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Abstract

We have two major tasks in this paper. The first is to obtain a reasonable estimate of the Japanese demand system, which includes leisure, income, and commodity choices. The second is to compute and evaluate the optimal tax equilibrium. We use Almost Ideal Demand System to estimate the Japanese demand system. The estimated demand system is found to be consistent with the microeconomic theory. We then evaluated the optimal commodity tax structure by calculating the equilibria under lump-sum taxation, optimal commodity taxation, and uniform commodity taxation. We found that the deadweight losses under uniform taxation are very small, and that the optimal commodity tax rates are strikingly close to uniform.

JEL Classification code:
C33 Models with Panel Data
D12 Consumer Economics: Empirical Analysis
D61 Allocative Efficiency; Cost-Benefit Analysis
H21 Efficiency; Optimal Taxation

1 Introduction

Many empirical studies of optimal commodity taxation have emphasized the fact that optimal tax structures are non-uniform. For example, Atkinson and Stiglitz [1972] computed optimal tax rates in a single consumer economy and concluded that the optimal tax rates ranged from 11.1% on durables to 42.0% on food for Sweden.[1] Another example is Harris and MacKinnon [1979], who pointed out that the optimal rate is highest on food (369.3 %) and lowest on transportation (6.4%) in the one consumer model.[2] Since these results were consistent with the theory of optimal commodity taxation, the non-uniform structure became the rule rather than the exception.[3] Uniform taxation, which is the dominant practice in many countries, was set aside as non-optimal, and therefore considered to be undesirable with a large deadweight loss.

However, a few recent studies produced results more favorable for uniformity. Hatta [1986] showed that there exists a welfare improving force towards uniformity on the theoretical basis. Fukushima [1989] added that the non-uniform results of Atkinson and Stiglitz critically depend on the magnitude of the compensated wage elasticity of labor supply. In particular, he has shown that non-uniformity is the artifact of an outrageously high labor supply elasticity. For example, it was arbitrary set at 3.35 for Sweden. Fukushima and Hatta [1989] re-calculated the optimal rates with exact same model and data set as Atkinson and Stiglitz, except for corrections for labor supply elasticities. They found that if compensated labor supply elasticity is set at a reasonable value, like 0.2, the optimal rate is lowest on durables at 22.7% and highest on food at 24.9%. They also showed that the optimal rates tend to move towards uniformity as the labor supply elasticity gets smaller. Fukushima [1991] re-calculated the optimal rates using the Harris and MacKinnon model, and he found that the optimal rates ranges from the

[1] Atkinson and Stiglitz [1972] estimated optimal rates for three countries, Sweden, Canada and OEEC. For all countries, they showed a similar non-uniformity.

[2] These estimates are taken from Table 4B of Harris and MacKinnon [1979] where utility function parameter σ=3.0 is assumed. Though HM presented the cases where optimal rates are nearly uniform, they did not relate their results to the values of labor supply elasticity, nor did they discuss the validity of their assumed parameter values.

[3] There are other estimates of optimal commodity tax rates. They include Deaton [1977], Ebrahimi and Heady [1988], Deaton and Stern [1986], Ray [1986], Murty and Ray [1987] and Srinivasan [1989]. Though these studies also emphasize the non-uniformity of optimal rates, they are not directly connected to our study. The reason is that their non-uniformity results are in large part due to the redistributive concerns, while our interest is on efficiency concerns. For instance, Deaton showed that the optimal rates move further away from uniformity as the concern for equity increases.

lowest 19.3%, to the highest 23.3%. By using a compensated labor supply elasticity of 0.2, the result is a bit closer to uniformity than the original HM's figures. These studies showed that non-uniformity of optimal rates were overemphasized both theoretically and empirically. They also showed that the magnitudes of optimal rates hinges on the assumed value of labor supply elasticity.[4]

Although these results points towards uniformity, they are not quite satisfactory to use for policy prescriptions for three reasons. First is the specification of labor supply in their models. The elasticity of labor supply estimates were not obtained from real data as a part of the demand system. Rather, they are obtained by adding an ad hoc labor sector to the estimated commodity model while assuming that the labor supply was weakly separable from consumption.[5] Second, the number of commodity groups are too small for practical purposes. The third is an econometric consideration. In their computation, the estimated demand system was based on a restrictive functional form which does not allow for complementarities among the commodities and leisure.[6]

In this study we estimate a complete demand system by employing a flexible functional form (Almost Ideal Demand System of Deaton and Muellbauer [1980]). The data are obtained from 47 Japanese cities over the period of 1979 to 1990 for ten expenditure groups and for leisure consumption. Unlike with time series data, income, wage rate, and prices are available separately for each observation. Thus we can estimate the demand system with high accuracy and without restrictive assumptions on preferences.

The estimated parameters are used to simulate the uniform tax and optimal commodity tax equilibria. Then the excess burden of optimal taxation is compared to that of uniform commodity taxation on a welfare basis by calculating compensating variations as a measure of welfare losses.

The plan of the paper is as follows. Section 2 presents a brief theory of optimal commodity taxation. Section 3 describes the Almost Ideal Demand

[4]It is curious that this point was overlooked in many of the empirical studies. Theoretically, there is no doubt that it is one of the crucial parameters to determine the optimal tax structure. If labor supply is completely inelastic, taxing on inelastic labor is identical to lump sum taxation, and the first best optimum is obtained. Second, if not completely inelastic, a smaller compensated labor supply elasticity points to a smaller distortion between leisure and consumption choices when labor is taxed, indicating a smaller deadweight loss by uniform commodity taxation.

[5]The separability of labor supply from other commodities is decisively rejected by many studies. For example, see Barnet [1979] and Browining and Meghir [1991].

[6]It was well demonstrated by Corlett and Hague [1953] that the complementarities between commodities and leisure are a decisive factor in the optimal commodity tax structure.

System. Section 4 briefly describes the estimation procedure. The data used are explained in Section 5. Estimation results are presented in Section 6. Section 7 offers an evaluation of optimal and uniform tax schemes and the conclusions are stated in Section 8.

2 The Optimal Taxation Problem

2.1 The Problem Stated

Let us begin by specifying a well behaved utility function of a person given by

$$u = u(q_1, ...q_n), \tag{1}$$

where q_i $(i = 1, 2, ..., n-1)$ is the consumption of commodity i and q_n is the consumption of leisure . The consumer is assumed to maximize (1) subject to a budget constraint of the form

$$\sum_{i=1}^{n} p_i q_i = y, \tag{2}$$

where p_i is the consumer's price of good i,and y is the total endowment income including the lump sum income,[7] i.e. we have

$$y \equiv I + p_n L, \tag{3}$$

where I is the lump sum income and L is the endowment of leisure.[8]

The solution of the maximization problem is called the Marshallian demand function and it is written as

$$q_i = q_i(p_1, ..., p_n, y). \tag{4}$$

[7] Normally, the value of I is assumed to be zero, i.e. there is no lump sum income and transfer allowed in the optimal taxation problem.

[8] If we define the net consumption of leisure x_n by

$$x_n \equiv q_n - L,$$

the budget constraint can be rewritten as

$$\sum_{i=1}^{n-1} p_i q_i + p_n x_n = I.$$

Then $-x_n$ is the labor supply and $-p_n x_n$ is the wage income of the consumer. Thus our utility maximization problem is identical to the familiar income-leisure choice of textbook microeconomics.

Substitute this into (1), we have an indirect utility function

$$u = v(p,\, y), \tag{5}$$

where $p = (p_1, ..., p_n)$. If we solve this expression for y, we get the expenditure function

$$y = e(p,\, u). \tag{6}$$

The optimal tax rates are obtained by maximizing (5) with respect to p_i (for $i = 1, 2, ..., n-1$)[9] subject to a tax revenue constraint

$$(p - p^0)'q(p,\, y) = r, \tag{7}$$

where r is the tax revenue and p^0 is the producer's price vector.

The solution to the problem is the optimal price vector from which we can obtain the optimal tax rates. The first order condition for the maximization is given by

$$\frac{\partial v(p,\, y)}{\partial p} - \lambda \left[q(p,\, y) + \frac{\partial q(p,\, y)}{\partial p} p \right] = 0, \tag{8}$$

and

$$(p - p^0)'q(p,\, y) - r = 0. \tag{9}$$

Though these equations are highly non-linear in prices, we can find the solution by an iterative method.[10] In this way, once the expenditure function and the Marshallian demand functions are specified and estimated, we can numerically obtain the optimal tax rates.

2.2 Structure of Optimal Commodity Taxation

We assume that there is no lump sum income allowed in the system so that $I = 0$. If this were not the case, the first best optimum is attained if all the required government revenue is collected through lump sum taxation. In the real world, however, most of the taxes actually employed are not lump sum, and the role of the lump sum tax is for comparison.

We also assume that we cannot tax the consumption of leisure. If we can tax leisure, uniform taxation on all goods and leisure will produce first best outcome since it is analytically equivalent to taxing the endowment of

[9] Since leisure is assumed to be nontaxable, we have $p_n = p_n^0$.

[10] See Judge et. al.[1985] Appendix B.

leisure.[11] However, putting a tax on leisure is impossible in real world since lesirue consumption decision is not easily observable. One can always avoid leisure taxation by telling a lie that he has consumed less leisure than actual.

In optimal taxation theory, these two assumptions prevent us from attaining the first best outcome and push us to search for second best solutions. There are many characterizations of the second best equilibrium. The following rules can help us to form intuitions concerning the magnitude of the tax rate vectors.[12] One of our purposes is to see how good these rules predict the magnitude of the optimal tax rates.

Samuelson's Basic Rule[13] *If an optimal tax structure is attained, a proportional increase in all tax rates reduces proportionally the compensated demand vector.*

This basic rule can be used to explain some special situations in the following lines.

Compensated Inverse Price Elasticity Rule *If the cross compensated substitution terms among the commodities are all zero, the optimal tax rate of a commodity should be proportional to the inverse of its own compensated price elasticity of demand.*

The intuition behind this is as follows. With cross substitution terms all zero, the only substitution effect of a tax rate increase is to reduce the good's own demand. At the optimum, according to Samuelson's basic rule, the proportion of the change must be identical across the commodities. Thus the good with a high own compensated elasticity should be charged with a low tax rate.

Homogeneity of the demand system implies that price elasticities add up to zero. If all cross elasticity terms are zero, own price elasticity is equal to wage elasticity with signs reversed. Thus the compensated inverse price elasticity rule is restated in the following way:

Compensated Wage Elasticity Rule *If the cross compensated substitution terms among the commodities are all zero, then the optimal tax rate of a commodity is inversely related to the compensated wage elasticity of demand for that good.*

The economics of this rule may be explained as follows. We know that

[11]This is due to the homogeneity property of the demand system. Notice that a tax on the endowment of leisure is a lump sum tax.

[12]These intuitions have limited use since they hold under special assumptions. See Hatta [1991] for proofs and more details.

[13]Samuelson [1951]

uniform commodity taxation is equivalent to wage taxation.[14] Wage taxation distorts consumption-leisure choices in the direction of encouraging leisure consumption. Thus, reducing the tax rate of a strong substitute of leisure accompanied by a revenue offsetting increase in other rates would reduce the distortion caused by uniform taxation. If compensated cross price elasticities are zero, then the resulting non uniformity causes no additional distortion between the commodities. Thus the resulting optimal tax rates become proportional to the inverse wage elasticities.

When cross price elasticities are not zero, the situation becomes more complex and we cannot find a simple rule to decide the magnitude of the optimal tax rates. Corlett and Hague [1953] used a three-good model (with two commodities and leisure), and showed that departing from uniform taxation by increasing the tax rate on the commodity more complementary with leisure (i.e. the good with lower wage elasticity) accompanied by a revenue offsetting decrease of the other rate improves the welfare. The intuition for this result is parallel to the case for the inverse wage elasticity rule. Uniform commodity taxation encourages leisure consumption. Thus raising the tax rate on the commodity which is more complementary with leisure (i.e. less substitutable for leisure), accompanied with a revenue offsetting decrease in the other tax rate, will reduce the distortion. Thus, Corlett and Hague essentially showed that the inverse compensated wage elasticity rule applies to the case of three goods despite the non-zero cross price terms.[15]

When the number of commodities are increased, the Corlett and Hague rule is no guide to the final optimal tax structure except for one special case of equal compensated wage elasticity for all goods. In this case, the optimal structure is uniform.[16]

[14]A uniform taxation on all goods (excluding leisure) is analytically equivalent to a proportional wage taxation. This is easily seen from the fact that the consumer's budget and revenue constraints are undisturbed by shifting tax structure from a uniform commodity taxation to a wage taxation.

[15]One difference we have to note is the point of evaluation of the wage elasticities compared. With the inverse wage elasticity rule, elasticities are evaluated at the optimal state, whereas with the Corlett and Hague rule, they are evaluated at the initial uniform tax equilibrium. For the three-good (two commodities and labor) economy, the difference of evaluation point does not change the result. However, for a general n-commodity economy, the elasticies could assume different orders when the evaluation point is altered. As a result, the elasticities evaluated at the initial uniform tax equilibrium could not be a perfect guide about the optimal tax structure even when the cross elasticities are all zero.

[16]See Sadka [1977].

2.3 The Role of Compensated Labor Supply Elasticity

The magnitude of wage elasticity of leisure is crucial in the discussion of optimal tax structures. Whenever we examine the optimal tax structure, we assume initial uniform taxation. This, as we repeated many times, is equivalent to wage taxation. Thus, when the wage elasticity of leisure is small, the distortion caused by uniform commodity taxation is small. In the extreme case, when leisure is completely inelastic in its own price, uniform commodity taxation is optimal.

Wage elasticity of leisure is closely related to wage elasticity of labor supply since the labor endowment minus leisure consumption is the labor supply. Thus we can replace the wage elasticity of leisure mentioned above by the labor supply elasticity. In the real world, we expect that the value of compensated labor supply elasticity is low enough so that uniform taxation can perform well enough as a substitute for optimal commodity taxation.[17]

3 The Almost Ideal Demand System

We use the Almost Ideal Demand System (AI Demand System) to obtain the estimate of the expenditure function and the Marshallian demand functions. The log expenditure function of the AI Demand System is given by

$$\log e(p,v) = \alpha_0 + \sum_i \alpha_i \log p_i + \frac{1}{2}\sum_i \sum_j \gamma^*_{ij} \log p_i \, \log p_j + v\beta_0 \prod_i p_i^{\beta_i}. \quad (10)$$

The linear homogeneity of the expenditure function with respect to the price vector requires the following constraints

$$\sum_i \alpha_i = 1, \quad \sum_i \beta_i = 0, \quad \sum_i \gamma^*_{ij} = \sum_j \gamma^*_{ij} = 0. \quad (11)$$

The parameters of the AI Demand System are estimated from a set of expenditure share equations of the form

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log(y/P), \quad i = 1,..,M, \quad (12)$$

[17] Of course, optimal taxation will attain higher welfare. However, administrative costs will be higher since different tax rates are applied to different commodities. If the dead-weight loss from uniform taxation is as small as the one from optimal taxation, uniform taxation can be a better choice if the entire costs are considered.

derived by applying the Shephard's lemma to (10). Here, w_i is the ith expenditure share, y is the total expenditure, M is the total number of goods, P is the price index defined by[18]

$$\log P = \alpha_0 + \sum_i \alpha_i \log p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \log p_i \log p_j, \tag{13}$$

where

$$\gamma_{ij} = \frac{1}{2}(\gamma_{ij}^* + \gamma_{ji}^*). \tag{14}$$

Under (11), the adding up conditions and homogeneity of the demand functions corresponding to (12) are all satisfied. Needless to say

$$\gamma_{ij} = \gamma_{ji} \quad \text{for } i, j = 1, .., M. \tag{15}$$

The parameter α_0 can be interpreted as the subsistence expenditure when all the prices are normalized at one.

The Hicksian substitution matrix is given by

$$S = [S_{ij}] = [\{\gamma_{ij} + \beta_i\beta_j \log(y/P) - w_i\delta_{ij} + w_i w_j\} \; y/(p_i p_j)], \tag{16}$$

where $\delta_{ij} = 1$ if $i = j$, else it is 0. The negative semi-definiteness of (16) can be checked by computing the eigenvalues of S.

Also, the expenditure elasticities η_i are given by

$$\eta_i = 1 + \beta_i / w_i. \tag{17}$$

We treat variations in expenditure patterns due to city and time specific factors and other random factors by introducing an additive disturbance to (12).

4 The Estimation Procedure

In the context of our data, the econometric specification of share equations in (12) may be written as

$$w_{ikt} = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i \log(Y/P) + u_{ikt}, \tag{18}$$

[18]The price index is the income required to attain the minimum utility level.

for $i = 1, \ldots, M$, $k = 1, \ldots, N$, $t = 1, \ldots, T$, where additional subscripts k and t represent region and time period, respectively. u_{ikt} is a mean zero disturbance term. Since disturbances in our data may depend on time specific factors other than prices and income variables, we assume that the disturbance terms have a variance component type structure. Namely, we write u_{ikt} as

$$u_{ikt} = \lambda_{it} + \nu_{ikt}, \tag{19}$$

where, λ_{it} is the time specific factor which uniformly affects all regions in a given year but changes over time, and ν_{ikt} represents other white noise random factors.

It is well-known in the econometric literature that when these time effects are correlated with the explanatory variables (fixed), usual OLS and GLS estimators will be biased. If that is the case we should correct for the biases by introducing time specific dummies. On the other hand, when these factors are uncorrelated with the explanatory variables (random), the GLS estimator is unbiased and more efficient than the dummy variable estimate.

When we have long time periods, correlation between time effects and other explanatory variables can be tested by the specification test, which compares the feasible GLS and dummy variable estimates.[19] In our data, however, we do not have long enough time periods (12years) to estimate the cross equation covariance of time effects (1 degree of freedom), and so there is little sense in obtaining feasible GLS estimates.

In order to control for time effects, we introduce time dummies for all the share equations. The resulting system in (18) and (19) is nonlinear in parameters, with fixed time effects. Although it is a common practice to estimate the system by replacing $\log P$ by the Stone's index, $\log P^* = \sum_i w_i \log p_i$, and applying OLS, we estimate the system by the fully non-linear maximum likelihood.[20]

5 The Data

The data on expenditures are obtained from *Annual Household Expenditure Survey* (HES) (*Kakei Chosa Hokoku*) which consist of a sample survey of

[19]See Hauseman and Taylor(1981) and Kang(1985).

[20]See Deaton and Muellbauer(1980), Anderson and Blundell (1983,1985) and Blundell, Pashardes, and Weber(1993). Anderson and Blundell reported that the effect of the proxy was fairly small when they compared two sets of estimates. Pashardes(1993), on the other hand, found significant biases caused by the proxy in the micro data. Needless to say, it is desirable to estimate the model by the maximum likelihood when it is feasible to do so.

workers' households in 47 prefectural capital cities. The published data are average values, and individual observation values are not available. Each year, a total of approximately 5,400 observations are taken from 47 cities, and one-sixth of the observations are replaced by new samples. The survey covers the following expenditure groups:

1. foods (including eating out) [FOOD]
2. housing (rent, repairs and maintenance, and water) [HOUS]
3. fuel, lights, and water [UTIL]
4. furniture and household utensils (including household durables and domestic services) [FURN]
5. clothes and footwear [CLTH]
6. medical care [MEDI]
7. transportation and communication [TRAN]
8. education [EDUC]
9. reading and recreation [RECR]
10. miscellaneous [MISC]

Since housing expenditure in HES does not include home owners' imputed rents, we adjusted our figures with the *National Survey of Family Income and Expenditures (Shohi Jittai Chosa)*, conducted in 1979, 84 and 89, using the proportions of housing tenure type.

The price indices corresponding to the above 10 expenditure groups of 47 regions are obtained from the *Consumer Price Index Report* (*Shohisha Bukka Shisu Nenpo*) in time series form (1985 = 100). For each of the 47 prefectures and 10 commodity groups, separate time series price indices are available. To account for regional differences in prices, these indices are adjusted to the regional price difference indices in 1982 and 87.[21]

Leisure and wage rates figures for those surveyed in HES are not available, so we had to rely on other sources. Work hours and wage rates are obtained

[21]This is by far a better method than using the regional dummies for the following reasons. First, the regional dummies only account for regional differences by either one or zero, whereas the regional price indices can introduce more fine regional differences. Second, two adjustment points (year 1982 and 1987) are taken, additing more reliability to our data.

from the annual *Wage Census (Chingin Sensasu)* conducted by the Japan ministry of labor. The monthly work hours are defined as male full-time workers' average work hours (all industries, all ages) per month including overtime work. Wage rates are obtained by dividing the average monthly salary (including bonus payment) by the average work hours. These figures are also available for each prefecture.

The total monetary endowment is defined as wage rate multiplied by total time endowment per month. We defined time endowment as 16 hours per day,[22] thus the monthly time endowment is 480 hours (16 hours per day times 30 days), and leisure per month (LSR) is 480 minus work hours. The descriptive statistics for these variables are summarized in Table 2.

The major difficulty in estimating the joint decision of leisure and commodity demand has been lack of appropriate data. It is easy to see that because in macro time series data we do not have a variation in prices and the wage rate in the given year, then we need a long time series, typically over 40 years. But with such data we cannot control for the effects of possible taste changes in estimation without introducing an *apriori* assumption on structural change. Also, in cross-section data, the wage rate may vary but prices are common to all the households, and so we cannot estimate the effects of price changes. With a large number of observations and varied prices in our data set such problems can be avoided. Furthermore, by introducing time-specific factors we can control for the effects of taste changes and still have enough degrees of freedom to estimate the parameters of flexible functional forms.

6 Estimation Results

We estimated the parameters of the AI demand system with maximum likelihood.[23] Although all the parameters, α_0, α_i, γ_{ij}, and β_i are estimable, we found that the likelihood is very flat with respect to changes in α_0, which is the subsistence income at which prices are normalized to one. To bypass this problem we fixed the value of α_0 at 12.50 which corresponds to the hourly wage rate being 560 yen, and/or monthly subsistence income being 268,300 yen. Hence the statistical inference in this section is conditional on this assumption. The effects of changes in α_0 on price and expenditure elasticity estimates are, however, of negligible order because of the compensating

[22]We assumed that the subsistent leisure is eight hours per day. We varied the number of hours only to get the similar estimates for both price and expenditure elasticities.

[23]We used the BHHH method (Berndt, Hall, Hall and Hausman (1974)) for iteration. Also, the log prices and wage rates are measured from their sample means in the estimation.

changes in α_i's.

Table 3 shows estimates for the parameters α_i, γ_{ij}, and β_i from the restricted model in which the homogeneity and symmetry constraints are imposed. Since it is rather hard to assess intuitively the results from the original parameter estimates, we discuss the results based on the estimates of the price and expenditure elasticities and the derivatives. The estimates of elasticities and derivatives are highly nonlinear in their parameters, and their estimates depend on the values of prices and wage rates. We evaluate the elasticities at the sample mean values of prices and wage rates, and the standard errors are obtained by applying Rao's (1973) δ-method.

6.1 Homogeneity, Symmetry and Negative Semi-Definiteness

The χ^2 test statistic for the Lagrangian multiplier test for the joint restriction of homogeneity and symmetry is 387.4, which is in excess of conventional critical values of χ^2 with 65 degrees of freedom. However, this should not be overemphasized since a large number of observations like ours tend to reject any null hypothesis in the standard hypothesis test. In the large sample case, Deaton (1997, p.131) suggests using a Bayesian procedure created by Schwartz(1978). Deaton proposes to reject the null only for the test statistic greater than the number of restrictions (65) multiplied by the log of sample size(564). Thus, in our case the critical value is 411.8, which implies non-rejection of the homogeneity and symmetry. Also, the parameter restrictions should be evaluated in terms of economic significance, rather than on purely statistical grounds. In fact, elasticities obtained from the restricted and the unrestricted estimates are fairly close to each other.[24]

Although a statistical test of the negative definiteness of the Hicksian substitution matrix cannot be done in the AI Demand System, we can check the negativity by looking at its eigenvalues. We evaluated the substitution matrix at the sample mean values of explanatory variables and $\alpha_0 = 12.5$ which corresponds to subsistence endowment of 268,000 Yen (hourly wage rate = 560 Yen). Out of the 11 eigen values, 9 of them are negative (one of them is always zero because of the adding up property), and the magnitude of the positive eigenvalue is very close to zero (see Note 3 of Table 4). Thus, the estimates are consistent with microeconomic demand theory.

[24]See Asano [1997] for more discussion and details of this point.

6.2 Test of Weak Separability

We tested the weak separability of leisure and other commodities by using the Goldman and Uzawa method.[25] And we found that the separability is decisively rejected in both the statistical and economic senses.[26]

6.3 Price and Expenditure Elasticities

Since it is rather hard to get intuition from the original parameter estimates, we discuss the results based on estimates of price and expenditure elasticities. As shown in Section 3, price and expenditure elasticities are dependent on expenditure shares which are also functions of prices and the total endowment. Table 4 presents estimates of the compensated price and expenditure elasticities in the extended demand system evaluated at sample mean values of prices and wage rate.[27]

The point estimates of the own price elasticities are all negative, as they should be, and they are highly significant. The magnitudes of the own price elasticities are given by Table 5, which shows the lowest own price elasticity is 0.284 for utilities, the highest is 1.053 for clothing.

The cross price elasticities exhibit both substitutability and complementarity. Although substitutability is dominant, significant complementarities are found between seven pairs of commodity groups. They are, housing-(furnishings, clothes), utilities-(transportation, recreation, miscellaneous), furnishings-education, and transportation-education. Also, leisure is a substitute for all the other commodity groups.

The magnitudes of expenditure elasticities are given by Table 6, which shows that the first four items (food, medical, utilities, and leisure) are necessities, and the last seven items (education, housing, clothing, recreation, furnishings, transportation, and miscellaneous) are luxuries. Needless to say, these classifications of commodity groups and the order of elasticities are in accordance with economic common sense.

6.4 Compensated Labor Supply Elasticity

Own price elasticities can be transformed into a labor supply elasticity, whose value is crucial to compute the dead weight losses of commodity taxation.

[25]See Goldman and Uzawa (1964, theorem 5).

[26]See Asano [1997] for more details.

[27]We evaluated the substitution matrix at sample mean values of the log prices and total endowment, and derived standard errors by the δ-method (Rao [1972]).

The computed labor supply elasticity is 0.39 which is fairly high but within the range of reasonable estimates.[28]

One fact that separates our result from many others is that the labor supply (i.e. total time endowment minus consumption of leisure) enters into the utility function without the separability assumption. This is a desirable feature since the separability has been decisively rejected by our test as well as by recent empirical studies.[29]

7 Evaluation of Optimal and Uniform Taxation

7.1 Optimal and Uniform Tax Rates

Optimal tax rates are computed by solving (8) and (9) by iterative methods. Table 7 shows the estimates of optimal tax rates, uniform tax rates, and compensating variations for three tax revenue requirements, 20, 50 and 100 thousand yen per household when its per hour wage rates are assumed to be 1,000, 1,500 and 2,000 yen. When the wage rate is 1,500 yen, the monthly expenditure is around 250 thousand yen, the closest to the sample mean. From the table, we can see that the optimal tax rates are remarkably close to the corresponding uniform rates for all three tax revenue requirements, though they are not exactly uniform.

Table 9 shows the ranking of the commodities based on their own compensated price elasticities, by their wage elasticities, and by the optimal tax rates. We notice that neither the compensated inverse elasticity rule nor the compensated wage elasticity rule can predict the ranking of the optimal tax rates at all. This is due to the presence of significant cross price effects in the substitution matrix.[30]

[28] In Borjas and Heckman [1979], the range was from 0.04 to 0.20, in Killingsworth [1983] it was from 0.14 to 0.20. More recently, Pencavel [1986] surveyed fourteen major empirical studies. He reported that five yielded estimates with wrong signs, which is inconsistent with theory. Of the acceptable estimates, the largest was 0.84 and the smallest was 0.04. Excluding the extreme values, the average was 0.11.

[29] For example see Barnett [1979], and Browining and Meghir [1991].

[30] Corlett and Hague [1953] could order two tax rates according to the values of the substitution elasticities in a three-good model. Their result does not extend to the n-good economy as we mentioned in Section 2.2.

7.2 Welfare Losses

We calculated three equilibria — lump sum, uniform, and optimal commodity taxation equilibria — for a series of fixed tax revenue requirements. Then we computed the compensating variations as a measure of welfare losses by the following procedure.

Let $(\bar{p}, \bar{u}), (p^*, u^*)$, and (p^u, u^u) be the equilibrium vectors of prices (p's) and corresponding utility level (u's) under lump sum taxation, optimal taxation, and uniform taxation, respectively. Then the compensating variation from lump sum to optimal taxation is given by

$$cv = e(\bar{p}, \bar{u}) - e(\bar{p}, u^*).$$

The CV from lump sum to uniform taxation are found in a similar fashion.[31]

Table 7 shows the compensating variations. We can see that the losses increase with tax revenue requirements.

Lump Sum vs. Optimal and Uniform Taxation If we compare lump sum taxation to optimal and uniform taxation, we can immediately see that the values of the welfare losses are small. The largest percentage (as a percentage of GNP) is 6.38% when the wage rate is 1,000 yen/hour and the revenue requirement is 100,000 yen. However, this is too large a tax revenue to raise from commodity taxation, as the required uniform tax rate is 79.4%. When optimal tax rates are computed around the sample mean (1,500 yen/hour wage rate and 50,000 yen tax revenue), the welfare losses are 0.54% to 0.59%. When the revenue requirement is only 20 thousand yen, the losses are even smaller. The results are robust even when the wage rate is increased.

Uniform vs. Optimal Taxation One of the remarkable results seen in Table 7 is that the differences in dead weight losses between optimal and uniform tax rates are negligibly small. The largest is 0.016% of GNP when the wage rate is 1,000 yen and the revenue required is 100,000 yen. Around the sample mean (wage rate is 1,500 yen and the revenue requirement is 50 thousand yen) the difference of the welfare loss is 1 yen, which results in an undetectable percentage of GNP. Thus we can safely state that uniform commodity taxation is indeed a practical substitute for optimal commodity taxation as long as efficiency is at issue.[32]

[31] See Varian [1984] for the definitions of CV. In fact, our measure of welfare based on the expenditure function is the money metric utility.

[32] We did not consider the equity issues in the present paper. However, we expect that the similar results hold if non linear income tax is used together with commodity taxation.

7.3 Welfare Losses When Food is not Taxed

Table 8 shows the optimal tax rates when food is not taxed. It shows that the welfare losses are not so large in terms of % of GNP. However, a comparison to Table 7 clearly shows that welfare losses are a great deal larger when food is not taxed.

8 Conclusions

Our project had two major tasks. The first was to obtain a reasonable estimate of the Japanese demand system, which includes leisure, income, and commodity choices. The second was to compute and evaluate the optimal tax equilibrium. We employed a flexible functional form, Almost Ideal Demand System, to estimate the Japanese demand system with good results. We found that the weak separability of labor supply and commodities, which is often assumed in previous studies, is decisively rejected. On the other hand, the homogeneity, symmetry, and the negative semi-definiteness of the demand system were not rejected. The elasticity estimates were found to be within the range expected by economic common sense. For instance, the point estimate of compensated labor supply elasticity, the crucial parameter to determine the optimal commodity tax structure, was 0.39. We also found the presence of significant substitutabilities and complementarities among the expenditure groups. Thus, the estimates were found to be consistent with the theory of demand.

Based on the simulated optimal commodity tax structure, we calculated the benchmark equilibrium under lump-sum taxation. Also, we computed equilibria under optimal commodity taxation and uniform commodity taxation. By comparing the simulated equilibria, we found that the deadweight losses under uniform taxation are very small. We also found that the deadweight losses from optimal taxation are almost identical to those from uniform taxation (Table 7). The optimal commodity tax rates are found to be strikingly close to uniform. The seemingly uniform optimal rates continued to be the case when food is not taxed (Table 8).

In addition, we found that the well-known rules of thumb in optimal taxation were inappropriate. Namely, the compensated inverse price elasticity rule, which is theoretically justified when there are no cross price effects among commodities, was not helpful at all in predicting the optimum rates. Also, the compensated wage elasticity rule, which is known as Corlett and Hague rule when there are only three goods (two commodities and leisure) and which is true theoretically in n-commodity economy if cross price effects are zero, was unable to predict the ranking nor the magnitude of optimal commodity rates (Table 9). Therefore, we urge care when using 'common sense knowledge' about optimal commodity tax structures, such as non-uniformity of optimal rates and the inverse price elasticity rule. Our study indicates that the cross price effects are sufficiently large to nullify the predictions made by such rules.

References

[1] Anderson, G.J. and Blundell, R.W. [1983] "Testing Restrictions in a Flexible Dynamic Demand System: An Application to Consumers Expenditure in Canada," *Review of Economic Studies*, Vol. 50, pp.397–410.

[2] Asano, Seki [1997] "Joint Allocation of Leisure and Consumption Commodities: A Japanese Extended Consumer Demand System 1979-90", *The Japanese Economic Review* 48, No.1, pp.65-80.

[3] Anderson, G.J. and Blundell, R.W. [1985] "Consumer Non Durables in the U.K.: A Dynamic Demand System," *Economic Journal* Vol.94, 35–44.

[4] Atkinson, A. and J. Stiglitz [1972] "The Structure of Indirect Taxation and Economic Efficiency," *Journal of Public Economics*, Vol.1, 97-119.

[5] Barnett, W.A. [1979] "The Joint Allocation of Leisure and Goods Expenditure," *Econometrica,* Vol. 47, No. 3, 539-563.

[6] Berndt, E.R.B., B.H. Hall, R.E. Hall and J.A. Hauseman [1974] "Estimation and Inferences in Nonlinear Structural Models", *Annals of Economic and Social Measurement*, Vol. 3, pp. 653-665.

[7] Blundell, R.W., P.Pashardes and G.Weber (1993) "What Do We learn about Consumer Demand Patterns from Micro Data?," *American Economic Review*, Vol.83, pp.570-597

[8] Borjas, G. and J. J. Heckman [1979] "Labor Supply Estimates for Public Policy Evaluation," in *Proceedings of the thirty first annual meeting of Industrial Relations Research Association*, 320-331, Madison, Wisc., Industrial Relations Research Association.

[9] Browning, M. and C. Meghir [1991] The Effects of Male and Female Labor Supply on Commodity Demands," *Econometrica*, Vol. 59, No. 4, 925-951.

[10] Corlett, W.J. and D.C. Hague [1953] "Complementarity and the Excess Burden of Taxation," *Review of Economic Studies*, Vol. 21, 21-30.

[11] Deaton, A. [1997] *The Analysis of Household Surveys*, Johns Hopkins University Press, Baltimore, USA.

[12] Deaton, A. and Muellbauer, J. [1980] "An Almost Ideal Demand System," *American Economic Review,* Vol.70, No.3, 312-326.

[13] Deaton, A. S. and Stern, N. H. [1986] "Optimally Uniform Commodity Taxes, Taste Difference and Lump-Sum Grants" *Economics Letters,* 20, 263-266.

[14] Ebrahimi, Ahmad and Heady, Christopher [1988] "Tax Design and Household Composition." *The Economic Journal,* Vol. 98, No.390, Supplement: Conference Papers, 83-96.

[15] Fukushima, T [1989] "Note on Structure of Indirect Taxation and Economic Welfare," *Economic Studies Quarterly,* Vol.40, No.4, 349-354.

[16] ______________, [1991] "Uniformity Versus Selectivity in Tax Structure: A Simulation Approach," *Osaka Economic Papers,* Vol. 40, No. 3-4, 350-366.

[17] ______________ and Hatta, T [1989] "Why not Tax Uniformly Rather Than Optimally?," *Economic Studies Quarterly,* Vol.40, No.3, 220-238.

[18] Harris, R. G. and J.G. MacKinnon [1979], "Computing Optimal Tax Equilibria," *Journal of Public Economics,* Vol. 11, 197-212.

[19] Hatta, T. [1991] "Four Basic Rules of Optimal Commodity Taxation", Osaka Economic Papers Vol. 40, No.3,4, pp.232-249.

[20] Hausman, J.A. and Taylor W.E. [1981] "Panel Data and Unobservable Individual Effects," *Econometrica,* Vol.49, No.6, 1377-98.

[21] Japan Management and Coordination Agency, Statistics Bureau [1979-90] *Household Expenditure Survey (Kakei Chosa Nenpo).*

[22] ______________ [1979-90], *Consumer Price Index Report (Shohisha Bukka Shisu Nenpo).*

[23] ______________ [1979, 84, 89], *National Survey of Family Income and Expenditure (Zenkoku Shohi Jittai Chosa Hokoku).*

[24] Japan Ministry of Labor [1979-90] *Wage Census (Chingin Sensasu).*

[25] Judge, G.J., Griffiths, W.E., Hill, R.C., Lütkepohl, H and Lee, T.C. [1985] *Theory and Practice of Econometrics,* 2nd Edition, Wiley, New York.

[26] Kang, Suk [1985] "A Note on the Equivalence of Specification Tests in the Two-Factor Multivariate Variance Components Model," *Journal of Econometrics,* Vol.28, 193-203.

[27] Killingsworth, M. R. [1983] *Labor Supply*, Cambridge University Press, Cambridge.

[28] Murty, M. N. and Ray, Ranjan [1987] "Sensitivity of Optimal Commodity Taxes to Relaxing Leisure/Goods Separability and to the Wage Rate," *Economics Letters* 24, 273-277.

[29] Pashsrdes,P. (1993) "Bias in Estimating the Almost Ideal Demand System with the Stone Index Approximation," *Economic Journal*, Vol.103, pp.908-915

[30] Pencavel, John [1986] "Labor Supply of Men," in O. Shenfelter and R. Layard, eds., *Handbook of Labor Economics*, Vol. 1, Amsterdam: North-Holland, 3-101.

[31] Rao, C.R. [1973] *Linear Statistical Inference and Its Applications*, 2nd ed., Wiley, New York.

[32] Ray, R. [1986] "Sensitivity of 'Optimal' Commodity Tax Rates to Alternative Demand Functional Forms," *Journal of Public Economics*, 31, 253-268.

[33] Sadka, E., [1977] "A Theorem on Uniform Taxation," *Journal of Public Economics*, Vol. 7, 387-391.

[34] Samuelson, P.A. [1951] "Memorandum for U.S.Treasury, 1951" later published as "A Theory of Optimal Taxation," *Journal of Public Economics*, Vol. 30, (1986), 137-143.

[35] Schwartz,G [1978] "Estimating the Dimension of a Model," *Annals of Statistics*,Vol.6, pp.461-464.

[36] Srinivasan, P. V. [1989] "Redistributive Impact of 'Optimal' Commodity Taxes: Evidence from Indian Data," *Economics Letters*, 30, 385-388.

[37] Varian, Hal R. [1987] *Microeconomic Analysis*, second edition, W. W. Norton and Company, Inc., New York.

Table 1 Variables

FOOD	Food including eating out
HOUS	Housing including imputed rent
UTIL	Electricity, gas, light and water charges
FURN	Furniture and household utensils
CLTH	Clothes and footwear
MEDI	Medical care
TRAN	Transportation and communication
EDUC	Education
RECR	Reading and recreation
MISC	Other living expenditure
LSR	Leisure (Monthly endowment(16x30) minus monthly work hours)

TABLE 2 Summary Statistics

Shares (%)

	1980	1985	1990
FOOD	10.8 (1.2)	9.8 (1.0)	8.7 (0.9)
HOUS	4.0 (0.7)	4.8 (0.8)	5.2 (0.9)
UTIL	2.1 (0.4)	2.3 (0.4)	1.9 (0.3)
FURN	1.7 (0.3)	1.7 (0.3)	1.5 (0.3)
CLTH	3.2 (0.5)	2.7 (0.4)	2.7 (0.3)
MEDI	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)
TRAN	3.5 (0.7)	3.6 (0.7)	3.7 (0.7)
EDUC	1.4 (0.3)	1.5 (0.3)	1.6 (0.3)
RECR	3.4 (0.6)	3.4 (0.5)	3.4 (0.5)
MISC	11.5 (2.2)	10.9 (2.0)	10.4 (2.0)
LSR	57.8 (0.7)	58.0 (0.7)	58.0 (0.7)
Total Expenditure (1000 yen)	255.3 (18.7)	310.7 (25.6)	355.8 (32.0)

Prices(1980=100)

FOOD	100.0 (3.2)	113.9 (3.5)	120.8 (4.2)
HOUS	100.0 (15.4)	115.2 (17.0)	128.0 (19.4)
UTIL	100.0 (8.5)	110.7 (8.0)	97.7 (7.3)
FURN	100.0 (5.0)	108.5 (4.1)	107.5 (3.8)
CLTH	100.0 (5.7)	116.7 (5.6)	133.6 (7.2)
MEDI	100.0 (3.2)	117.1 (2.6)	123.9 (2.6)
TRAN	100.0 (2.8)	110.9 (2.4)	113.0 (2.7)
EDUC	100.0 (14.2)	130.7 (17.6)	158.9 (22.6)
RECR	100.0 (4.4)	113.9 (5.3)	123.9 (6.9)
MISC	100.0 (2.5)	114.1 (2.8)	121.1 (3.5)

Wage Rate (yen/hour)	1267.8 (158.6)	1574.8(204.8)	1879.2(258.3)
Work Hours (hours/month)	202.1 (4.3)	201.6(3.2)	201.9(2.6)

Note : Standard deviations in the parentheses.

TABLE 3 Parameter Estimates, Restricted Model

	i =	1 Food	2 Hous	3 Util	4 Furn	5 Clth	6 Medi	7 Tran	8 Educ	9 Recr	10 Misc
αi	Cnst	0.1446	0.0453	0.0274	0.0094	0.0227	0.0131	0.0181	0.0149	0.0212	0.0384
	(t-val)	(42.19)	(13.81)	(26.98)	(5.81)	(12.52)	(14.91)	(4.98)	(7.80)	(9.62)	(7.10)
γij											
j=2	Hous	0.0002									
	(t-val)	(0.08)									
	3 Util	0.005	0.0019								
	(t-val)	(2.37)	(3.25)								
	4 Furn	0.0063	-0.0036	0.0009							
	(t-val)	(1.89)	(-3.92)	(0.84)							
	5 Clth	0.0103	-0.0047	0.0025	0						
	(t-val)	(3.36)	(-4.86)	(2.48)	(-0.02)						
	6 Medi	0.0023	0.0004	0.0004	0	-0.0008					
	(t-val)	(1.06)	(0.82)	(0.48)	(0.01)	(-0.76)					
	7 Tran	-0.0109	-0.0038	-0.005	-0.002	0.0022	-0.0027				
	(t-val)	(-1.74)	(-1.98)	(-2.52)	(-0.64)	(0.71)	(-1.25)				
	8 Educ	0.0029	0.0051	0.001	-0.0025	0.0013	-0.001	-0.0065			
	(t-val)	(1.54)	(5.66)	(1.64)	(-2.72)	(1.38)	(-1.84)	(-3.36)			
	9 Recr	-0.0051	-0.0027	-0.0049	-0.0041	-0.0018	0.0008	-0.0023	0.0013		
	(t-val)	(-1.21)	(-2.15)	(-3.50)	(-1.80)	(-0.85)	(0.49)	(-0.55)	(1.03)		
	10 Misc	-0.0011	-0.0101	-0.0074	0.0054	-0.0036	-0.0005	0.0181	-0.0061	0.0133	
	(t-val)	(-0.15)	(-3.79)	(-3.21)	(1.44)	(-0.95)	(-0.19)	(2.38)	(-2.50)	(2.74)	
	11 Lsr	-0.0243	-0.0003	-0.0089	-0.0018	-0.0030	-0.0013	-0.0020	0.0015	0.0005	-0.0341
	(t-val)	(-10.44)	(-0.22)	(-12.32)	(-1.58)	(-2.47)	(-1.98)	(-0.82)	(1.35)	(0.32)	(-10.79)
βi	ln(Y/P)	-0.0465	0.0044	-0.0062	0.0069	0.0065	-0.0039	0.0181	0.0003	0.0132	0.0734
	(t-val)	(-13.35)	(1.33)	(-6.03)	(4.17)	(3.53)	(-4.36)	(4.90)	(0.17)	(5.91)	(13.34)

Note: The figures in the parentheses are t-values. The estimates are obtained by excluding leisure from the system by the adding up constraint. Also, we assumed the following:

1. Total available leisure is 16 hours per day, which implies that the resulting average monthly monetary endowment is 717.4 thousand yen.
2. α_0 is set to 12.5 which corresponds to the hourly wage rate being 560 yen and the monthly monetary endowment being 268.3 thousand yen.

TABLE 4 Estimates of Price and Expenditure Elasticities, Restricted Model

Expenditure Elasticities

	Food	Hous	Util	Furn	Clth	Medi	Tran	Educ	Recr	Misc	Lsr
Elas'ty	0.529	1.089	0.707	1.425	1.224	0.58	1.504	1.022	1.387	1.664	0.886
(s.e.)	(0.035)	(0.067)	(0.049)	(0.102)	(0.063)	(0.097)	(0.103)	(0.128)	(0.065)	(0.050)	(0.006)
Share	9.9%	5.0%	2.1%	1.6%	2.9%	0.9%	3.6%	1.5%	3.4%	11.1%	58.0%

Price Elasticities Kij (pj/qi)

j =	1 Food	2 Hous	3 Util	4 Furn	5 Clth	6 Medi	7 Tran	8 Educ	9 Recr	10 Misc	11 Lsr
i=1 Food	-0.732	0.049	0.074	0.076	0.130	0.035	-0.083	0.044	-0.023	0.065	0.364
(t-val)	(-8.46)	(2.51)	(3.50)	(2.28)	(4.20)	(1.56)	(1.31)	(2.33)	(-0.55)	(0.87)	(15.89)
2 Hous	0.098	-0.595	0.058	-0.055	-0.065	0.018	-0.040	0.118	-0.018	-0.087	0.568
(t-val)	(2.51)	(-17.46)	(5.02)	(-3.00)	(-3.34)	(1.66)	(-1.02)	(6.49)	(-0.73)	(-1.65)	(20.47)
3 Util	0.347	0.137	-0.284	0.058	0.144	0.029	-0.207	0.061	-0.202	-0.261	0.178
(t-val)	(3.50)	(5.02)	(-6.29)	(1.11)	(3.06)	(0.75)	(-2.19)	(2.19)	(-3.05)	(-2.40)	(5.35)
4 Furn	0.465	-0.168	0.076	-0.892	0.030	0.007	-0.082	-0.141	-0.210	0.473	0.442
(t-val)	(2.28)	(-3.00)	(1.11)	(-5.79)	(0.30)	(0.081)	(-0.41)	(-2.45)	(-1.51)	(2.06)	(6.48)
5 Clth	0.442	-0.111	0.105	0.017	-1.053	-0.020	0.115	0.061	-0.025	0.004	0.463
(t-val)	(4.20)	(-3.34)	(3.06)	(0.30)	(-13.98)	(-0.54)	(-1.09)	(-1.84)	(-0.34)	(0.03)	(11.53)
6 Medi	0.370	0.094	0.067	0.012	-0.063	-0.729	-0.262	-0.094	0.112	0.030	0.464
(t-val)	(1.56)	(1.66)	(0.75)	(0.081)	(-0.54)	(-3.28)	(-1.13)	(-1.59)	(0.66)	(0.11)	(6.59)
7 Tran	-0.229	-0.055	-0.122	-0.037	0.093	-0.068	-0.533	-0.165	-0.024	0.650	0.491
(t-val)	(1.31)	(-1.02)	(-2.19)	(-0.41)	(-1.09)	(-1.13)	(-2.26)	(-3.07)	(-0.20)	(3.09)	(7.47)
8 Educ	0.289	0.386	0.085	-0.150	0.117	-0.057	-0.390	-0.792	0.121	-0.287	0.678
(t-val)	(2.33)	(6.49)	(2.19)	(-2.45)	(-1.84)	(-1.59)	(-3.07)	(-10.88)	(1.45)	(-1.82)	(9.42)
9 Recr	-0.067	-0.026	-0.126	-0.100	-0.021	0.030	-0.026	0.054	-0.815	0.527	0.569
(t-val)	(-0.55)	(-0.73)	(-3.05)	(-1.51)	(-0.34)	(0.66)	(-0.20)	(1.45)	(-6.84)	(3.74)	(13.00)
10 Misc	0.058	-0.039	-0.05	0.069	0.001	0.002	0.211	-0.04	0.163	-0.604	0.228
(t-val)	(0.87)	(-1.65)	(-2.40)	(2.06)	(0.03)	(0.11)	(3.09)	(-1.82)	(3.74)	(-5.67)	(8.41)
11 Lsr	0.062	0.049	0.007	0.012	0.023	0.007	0.03	0.018	0.034	0.043	-0.285
(t-val)	(15.89)	(20.47)	(5.35)	(6.48)	(11.53)	(6.59)	(7.47)	(9.42)	(13.00)	(8.41)	(-75.05)

Note: The elasticities are evaluated at the sample means of log prices, wage rate and total endowment. The numbers in the parentheses are standard errors for expenditure elasticities, and t-values for price elasticities.

Table 5 Own Price Elasticity

Util	0.284
Lsr	0.285
Tran	0.533
Hous	0.593
Misc	0.604
Medi	0.726
Food	0.732
Educ	0.792
Recr	0.815
Furn	0.892
Clth	1.053

Table 6 Expenditure Elasticity

Food	0.529
Medi	0.580
Util	0.707
Lsr	0.886
Educ	1.022
Hous	1.089
Clth	1.224
Recr	1.387
Furn	1.425
Tran	1.504
Misc	1.664

Table 7 Optimal Tax Rates and Welfare Losses

Labor Non-Taxable

Wage Rate	¥1,000			¥1,500			¥2,000		
Rev. required	¥20,000	¥50,000	¥100,000	¥20,000	¥50,000	¥100,000	¥20,000	¥50,000	¥100,000
Elasticity of Labor Supply	0.379	0.375	0.367	0.390	0.388	0.382	0.398	0.396	0.392
FOOD	9.9	28.6	76.5	6.6	18.2	43.5	5.0	13.5	30.7
HOUS	10.2	29.5	79.0	6.9	19.0	45.5	5.3	14.2	32.4
UTIL	10.0	28.9	77.3	6.7	18.5	44.2	5.1	13.7	31.2
FURN	10.4	30.2	81.2	7.1	19.6	46.9	5.4	14.6	33.5
CLTH	10.3	29.8	79.8	7.0	19.2	46.1	5.3	14.4	32.8
MEDI	9.9	28.6	76.5	6.7	18.3	43.6	5.1	13.5	30.8
TRAN	10.5	30.4	82.0	7.1	19.7	47.3	5.5	14.8	33.7
EDUC	10.2	29.4	78.6	6.9	18.9	45.3	5.3	14.1	32.2
RECR	10.4	30.2	81.3	7.1	19.5	46.9	5.4	14.6	33.4
MISC	10.6	30.6	82.3	7.2	19.9	47.8	5.6	14.9	34.2
Uniform	10.3	29.6	79.4	7.0	19.1	45.8	5.3	14.3	32.6
CV opt	¥388	¥2,771	¥14,379	¥271	¥1,846	¥8,659	¥211	¥1,409	¥6,327
(%GNP)	0.18	1.27	6.36	0.09	0.59	2.72	0.05	0.35	1.56
CV uni	¥389	¥2,778	¥14,408	¥271	¥1,850	¥8,674	¥212	¥1,411	¥6,334
(%GNP)	0.18	1.27	6.38	0.09	0.59	2.73	0.05	0.35	1.56
EV opt	¥369	¥2,424	¥10,612	¥262	¥1,692	¥7,171	¥206	¥1,321	¥5,516
(%GNP)	0.17	1.11	4.70	0.09	0.54	2.25	0.05	0.33	1.36
EV uni	¥370	¥2,433	¥10,660	¥263	¥1,697	¥7,200	¥207	¥1,324	¥5,533
(%GNP)	0.17	1.11	4.72	0.09	0.55	2.26	0.05	0.33	1.36

cv opt-uni	¥1	¥7	¥30	¥1	¥4	¥16	¥0	¥2	¥7
(%GNP)	0.001	0.003	0.016	0.000	0.001	0.006	0.001	0.001	0.002

Table 8 Optimal Tax Rates when Food is non-taxable

Labor, Food Non-Taxable

Wage Rate	¥1,000			¥1,500			¥2,000		
Rev. Required	¥20,000	¥50,000	¥100,000	¥20,000	¥50,000	¥100,000	¥20,000	¥50,000	¥100,000
Elasticity of Labor Supply	0.379	0.375	0.364	0.390	0.388	0.382	0.398	0.396	0.392
FOOD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HOUS	14.1	44.0	151.8	9.0	25.8	68.3	6.6	18.3	44.3
UTIL	13.6	42.3	143.8	8.6	24.5	64.1	6.2	17.2	41.2
FURN	14.6	46.4	168.4	9.4	27.2	73.6	7.0	19.3	47.4
CLTH	14.3	44.9	157.9	9.2	26.4	70.4	6.8	18.7	45.6
MEDI	13.3	41.4	139.3	8.4	23.9	62.2	6.1	16.8	40.0
TRAN	14.7	46.3	160.9	9.5	27.2	72.5	7.0	19.4	47.1
EDUC	14.0	43.7	150.1	8.9	25.6	67.5	6.6	18.1	43.8
RECR	14.6	45.8	160.1	9.3	26.9	71.7	6.9	19.1	46.5
MISC	14.9	47.0	164.9	9.6	27.8	74.5	7.2	19.9	48.6
Uniform	14.5	45.6	159.7	9.3	26.8	71.6	6.9	19.1	46.5
CV opt	¥732	¥5,678	¥37,219	¥466	¥3,324	¥17,287	¥342	¥2,355	¥11,278
(%GNP)	0.34	2.59	16.32	0.15	1.07	5.43	0.09	0.59	2.78
CV uni	¥746	¥5,786	¥37,932	¥477	¥3,402	¥17,707	¥352	¥2,419	¥11,590
(%GNP)	0.35	2.64	16.65	0.16	1.09	5.56	0.09	0.61	2.86
EV opt	¥690	¥4,815	¥24,594	¥448	¥2,995	¥13,664	¥332	¥2,182	¥9,554
(%GNP)	0.32	2.20	10.79	0.15	0.96	4.29	0.08	0.55	2.35
EV uni	¥703	¥4,910	¥25,088	¥458	¥3,068	¥14,013	¥342	¥2,243	¥9,829
(%GNP)	0.33	2.24	11.01	0.15	0.99	4.40	0.09	0.56	2.42

cv opt-uni	¥14	¥108	¥713	¥11	¥78	¥420	¥9	¥64	¥312
(% of GNP)	0.007	0.050	0.323	0.003	0.026	0.136	0.002	0.016	0.079

Table 9 Ranking by Elasticities and Optimal Tax Rates

by compensated own price elasticity		by compensated wage elasticity		by Optimal tax rate(%)	
UTIL	0.284	UTIL	0.178	MISC	19.9
TRAN	0.533	MISC	0.228	TRAN	19.7
HOUS	0.595	FOOD	0.364	FURN	19.6
MISC	0.604	FURN	0.442	RECR	19.5
MEDI	0.729	CLTH	0.463	CLTH	19.2
FOOD	0.732	MEDI	0.464	HOUS	19.0
EDUC	0.792	TRAN	0.491	EDUC	18.9
RECR	0.815	HOUS	0.568	UTIL	18.5
FURN	0.892	RECR	0.569	MEDI	18.3
CLTH	1.053	EDUC	0.678	FOOD	18.2