Short of Time or Short of Money? - A Two Constraint Demand System on Canadian Food Consumption

by

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Abstract

This research develops a food demand system model based on the Linear Almost Ideal Demand System (LA/AIDS). The major contribution of this research is that the opportunity cost of time on food cooking/cleaning up is modeled in the demand system. Different from the traditional one constraint demand, this two constraints LA/AIDS model better captures consumer behavior and attitude toward food choice –food at home (FAH), sugar sweetened beverage (SSB), food away from home (FAFH). Using Statistics Canada Food Expenditure Survey (FES) and General Social Survey-time use, a two sample two stage least square (2S2SLS) is an applied in the data estimation. The empirical results show most coefficient estimates and own price elasticities are significant. FAH and FAFH are found to be more price elastic compared to a one constraint model, and SSB is found to be more price inelastic. This research provides a new perspective to estimate potential food policies, such as, a tax on SSB, or a food tax on "junk food".

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Chapter I: Introduction

Overweight and obesity represent a rapid growing threat to the health of populations in both developed and some developing countries. Based on recent research from Health Canada about one-quarter of Canadian adults are obese (Statistics Canada, 2004). When obesity is combined with overweight, the prevalence in 2008 was 62.1% (Public Health Agency of Canada, 2011).A lot of reasons affect the obesity and overweight such as dietary structure, dietary mode or exercise.

In this research, I will focus on the dietary mode to cause the obesity and overweight. Eating food away from home (FAFH) has been found to matter for Obesity. Binkley, Eales, and Jekanowski used the 1994-96 Continuing Survey of Food Intake by Individuals (CSFII) and found a positive relationship between respondents' Body Mass Index (BMI) and FAFH consumed in the previous 24 hours. They concluded that "FAFH, and particularly fast food consumption, are likely to be contributing factors to increased obesity," (Binkley, Eales, and Jekanowski 2000). Todd, Mancino, and Lin, using the 1994-96 CSFII and the 2003-04 National Health and Nutrition Examination Survey (NHANES) data, concluded that FAFH " . . . is a contributing factor to poor diet quality and that concern about FAFH's effect on obesity is warranted," (Todd, Mancino, and Lin 2010). Kolodinsky and Goldstein (2011) used the ATUS and EH Module data to investigate the relationships between time use and food patterns and obesity, and found that increases in time spent in meal preparation and cleanup are associated with decreases in BMI. Kalenkoski and Hamrick (2013) found time-poor individuals may not be able to prepare and eat healthy meals or to exercise. In the theoretical research, Beck (1965) generated a model to explain the substitutability between home production and work. They find home production is not a leisure and need time devotion as work does. A key economic variable in understanding food at home (FAH) versus food away from home (FAFH) decision is the cost of time in preparing FAH (Becker 1965). In the food demand study, Park & Capps (1997) estimates the demand for prepared food. He classified the food into four groups- ready to eat, ready to cook, FAH (except prepared meals) and FAFH, based on the household manager's opportunity cost of time. He used probit model to estimate the demand for each group of food separately. However, his measurement does not include the time cost in the estimation.

Given the important role time plays in food production and possibly health outcomes, it is surprising that there are fewer research estimates the time cost in FAH. Traditional economic models of consumer behavior assume that the demand for goods originates from an optimization problem where consumers maximize utility from the consumption of goods subject to a monetary budget constraint. Time cost is an increasing problem in modern society. Every day, people allocate their time in different activities, such as basic needs (i.e. sleeping), household production (i.e. child care, cooking, cleaning up), work, and leisure. How to make this decision and where to allocate their time is the question. The joint effects of time in the utility function and as a resource constraint (time constraint) have not received much attention in the context of demand for goods.

In this research, I will set up a two-constraint food demand system. When consumers make decisions on food choices activities- Food At Home (FAH), Sugar sweetened beverage (SSB), Food Away From Home (FAFH), they will consider both monetary budget and time budget constraints. I investigate how these two factors - price and time, affect consumer food choice. Further, I would like to estimate the elasticities using both one constraint and two constraint model and compare their differences. I believe when both monetary and time budget constraints are included in the demand system, the elasticities will be different than the traditional case where only monetary constraint is considered. For example, a price increase on FAFH will make households spend less on FAFH consumption, while spend more on FAH, if FAFH and FAH are substitutes. When both monetary and time constraints are considered, the substitution effects might not as strong as simply monetary constraint, since some time "poverty" households might find it less attractive to cook at home even they suffer a higher money cost in FAFH.

The rest of the thesis is organized as follows. Chapter 2 presents a literature review on traditional demand system and two constraint demand system. Chapter 3 specifies the model and the estimation procedure. Chapter 4 outlines the empirical estimation results, including data description, estimation procedure, model tests and elasticity estimation. Chapter 5 concludes the study.

Chapter II: Literature review

A. Traditional demand system

In practice, there are several approaches for food demand modelling, varied by choices about functional form, assumptions concerning separability and aggregation of goods, and statistical methods to be used. These modeling choices have different interpretation and structure, hence generate different elasticities of demand in policy analysis. In the following sections, I will discuss single-equation model, and four models consistent with demand theory in details.

1. Single-Equation Models of Demand

Single-Equation models of demand is the earliest studies of food consumption estimation method. The functional forms for single equation approach include Linear, semi-log, and double-log models. To date, single equation model is still very popular for its easy estimation and interpretation of parameters

$$q_i = c_{0i} + c_{1i}M + \sum_{j}^{n} c_{ji}p_j$$

where q_i is the quantity of food i, M is total expenditure, and p_j is the price of food j. However, the disadvantage of these models is that it is inconsistent with standard utility maximization theory. As Okrent (2010) mentioned " For the double-log model to satisfy the adding-up restrictions (Engel aggregation in particular), all of the expenditure elasticities must be unit elastic (Deaton and Muellbauer 1980, p.17; Johnson, Hassan and Green 1984, p.75). Thus, the expenditure shares will add to one only if the elasticities of demand with respect to expenditure are restricted to implausible values. Estimates from such models may have limited use in food demand analysis because they violate the adding-up condition."

2. Linear Expenditure System (LES)

The LES is to specify a utility function and solve for demand equation that maximizes the utility function subject to the budget constraint.

$$Max.\ u(q) = \sum_{i=1}^{n} \beta_i \, ln(q_i - \gamma_i)$$

$$s.t. \sum_{i=1}^{n} p_i \, q_i = M$$

Thus, the utility function is Stone-Geary utility function, where q_i is the quantity of food i, M is total expenditure, and p_i is the price of food i. where $0 < \beta_i < 1, \sum_i \beta_i = 1, (q_i - \gamma_i) > 0$.

Yields, using the Lagrangian function to solve the q_i and get the form of Linear Expenditure System

$$q_i = \gamma_i + \frac{\beta_i (M - \sum_{i=1}^{n} p_i \gamma_i)}{p_i}, i = 1, \dots, n.$$

and times p_i on both sides and get the resulting expenditure function for good i is:

$$p_i q_i = p_i \gamma_i + \beta_i (M - \sum_{i=1}^{n} p_i \gamma_i), i = 1, \dots, n.$$

The adding-up, homogeneity and symmetry conditions hold when $\sum_{i=1}^{n} \beta_i = 1$. Because of the LES utility function being too restrictive for demand analysis , it is a poor approximation of the actual data generating process.

Put q_i into the utility function and then get the indirect utility function is

$$v(p, M) = (M - \sum_{i=1}^{n} p_i \gamma_i) / \prod_{i=1}^{n} p_i^{\beta_i}$$

By inversion, the cost functions is

$$c(p, u) = \sum_{i=1}^{n} p_i \gamma_i + u \prod_{i=1}^{n} p_i^{\beta_i}$$

If the cost function is concave and the compensated law of demand to hold, $\beta_i > 0$, it means that all goods must be normal and substitutes for each other Another restrictive property of the LES is that it represents an additive utility function, so the price elasticities are approximately proportional to the expenditure elasticities (Deaton and Muellbauer 1980, p.66).

3. Indirect Translog Demand System (ITL)

Roy's identity is used to recover Marshallian demand functions from a specified indirect utility function. A second way to derive Marshallian demand functions is by specifying an indirect utility function and applying Roy's identity to recover the Marshallian demand functions. There are three constraints---- homogenous of degree zero, Engel aggregation and Slutsky symmetry. Christensen, Jorgenson and Lau (1975) specified a quadratic approximation to the indirect utility function.

$$\log v(p, M) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \log(p_i/M) + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \log(p_i/M) \ln (p_j/M)$$

where M is total expenditure, p_i is the price of food i and p_j is the price of food j.

Applying Roy's identity to last equation yields the Translog demand system

$$w_i(p, M) = \frac{\partial V(p,M)/\partial \log p_i}{\partial V(p,M)/\partial \log M} = \frac{\alpha_i + 0.5 \sum_{j=1}^{n} \beta_{ij} \ln(p_j/M)}{\sum_{j=1}^{n} \alpha_j + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln(p_j/M) \ln(p_k/M)}, i = 1, \ldots, n.$$

where the expenditure share equations with the conventional normalization that $\sum_{j=1}^{n} \alpha_j = 1$.

This system is known as the indirect translog demand system (ITL). The ITL indirect utility function is a generalization of the Cobb-Douglas form and reduces to the Cobb-Douglas when all of the βs are zero.

4. The Rotterdam model

A differential approximation is applied directly to the demand function. The name of the model "Rotterdam" originated from Theil (1965) and Barten (1966). It starts with the Marshallian demands $q_1 = g_1(p_1, p_2, M)$, $q_2 = g_2(p_1, p_2, M)$.

Totally differentiate, then get

$$dq_1 = \frac{\partial g_1}{\partial p_1} dp_1 + \frac{\partial g_1}{\partial p_2} dp_2 + \frac{\partial g_1}{\partial M} dM$$

$$dq_2 = \frac{\partial g_2}{\partial p_1} dp_1 + \frac{\partial g_2}{\partial p_2} dp_2 + \frac{\partial g_2}{\partial M} dM$$

Multiply by $\frac{p_i q_i}{M}, \frac{1}{q_i}, \frac{p_i}{p_i}, \frac{M}{M}$

$$\frac{p_i q_i}{M} \frac{dq_1}{q_1} = \frac{p_i q_i}{M} \frac{\partial g_1}{\partial p_1} \frac{p_1}{q_1} \frac{dp_1}{p_1} + \frac{p_i q_i}{M} \frac{\partial g_1}{\partial p_2} \frac{p_2}{q_1} \frac{dp_2}{p_2} + \frac{p_i q_i}{M} \frac{\partial g_1}{\partial M} \frac{M}{q_1} \frac{dM}{M}$$

$$w_1 d\ln q_1 = w_1 e_{11} d\ln p_1 + w_1 e_{12} d\ln p_2 + w_1 e_{1M} d\ln M$$

Use Slutzky equation to "compensate" the demands ($e_{ij} = e_{ij}^h - w_j e_{iM}$)

$$w_1 \mathrm{dlnq}_1 = w_1(e_{11}^h - w_1 e_{1M})\mathrm{dlnp}_1 + w_1(e_{12}^h - w_2 e_{1M})\mathrm{dlnp}_2 + w_1 e_{1M}\mathrm{dlnM}$$

$$w_1 \mathrm{dlnq}_1 = \gamma_{11}\mathrm{dlnp}_1 + \gamma_{12}\mathrm{dlnp}_2 + \beta_1[\mathrm{dlnM} - \sum_j w_j\, \mathrm{dlnp}_j]$$

Similarly,

$$w_2 \mathrm{dlnq}_2 = \gamma_{21}\mathrm{dlnp}_1 + \gamma_{22}\mathrm{dlnp}_2 + \beta_2[\mathrm{dlnM} - \sum_j w_j\, \mathrm{dlnp}_j]$$

where $\gamma_{ij} = w_i e_{ij}^h$ and $\sum_j w_j\, \mathrm{dlnp}_j$ is the stone index.

The Rotterdam model is:

$$w_i \mathrm{dlnq}_i = w_i \sum_j e_{ij}^h \mathrm{dlnp}_j \; + w_i e_{ix} \mathrm{dln}\overline{M}$$

where $\mathrm{dln}\overline{M} = \mathrm{dlnx} - \sum_j w_j\, \mathrm{dlnp}_j$

Or, using the regression coefficients,

$$w_i \mathrm{dlnq}_i = \sum_j \gamma_{ij} \mathrm{dlnp}_j \; + \beta_i \mathrm{dln}\overline{M}$$

Interpretation of the coefficients:

γ_{ij} is Slutzky coefficient.

The model is estimated subject to the following theoretical restrictions:

$\sum_{i=1}^{n} \beta_i = 1$, $\sum_i \gamma_{ij} = 0$ for Engel aggregation,

$\sum_{i=1}^{n} \gamma_{ij} = 0$ for linear homogeneity,

and $\gamma_{ij} = \gamma_{ji}$, $i \neq j$ for symmetry.

When the linear homogeneity restriction is imposed, each equation has n unknown parameters and n independent variables. The system can be estimated with one equation deleted after imposing Engel aggregation and symmetry. If equation n is deleted, its parameters can be recovered by summing the n-1 equations and by using the constraints of homogeneity, Engel aggregation, and symmetry. The imposition of theoretical restrictions on the model has the virtue of reducing the number of unknown parameters and improving the efficiency of the estimation.

Estimation can be subject to the restriction of symmetry. Theory also requires negative semi-definiteness of the Slutsky matrix; but, rather than being imposed, that restriction usually is just checked at the point of approximation.

5. The Almost Ideal Demand System

The almost ideal demand system (AIDS) is firstly created by Deaton (1980). Shephard's lemma is used to recover the Hicksian demand functions from a specified expenditure function. The AIDS model in budget shares is

$$w_i = \alpha_i + \sum_k \gamma_{ik} \log p_k + \beta_i \log\left(\frac{m}{P}\right),$$

where the price deflator of the logarithm of income is

$$\log P = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj}^* \log p_k \log p_j$$

The restrictions on the demand functions are deduced from the cost function, using Shephard's duality lemma. The theoretical constraints must be satisfied in AIDS:

$$\sum_{i=1}^{n} \alpha_i = 1 \text{ for adding up,}$$

$$\sum_{i=1}^{n} \gamma_{ij}^{*} = 0 \text{ and } \sum_{i=1}^{n} \beta_i = 0 \text{ for linear homogeneity,}$$

$$\gamma_{ij}^{*} = \gamma_{ji}^{*} \text{ for symmetry.}$$

Equation can be interpreted as a Marshallian or uncompensated demand function in budget shares. The Hicksian price elasticities of good i with respect to good j can be derived from the Marshallian price elasticities by using the Slutsky equation in elasticities. The expression for the Marshallian price elasticity becomes

$$\varepsilon_{ij}^{M} = -\delta_{ij} + \frac{1}{w_i}[\gamma_{ij} - \beta_i(\alpha_j + \sum_k \gamma_{kj} \log p_k)]$$

where δ_{ij} is the Kronecker delta, defined as : $\delta_{ij} = 1$ for own price elasticity with (i=j); $\delta_{ij}=0$ otherwise. The income elasticity for good i is

$$\eta_i = 1 + \frac{\beta_i}{w_i}$$

The AIDS model permits testing negative semi-definiteness of the Slutsky matrix at each data point.

The Slutsky matrix is negative semi-definite, if

$$\varepsilon_{11}^{H} < 0 \text{ and } \det\begin{bmatrix}\varepsilon_{11}^{H} & \varepsilon_{12}^{H}\\ \varepsilon_{21}^{H} & \varepsilon_{22}^{H}\end{bmatrix} = \varepsilon_{11}^{H}\varepsilon_{22}^{H} - \varepsilon_{21}^{H}\varepsilon_{12}^{H} > 0,$$

where ε_{ij}^{H} is the Hicksian elasticity for good i with respect to the price of good j. Equation for the AIDS model is analogous to equation for the Rotterdam model and can be used to compute an upper bound on the percent of non-violations of negative semi-definiteness of the Slutsky matrix.

The linear approximation for the AIDS model: LA-AIDS

The *Almost Ideal Demand System* (AIDS) model of Deaton and Muellbauer (1980b) has been widely used in *demand* analysis. Owing to its simplicity, the linear approximate almost ideal demand system (LA/AIDS) is popular for empirical studies. Both AIDS and LA/AIDS, with budget shares of the various commodities linearly related to the logarithm of real total expenditure, assume linear Engel curves.

Most of the recent food demand studies applied the LA/AIDS due to their simply calculation. It is also realistic to assume a linear engel curve for most of the food categories. Deaton and Muellbauer (1980a, b) suggest Stone's price index. When linearized by the use of Stone's index, PIGLOG was named the almost ideal demand system (AIDS) by Deaton and Muellbauer.$lnP = \sum_i w_i lnp_i$ Estimation of the resulting LA-AIDS model has a potentially endogeneity problem because the expenditure share w_i is on both sides of the demand function for good i. One possible solution is to use average budget share $\overline{w_i}$. In the price elasticity estimation, I will follow the method recommended by Green and Alston (1990).

The Marshallian price elasticities, expressed in expenditure share form, are

$$\varepsilon_{ij} = \frac{\partial \mathrm{logq_i}}{\partial \mathrm{logp_j}} = -\delta_{ij} + \frac{\partial \mathrm{logw_i}}{\partial \mathrm{logp_j}} = -\delta_{ij} + \frac{1}{\mathrm{w_i}} \frac{\partial \mathrm{w_j}}{\partial \mathrm{logp_j}}$$

and the income elasticities are

$$\frac{\partial \mathrm{logq_i}}{\partial \mathrm{logm}} = 1 + \frac{\partial \mathrm{logw_i}}{\partial \mathrm{logm}} = 1 + \frac{1}{\mathrm{w_i}} \frac{\partial \mathrm{w_i}}{\partial \mathrm{logm}}$$

Applying to the demand functions yields

$$\varepsilon_{ij} = -\delta_{ij} + \frac{1}{w_i}(\gamma_{ij} - \beta_i \frac{\partial \log P}{\partial \log p_i})$$

B. Two constrains demand system

Shaikh & Larson (2001 and 2003) developed a two-constraint Almost Ideal Demand system and apply it into recreation demand analysis, where consumer not only face money price constraint, but also a time budget. They analyze a set of whale -related activities, including whale-watching trips to any whale -watching site, time donations to whale-related organizations, and money donation to whale-related organizations. Each of these related goods has an associated money and time price. The price for whale-related trips is the total of money price and travel time plus hours watched, which will be converted to dollars by an endogenously determined marginal value of time. The time donations have only time cost without a money price, while the money donations have only a money price which is measured by the federal and local income tax rate. The time price of a money donation is essentially the time it takes to write and mail a check, so it is negligible. Larson and Shaikh (2001) verified the consistency of the demand system of using full prices and full budget in theory.

Chapter III: Model Specification and Estimation Procedure

A. Theoretical model

The general utility maximization problem for an individual when facing both money cost and time cost is:

$$\max U(x)$$

$$\text{s.t. } \boldsymbol{px} = M \qquad (1)$$

$$\boldsymbol{tx} = T \qquad (2)$$

where $U(x)$ is a twice differential utility function, $\boldsymbol{x}$ is a vector of n consumption goods, with corresponding money prices **p** and time input **t**. Here *M* represents money expenditure, and *T* is the total time. The indirect utility function is defined as

$$V(\boldsymbol{p},\boldsymbol{t},M,T) = \max U(\boldsymbol{x}) + \lambda(M - \boldsymbol{px}) + \mu(T - \boldsymbol{tx})$$

The Lagrange multipliers λ and μ represent the shadow values of money and time spent, respectively. Here, the constraint (2) is measured by time devotion. In order to measure under the same scale, we need to convert time into money units. That is, we need to find the value of time. There are several approaches to define value of money. In this research, I use an exogenous value to capture the value of time. The vector of full price is expressed as the summation of money price plus time value/unit. That is,$\boldsymbol{p}^F = \boldsymbol{p} + \rho\boldsymbol{t}$, where $\boldsymbol{p}^F$ is a vector of full price. $\boldsymbol{p}$ is the money price of the product. $\rho\boldsymbol{t}$ is the time value of the product, with $\boldsymbol{t}$ representing for the time used for generating one unit of the product, and ρ is the value of time. The full budget is the summation of money expenditure and time budget. That is, $M^F = M + \rho T$ where M^F is the full budget and T is the total time used.

So, the consumer's choice problem is:

$$\max U(\boldsymbol{x})$$

$$s.t. \quad \boldsymbol{p}^F\boldsymbol{x} = M^F$$

The implicit demand is $\boldsymbol{x} = \boldsymbol{x}\,(\boldsymbol{p}^F, M^F)$

Following Shaikh & Larson (2001 and 2003), a Two-constraint LA/AIDS demand function in budget share form can be expressed as

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j^F + \beta_i \log(M^F/P),$$

where P is a price index which is defined as

$$\log(P) = \sum_i \overline{w_i} lnp_i$$

i=1, 2, 3 represent for the FAH, SSB, FAFH, respectively.

B. Assumptions

In this research, we have three categories of food - FAH (x_1), SSB (x_2), and FAFH (x_3). We have two assumptions:

1) When time cost of cooking is considered, compared with the traditional demand model, the price elasticity of FAH will increase, whereas the price elasticity for FAFH is less elastic than before. The cost of FAH is the cost of raw materials plus time cost of cooking and the cleaning up time. We assume Food prep/cleanup are the primary activity. Based on Hamermesh (2007), evidence from the 1991–92 German *Zeitbudgeterhebung*, which includes reports of secondary activities, suggests that this is not a problem. Only 5% of all eating time was reported as secondary, far less than the average incidence of secondary time reported. Cleaning, cooking, and shopping (for all items, not just groceries) accounted for only 9% of all secondary activities, less than their representation among primary activities. When people report eating, shopping, food preparation, or clean-up, it is the primary activity, with television watching, radio listening, or childcare often being secondary to them.
2) For cost of FAFH, it includes the costs for raw materials, wage payments plus some fixed costs of furnaces and energy costs, and other overheads. I assume FAFH has no time cost. We classify an activity such as eating out is leisure, so that it may and perhaps should not be included as a time input into this commodity. As a result, price elasticity of FAH will become greater than before and the FAFH will become smaller than before because of incorporating the time cost.

Based on the above assumption, we measure the full prices of above three categories of food. We assume FAH (x_1) have both money cost and time cost. So,$p_1^F = p_1 + \rho t_1$, where t_1 is meal's prep/cleanup time. The prepared food (x_2) category includes non-alcoholic beverages and snacks, which we assume only money cost matters and there is no prep/cleanup time. So, $p_2^F = p_2$. FAFH (x_3) have only money costs, and time costs are negligible and treated as 0.

C. Data combination

TSIV v.s. TS2SLS

In this research, we need both money cost and time usage. However, currently for the public dataset, there is no single sample that contains all relevant variables we need. In this section, we use a two-sample two stage least square (TS2SLS) method first generated by Angrist and Krueger (1992), then further developed by Inoue and Solon (2010).

In a linear regression model

$$\mathrm{Y} = \mathrm{X}\beta + \varepsilon$$

with X observed in sample 2 and Y in sample 1, while there are some common variables Z in both sample 1 and 2. All the common variables Z are exogenous. Angurist and Krueger (1992) pointed out that under certain conditions, consistent instrumental variables estimation is still possible even when only *Y* and *Z* (but not *X*) are observed in one sample, and only *X* and *Z* (but not *Y*) are observed in a second distinct sample. In that case, the two-sample instrumental variables (TSIV) estimator is,

$$\hat{\beta}_{TSIV} = (Z_2'X_2/n_2)^{-1}(Z_1'Y_1/n_1)$$

The TS2SLS estimator is:

$$\hat{\beta}_{TS2SLS} = \left(\hat{X}_1'\hat{X}_1\right)^{-1}\hat{X}_1'Y_1$$

where $\hat{X}_1' = Z_1(Z_2'Z_2)^{-1}Z_2'X_2$

It is equivalent to show in the exactly identified case.

$$\hat{\beta}_{TS2SLS} = (Z_2'X_2/n_2)^{-1}C(Z_1'Y_1/n_1)$$

where $= (Z_2'Z_2/n_2)(Z_1'Z_1/n_1)^{-1}$. $\hat{\beta}_{TS2SLS}$ differs from $\hat{\beta}_{TSIV}$ by inserting the *C* matrix, which can be viewed as a sort of correction for differences between the two samples in their empirical covariance matrices for *Z*. Inoue and Solon (2010) derive and compare the asymptotic distributions of the TSIV and TS2SLS. They find that the commonly used TS2SLS estimator is more asymptotically efficient than the TSIV estimator. [1]

The major concern of applying TS2SLS is the relative efficiency of the estimator. How to estimate standard errors for the TS2SLS estimator? Currently in the published literature, there are three methods to address this issue. Currie and Yelowitz (2000) cited "Angrist and Krueger (1995) did not state exactly how they corrected their standard error estimates, but in private correspondence, the authors have informed Inoue and Solon (2008) that with the benefit of some astute advice from Steve Pischke, they correctly followed the method recommended by Murphy and Topel (1985)". Dee and Evans (2003) noted that in their exactly identified model, the TS2SLS estimator could be reinterpreted as an indirect least squares estimator, and they used that insight to motivate a straightforward delta method for estimating standard errors. Bjorklund and Jantti (1997) used a bootstrap approach to get an efficient standard error. In this research, following Bjorklund and Jantti (1997) I will use a bootstrap approach to get an efficient standard errors.

Many empirical researchers used a two-sample approach (e.g., Bjorklund & Jantti, 1997; Currie & Yelowitz, 2000; Dee & Evans, 2003; Borjas, 2004), nearly all have used the two-sample two-stage least squares (TS2SLS) estimator.

Borjas (2004) estimates the relation between the probability of receiving food assistance and food insecure. A TS2SLS approach is applied in his research since the explanatory variable - probability that a household in the Food Security Supplements receives public assistance - is not available in the primary dataset. In his research, the first-stage regression on program participation is estimated from

[1] We also resolve some confusion in the literature about how to estimate standard errors for the TS2SLS estimator.

another data source. These regressions are then used to predict the probability that a particular household in the Food Security Supplements receives public assistance.

Using TS2SLS, Dee and Evans (2004) estimate the impact of self-reported teen drinking on education achievement. Because of the causal effects, Dee and Evans (2004) constructed an instrument variable -teen drinking, based on demographic variables and minimum legal drinking age (MLDA) by states and time in the first stage.

Hamermesh (2007) estimates impact of household wage and income on food expenditure and time for cooking/cleaning up. In order to obtain unbiased estimates of the impact of time prices and incomeson goods and time inputs in eating, instrumental measures of these variables are needed. A TS2SLS is used. He instruments household income using data sets that draw randomly from the same populations as the primary data sets used.

Lusardi (1996) estimates Euler equations-that is, the first-order conditions of the consumers' maximization problem-using data from two datasets. Consumption data are taken from the Consumer Expenditure Survey. Income data are taken from the Panel Study of Income Dynamics. Because the data for the estimation come from two samples, he uses a generalization of the instrumental variables estimator-the TSIV estimator.

Chapter IV: Empirical Estimation

A. Data Description

Currently, there is no public microdata contains both time usage and food expenditures in Canada. However, there are detailed food expenditure surveys covering large samples of households, and there are surveys record detailed one day time budgets for an individual in a household that covers large samples, respectively. In this research, we will combine Canadian households' goods expenditures and time usage (as recorded in time diaries) from two surveys.

Stats Canada conducted Food expenditure survey at 1984, 1986, 1990, 1992, 1996, 2001. They conducted General Social Survey-time use every five years. The round is as follows: 1986, 1992, 1998, 2004, 2010. The selection criterion is the two surveys must be conducted in the same year. In this study, I consider using the 1992 General Social Survey-time use in Canada, a survey that obtained one day's time diaries from single individual in a household. The 1992 Food Expenditure Survey (FES1992) contains detailed categories of spending and quantities as well as a set of demographic variables that are similar in breadth to those included in the GSS-time use (1992).

Starting from 1984, Statistics Canada has conducted food expenditure survey altogether six rounds. In FES 1992, respondents kept detailed diaries of all food expenditures including both food at home and food away from home. The detailed food category file presents expenditures and quantities of 257 food categories by household. Statistics Canada has derived a set of household weights for use with the publicly available microdata files that take into account survey design and non-response. When weighted, the sample is generally representative of the Canadian population. In all subsequent analysis the results incorporate these weights. In this research, we convert all expenditures and quantities to a weekly basis.

For the purpose of this research, all food items are aggregated into 3 categories - FAH, SSB and FAFH, taking into account the opportunity cost of time, consumer preferences, and consumer willingness to substitute one product for another.

Prior to aggregation, the quantities of each category of goods were converted to kilograms to ensure that the demand model used to estimate elasticities is under the same units of measurement. The conversion factors used are those developed by Agriculture and Agri-Food Canada (Pomboza *et al.*, 2007).

The General Social Survey (GSS)-time use 1992 was collected monthly from January to December. The sample was evenly distributed over the 12 months to counterbalance seasonal variation in the information gathered. It was then divided equally among the seven days of the week. Survey conducted by Statistics Canada was using telephone interview. GSS-time 1992 use collected time diaries for only one (adult) household member. FES 1992 survey recorded the expenditure of the whole household including every member in the household. So I made a data selection. In FES 1992, data for a single adult and lone parent households are used, and the rest types of household are dropped.[2] As a result, the sample we use contains 2880 observations.

Table 1 provides summary statistics of selected variables.

[2] In order to merge two dataset, Hamermash (2007) in his research only use the two adults household, since the Time use survey only keep records of time spend of couples.

Table 1: Summary Statistics for one constraint demand system

	One constraint demand system	
	Mean	Standard deviation
P_FAFH	8.00	4.00
P_FAH	2.85	1.32
P_SSB	1.42	0.76
S_FAFH	0.26	0.26
S_FAH	0.70	0.26
S_SSB	0.03	0.06
Expenditure	66.19	49.22
Area size 1 (URBAN AREAS: POPULATION OF 100,000 OR MORE)	0.66	0.47
Area size 2 (URBAN AREAS: POPULATION OF 30,000-99,999)	0.13	0.33
Area size 3 (URBAN AREAS: POPULATION LESS THAN 30,000)	0.12	0.32
Area size 4 (RURAL)	0.09	0.29
Quart 1	0.25	0.43
Quart 2	0.24	0.43
Quart 3	0.24	0.43
Quart 4	0.26	0.44
Area 1 (Atlantic)	0.18	0.38
Area 2 (Ont & Quebec)	0.45	0.50
Area 3 (Prarie)	0.26	0.44
Area 4 (B.C)	0.11	0.32

B. Estimation Process

In the first stage, cooking/cleaning up time is estimated using data from General Social Survey -Time Use (1992) based on household demographic variable and working activities.

$$T_h^{TUS} = Z^{TUS'}\delta + u_h \tag{1}$$

where T_h^{TUS} is the cooking/cleaning time of household h, $h = 1,\ldots,H$ households; Z^{TUS} represents explanatory variables in the TUS including gender, age and education of reference person, number of kids under four, number of kids greater than 5 and less than 18, working status - no employment, part-time and full-time working, and birth place. α is the related coefficients. u_h is the error term.

Ordinary Least Squares (OLS) is applied in TUS to estimate equation (1), and the estimated coefficients $\hat{\delta}$ is obtained. The predicted cooking/cleaning up time $\hat{T}_h^{FES}$ is constructed using $\hat{\delta}$ and common set of explanatory variables in FES.

$$\hat{T}_h^{FES} = Z^{FES'}\hat{\delta} \tag{2}$$

$$s_{ih} = \sum_{k=1}^{3} \alpha_{ik} ln({p_{kh}}^F) + \beta y_h + \sum_{t=1}^{T} \gamma_{it}\, z_{th} + e_{ih} \tag{3}$$

$$y_h = lnx_h - \sum_{i=1}^{N} \bar{s}_i \ln ({p_{ih}}^F) \tag{4}$$

$${p_{1h}}^F = p_{1h} + \rho \hat{t}_h^{FES} \tag{5}$$

$${p_{2h}}^F = p_{2h} \tag{6}$$

$${p_{3h}}^F = p_{3h} \tag{7}$$

for $i = 1,\ldots,3$ food categories and $h = 1,\ldots,H$ households. In equation (3), s_{ih} is the budget share for food product i in household h; ${p_{kh}}^F$ is the full price of food k for household h, $k = 1,\ldots,3$ food categories; the parameter α_{ik} describes price effects; y_h is the log of real expenditure of household h; the parameter β is the estimated coefficient, $\boldsymbol{z_h} = (z_{th},\ t = 1, \ldots, T)$ is a vector of household characteristics and t indexes demographic variables; parameter γ_{it} estimates demographic shifters in budget shares. Finally, e_{ih} is the error term. In equation (4), x_h is the total food expenditure; $\bar{s}_i$ is the sample average budget share of food item i over all households. [3] In equation (5), ${p_{1h}}^F$ is the full price of FAH, p_{1h} is the money price of FAH, ρ is the time value of cooking/cleaning up. In equation (6), ${p_{2h}}^F$ is the full price of SSB, and p_{2h} is the money price of it. In equation (7), ${p_{3h}}^F$ is the full price of FAFH, and p_{3h} is the money price of it.

The following theoretical restrictions are satisfied:

$$\sum_{i=1}^{N} \beta_{i0} = 1, \sum_{i=1}^{N} \beta_{ir} = 0 \text{ for } r = 1, \ldots R, \sum_{i=1}^{N} \gamma_{it} = 0, \sum_{i=1}^{N} \alpha_{\mathrm{ik}} = 0 \tag{8}$$

$$\sum_{k=1}^{N} \alpha_{\mathrm{ik}} = 0 \tag{9}$$

$$\alpha_{ik} = \alpha_{ki} \tag{10}$$

When equations (8) and(9) hold, equation (3) represents a system of demand functions homogeneous of degree zero in prices and total expenditure. Equation (10) guarantees Slutsky symmetry of the demand equations. Budget shares sum to one ($\sum_{i=1}^{N} \boldsymbol{s_i} = 1$).

In the second stage, a Seemingly Unrelated Regression (SUR) will be used to estimate the two constraint demand system. Stata 12 is used in the estimation.

C. Estimation Results

Table 2 displays the estimates relationship between time use for cooking/cleanup and gender, age, education, kid0004, kid0518, working status (part-time/full-time) and birthplace. I find females use more time cooking than male. Further, I find the older the age of the reference person, the more cooking time she/he needs. However, I do not find the significant impact of education on the time use for

[3] $\sum_{i=1}^{N} \bar{w}_i \ln{(p_{ih})}$ is also called Stone price index (Deaton *et al.*, 1980).

cooking/cleanup. When the household have one more child that the age is between 0 and 4, the household will take 20.04 more minutes for the cooking and cleaning. For the household with child's age between 5 and 18, increasing one more child will rise the cooking time by 17.78 minutes. I also find the household from Asian use less cooking time than the household from Canada/U.S./Europe.

Table 2: Estimation of time cooking and cleaning up

Variables	Estimated Coefficients	Robust Std. error
Gender (male=1)	-11.01***	1.98
Age of reference people	4.07***	0.33
Education	1.04	1.30
Household has kid<=5	20.15***	4.19
Household has 5<kid<17	17.91***	2.25
Working status (work=1)	-5.47***	1.02
Birthplace (US & Canada=1)	4.78	3.04
Constant	23.23***	5.46

Note: Sampling weights are used in all regressions, *, ** and * denote significance at the 10%, 5% and 1% levels.**

In this section, I estimate four demand systems. (1) One constraint demand system, with only money constraint; (2) a two constraints demand system with both money and time constraints, using income/hour as an approximate for value of time; (3) a two constraints demand system with both money and time constraints, using wage rate to estimate the value of time; (4) a two constraints demand system with both money and time constraints, using minimum wage rate to measure the value of time.

1. One constraint demand

I first estimate a one constraint demand system. The uncompensated (Mashallian) price demand elasticities is

$$\varepsilon_{ij}^{M} = \frac{1}{\overline{s_\iota}} \alpha_{\mathrm{ij}} - \delta_{\mathrm{ij}}$$

Where δ_{ij} is the Kronecker delta with $\delta_{\mathrm{ii}} = 1$ for the own price elasticities and $\delta_{\mathrm{ij}} = 0$ for the cross price elasticities. $\overline{s_\iota}$ is estimated using sample/subsample mean of the budget share for each food category. The compensated (Hicksian) demand elasticities are obtained through the Slutsky equation: $\varepsilon_{ij}^{h} = \varepsilon_{ij}^{m} + \eta_i \bar{s}_j$, where η_i is the expenditure elasticity.

In this analysis, only money cost is considered. The estimated coefficients of the LA/AIDS demand system are reported in Table 3.

Table 3: Estimated Coefficients of one constraint demand

		Coefficients	Robusted Std. Err.
S1	y	-0.0772	0.00631
	Inp1	0.0175	0.00840
	Inp2	0.00992	0.00227
	Inp3	-0.0274	0.00810
	Prv1	0.0594	0.0232
	Prv2	0.0196	0.0146
	Prv3	-0.00870	0.0179
	Area1	-0.0486	0.0183
	Area2	-0.0162	0.0222
	Area3	-0.0130	0.0225
	Quart1	-0.00226	0.0133
	Quart2	-0.0235	0.0135
	Quart3	-0.0104	0.0135
	Constant	0.973	0.0296
S2	y	-0.00572	0.00142
	Inp1	0.00992	0.00227
	Inp2	-0.00631	0.00217
	Inp3	-0.00361	0.00196
	Prv1	0.0167	0.00521
	Prv2	0.0146	0.00330
	Prv3	0.00932	0.00403
	Area1	-0.00704	0.00411
	Area2	-0.00991	0.00500
	Area3	-0.00591	0.00507
	Quart1	0.00332	0.00300
	Quart2	0.00319	0.00303

Quart3	0.00239	0.00303
Constant	0.0404	0.00698

Table 4 reports the estimated Mashallian elasticities. The own price elasticities for FAH (SSB, FAFH) is -0.898 (-1.184, -0.965). Consumers are more sensitive to the price change of SSB and FAFH compared to FAH.

Table 4: Demand system with one constraint

	FAH	SSB	FAFH
FAH	-0.898	0.303	-0.187
SSB	0.091	-1.184	-0.097
FAFH	0.038	-0.103	-0.965

Consistent with most of the food demand study, as a necessity the own price elasticity of food at home is less than 1 (-0.898), implying an inelastic food demand. The own price elasticity for SSB is elastic (-1.184). Using Canadian FES 2001, Pomboza (2005) found the own price elasticity is -1.17, which implied there is no huge departure between our estimation and the rest of the studies. The estimated own price elasticity of FAFH is -0.965.

2. Two constraints demand

In the rest of this section, I estimate series of two constraints food demand systems varied by the measurement of value of time cooking/cleaning up. Similar like the one constraint demand system, the uncompensated (Mashallian) full price demand elasticities is

$$\varepsilon_{ij}^{MF} = \frac{1}{s_i^F}\alpha_{ij} - \delta_{ij}$$

Where δ_{ij} is the Kronecker delta with $\delta_{ii} = 1$ for the own price elasticities and $\delta_{ij} = 0$ for the cross price elasticities. $\overline{s_i}$ is estimated using sample/subsample mean of the budget share for each food category including the time cost. The compensated (Hicksian) demand elasticities are obtained through the Slutsky equation: $\varepsilon_{ij}^{Hf} = \varepsilon_{ij}^{MF} + \eta_i \overline{s_j^F}$, where η_i is the expenditure elasticity.

Using 1/3 wage rate

I first estimate a two constraint demand system using 1/3 wage rate as an approximate for value of time. As mentioned by Shaikh and Larson (2003) several studies have followed the basic logic of Becker's early work assuming the opportunity cost of recreation time is an exogenous parameter, such as wage rate. Cesario (1976), McConnell and Straind (1981), and Smith (1983) use fraction of wages to measure opportunity cost of recreation. Following their methodology, in this paper, I firstly use 1/3 wage rate to measure the opportunity cost of cooking/cleaning up. Table 5 reports the estimated coefficients of a two constraint demand system using 1/3 wage rate as a measurement of value of time cooking/cleaning up.

Table 5: Estimates of a two constraint demand using 1/3 wage rate

		Coefficients	Robust Std. Err.
S1	Y	-0.0357	0.00619
	Inp1	-0.0936	0.00672
	Inp2	0.0111	0.00190
	Inp3	0.0825	0.00666
	Prv1	0.0513	0.0227
	Prv2	0.00600	0.0143
	Prv3	-0.0114	0.0175
	Area1	-0.0340	0.0179
	Area2	-0.0142	0.0217
	Area3	0.00120	0.0220
	Quart1	-0.00219	0.0130
	Quart2	-0.0226	0.0132
	Quart3	-0.0155	0.0132
	Constant	0.771	0.0283
S2	Y	-0.00465	0.00156
	Inp1	0.0111	0.00190
	Inp2	-0.00619	0.00219
	Inp3	-0.00488	0.00205
	Prv1	0.0174	0.00570
	Prv2	0.0149	0.00361
	Prv3	0.00891	0.00440
	Area1	-0.00839	0.00451
	Area2	-0.0105	0.00547
	Area3	-0.00685	0.00555
	Quart1	0.00349	0.00328
	Quart2	0.00292	0.00332

Quart3	0.00216	0.00331
Constant	0.0369	0.00766

Table 6 reports the estimates the related Mashallian price elasticity of AIDS demand system with two constraints. Apparent differences in elasticities have been found. The Mashallian own price elasticity for FAH (SSB, FAFH) is -1.097 (-1.181. -1.334).

Table 6: Mashallian price elasticities using One third wage

	FAH	SSB	FAFH
FAH	-1.097	0.0514	0.153
SSB	0.337	-1.181	-0.142
FAFH	0.272	-0.0588	-1.334

Using average income before tax (1/3 income rate)

I then estimate a two constraint demand system using 1/3 income rate as an approximate for value of time. In Canadian FES 1992 data, household income before are also reported. I notice some of the reference household report a zero annual wage, however a positive income. Or some reference people in a household report an annual wage which is different from their reported income before tax. It is possible the reference people in a household does not involved in any full time/part time/contracted/sessional working activity, however might has other source of financial income, for example, from government transfer, or other financial investments or heritage. In this paper, I use a 1/3 of the income rate to measure the opportunity cost of cooking/cleaning up time. Table 6 reports the estimates of AIDS demand system with two constraints using 1/3 income rate as a measurement of opportunity cost of cooking/cleaning up.

Table 7: Estimates of a two constraint demand using 1/3 income rate

		Coefficients	Robust Std. Err.
S1	y	-0.0288	0.00616
	Inp1	-0.102	0.00646
	Inp2	0.0104	0.00182
	Inp3	0.0911	0.00643
	Prv1	0.0480	0.0225
	Prv2	0.00326	0.0142
	Prv3	-0.0109	0.0174
	Area1	-0.0349	0.0178
	Area2	-0.0172	0.0216
	Area3	0.00191	0.0219
	Quart1	-0.000749	0.0129
	Quart2	-0.0208	0.0131
	Quart3	-0.0133	0.0131
	Constant	0.753	0.0280
S2	y	-0.00453	0.00157
	Inp1	0.0104	0.00182
	Inp2	-0.00559	0.00216
	Inp3	-0.00482	0.00205
	Prv1	0.0177	0.00574
	Prv2	0.0151	0.00363
	Prv3	0.00895	0.00443
	Area1	-0.00811	0.00453
	Area2	-0.0101	0.00550
	Area3	-0.00667	0.00558
	Quart1	0.00333	0.00330
	Quart2	0.00277	0.00334
	Quart3	0.00182	0.00333
	Constant	0.0362	0.00773

Table 8 presents the related the Mashallian price elasticity. The Mashallian own price elasticity for FAH (SSB, FAFH) is -1.116 (-1.163. -1.36).

Table 8: Mashallian price elasticities using one third income

	FAH	SSB	FAFH
FAH	-1.116	0.0436	0.158
SSB	0.317	-1.163	-0.14
FAFH	0.312	-0.0516	-1.36

Using Minimum wage rate varied by province

The last estimates report a two constraint demand system using provincial minimum wage rate as an approximate for value of time. In this paper I assume everyone's opportunity cost of cooking/cleaning up has a value, even if household may have zero annual wages. The benefit of using this measurement is every household has a positive opportunity cost of time. Table 8 reports the minimum wage rate varied by province in 1992.

Table 9: Minimum wage rate varied by province in 1992

Province	Minimum Wage Rate
Federal	4.00
Alberta	5.00
British Columbia	5.50
Manitoba	5.00
New Brunswick	5.00
Newfoundland and Labrador	4.75
Northwest Territories	7.00
Nova Scotia	5.00
Ontario	6.35
Prince Edward Island	4.75
Quebec	5.70
Saskatchewan	5.35
Yukon	6.24

Table 10 reports the estimates of AIDS demand system with two constraints using provincial minimum wage rate as a measurement of opportunity cost of cooking/cleaning up.

Table 10: Estimates of a two constraint demand using minimum wage rates

		Coefficients	Robust Std. Err.
S1	y	0.0115	0.00821
	Inp1	-0.0256	0.00817
	Inp2	0.00830	0.00227
	Inp3	0.0173	0.00795
	Prv1	0.0667	0.0236
	Prv2	0.0132	0.0149
	Prv3	-0.00649	0.0182
	Area1	-0.0504	0.0186
	Area2	-0.0205	0.0226
	Area3	-0.0755	0.0229
	Quart1	0.00245	0.0136
	Quart2	-0.0203	0.0137
	Quart3	-0.0143	0.0137
	Constant	0.706	0.0323
S2	y	-0.00368	0.00200
	Inp1	0.00830	0.00227
	Inp2	-0.00516	0.00226
	Inp3	-0.00314	0.00197
	Prv1	0.0168	0.00535
	Prv2	0.0142	0.00340
	Prv3	0.00886	0.00413
	Area1	-0.00665	0.00422
	Area2	-0.00957	0.00513
	Area3	-0.00547	0.00521
	Quart1	0.00320	0.00308
	Quart2	0.00293	0.00312

	Quart3	0.00194	0.00311
	Constant	0.0294	0.00900

Table 11 presents the related Mashallian price elasticity of the demand system. The Mashallian own price elasticity for FAH (SSB, FAFH) is -1.048 (-1.151. -1.046).

Table 11: Mashallian elasticities using minimum wage rate

	FAH	SSB	FAFH
FAH	-1.048	0.000256	0.0131
SSB	0.253	-1.151	-0.0905
FAFH	0.0734	-0.00402	-1.046

For the two constraint demand specifications, Larson and Shaikh (2011) have verified in theory that the theoretical constraints including homogeneity, symmetric. In general, I find once time cost in cooking and cleaning up is incorporated, the own price elasticities of FAH increased compared to the classical one constraint AIDS model; meanwhile, the own price elasticities for SSB decreased.

Once opportunity cost of time is modeled in the demand system, this two constraints AIDS better captures consumer behavior and attitude toward food choice. In fact, the two constraint demand models is a true behavior of consumer. When consumer make a decision of food choice, i.e., cooking at home or dining out, there is a trade-off between money and time. Cooking at home may save money but need cooking /cleaning up time. FAFH are expensive, but time saving. In the labor market, as more female goes to the job market. The opportunity cost of cooking/cleaning up is a serious problem in modern society. Without considering the time cost in cooking, a traditional one constraint demand cannot fully explain consumer choice.

This give us another look at the current and potential food policy. In fact, many states in U.S have already adopted a small taxes in SSB in order to control the obesity. Does a food tax on SSB actually can change the consumer behavior from unhealthy food to healthy food as most public health researches described? The answer is no. When opportunity cost of money is modeled in the consumer behavior in the research, we find consumers are less elastic with price change for SSB. That is, a food tax on unhealthy food may not obtain their original purpose, since consumers are less sensitive to the price change on unhealthy food (SSB) and more sensitive to the price change of healthy food (FAH), when both money cost and time cost are important in their food choice. In Canada, many public health researchers advocate "fat taxes" on unhealthy food such as food contains higher calorie, fast food. When a “junk food tax” is imposed on FAFH (i.e. fast food), my result on two constraint demand system showing that this kind of food policy will be more effective in changing consumer behavior.

Chapter V: Conclusion and Implications

This research develops a food demand system model based on the LA/AIDS. Different from the traditional one constraint demand, the two-constraint utility maximization model of food choices results in demands that are functions of both full prices and full budgets—a requirement of models of choice subject to both time and money constraints.

A share system based on the AIDS is estimated. Most coefficient estimates are found to be significant and used to calculate elasticities. FAH and FAFH are found to be more own-price-elastic compared with one constraint model, and SSB is found to be more own-price-inelastic.

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