would be able to seek out low-priced or discount goods and substitute them for expensive goods. As a result, the household might face a larger upward bias.

This paper obtains the following results. The overall bias between 1989 and 2004 is 0.5 percentage points per year. If CPI bias is corrected, the inflation rate would be 0.14 percent rather than the official inflation rate of 0.65 percent between 1989 and 2004. In addition, from an analysis based on household characteristics, households without pre-school children face an upward bias of 0.66 percentage points per year, larger than the bias of 0.36 percentage points per year for households with pre-school children. Thus, households without pre-school child face a lower inflation.

2 Model

This paper follows the approach of Hamilton (2001) and Costa (2001) to estimate the Japanese CPI bias. This method depends on several assumptions. First, the income elasticity of food is assumed to vary from unity. This assumption assures that the food share declines as real income increases and allows an inference of the real income from the food share. Second, food has no durability so that food expenditure is identical to food consumption. This implies that food expenditure in a period cannot produce a flow of food consumption to another period. Third, the food component can be separated from the non-food component in a utility function. This assumes that CPI bias of non-food items does not affect the food share through an unexpected mechanism. Fourth, household preference is stable over time. This condition ensures that the shift of the Engel curve is caused only by CPI bias.

An Engel curve is derived from the Almost Ideal Demand System by Deaton and Muellbauer (1980), and it can be written as a linear function of the food share and the log of real income:

$$\omega_{it} = \phi + \gamma(\ln P_t^f - \ln P_t^{nf}) + \beta(\ln Y_{it} - \ln P_t) + X'\theta + u_{it}, \quad (1)$$

where ω_{it} is the food-income ratio of a household i at time t and Y is the nominal household income. The vectors P^f, P^{nf}, and P are true but unobservable price indices of food, non-food items, and all goods, respectively. The vector X represents the household characteristics, and u is the error term. Here, I assume that the true price index of all goods is the weighted average of the true price indices of food and non-food items:

$$\ln P_t = \alpha \ln P_t^f + (1-\alpha)\ln P_t^{nf}. \tag{2}$$

In addition, I assume that each true price index is obtained by removing the error from the observed price index:

$$\ln P_t^G = \ln P_t^{'G} + \ln(1+E_t^G), \tag{3}$$

where $P'$is the observed price index and G represents food, non-food items, and all goods. The term E_t is the percent cumulative measurement error in the cost of living index from time 0 to t. In this paper, the term E_t represents the cumulative CPI bias. By defining $y \equiv \ln Y$, $\pi \equiv \ln P'$, and $\varepsilon \equiv \ln(1+E)$ and substituting two price assumptions, I get the Engel curve to be estimated:

$$\begin{aligned} \omega_{it} &= \phi + \gamma(\pi_t^f - \pi_t^{nf}) + \beta(y_{it} - \pi_t) + X'\theta + \gamma(\varepsilon_t^f - \varepsilon_t^{nf}) - \beta\varepsilon_t + u_{it} \\ &= \phi + \gamma(\pi_t^f - \pi_t^{nf}) + \beta(y_{it} - \pi_t) + X'\theta + \sum_{t=1}^{T}\delta_t D_t + u_{it}, \end{aligned} \tag{4}$$

where D_t represents the year dummy and $\delta_t = \gamma(\varepsilon_t^f - \varepsilon_t^{nf}) - \beta\varepsilon_t$. Then, assuming the relative bias between food and non-food items is constant over time, $\varepsilon_t^f = \varepsilon_t^{nf}$, I have

$$\varepsilon_t = \ln(1 + E_t) = \frac{-\delta_t}{\beta}. \tag{5}$$

Therefore, I can calculate the cumulative percentage point of the CPI bias at time t

$$\text{BIAS}_t^{\text{linear}} = 1 - \exp\left(\frac{-\delta_t}{\beta}\right). \tag{6}$$

Costa (2001) applies the quadratic functional form of the Engel curve. The quadratic form of the Engel curve can be written as follows:

$$\omega_{it} = \mu + \gamma(\pi_t^f - \pi_t^{nf}) + \beta_1(y_{it} - \pi_t) + \beta_2(y_{it} - \pi_t)^2 + X'\theta + \sum_{t=1}^{T} \delta_t D_t + v_{it}. \tag{7}$$

I then calculate the cumulative bias as follows:

$$\text{BIAS}_t^{\text{quad}} = 1 - \exp\left(\frac{\beta_1 \pm \sqrt{\beta_1^2 + 4\beta_2\delta_t}}{2\beta_2}\right). \tag{8}$$

3 Data

This section introduces the data set used in this study and explains the construction of the analysis sample. The cross-sectional data set used in this paper is from the National Survey of Family Income and Expenditure, published by the Ministry of Internal Affairs and Communication. This survey was conducted to collect comprehensive data on family income, expenditure, saving, debt, durable consumer goods, and assets. The survey started in 1959 and has been conducted every five years thereafter. It covers more-than-two-person households and one-person households. The survey of more-than-two-person households is conducted for three months, from September to November. One-person households are surveyed in October and November. A household is requested to fill in the household accounts, household questionnaire, consumer durables questionnaire, and annual income and saving questionnaire. This paper uses 80% re-sampled and anonymized data sets for 1989, 1994, 1999, and 2004, focusing on the sample of more-than-two-person households. Each data set contains almost 45,000 households in each year. I restrict the sample to households headed by persons aged 20 to 59 years. I eliminate households that produce food for personal consumption, specifically households headed by persons falling under farmer and fisher categories. In addition, I exclude expenditures on housing, alcohol, and food eaten out.

The food share, obtained by dividing food expenditure by living expenditure, is used as a dependent variable that takes a value between zero and one. The exclusion of alcohol and food eaten out produces negative food expenditure and living expenditure values.[*1] Thus, I restrict the sample to food shares between zero and one. To exclude

[*1] Some households reported zero for expenditure, food expenditure, or income even if they reported non-zero annual income, food consumption, rent, or saving. For unknown reasons, respondents did not expend during the sample period.

observations where food demand might be unusual, the sample is trimmed at the 3rd and the 97th percentile values of the cross-sectional distributions of food share and real living expenditure for each survey year. Without the trimming, the Engel curve predicts that the food share takes a negative value at some expenditure levels.

The description of the independent variable is as follows. The independent variable includes the real living expenditure, the relative price of food and non-food items, family characteristics, year dummy variables, and region dummy variables. The real living expenditure is deflated by the official Japanese CPI. The demographic controls are as follows: the number of adult family members aged 18 to 59 years, the number of elderly people, that is, family members aged 60 years and more, the number of pre-school children, the number of elementary-school-going children, and the number of children going to junior high or high school. Control variables also include dummy variables of being employed, which takes one if a household head is employed, job type of household head, and age of household head. Industry dummy variables that indicate the industry of household head's job are included. The industry category includes mining, construction, manufacturing, electricity, gas, heat supply, and water, transport and communication, wholesale and retail trade, finance and insurance, real estate, service, government, and others. The year dummy variables are for 1989, 1994, 1999, and 2004. The region dummy variable takes one if a household lives in an urban area.

The construction of price indices is as follows. I use the official 2010-base price indices reported by the ministry: the Japanese CPI, the food price index, and the non-food price index. Since the definition of urban area in the analysis sample contains small cities around the main big cities and is different from that in the price indices sample, nationwide price indices are used for households living in rural areas; price indices of cities with a population of more than 50,000 are used for households living in urban areas. I constructed three price indices, excluding alcohol, food eaten out, and housing.[*2]

4 Empirical Analysis

4.1 Analysis of Summary Statistics

Table 1 shows summary statistics of the food share and the real living expenditure per month for each sample period. The food share decreased by 15 percent during the sample period, from 25.9 percent in 1989 to 22.0 percent in 2004. The decrease of the food share implies the improvement of living standard and necessitates the increase of real living expenditure. However, the real living expenditure decreased by 4.6 percent during the sample period, from 243,600 yen in 1989 to 232,400 yen in 2004.[*3] The twisted relationship suggests the underestimation of CPI deflated real

[*2] The calculation method is explained in Appendix A.

[*3] The National Health and Nutrition Survey showed the trend in nutrient intake of energy between 1990 and 2004 dropped by 124 kilocalories (6 percent). This suggests a decrease in

living expenditure because of upward bias in the CPI.

Table 2 shows the summary statistics for household characteristics: job type of household head, age of household head, rate of home owners, and proportion of households living in the urban area. The table shows that job types of almost half of the household heads are manufacturing and service. The share of manufacturing jobs decreased by 4.5 percentage points from 1989 to 2004, in contrast to a 3.7 percentage point increase in service jobs. In this data set, household heads aged 20 to 24 years constitute less than 1 percent of the total. Most household heads are more than 30 years old.

Table 3 shows the changes in the numbers of children.[*4] The table shows the proportion childless households increases over time. Almost 30 percent of households in 1989, and 40 percent in 2004, have no children. Although the proportion of single-child households is stable during the sample period, that of households with two children declines by about 10 percentage points.

Figure 1 shows Engel curves, specified as quadratic functions of the real living expenditure, for each year. If the Japanese CPI accurately corresponds to the changes in the true cost of living, the Engel curve is stable across different periods. However, the figure shows the curves shift downward in different periods. This implies the CPI

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the importance of food. However, if this results in higher expenditure on other goods, it might imply that living standards have increased.

[*4] The definition of children includes pre-school children and those who go to elementary school and junior high or high school.

is potentially upwardly biased.

4.2 Analysis of Overall Bias

Estimating the Engel curve, I regressed the food share on the log of real living expenditure, year dummy variable, log of relative price, and dummy variables of family characteristics- being a home owner, living in urban areas, being employed, job type of household head, age of household head, and number of adults, elderly people, pre-school children, children in elementary school, and children in junior high or high school. Regressing the quadratic Engel curve, I included the quadratic term of the log of real living expenditure as an independent variable. Table 4 shows regression results for the linear and quadratic Engel curves. With the linear model, the coefficient of the log of real living expenditure is statistically significant even at the 1 percent significance level. The result shows the food share declines as the real living expenditure increases. A 1 percent increase in real living expenditure results in a 0.17 percent decrease in the food share. With the quadratic specification, the coefficient of the quadratic term is statistically significant at the 1 percent significance level. This result shows the quadratic Engel curve nests the linear specification and is more appropriate.[*5] This implies that the linear Engel curve might overestimate the bias.

[*5] Unayama (2008) estimated the quadratic almost ideal demand system for food and other goods using the Japanese Family Income and Expenditure Survey from 1982 to 2000. The paper did not obtain evidence of a significant quadratic form for food. The paper focused on households with two married adults but no child, living in their own houses. The dissimilar results might

The income elasticities of the two specifications are about 0.440, evaluated at the sample means of the food share and the log of real living expenditure.

The crucial variable of this study is the year dummy variable. Again, if the Japanese CPI is not biased and corresponds to the true cost of living, the Engel curve would be stable across the sample period. If so, the parameters of the year dummy variables would not differ from zero. However, regression results from both the linear and the quadratic models show that the dummy variables, dummy-94, dummy-99, and dummy-04, are statistically significant. This evidences an upward bias in the official Japanese CPI.

Estimates of the annual bias are reported in Table 5.*6 The overall upward bias between 1989 and 2004 based on the linear Engel curve is 1.7 percentage points per year. The annual bias increases every five years: 1.6 percentage points during 1989-1994, 2.0 percentage points during 1994-1999, and 2.5 percentage points during 1999-2004. Based on the quadratic Engel curve, the overall bias is 0.51 percentage points per year from 1989 to 2004-a lower size of the bias compared to the linear model. In addition, the bias increases in later periods, although it is much lower compared to the linear model: 0.4 percentage points for 1989-1994, 0.5 percentage

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be due to sample construction differences.

*6 The annual bias is calculated as follows:

$$\text{annual bias} = ((1 + BIAS)^{\frac{1}{\text{period}}} - 1) * 100$$

where $BIAS$ is as defined in equation 6 or 8.

points for 1994-1999, and 0.7 percentage points for 1999-2004.

The 1.7 percentage point annual bias based on the linear Engel curve is larger than the 0.9 percentage points estimated by Shiratsuka (1999), but is close to the 1.8 percentage points reported by Broda and Weinstein (2007). On the other hand, the 0.5 percentage point estimate based on the quadratic Engel curve is much lower compared to the previous two studies. This estimate is similar to the lower bound reported by Ariga and Matsui (2003). As the regression result shows that the quadratic term is statistically significant, the estimated annual bias from the linear model could be overestimated.

Estimates of annual bias indicate that the official Japanese CPI and the inflation rate might not be measured correctly. Figure 2 shows the official Japanese CPI and the revised CPI. The revised CPI is obtained from Equation 3 and the estimated annual bias. The figure shows the official CPI is placed above the revised CPI. In 2004, the cumulative bias amounts to almost 7 percentage points. The revised CPI implies lower inflation and more serious deflation. It shows moderate inflation from 1992 to 1998 and severe deflation, more acute than suggested by the official CPI, thereafter. The inflation rate based on the official CPI is 0.65 percent from 1989 to 2004. This contrasts with the 0.14 percent inflation rate for the same period based on the revised CPI. However, bias correction suggests severe deflation after 1998. After 1998, the deflation rate is 0.95 percent based on the corrected CPI and 0.36 percent according to the official CPI.

4.3 Demographic Analysis

The above discussion shows that the CPI is upwardly biased and presents the degree of bias across the sample period. This subsection examines the cause of bias by examining the difference in bias across demographic groups that presumably represent the difference in the opportunity costs of shopping time.

The Ministry of Internal Affairs and Communications survey, in principle, corrects normal retail prices or normal service charges. Thus, outlet or discount sale prices are excluded. However, compared to households with pre-school children, those without pre-school children have more time to seek out low-priced or discount goods and substitute them for expensive goods. This results in a larger upward bias for them.

Table 6 shows bias estimates for households with and without pre-school children. Households with pre-school children faced an overall bias of 0.36 percentage points per year from 1989 to 2004, compared to 0.66 percentage points for those without pre-school children. Thus, households with pre-school children presumably have less shopping time, resulting in lower upward bias. A household without a pre-school child can spend more time looking for cheaper goods and faces lower inflation, resulting in a larger CPI bias for the household.

5 Summary and Conclusion

In this paper, I estimated the upward bias of the Japanese CPI based on Engel's law, using National Survey of Family Income and Expenditure data. The estimated overall bias was 0.5 percentage points per year between 1989 and 2004. This estimate is close to the lower bound reported by Ariga and Matsui (2003), but lower than the result reported by Shiratsuka (1999) and Broda and Weinstein (2007).

The 0.5 percentage point upward bias implies that the official CPI overstates the true cost of living. Consequently, the bias-corrected annual inflation rate from 1989 to 2004 was estimated to be 0.14 percent, whereas the official inflation rate was 0.65 percent during the same period. The deflation during the period was severe, especially after 1998, when the rate of deflation was 0.95 percent compared to 0.36 percent based on official statistics. These results suggest that government policy payments index-linked to the Japanese CPI, such as pension, might overcompensate the recipients.

A demographic analysis showed that, compared to households with pre-school children, those without pre-school children faced a larger bias and lower inflation since they presumably have enough time to visit different stores and can seek out low-cost goods. The result offers suggesting evidence that the ignorance of sales, discount or brand substitution is an important source of CPI bias.

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AppendixA Price Data

Since this analysis eliminates the effect of alcohol, food eaten out, and cost of housing, the data of the Japanese CPI, the food price, and the non-food price are calculated as follows:

For CPI,

$$\text{CPI} = \frac{p_T \times w_T - p_A \times w_A - p_O \times w_O - p_H \times w_H}{w_T - w_A - w_O - w_H}.$$

For food price,

$$\text{food-price} = \frac{p_F \times w_F - p_A \times w_A - p_O \times w_O}{w_F - w_A - w_O}.$$

For non-food price,

$$\text{non-food-price} = \frac{p_T \times w_T - p_F \times w_F - p_H \times w_H}{w_T - w_F - w_H}.$$

The variables p_T, p_F, p_A, p_O, and p_H are the price indices of total, food, alcohol, food eaten out, and cost of housing. The variables w_T, w_F, w_A, w_O, and w_H represent the weights of these variables.

Table1 Summary Statistics 1

Year	1989	1994	1999	2004
Observations	29,592	28,739	26,726	23,819
Food share (%)	26.0	23.3	22.7	22.1
	(10.8)	(10.4)	(10.8)	(10.9)
Real living expenditure per month (1000 yen)	246.4	246.7	236.9	231.0
	(108.8)	(118.5)	(117.7)	(120.5)

Source: National Survey of Family Income and Expenditure.
Notes: The food share is obtained by dividing the food expenditure by the real living expenditure.
The real living expenditure per month is deflated by the official 2010-base CPI.
Standard deviations are in parentheses.

Table2 Summary Statistics 2

	1989	1994	1999	2004
Variable	Percent	Percent	Percent	Percent
Employed	98.00	98.18	97.47	97.28
Mining	0.32	0.22	0.17	0.18
Construction	12.54	12.44	13.05	12.29
Manufacturing	25.55	24.45	23.37	21.52
Electricity, gas, heat supply and water	1.29	1.43	1.29	1.48
Transport and IT	9.07	9.12	8.56	9.36
Wholesale and retail trade	15.58	15.34	14.71	14.41
Finance and insurance	3.56	3.66	3.38	3.22
Real estate	0.78	0.81	0.93	0.99
Service	18.46	20.14	21.38	21.98
Government	10.78	10.55	10.57	11.79
Others	2.06	1.85	2.57	2.78
Age 20-24	0.75	0.79	0.84	0.63
Age 25-29	5.05	4.69	5.18	4.32
Age 30-34	11.45	11.16	10.80	10.39
Age 35-39	18.47	15.18	14.02	14.13
Age 40-44	20.63	19.44	16.68	16.04
Age 45-49	17.73	19.29	18.29	17.20
Age 50-54	13.75	16.58	18.08	18.29
Age 55-59	12.17	12.87	15.97	18.85
Home owner	70.4	65.7	67.8	70.3
Living in urban area	40.6	42.4	42.7	40.9

Source: National Survey of Family Income and Expenditure.

Table3 Summary Statistics 3

	1989 Percent	1994 Percent	1999 Percent	2004 Percent
Total children				
0	27.87	33.69	37.31	38.82
1	21.96	22.13	21.79	22.88
2	36.04	31.37	29.28	27.91
3	13.07	11.95	10.59	9.49
4	0.99	0.80	0.97	0.76
5	0.07	0.07	0.06	0.14

Source: National Survey of Family Income and Expenditure.

Table4 Results of Selected Regression Coefficients

	Linear model coefficient	Quadratic model coefficient
Constant	2.432***	5.783***
	(0.008)	(0.173)
Log (real living expenditure)	-0.171***	-0.718***
	(0.001)	(0.028)
(Log (real living expenditure))^2		0.022***
		(0.001)
Dummy-94	-0.015***	-0.015***
	(0.001)	(0.001)
Dummy-99	-0.034***	-0.034***
	(0.001)	(0.001)
Dummy-04	-0.058***	-0.059***
	(0.001)	(0.001)
sample size	108,876	108,876
Adjusted R^2	0.394	0.396

Note: The results are obtained by regressing the food share on the log of the real living expenditure, the log of the relative price, and dummy variables of home owner, living in the urban area, employed, job types, ages, adults, elderly people, pre-school children, children in elementary school, children in junior high or high school, and year dummy variables.

The robust standard errors are in parentheses.

Nonlinear least-squares estimation is used.

$***$: Significant at the 1 percent level

Table5 Annual Bias (percentage point)

	1989-2004	1989-1994	1994-1999	1999-2004
Linear	1.70	1.61	1.99	2.52
	(0.02)	(0.09)	(0.09)	(0.08)
Quadratic	0.51	0.42	0.52	0.67
	(0.02)	(0.03)	(0.03)	(0.03)

Source: National Survey of Family Income and Expenditure.

Note: Standard errors from 500 bootstrap replications are in parentheses.

Table6 Annual Bias by Demographics (percentage point)

	1989-2004	1989-1994	1994-1999	1999-2004
Households	0.36	0.32	0.38	0.42
with pre-school children	(0.01)	(0.03)	(0.03)	(0.04)
Households	0.66	0.53	0.65	0.92
without pre-school child	(0.05)	(0.04)	(0.06)	(0.09)

Source: National Survey of Family Income and Expenditure.

Note: The results are obtained by regressing the food share on the log of the real living expenditure, the quadratic term of the log of the real living expenditure, the log of the relative price, and dummy variables of home owner, living in the urban area, employed, job types, ages, adults, elderly people, and year dummy variables.

Standard errors from 500 bootstrap replications are in parentheses.

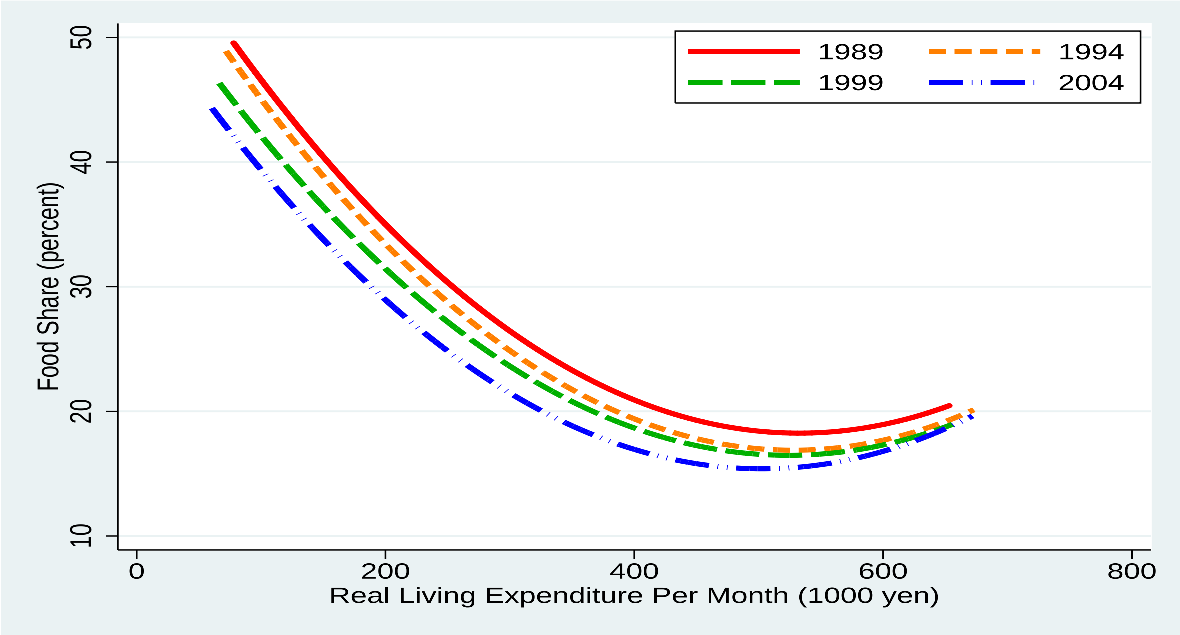

Figure1 Engel curves

Source: National Survey of Family Income and Expenditure.

Note: The lines are simple Engel curves for each year.

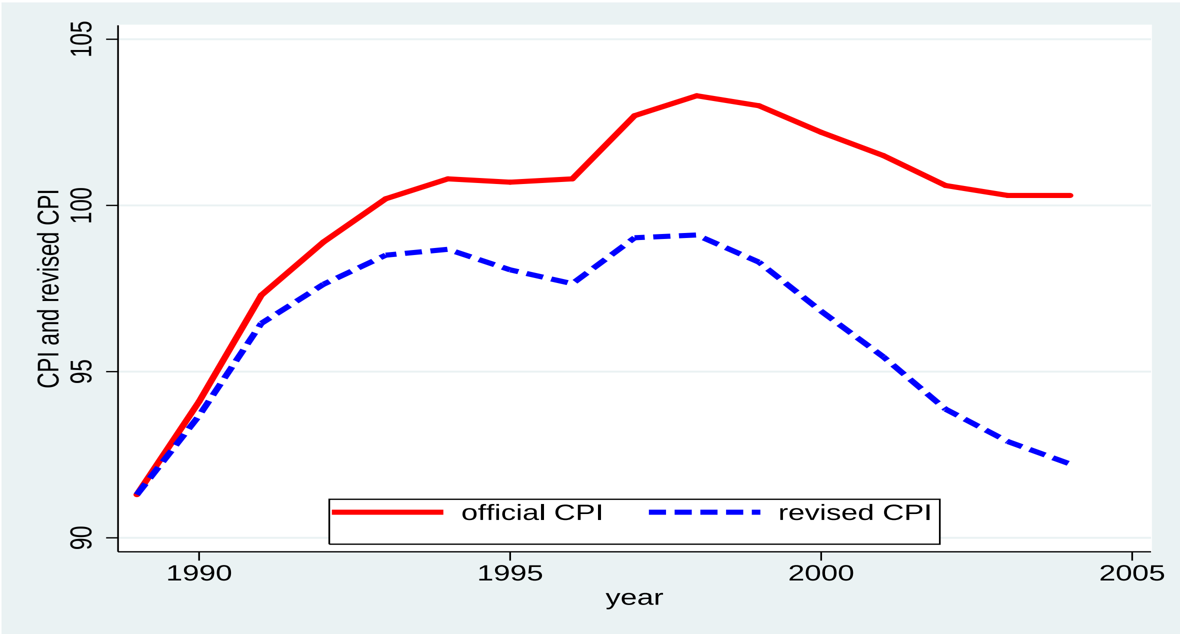

Figure2 CPI and revised CPI

Source: 2010-base Official CPI statistics. Revised CPI figures are based on author's calculation.