ESSAYS ON TAXATION: POSITIVE AND NORMATIVE ASPECTS

BY

HARRY TSANG

DISSERTATION

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Doctoral Committee:

Professor Firouz Gahvari, Chair
Professor J. Fred Giertz
Professor Hadi Salehi Esfahani
Assistant Professor Seung-Hyun Hong

ABSTRACT

This dissertation consists of three essays on taxation. The first essay examines whether government policy, through the use of tax incentives, is able to encourage household savings. This essay analyzes the impact of the 1990 Education Savings Bond Program. This policy created an additional tax incentive for owners of existing government savings bonds, by allowing interest earnings to be exempt from income taxes in years where the household incurs a qualified education expense. Using the 1989 and 1992 Survey of Consumer Finance data sets, a difference-in-difference methodology is used to measure how household savings has changed over time for households with college-bound children as opposed to those without. Households without college-bound children do not need to save for education and thus are not affected by the program. The comparison of savings for the two groups, correcting for individual characteristics, reveals the impact of the Education Savings Bond Program. In addition, this procedure allows one to infer if there has been a crowding out effect due to the Education Savings Bond Program. The results indicate that the policy has not had an effect on household savings.

The second essay uses two different estimation procedures to calculate the incidence of environmental taxes and compares the results. Both estimation procedures assume non-separability of leisure and so the labor response is incorporated into estimates of household behavior. The first method is the Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer. The AIDS model assumes linear Engel curves and if this assumption is violated then welfare estimates are biased. The Quadratic Almost Ideal Demand System (QUAIDS) model of Banks, Blundell and Lewbel extends the AIDS model to allow for non-linear Engel curves. Households consume three goods – a composite clean good, a composite energy good and leisure. Data on household consumption is from the Interview Survey component of the Consumer Expenditure Survey. The AIDS model finds the energy good and

leisure to be substitutes while the QUAIDS model finds no relationship between the two goods. Moreover the AIDS model is found to overestimate the welfare loss of environmental taxes on low-income households but underestimate the welfare loss of environmental taxes on high-income households.

The third essay again uses the Almost Ideal Demand System model of Deaton and Muellbauer to estimate demand for junk food as well as calculate the incidence of taxes on junk food. The model assumes households consume three goods – a composite healthy food good, a composite unhealthy food good (junk food) and a composite nonfood good. Data on household consumption is from the Diary Survey component of the Consumer Expenditure Survey. The Diary Survey collects detailed data on food expenditures. Price data consists of price indices for various commodities which is available from the Bureau of Labor Statistics. The compensated own-price elasticities indicate that both healthy food and junk food have inelastic demand. In addition, healthy food and junk food are found to be substitutes. The elasticity values found are consistent with the literature.

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CHAPTER 1

EDUCATION SAVINGS BONDS AND SAVINGS BEHAVIOR

1.1 Introduction

The Education Savings Bond Program, implemented in 1990, is a policy that allows households to exempt interest income if government savings bond owners have qualified higher education expenses in the same year the bonds are redeemed. This policy does not create a new class of savings bonds but rather creates an additional tax incentive. Previously, government savings bonds featured tax-free accrual of interest income. The new incentive is the ability to exempt this interest income from taxation. The question is how did households respond to this policy? Did savings bonds become more attractive to households, and if so is this at the expense of other assets?

There has been an extensive debate on the ability of the government to motivate savings behavior through the use of tax incentives. Individual retirement accounts, IRAs, and 401(k) plans were created to encourage retirement saving since the low saving rate threatened the financial health of retired households. The federal government created the Coverdell Education Savings Accounts and the states created 529 savings plans to address the ability of middle-class households to handle rising higher education costs.

The difficulty in identifying the effectiveness of saving incentives arises from the inability to control for individual specific saving behavior, which causes certain households to be high savers. Research on the effectiveness of IRA and 401(k) plans has consistently shown that contributors have higher savings than non-contributors, yet one must be cautious in interpreting contributions as new saving. IRA and 401(k) contributors have higher propensities to save and thus would be expected to have larger asset balances.

In this study, the 1989 and 1992 Survey of Consumer Finance data sets are pooled together in order to use a difference-in-difference methodology to identify the policy effect. The method examines how the difference in household savings, between households with college-bound children and households without college-bound children, has changed over the 1989-1992 time period. The identification strategy behind this methodology is based on two random sources of variation – the policy being implemented in 1990 and the policy only affecting households with college-bound children. The key to this identification strategy is the assumption that whether a household is in the treatment or control group is independent of their propensity to save. Therefore whether one is a high saver or low saver should be independent of having college-bound children. The data indicates that the saving behavior of the two groups is similar prior to 1990.

The result is that the 1992 difference between the two groups, net of the 1989 difference, is the effect of the Education Savings Bond Program. The same rationale allows one to use the difference-in-difference methodology to infer what indirect impact the Education Savings Bond Program has had on other assets such as stocks, bonds, mutual funds and money market accounts. The results indicate that households did not respond to the policy; there is no significant change in the difference in asset balances between the treatment and control group. This includes an analysis of the household bond portfolio which seems the most plausible source of substitution. In addition focusing the analysis on households who would be financially literate does not reveal a policy effect. This includes households who already own savings bonds and therefore would be most likely to respond to this policy since they already have a taste for savings bonds. The drawback in the Education Savings Bond Program seems to be that it targets a financial asset that is not widely held by households. In addition the incentive lacks "bite" because the tax savings for the average household, from being able to exempt interest income, is modest due to the small amount held in savings bonds.

1.2 Saving Incentives and Theory

1.2.1 Retirement and Education Saving Incentives

Government savings bonds are one of several investment securities offered by the government, the others being Treasury bills, bonds and notes. There are two types of government savings bonds – series EE and series I.[1] The interest rate for series I is based on the inflation rate, while for series EE bonds it is a variable market-based rate based on 5-year U.S. Treasuries.[2] Although federal income taxes must be paid on the interest income, it can be deferred until the bonds are redeemed or until final maturity. This deferral of interest income taxes is one benefit over Treasury bills, bonds and notes.

The Education Savings Bond Program does not create a new class of savings bonds, but rather allows the owners of series EE or series I bonds to exempt the interest income from federal income taxes. In order to claim the exemption, either the bondholder, spouse or dependant has to have a qualified higher education expense in the same calendar year that the bonds are redeemed. Eligibility for the interest income exemption is based on being below an inflation-adjusted income threshold. In 2003, a married couple filing a joint tax return has to have a modified adjusted gross income of $87,750 or less to be eligible for the full interest income exemption. The exemption is phased out so that households with income above $117,750 are no longer eligible and the range for single households is from $58,500 to $73,500. Although the saving incentive literature focuses on tax-deferred retirement accounts, some of the issues that affect the analysis of tax-deferred retirement accounts also affects the analysis of the Education Savings Bond Program.[3]

The saving incentive literature focuses on IRAs and 401(k) plans, however Keogh plans have been available since 1963 for self-employed persons with no retirement security. The Employee Retirement Income Security Act of 1974 created the IRA as a means of providing retirement security to the significant portion of households not covered by a private pension plan. The 1978 Revenue Act created the 401(k) plan. The Economic Recovery Tax Act of 1981 popularized IRAs and 401(k)'s by expanding eligibility of IRAs to virtu-

[1]The Treasury Department discontinued series H bonds in September 1 of 2004. However they were never eligible for the Education Savings Bond Program.

[2]The Bureau of the Public Debt announced that series EE bonds would earn a fixed rate of return beginning with bonds issued in May of 2005

[3]The primary difference is that the Education Savings Bond Program targets a specific asset, while all financial assets can be invested in a tax-deferred savings account. There is also no tax deduction for buying savings bonds, unlike the tax-deductibility of contributions to a savings account. There is a penalty for misusing funds in a tax-deferred savings account, but there is no penalty if the savings bonds are not redeemed in the same year that there is a higher education expense. The only impact is that the bond owner would have to pay income taxes on interest income, which he would have done in the absence of the policy.

ally all workers and also clarified the tax rules governing 401(k) plans. This growth in IRAs continued until the 1986 Tax Reform Act which eliminated the tax-deductibility of contributions for those above an income threshold, although the tax-free accrual of interest remained. Unaffected by TRA86, 401(k) plans have become the household's vehicle of choice for retirement planning.

The popularity of IRAs and 401(k)'s led people to believe that tax incentives could encourage household savings. To help households handle the rising higher education costs and to promote saving, both the federal and state legislatures enacted their own education saving incentives. Congress expanded IRA accounts to include saving for education with the creation of the Education IRA in 1997. This was renamed the Coverdell Education Savings Account in 2001 after Senator Paul Coverdell of Georgia, who first proposed the legislation.[4] Almost all of the states have created their own 529 savings plans, which is a state version of the Coverdell ESA.

As the original name of the Coverdell suggests, these education savings accounts are essentially IRAs but with the focus on education expenses as opposed to retirement. Both the retirement and education savings accounts feature tax-free accrual of interest as well as an annual contribution limit, income threshold and penalties for misusing account assets. Unlike IRA and 401(k) accounts, contributions to both the Coverdell ESA and the 529 plans are not deductible at the federal level. Certain states do allow contributions to be deductible for state income tax purposes.[5]

1.2.2 Theory on the Effectiveness of Saving Incentives

The different characteristics of these savings accounts have different effects on the incentive to save. Since income taxes are deferred until withdrawal, assets in tax-deferred retirement accounts earn a higher rate of return. The existence of an annual contribution limit combined with empirical evidence

[4] Downing

[5] Almost all of the states offer their own 529 savings plans, which are also open to residents of other states. Contributions can be deducted from state income taxes for some of the states. However if contributions can be deducted, that is only available for residents of that state and not out-of-state residents.

that shows a significant number of households contributing up to the limit,[6] raises the question of whether a marginal incentive to save exists. If households annually save the maximum amount so that the next dollar saved earns the after-tax rate of return, then a marginal incentive to save does not exist. However if a life-cycle model is the appropriate framework for evaluating savings behavior then lifetime contribution limits should be considered. Since these limits do not bind, a marginal incentive to save does exist (Skinner 1991).

Another important factor is the tax-deductibility of contributions to a retirement account. This lowers the cost of contributions. Therefore saving in a retirement account is now more attractive and this is partly why some believe tax incentives encourage households to reshuffle saving. If income taxes are lower at retirement, then the ability to defer taxes until retirement will also further encourage saving in a retirement account.

The last factor is the liquidity constraint created by the penalty for early withdrawal. If households withdraw funds from an IRA or 401(k) plan before the age of 59, then there is a 10% penalty. Education savings accounts have a similar penalty if the funds are not used for a qualified higher education expense. If the need for precautionary savings motivates households to save then this liquidity issue means retirement accounts and conventional savings accounts are imperfect substitutes. This reduces the desire to replace savings in a conventional account with savings in a retirement account. However most IRA contributors have considerable assets or are close to the retirement age which limits the impact of the liquidity constraint. Since these households are not affected by this issue they are the most likely to reshuffle saving.[7] As a consequence of all these features, economic theory does not provide clear guidance on the ability of these saving incentives to increase the saving rate.

In regards to savings bonds and the Education Savings Bond Program, the incentive effect comes from the fact that interest income is now exempt from taxation upon withdrawal as long as there is a qualified higher education expense. This is because the Education Savings Bond Program creates an additional tax incentive that any series EE or I savings bond owner can take advantage of if they have a qualified education expense. The policy does not

[6]Burman, Cordes and Ozanne (1990) find that 75% of contributions were made at the limit.

[7]Gale and Scholz (1994)

create any new bond that is only for education purposes. Therefore there is no penalty if the bond is not used for education purposes. The only liquidity issue is that all savings bonds have to be held for at least 12 months before they can be redeemed.

1.2.3 Empirical Evidence on the Effectiveness of Saving Incentives

In the saving incentives literature there is great difficulty in identifying the impact of tax incentives because there is difficulty in controlling for the self-selection problem with regards to high savers. The literature on IRAs shows that IRA owners are wealthier and have substantially more assets, both conventional and tax-advantaged.[8] However this by itself does not indicate that IRAs are new saving because it is difficult to control for propensities to save.[9] If those that choose to invest in IRAs have a higher propensity to save, it should not be a surprise that they will have more assets and therefore is not automatic proof of a positive effect.

This difficulty in controlling for the propensity to save is seen in the research of two groups of authors who use the same data to estimate the effectiveness of IRA accounts but find conflicting results. Venti and Wise (1986, 1987, 1988, 1990) and Gale and Scholz (1994) use the 1983 and 1986 Survey of Consumer Finance data sets, but the former finds that IRA contributions represent new saving while the latter finds that it represents reshuffled saving.[10]

What is driving the different estimates is differences in interpretation of the data and also differences in modeling. Venti and Wise examine all households and find that very few households hold IRAs. If IRAs are good substitutes for other saving then households should first invest in IRAs. However since most households do not invest in IRAs it must be that they are not perfect substitutes and therefore IRA contributions must be from consumption

[8]Both proponents and critics agree that the data indicates that households with IRAs have higher assets, where they differ is on what this means in regard to modeling and explaining saving behavior.

[9]Diamond and Hausman find propensities to save to vary across households.

[10]Although the saving incentive literature is centered around these two, the first analysis was actually conducted by Hubbard (1984) on IRA and Keogh accounts. He found that contributions raised the saving rate, with the amount of the increase being correlated with the marginal tax rate.

(Gravelle 1991). Gale and Scholz on the other hand believe that whether or not IRAs are perfect substitutes depends on who holds IRAs. Since IRA contributors are older and also wealthier, they are less likely to be affected by the liquidity constraint of IRAs and therefore more likely to find the accounts to be good substitutes.[11] As a result the Gale and Scholz model estimates different saving equations for IRA contributors and noncontributors.

Further research has not been able to settle the debate. For instance, Feenberg and Skinner (1989) use the IRS-Michigan tax panel data set and find that IRA contributors have significantly larger amounts of non-IRA assets. Although proponents of saving incentives cite this as evidence of new saving and this is evidence that the simple reshuffling story is not true, it however does not completely rule out the possibility that there were other means of substitution. What it does show is that IRA contributors have a higher taste for saving when compared to noncontributors.

Attanasio and Delaire (1994) compare the behavior of new IRA contributors to old contributors as a means of controlling for unobserved heterogeneity in saving behavior. IRA eligibility rules were liberalized in 1982 and so a new pool of households suddenly found themselves eligible to open IRA accounts. If IRAs represent new saving, then new contributors should experience a larger decrease in consumption relative to existing contributors. If IRAs represent reshuffled saving, new contributors will instead see a decline in the amount of other saving. Attanasio and Delaire find that IRAs represent reshuffled saving because new contributors experienced a decline in other assets, but not in consumption. Proponents of IRAs though argue that even if the initial effect is a reshuffling, households do not have enough other financial assets to continue reshuffling and so contributions eventually become new saving.[12]

Poterba, Venti and Wise (1995) compare households eligible for 401(k)'s versus those that are not eligible for 401(k)'s and find that 401(k) savings plans represent new saving. 401(k) plans are sponsored by firms and so eligibility is independent of individual saving behavior. A comparison of the two groups of households finds that total financial assets is higher for the

[11] A very detailed discussion on the effectiveness of IRA and 401(k)'s can be found in Gravelle (1991), Skinner (1991), Hubbard and Skinner (1996); Poterba, Venti and Wise (1996) and Engen, Gale and Scholz (1996).

[12] Poterban, Venti and Wise (1996)

eligible group, but most importantly non-IRA/401(k) assets for the eligible group are no lower and actually slightly higher than for the non-eligible group. The question though is whether or not eligibility for 401(k) plans is truly exogenous since it seems, especially for small firms, reasonable that employers will only offer 401(k) plans if their employees request them. Engen and Gale (2000) expand the 401(k) research by examining how the effect varies by earnings group. They find that households with low earnings are more likely to represent new saving.

Research on Coverdell ESA and 529 plans is limited since the plans have only recently been created. The 2001 Survey of Consumer Finances asks if households have an Education IRA, but does not separate the amount from other IRA accounts. In addition, the percentages of households who use the accounts are so low as to preclude any meaningful econometric investigations. Dynarski (2004 a and b) examines the structure of the savings plans within the framework of the college financial aid system and determines that high-income households benefit the most by using the plans as a tax shelter. Middle-class families, the intended target, are hurt because greater savings reduces the amount of financial aid they are eligible for. Ma (2003) is able to use data from TIAA-CREF to study the behavior of the firm's clients and finds that the savings plans create new savings.

1.3 Data and Methodology

1.3.1 Methodology

The identification strategy for the difference-in-difference method requires two exogenous sources of variation. The first source of variation comes from comparing household savings across time. For the analysis, the 1989 and 1992 Survey of Consumer Finance data sets are used.[13] Since many factors

[13]The SCF uses a dual-frame sample design which consists of a multi-stage national area probability sample and a list sample based on administrative data provided by the Statistics of Income Division of the IRS (cite). The purpose of the list sample is to allow the SCF to over-sample high-income households since the distribution of asset holdings varies depending on the asset. Many assets such as checking and savings accounts are commonly held so a national area probability sample provides adequate coverage. However, for other financial assets such as stocks and bonds or property investment, the holdings are highly skewed towards the high end of the income distribution and hence the need to

correlated with time could drive the change in household savings during the 1989-1992 period, a control group, which is not affected by the policy, is needed.

The Education Savings Bond Program is aimed at households with a qualified higher education expense, but only if the expense is for the bondholder, the spouse or a dependent that is claimed as an exemption on tax returns.[14] The most likely target of this policy is households with children who are about to or will be in the future going for their undergraduate degree. Therefore the treatment group is composed of households with children under the age of 25, since for tax purposes a dependent is either a child under the age of 19 or under the age of 24 and a full-time student.[15] Similarly a control group composed of households without children or children over the age of 25 should not be affected by the policy. In the case of households without children, not having a child means there is no education expense. In the case of children over the age of 25, the child most likely has already attended college, however even if they are still in college the parents can no longer claim them as a dependant. This method of sorting households into treatment and control groups seems to be uncorrelated with the implementation of the policy. There is no correlation between a household having a child, but also that child being under the age of twenty-five, and the creation of the policy in 1990.

The regression equation that is estimated is:

$$\textit{savings bonds} = \alpha_0 + \alpha_1 \times 1992 + \gamma \times T + \beta \times 1992 \times T + \eta \times X \qquad (1.1)$$

Ideally data on both asset balances and annual savings would be used to examine how saving behavior changes. However the SCF does not report information on annual savings and because two independent cross-sections are used, it is not possible to construct this variable. As a result, the analysis measures how average balances for an asset has changed due to the policy. 1992 is a dummy variable indicating 1992 observations and T is a dummy variable indicating the treatment group households. The $1992\times T$ dummy variable identifies the treatment group in 1992, therefore β is the parameter

specifically target high income households to ensure enough are included to provide an accurate response.

[14] IRS Publication 970

[15] IRS Publication 501

of interest. X is a vector of individual characteristics - age, education, marital status, ethnicity, number of children, home ownership, unemployed, and retired. From the life-cycle literature, age indicates where along the hump-shaped income and consumption profiles a person is located. Education is the highest level of education attained and is measured by the number of years of schooling. Home ownership, retired and unemployed are dummy variables while number of children is the number of children in the household. Ethnicity is a set of dummy variables indicating whether one is black, Hispanic or Asian.

The difference-in-difference estimator, β, captures the following effect:

$$\beta = (S_{T,92} - S_{C,92}) - (S_{T,89} - S_{C,89}) \tag{1.2}$$

Where S is asset balances, T is the treatment group of households with children under the age of 25 and C is the control group of households without children or children over the age of 25. β is the difference in asset balances between the treatment and control group in 1992 net of the difference in 1989. The policy effect is the difference in saving behavior between the two groups due to the implementation of the policy. Therefore the 1989 difference is needed to take into consideration any pre-existing differences between the two groups.

If a positive effect on savings bond balances is found, the next question is did crowding out occur? It is important to analyze the impact on other assets to ensure that a positive effect on savings bonds is not at the expense of another asset. If asset balances of stocks or other bonds fall, then there is no positive effect on household savings, merely a shift in preferences towards savings bonds. The same rationale that allows one to use the difference-in-difference method to examine the policy impact on savings bond balances can be used to identify the policy impact on other asset balances. Since the only difference between the treatment and control group in 1992 is the implementation of the policy, then the 1992 difference in asset balances between the two groups, net of pre-existing differences, is also the policy effect for these other assets. Therefore the difference-in-difference procedure is estimated on other assets to see if crowding out occurs, where the dependent variable is the balance for these other assets.

The focus of the SCF data set is household financial behavior and therefore detailed asset data is available. The SCF reports data on savings in stocks, bonds, mutual funds and money market accounts. In addition the SCF separates bonds into savings bonds, mortgage bonds, treasury bonds, state and municipal bonds and corporate/foreign bonds. There are also several mutual funds which are comprised of bonds such as tax-free bond funds, government bond funds and other bond funds. The difference-in-difference analysis is applied to both the overall household asset portfolio as well as this more detailed bond portfolio. There is an emphasis on bond holdings since these assets are most similar to savings bonds and therefore the most likely source of any asset substitution if crowding out occurs.[16]

The different assets are separated into five categories which are based on Poterba and Samwick's (2002) analysis of the effects of taxation on asset portfolio composition. The benefit of this decomposition is that it arranges assets by tax treatment. Poterba and Samwick separate stocks into taxable equity (directly-held) and taxable equity (mutual funds) due to differences in tax treatment, although this should be unnecessary for the purposes of the Education Savings Bond Program. In the case of bonds it does seem prudent to separate taxable and tax-exempt bonds since government savings bonds are more similar to the latter. Interest-bearing accounts includes checking accounts, savings accounts, money market accounts and certificates of deposit.[17]

1.3.2 Data Set

The combined sample consists of 4,299 observations.[18] In addition to being below an income threshold, households have to file a joint tax return, if married, or file as a single household. Observations that do not meet the proper

[16]Both savings bonds and treasury bonds are exempt from state and local taxation while state and municipal bonds are exempt from federal income taxation. These bonds are also seen as being less risky because they are issued by the government.

[17]The full analysis included regressing on all of the asset variables that comprise the first five categories in addition to a more extensive combination of aggregate asset measures, but yielded the same results. In the full analysis housing value, debt and long-term savings – such as retirement plances and life insurance – are also included. However this more extensive analysis does not change the analysis or interpretation of the results.

[18]1,874 of these observations are in the treatment group while 2,425 are in the control group. 1,938 are from the 1989 sample and 2,361 are from the 1992 sample. 858 are in the 1989 treatment group; 1,080 are in the 1989 control group; 1,016 are in the 1992 treatment group; 1,345 are in the 1992 control group

Table 1.1: Asset Variable Descriptions

Asset Variable	Description
Taxable Equity (directly-held)	All holdings of stocks outside of mutual funds and tax-deferred retirement accounts.
Taxable Equity (mutual funds)	All holdings of stocks within mutual funds.
Taxable Bonds	Federal government bonds, corporate bonds and foreign bonds directly held or held within mutual funds, but not in tax-deferred retirement accounts.
Tax-Exempt Bonds	State and municipal bonds directly held or in mutual funds, but not in tax-deferred retirement accounts.
Interest-Bearing Accounts	Checking, savings, money market and CD's.
Short-Term Financial Assets	Equity (directly-held), equity (mutual funds), taxable bonds, tax-exempt bonds, interest-bearing accounts.
Bond Portfolio	Savings bonds, treasury bonds, state and municipal bonds, mortgage bonds, tax-free bond funds, government bond funds and other bond funds.

filing status or are above the income threshold are not included in the sample. Table 1.2 lists demographic information for the 1989 population, separated by treatment and control group.[19] The treatment and control group are similar in education levels. The treatment group is also younger, more likely to be married and earns slightly more money. The average household in the treatment group has two children, while the control group has almost zero. The average household in the treatment group is also more likely to own their home. The treatment group is only slightly less likely to be unemployed, but significantly less likely to be retired.

Table 1.3 lists household asset balances for the 1989 population. Columns I and II are for the original sample and columns III and IV are for when households older than 65 are dropped. From columns I and II a distinct

[19]In the SCF, information about the household is focused on a primary economic unit (PEU) - which is considered to be the economically dominant single individual or couple and those who are financially dependent on them. Individuals who are in the household but are financially independent of this core individual/couple are not considered to be a part of the PEU. The head of the household is either the single individual, the male in a mixed-sex household or the older individual in the case of a same-sex couple. Demographic characteristics in this paper refer to the head of the household only.

Table 1.2: Demographic Characteristics

Demographic Characteristics 1989 Population	Original Sample Col. I Treatment	Col. II Control	Drop 65+ Col. III Treatment	Col. IV Control
Age	39.26	53.72	39.18	44.52
Education	12.97	12.77	12.97	13.30
Married (%)	79.91	46.84	79.85	42.81
AGI ($)	27,255.62	22,151.63	27,254.13	23,759.67
Retired (%)	1.80	27.37	1.60	8.52
Unemployed (%)	7.51	10.62	7.53	8.47
# of Children	2.03	0.10	2.03	0.10
Own Home (%)	67.44	59.50	67.38	52.39

Data is from 1989 Survey of Consumer Finance.

pattern emerges where the treatment group consistently has lower balances than the control group. The exception is government bond fund balances. Asset balances for government bond funds average $344.16 for the treatment group compared to $248.94 for the control group.[20] For the asset of interest, savings bonds, the treatment group has one-third the value – $476.61 for the treatment group versus $1,561.70 for the control group. For short-term financial assets the difference is substantial, the treatment group has balances of $12,489.84 while the control group has balances of $42,337.19. Although the treatment and control group do not have to be perfectly identical for the difference-in-difference methodology to be valid, the systematic and sizable differences in asset balances does raise concerns about the validity of comparing the two groups.

1.3.3 Understanding the Difference Between Treatment and Control

The difference between the treatment and control group is that the control group consists of older households, because their children are older, and households with no children. The question now is whether this implies that the desire to save for the control group differs from the treatment group. The two major motivations for saving are the life-cycle hypothesis and the bequest motive hypothesis. If the former dominates, then older households

[20] All dollar values are in 1989 dollars.

Table 1.3: Asset Balances

Asset Variable 1989 Population $	Original Sample Col. I Treatment	 Col. II Control	Drop 65+ Col. III Treatment	 Col. IV Control
Savings Bonds	479.61	1,561.70	480.49	697.48
Taxable Equity	2,174.34	10,399.98	2,180.50	4,129.15
Taxable Equity (Mutual Funds)	539.85	1,693.79	529.89	815.41
Taxable Bonds	614.25	3,300.66	614.78	1,144.40
Tax-Exempt Bonds	702.22	5,746.37	703.72	1,872.73
Interest-Bearing Accounts	7,999.26	20,850.39	7,979.84	9,913.50
Short-Term Financial Assets	12,489.84	42,337.19	12,469.45	18,443.79
Bond Portfolio	1,156.24	6,737.78	1,157.19	1,997.05
Tax-Free Bond Fund	82.52	1,334.40	82.77	517.08
State and Municipal Bonds	468.03	3,434.54	468.82	910.93
Government Bond Funds	344.16	248.94	345.21	112.55
Other Bonds Funds	26.07	220.29	26.15	214.50
Mortgage Bonds	27.38	326.58	27.40	95.60
Treasury Bonds	181.22	1,414.97	180.49	293.04

will have higher savings because they are further along the life-cycle, but not because they have a different desire to save. If the latter dominates then the saving behavior of the control group will differ because households with no children will not have any motive to save.

Table 1.4 reports the age distribution by treatment and control group for the 1989 population. From columns I and II, the treatment group is substantially younger with 92.59% between the ages of 25 and 54 while 53.06% of the control group is older than 55 and 33.53% is older than 65. Table 1.5 lists asset balances by age interval. The differences in asset balances between the treatment and control group are much smaller for most of the age intervals. For instance, asset balances for savings bonds are very comparable for the 35-44 age range, the treatment group has balances of $621.95 versus $803.45 for the control group, and the 45-54 age range, the treatment group has balances of $473.93 versus $416.52 for the control group. For short-term financial assets, the difference in savings is less than $2,000 for the 25-34, 35-44 and 45-54 age ranges.

In addition the pattern of the treatment group always holding less, which is evident in Table 1.3, disappears once age is accounted for. In Table 1.5, for taxable equity, the treatment group holds less for the 35-44 and 55-64

Table 1.4: Age Distribution

Age Intervals	Original		Drop 65+	
Cumulative Distribution	Col. I	Col. II	Col. III	Col. IV
1989 Population	Treatment	Control	Treatment	Control
25 – 34	33.95	18.32	34.25	27.56
35 – 44	71.90	32.22	72.53	48.47
45 – 54	92.59	46.40	93.39	69.81
55 – 64	99.14	66.47	100.00	100.00
65+	100.00	100.00	–	–

Table 1.5: Asset Balances By Age Intervals

Asset Variable	25 - 34		35 - 44		45 - 54	
1989 Population	Col. I	Col. II	Col. III	Col. IV	Col. V	Col. VI
$	Treatment	Control	Treatment	Control	Treatment	Control
Savings Bonds	327.93	193.32	621.95	803.45	473.93	416.52
Taxable Equity	1,186.67	801.46	1,534.06	2,015.15	4,254.10	3,476.00
Taxable Equity (MF)	17.33	43.93	534.32	297.33	1,199.99	715.77
Taxable Bonds	23.99	0.78	530.61	627.56	452.92	908.04
Tax-Exempt Bonds	228.74	105.93	1,059.55	1,459.37	942.57	739.27
Interest-Bearing Accts	4,387.22	4,552.78	7,577.58	6,157.53	10,848.67	10,362.19
Short-Term Fin Assets	6,168.15	5,694.53	11,830.54	11,359.86	18,149.37	16,603.26
Bond Portfolio	352.46	254.15	1,860.85	1,329.36	1,442.19	949.64
Tax-Free Bond Fund	58.78	16.46	58.44	715.46	85.38	231.06
State and Muni Bonds	0.78	60.83	786.33	409.13	842.46	279.26
Govt Bond Funds	0.00	0.00	6.19	395.02	201.85	108.05
Other Bond Funds	0.00	0.00	34.95	0.00	51.49	533.46
Mortgage Bonds	0.00	0.00	53.57	0.00	29.56	28.76
Treasury Bonds	23.75	0.00	399.00	116.77	96.24	225.10
	55 - 64		65+			
	Treatment	Control	Treatment	Control		
Savings Bonds	547.15	1,328.49	191.87	3,391.11		
Taxable Equity	4,919.67	9,330.21	157.40	23,641.68		
Taxable Equity (MF)	1,306.24	1,996.25	3,806.70	3,551.82		
Taxable Bonds	4,413.27	2,797.25	440.73	7,864.94		
Tax-Exempt Bonds	644.55	4,720.06	209.87	13,918.00		
Interest-Bearing Accts	20,441.43	17,431.38	14,358.93	43,997.72		
Short-Term Fin Assets	32,219.99	37,180.06	19,165.50	92,882.84		
Bond Portfolio	867.31	4,928.62	842.47	16,766.21		
Tax-Free Bond Fund	319.01	1,085.53	0.00	3,044.70		
State and Muni Bonds	208.85	2,548.45	209.87	8,767.74		
Govt Bond Funds	4,154.78	37.59	0.00	538.44		
Other Bond Funds	43.31	345.92	0.00	231.64		
Mortgage Bonds	26.19	302.42	20.99	816.49		
Treasury Bonds	85.12	749.26	419.75	3,790.87		

age ranges, but holds more for the 25-34 and 45-54 age ranges. For interest-bearing accounts, the treatment group holds more for all age intervals except for the 25-34 and 65+ age ranges.

The age interval where the discrepancy in savings is greatest is the 65+ age interval. Savings bond balances for this age interval is $191.87 for the treatment group and $3,391.11 for the control group. Taxable equity balances for the 65+ age interval are $157.40 for the treatment group and $23,641.68 for the control group. The systematic and significant differences in the treatment and control group that were found earlier are being driven by the fact that 65+ households are such a large part of the control group. Because these households are retired, it is not surprising that their savings differs from the general population. A new sample is created which drops 65+ households.

Columns III and IV in Table 1.3 report asset balances for the 1989 treatment and control group but now with the 65+ households dropped. Average balances for the treatment group are much more comparable to average balances of the control group. In 1989, the treatment group has savings bond balances of $480.49, while the control group has balances of $697.48. Balances for taxable equity, tax-exempt bonds and short-term financial assets are all more similar when the 65+ households are dropped from the sample. The average asset balance for the control group falls from $10,399.98 to $4,129.15 for taxable equity and from $5,746.37 to $1,872.73 for tax-exempt bonds. Short-term financial asset balances for the control group fall from $42,337.19 to $18,443.79, which is significantly closer to the average balance of $12,469.45 for the treatment group.

Regression analysis is used to test the significance of the difference in average asset balances between the treatment and control group. The asset balance is regressed on a dummy variable indicating the treatment group. A separate version includes controls for age.

$$asset\ balance = \alpha_0 + \gamma \times T + \eta_1 \times Age + \eta_2 \times Age^2 \qquad (1.3)$$

The results in Table 1.6 confirm the story found by examining asset balances by age intervals. Column I is the results regressed on the original sample but with no age controls. The estimates are negative because the treatment group has lower average balances. The estimates are significant because the treatment group has much lower average balances. When age controls are added, column II, the estimates are now smaller and no longer significant. For savings bonds, controlling for age reduces the estimated difference from –$1,082.08 to –$170.53, while for tax-exempt bonds controlling for age reduces the estimated difference from –$5,044.15 to –$296.12. Also not all the estimates are negative because now in certain cases, such as taxable equity (mutual funds) or taxable bonds, the treatment group has larger average balances.

Columns III and IV repeat the previous analysis but for the new sample which excludes 65+ households. Comparing column I to column III reveals the impact of dropping 65+ households. In column III, where there are no age controls and the 65+ households are dropped, the estimates are much smaller and no longer significant in almost all of the cases. The estimated difference for savings bonds falls from –$1,082.08 to –$216.99. For taxable bonds, the estimated difference falls from –$2,686.40 to –$529.62. This improvement in the comparability of average asset balances is because the age profiles of the two groups is now much more similar as seen in columns III and IV of Table 1.4, although it should be noted the treatment group is still significantly younger.

The second issue is whether or not the subset of households without children are fundamentally different than households with children. If savings is motivated by a bequest motive then households without children have no motive to save. The question is who are these childless households. Table 1.7 is the age profile, by treatment and control group, where the control group now consists only of households with children over the age of 25. The control group is now much older. Only 7.74% are between the ages of 25-34, previously it was 27.56%, and only 21.7% are between the ages of 25-44, previously it was 48.47%. Therefore the childless households are not necessarily households who have decided to not have children. Instead they are younger households who have yet to have a child. Although they currently do not have a child, it cannot be said with certainty that they will never have children and thus it is not clear that these childless households have fundamentally different saving behavior.

Table 1.6: Regression To Test Difference In Asset Balances Between Treatment And Control Group

Estimates for γ 1989 Population $	Original Control Col. I No Controls	 Col. II Age Controls	Drop 65+ Col. III No Controls	 Col. IV Age Controls
Savings Bonds	–1,082.08‡	–170.53	–216.99	–57.73
	(369.91)	(196.60)	(187.31)	(170.14)
Taxable Equity	–8,225.64†	–1,376.93	–1,948.65†	–12.65
	(3,344.78)	(1,448.30)	(896.23)	(840.90)
Taxable Equity (Mutual Funds)	–1,153.94†	5.60	–285.52	101.29
	(499.73)	(359.40)	(306.18)	322.75
Taxable Bonds	–2,686.40‡	58.37	–529.62	567.22
	(988.21)	(700.27)	(559.46)	(805.09)
Tax-Exempt Bonds	–5,044.15‡	–296.12	–1,169.01	–457.68
	(1,772.70)	(934.86)	(615.24)	(653.26)
Interest-Bearing Accounts	–12,851.13‡	1,868.45	–1,933.66	1,430.53
	(2,499.92)	(1,707.96)	(1,330.78)	(1,823.77)
Short-Term Financial Assets	–29,847.35‡	574.85	–5,974.34‡	1,576.57
	(5,484.29)	(2,931.76)	(2,200.52)	(2,605.20)
Bond Portfolio	–5,581.54‡	–373.07	–839.86	–88.84
	(1,699.65)	(782.99)	(472.34)	(376.58)
Tax-Free Bond Fund	–1,251.88	–274.83	–434.31	–244.49
	(972.28)	(484.16)	(437.88)	(562.20)
State and Municipal Bonds	–2,966.50†	41.73	–442.11	–74.52
	(1,304.06)	(695.21)	(375.63)	(275.85)
Government Bond Funds	95.22	542.71	232.66	656.76
	(345.20)	(592.07)	(347.29)	(815.01)
Other Bond Funds	–194.21	–100.01	–188.35	–110.54
	(148.96)	(138.65)	(195.77)	(114.55)
Mortgage Bonds	–299.20	–65.99	–68.20	6.02
	(204.87)	(59.47)	(50.96)	(22.12)
Treasury Bonds	–1,233.75	–178.27	–112.55	37.38
	(477.74)	(219.32)	(181.91)	(119.48)

† significant at 5% level; ‡ significant at 1% level

Table 1.7: Age Distribution

Cumulative Distribution 1989 Population	Col. III Treatment	Col. IV Control
25 – 34	34.25	7.74
35 – 44	72.53	21.70
45 – 54	93.39	51.71
55 – 64	100.00	100.00

1.4 Results

1.4.1 Savings Bonds

The regression equation is estimated with four different combinations of demographic variables. First no additional demographic variables are included. The second and third include controls for age – first by adding a quadratic age term and second by using dummy variables to reflect age intervals. Lastly the regression equation is estimated with the full set of demographic variables – age, age^2, education, ethnicity, marital status, number of children and dummy variables for being retired or owning a home.

The results from Table 1.8 indicate that the policy had no significant effect on the difference in asset balances between the treatment and control group. β is \$222.17 when no controls are included, although adding control variables does not change the results with $\beta = \$220.50$ when the full set of demographic variables is included. Table 1.9 lists asset balances by year and by treatment group. The estimate of \$222.17 for β can be decomposed as follows:

$$\begin{aligned}\beta &= (S_{T,92} - S_{C,92}) - (S_{T,89} - S_{C,89}) \\ &= (\$598.35 - 593.18) - (480.49 - 697.48) \\ &= 5.17 - (-216.99) = 222.17\end{aligned}$$

Although β is found to be insignificant the data indicates that there potentially could have been a response. Savings bond balances increased from \$480.49 to \$598.38 for the treatment group while they decreated from \$697.48 to \$593.18 for the control group. Therefore the estimate of \$222.17 is based on an increase of \$117.86 from the treatment group and a decrease of \$104.30 by the control group. However as the standard errors indicate there is significant variation so although on average there is this pattern, it does not necessarily hold for individual households.

1.4.2 Crowding Out

Table 1.10 reports the estimates for β only for the remaining asset variables. Similar to savings bonds, the estimates are insignificant. This includes the household bond portfolio and the individual bonds which would be the most likely source of substitution. From Table 1.9, the overall bond portfolio increases from $1,157.19 to $1,259.33 for the treatment group but only increases from $1,997.05 to $2,017.17 for the control group. However this implies that the increase for the treatment group is only $82.02 larger than than the control group.

The asset balance data does seem to suggest that some substitution has occurred. For instance government bond fund balances fell for the treatment group, $345.21 to $153.16, while rose for the control group, $112.55 to $388.29. In addition state and municipal balances fell for the treatment group, $468.82 to $423.89, while they rose for the control group, $910.93 to $1,156.18. Any savings bonds in a government bond fund would not be eligible for the policy because they are not directly held by the household, while state and municipal bonds offer similar levels of riskiness as government savings bonds. However without a significant estimate or a more clear pattern in household bond holdings, it is difficult to make any definitive conclusions about crowding out.

1.4.3 Alternative Explanations

IRA plans generated a sizable response in the mid-eighties. However some argue that the popularity behind IRA plans was not necessarily due to the tax incentives but rather due to the heavy promotion from the financial services industry. Meanwhile the Education Savings Bond program targets an asset that is not a substantial part of the household asset portfolio. The average American household holds less than $1,000 in savings bonds. It is possible that the policy was not as heavily promoted and thus households were not aware of the benefit. It is possible that only savings bond owners or financially savvy investors responded. As a result the following analysis focuses on either the population of savings bond owners only or some measure of financial savvy – owning an IRA, education level or being wealthy. The rationale for these three different measures is that they indicate households with a taste for saving. The IRA literature clearly shows that IRA participants have a high taste for saving. In addition the empirical data suggests that savings increases with both education and wealth. The new regression equation is:

$$savings\ bonds = \alpha_0 + \alpha_1 \times 1992 + \gamma \times T + \beta_1 \times 1992 \times T \tag{1.4}$$

$$+\alpha_2 \times savvy + \phi_1 \times 1992 \times savvy + \phi_2 \times T \times savvy +$$

$$\beta_2 \times 1992 \times T \times savvy + \eta \times X$$

where *savvy* is the dummy variable for financial sophistication, or the set of dummy variables in the case of education and income. The $1992 \times savvy$ coefficient captures any difference in financial sophistication across years for the control group. The $T \times savvy$ coefficient captures any pre-existing difference in financial sophistication between the treatment and control group. The new parameter of interest is $1992 \times T \times savvy$ and captures any policy effect on the financially sophisticated in the treatment group in 1992. This new parameter measures how the effect on the treatment group in 1992 varies between IRA owners and non-IRA owners or across education or income levels.

Table 1.11 reports the difference-in-difference estimates for β when the sample is restricted to savings bond owners only. The estimates are insignificant which implies that bond holders did not respond despite them being the households most likely to be aware of the program. Table 1.12 reports results for IRA owners and the variable of interest is $1992 \times T \times IRA$. The estimate is insignificant. The savings bond balances of IRA owners in the treatment group in 1992 does not differ from the savings bond balances for non-IRA owners in the treatment group, after having controlled for being an IRA owner, being an IRA owner in 1992 and being an IRA owner in the treatment group. Table 1.13 reports results by education interval and the parameters of interest are $1992 \times T \times$ *Education Level*. Again the results are insignificant. Table 1.14 reports results by income quintiles and the parameters of interest are $1992 \times T \times$ *Income Quintile*. Again the results are insignificant.

The design of the policy may indicate why there is a lack of interest. Savings bonds are not a substantial portion of the household asset portfolio. In addition the tax incentive is not very significant. Savings bonds already feature tax-free accrual of interest income. The incentive is the ability to exclude this income from taxation. However since households do not hold significant amounts of savings bonds, the tax benefit is small and therefore may not be valuable enough to alter a household's preferences for savings bonds. Consider a hypothetical household which has $1,000 saved in savings bonds, which earn a 5% rate of return and the household faces a marginal tax rate of 35%. The interest income is $50 and so the Education Savings Bond Program generates a tax savings of $17.50 for the household.

1.5 Conclusion

The Education Savings Bond Program was analyzed to see if tax incentives could encourage households to save. The difficulty in identifying the effect of tax incentives is being able to separate the policy effect from the effect of being a high saver. This problem is prevalent in both the IRA and 401(k) literature. The benefit of the Education Savings Bond Program is that the beneficiaries of the policy – households with a higher education expense – should not be correlated with being a high saver. The regression results indicate no significant policy response. This includes exploring asset balances for other assets in an effort to see if crowding out occurs. Focusing the analysis on households who are most likely to be financially literate and who have a taste for saving does not yield a policy effect either. One possibility that could explain the lack of a policy response is the design of the tax incentive. The Education Savings Bond Program did not create a new class of savings bonds, but rather added an additional tax incentive to existing savings bonds. However the tax incentive is being able to exempt interest income from taxation and since the average household does not hold significant amounts of savings bonds, the value of this incentive is modest.

Table 1.8: Savings Bonds Regression Results

Drop 65+ $ 1989 Dollars	Col. I No Controls	Col. II Age Controls	Col. III Age Dummies	Col. IV Full Controls
1992	–104.30	–119.40	–118.59	–132.39
	(198.78)	(197.95)	(198.89)	(190.31)
Treatment	–216.99	–116.61	–136.67	–135.34
	(187.28)	(166.85)	(173.94)	(247.24)
1992 × Treatment	222.17	225.58	224.64	220.50
	(241.63)	(241.92)	(242.14)	(234.57)
Age	–	34.80	–	0.38
		(54.90)		(41.47)
Age Squared	–	–0.16	–	0.18
		0.68)		(0.51)
35 – 44	–	–	363.59†	–
			(142.97)	
45 – 54	–	–	270.22	–
			(131.49)	
55 – 64	–	–	614.51‡	–
			(229.19)	
Education	–	–	–	59.97‡
				(19.10)
Married	–	–	–	185.19
				(133.05)
Number of Children	–	–	–	–49.39
				(101.39)
Retired	–	–	–	–184.08
				(641.91)
Unemployed	–	–	–	–155.42
				(138.61)
Home	–	–	–	397.21‡
				(106.39)
Asian	–	–	–	–35.20
				(220.73)
Black	–	–	–	18.62
				(245.15)
Hispanic	–	–	–	–217.69†
				(99.44)

† significant at 5% level; ‡ significant at 1% level
Standard errors are in parentheses

Table 1.9: Asset Balances Across Years

Asset Variable	Treatment Group		Control Group	
$ 1989 Dollars	Col. I	Col. II	Col. III	Col. IV
	1989	1992	1989	1992
Savings Bonds	480.49	598.35	697.48	593.18
Taxable Equity	2,180.50	4,182.66	4,129.15	4,358.54
Taxable Equity (Mutual Funds)	529.89	1,228.33	815.41	1,996.96
Taxable Bonds	614.78	749.22	1,144.40	1,086.88
Tax-Exempt Bonds	703.72	1,036.75	1,872.73	2,076.88
Interest-Bearing Accounts	7,979.84	6,170.34	9,913.50	9,584.33
Short-Term Financial Assets	12,469.45	13,477.81	18,443.79	19,411.21
Bond Portfolio	1,157.19	1,259.33	1,997.05	2,017.17
Tax-Free Bond Fund	82.77	294.12	517.08	497.62
State and Municipal Bonds	468.82	423.89	910.93	1,156.18
Government Bond Funds	345.21	153.16	112.55	388.29
Other Bond Funds	26.15	70.84	214.50	193.29
Mortgage Bonds	27.40	18.40	95.60	25.18
Treasury Bonds	180.49	218.69	293.04	242.63

Table 1.10: Regression Results For Other Assets

Estimates for β $ 1989 Dollars	Col. I No Controls	Col. II Age Controls	Col. III Age Dummies	Col. IV Full Controls
Taxable Equity	1,772.77	1,884.11	1,828.77	1,889.03
	(2,040.57)	(2,033.42)	(2,058.46)	(2,032.80)
Taxable Equity (MF)	–483.11	–448.46	–452.30	–474.84
	(591.02)	(584.17)	(589.40)	(585.72)
Taxable Bonds	191.95	241.14	214.15	151.16
	(645.74)	(640.99)	(641.32)	(626.11)
Tax-Exempt Bonds	128.88	179.70	178.67	78.06
	(992.41)	(975.83)	(978.73)	(1,017.67)
Interest-Bearing Accounts	–1,480.34	–1,339.99	–1,426.32	–1,539.36
	(1,639.32)	(1,615.34)	(1,624.98)	(1,631.23)
Short-Term Financial Assets	40.94	422.38	246.97	–12.13
	(3,448.16)	(3,367.25)	(3,407.17)	(3,373.09)
Bond Portfolio	82.02	131.46	119.96	16.26
	(953.50)	(932.36)	(930.52)	(967.49)
Tax-Free Bond Fund	230.81	240.35	244.37	238.05
	(561.91)	(553.20)	(557.88)	(559.54)
State & Municipal Bonds	–290.18	–255.25	–260.92	–346.35
	(840.58)	(824.10)	(822.96)	(870.98)
Government Bond Funds	–467.79	–450.82	–458.13	–479.25
	(386.28)	(375.44)	(380.15)	(399.56)
Other Bond Funds	65.90	73.35	69.61	55.49
	(210.70)	(215.08)	(213.08)	(200.25)
Mortgage Bonds	61.42	64.42	63.31	61.32
	(63.32)	(63.33)	(63.21)	(61.65)
Treasury Bonds	88.61	96.72	92.94	80.79
	(239.27)	(238.60)	(235.72)	(235.96)

† significant at 5% level; ‡ significant at 1% level
Standard errors are in parentheses

Table 1.11: Regression Results For Savings Bond Owners Only

Estimates for β \$ 1989 Dollars	Col. I No Controls	Col. II Age Controls	Col. III Age Dummies	Col. IV Full Controls
Savings Bonds	1,176.93	1,373.68	1,293.37	1,364.23
	(1,081.85)	(1,066.20)	(1,048.24)	(1,078.78)
Taxable Equity	3,239.22	4,025.54	4,218.65	4,037.66
	(3,491.07)	(3,623.26)	(3,580.81)	(3,686.74)
Taxable Equity (MF)	–1,662.51	–1,401.66	–1,552.61	–1,407.83
	(1,725.80)	(1,697.50)	(1,739.81)	(1,726.87)
Taxable Bonds	256.69	466.14	469.30	289.98
	(1,436.08)	(1,461.88)	(1,506.27)	(1,522.07)
Tax-Exempt Bonds	1,586.12	1,897.78	1,750.76	1,956.55
	(2,266.66)	(2,221.12)	(2,276.73)	(2,255.28)
Interest-Bearing Accounts	–1,404.96	–324.50	–310.79	–125.19
	(3,877.16)	(3,720.82)	(3,752.46)	(4,053.40)
Short-Term Financial Assets	2,191.30	4,961.62	4,869.53	4,992.64
	(8,127.89)	(7,964.12)	(8,091.43)	(8,157.00)
Bond Portfolio	2,610.21	2,663.18	2,487.42	2,502.06
	(2,254.39)	(2,200.67)	(2,240.72)	(2,239.58)
Tax-Free Bond Fund	–630.54	–563.66	–614.27	–566.66
	(1,126.16)	(1,092.11)	(1,123.80)	(1,116.09)
State & Municipal Bonds	1,081.33	1,292.14	1,222.17	1,326.36
	(1,658.78)	(1,638.43)	(1,670.97)	(1,649.52)
Government Bond Funds	–220.25	–196.62	–205.01	–181.46
	(357.94)	(350.05)	(353.08)	(361.25)
Other Bond Funds	90.64	139.98	104.24	119.86
	(979.81)	(1,021.43)	(996.87)	(1,081.27)
Mortgage Bonds	144.08	154.88	147.07	162.81
	(130.31)	(134.98)	(132.89)	(142.07)
Treasury Bonds	–242.13	–157.53	–175.19	–351.34
	(762.03)	(758.96)	(797.21)	(813.45)

† significant at 5% level; ‡ significant at 1% level
Standard errors are in parentheses

Table 1.12: Financial Savvy Measure: IRA Owners

Savings Bond Estimates IRA Owners	Col. I No Controls	Col. II Age Controls	Col. III Full Controls
1992	–168.00	79.57	–187.29
	(160.53)	(528.78)	(160.64)
Treatment	–32.33	10.51	–1.42
	(168.88)	(187.47)	(227.98)
1992 × Treatment	223.81	226.70	219.14
	(204.91)	(203.75)	(203.53)
IRA	967.14†	866.96	679.80
	(481.63)	(451.25)	(460.61)
1992 × IRA	71.35	79.57	102.96
	(529.01)	(528.78)	(537.95)
Treatment × IRA	–531.54	–478.54	–469.33
	(594.76)	(572.06)	(569.22)
1992 × Treatment × IRA	196.44	177.54	160.75
	(791.91)	(791.35)	(799.49)
Age Controls	No	Yes	Yes
Demographic Controls	No	No	Yes

† significant at 5% level; ‡ significant at 1% level
Standard errors are in parentheses

Table 1.13: Financial Savvy Measure: Education

Savings Bond Estimates Education Intervals	Col. I No Controls	Col. II Age Controls	Col. III Full Controls
1992	–406.61	–422.00	–421.36
	(432.48)	(434.20)	(427.86)
Treatment	–426.35	–273.99	–289.90
	(454.00)	(410.58)	(481.53)
1992 × Treatment	390.64	406.64	390.21
	(489.63)	(496.89)	(490.33)
1992 × Treatment × No High School	–660.85	–684.57	–635.27
	(619.79)	(628.30)	(642.93)
1992 × Treatment × Some College	–887.00	–861.39	–808.20
	(617.47)	(620.51)	(620.17)
1992 × Treatment × College Degree	136.79	138.09	149.94
	(955.39)	(962.31)	(955.80)
1992 × Treatment × Graduate Degree	776.48	772.69	817.48
	(891.62)	(887.97)	(905.47)
Education Dummies	Yes	Yes	Yes
1992 × Education Dummies	Yes	Yes	Yes
Treatment × Education Dummies	Yes	Yes	Yes
Age Controls	No	Yes	Yes
Demographic Controls	No	No	Yes

† significant at 5% level; ‡ significant at 1% level
Standard errors are in parentheses

Table 1.14: Income Intervals Regression Results

Savings Bond Estimates Income Intervals	Col. I No Controls	Col. II Age Controls	Col. III Full Controls
1992	–377.82	–392.43	–272.50
	(226.23)	(229.73)	(205.44)
Treatment	–379.87	–258.29	–139.49
	(256.60)	(253.94)	(344.94)
1992 × Treatment	449.27	462.09	412.21
	(367.39)	(366.57)	(370.42)
1992 × Treatment × Quintile 1	–217.52	–269.76	–211.83
	(379.99)	(376.63)	(382.32)
1992 × Treatment × Quintile 2	–798.67	–781.06	–670.04
	(517.12)	(515.52)	(525.08)
1992 × Treatment × Quintile 3	–720.23	–688.02	–502.14
	(640.38)	(641.59)	(658.09)
1992 × Treatment × Quintile 4	–61.06	3.43	278.09
	(1,370.27)	(1,362.39)	(1,413.63)
Quintile Dummies	Yes	Yes	Yes
1992 × Income Quintile Dummies	Yes	Yes	Yes
Treatment × Income Quintile Dummies	Yes	Yes	Yes
Age Controls	No	Yes	Yes
Demographic Controls	No	No	Yes

† significant at 5% level; ‡ significant at 1% level
Standard errors are in parentheses

CHAPTER 2

NON-LINEAR ENGEL CURVES AND THE INCIDENCE OF ENVIRONMENTAL TAXES

2.1 Introduction

Growing concern about the environmental costs of household energy consumption has led to increased debate about the appropriate level of environmental taxes. Environmental taxes, such as the gasoline tax, are regressive and if one is also concerned about equity then the optimal environmental tax rate should be calculated within an optimal income tax framework. A complete optimal tax model includes the cross-price elasticity for leisure, yet many previous analyses assume either separability in leisure or that labor supply is constant (Cremer, Gahvari and Ladoux 1998, 2003). West and Williams (2004, 2007) address this when they estimate a household demand model in order to calculate the optimal gasoline tax. They use the Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer (1980a) which does not assume separability between consumption goods and leisure. This paper also uses the AIDS model to estimate household demand and then calculates cross-price elasticities, including the cross-price elasticity of leisure with respect to the energy good price. The AIDS model does assume linear Engel curves which could potentially bias welfare estimates if income effects are non-linear. This leads Banks, Blundell and Lewbel (1997) to extend the AIDS model by assuming non-linear Engel curves. They name their extension the Quadratic Almost Ideal Demand System (QUAIDS). The objective is to estimate household demand for energy using the AIDS and QUAIDS models, and to compare the corresponding environmental tax incidence calculations for a tax on total household energy consumption.

Household consumption consists of a composite clean good, a composite energy good and leisure. If the household is married then male and female leisure consumption is estimated separately. The composite energy good consists of gasoline consumption and home energy consumption – electricity, natural gas or home heating fuels and oils. The composite clean good is the difference between total household consumption and the composite energy good. Leisure consumption is calculated using a time endowment of 14 hours per day. Consumption data is from the 1996-1999 Consumer Expenditure Survey while the price for the clean and energy goods comes from the Bureau of Labor Statistics. Households are separated into married and single households. Married households are further separated into households with only one working spouse and households with two working spouses. The AIDS and QUAIDS models are estimated on each sample separately. Cross-price elasticity estimates and welfare loss estimates are calculated using the estimated parameters.

The rationale for the QUAIDS model is that the relationship between budget shares and income is not always linear for every good. However it is not necessarily non-linear for every good either. Banks, Blundell and Lewbel develop their QUAIDS model to be flexible enough so that the non-linear Engel curve specification does not have to be applied to each good. The QUAIDS model is first applied to all goods, however the non-linear Engel curve specification is only applicable to the energy good and leisure and then only for the single household sample. Therefore a mixed-QUAIDS model is estimated on single households only, where the clean good is estimated according to the AIDS specification and the energy good and leisure according to the QUAIDS specification. The compensated cross-price elasticity of labor supply with respect to the energy good price is –0.0159 and significant for the single household AIDS model, and 0.0514 but insignificant for the single household QUAIDS model. Moreover the AIDS model overestimates welfare loss for low-income single households and underestimates welfare loss for high-income single households. The AIDS model is the appropriate model for both married household samples.

2.2 Data Set and Sample

The Consumer Expenditure Survey (CES) consists of two separate and independent components – an Interview Survey, which tracks household consumption over four consecutive quarters,[1] and a Diary Survey, which tracks daily consumption over a two-week period. The Interview Survey focuses on large expenditures, such as durable goods, or expenditures, such as rent or utilities, that occur on a regular basis. The Interview Survey also includes average three-month estimates of expenditures on smaller items such as food and alcohol. Therefore the survey covers approximately 95% of a household's expenditures.[2] The 1996-1999 Interview Surveys are used for this analysis. Four quarters of data are available for each year. Although it is possible for an individual household to appear in up to four consecutive quarters, this is too short a time period to be able to create a panel data set. Annual consumption cannot be calculated since four quarters of data is not available for every household. A pooled cross-sectional data set is created by treating each of the sixteen quarters as an independent sample.

The CES sampling methodology is designed to cover the consumption behavior of the U.S. civilian non-institutional population. Households over the age of 65 or under the age of 18 are dropped. Married households are dropped if either spouse is over 65 or under 18. Households over the age of 65 are assumed to be retired and their labor-leisure choice differs from households where either spouse is still working. Similarly, households under the age of 18 are dropped because they are assumed to still be in high school. If neither spouse in the household works, the household is dropped regardless of the reason for unemployment. The following occupation codes are also dropped – armed forces, self-employed and farming, forestry and fishing. Self-employed households are dropped because of their ability to dictate, to some degree, their income and hours worked. The other two occupation codes are dropped because the nature of their work implies a different labor-leisure choice than other occupations.[3] This yields a sample of 43,516 households.

The CES reports aggregate household expenditures as well as detailed ex-

[1] Households are interviewed for five quarters. The first quarter collects demographic and baseline consumption information. Consumption data is only collected for the latter four quarters.

[2] http://www.bls.gov/opub/hom/pdf/homch16.pdf

[3] This paper is a companion to another paper that calculates optimal income and environmental tax rates within a Mirrlees framework. Occupation codes are used to proxy for skill types and since households who do not work cannot report occupation codes, they are dropped. In addition, to keep the numerical calculations feasible the number of skill types considered is kept to a minimum. Since these three occupation codes are slightly problematic, and also a small portion of the sample, they are dropped to facilitate the numerical calculations.

penditures on various categories such as food, apparel, entertainment, housing and transportation. The CES also reports consumption information on the actual items that comprise each category. In the model households consume a composite clean good, a composite energy good and leisure. The energy good consists of gasoline and home energy consumption – electricity, natural gas or home heating fuels and oils.[4] The clean good expenditure is the difference between total household expenditures and the energy good. Leisure is separated into male leisure and female leisure if the household is married and both spouses work. The CES reports quarterly expenditures, however the analysis is based on weekly expenditures. Therefore the quarterly data is converted to weeekly data by assuming thirteen weeks in a quarter.

The CES reports annual salary as well as hours worked per week and weeks worked per year, which is used to calculate a hourly gross wage rate. The NBER TaxSim program[5] is used to calculate effective state and federal marginal income tax rates, which are then used to calculate a hourly net wage rate. The leisure expenditure is calculated by multiplying hours of leisure by the net wage rate. Hours of leisure is constructed by assuming each individual has a daily time endowment of 14 hours per day and works five days a week, for a weekly time endowment of 70 hours.[6] In the optimal income tax model of Mirrlees, individuals have an earnings ability, or maximum earnings potential, based on their time endowment and wage rate. This time endowment is supposed to capture the household's labor-leisure decision.[7]

[4]A small number of households, 826, have zero energy expenditures. It is possible for households to have zero gasoline expenditures, since not all households own automobiles. However since all households in the data set own or rent a home or apartment, all households should have some energy expenditure. Only 2.66% of these zero energy households own a home. It seems reasonable to assume these 826 households do actually consume energy. However since almost all rent, perhaps utilities is included in the rent. Therefore households who report zero energy consumption are dropped since actual energy consumption most likely does not equal reported consumption.

[5]www.nber.og/taxsim

[6]Three hundred seventy-six households are found to have zero or negative leisure hours because their weekly hours worked exceeds the time endowment. Since such a small percentage of households bind at the time endowment, these households are dropped. Some households have both zero energy and zero leisure expenditures and therefore only 1,186 households are dropped for a final sample size of 42,330 households.

[7]An individual can allocate their time between labor (taxable work), leisure and non-taxable work. From a taxation perspective, the government wants to distinguish labor from leisure since leisure is considered a commodity good. Therefore it is important to identify between labor, leisure and non-taxable work. However it is not possible to separate leisure

The sample is separated into married and single households to account for differing labor supply responses. In addition the married households are separated into households where both spouses work and households where only one spouse works. This is to account for the possibility that households where only one spouse works behave differently than households where both spouses work. In the case of married households with only one working spouse, leisure demand is only estimated for the working spouse.

The CES only reports information on expenditures. Therefore data on prices comes from the Bureau of Labor Statistics. The BLS "all-items-less-energy" price index is used as the clean good price and the "energy" price index is used as the energy good price.[8] The indices are divided by 100 so that prices are equivalent to a dollar price. Both price indices are national indices reported on a monthly basis. Since the CES reports expenditures on a quarterly basis, quarterly prices are calculated to correspond to each household's three-month reporting period.

Table 2.1 reports summary statistics for single households and married households with one working spouse. Table 2.2 reports summary statistics for married households where both spouses work. Single households spend only 5.26% of their weekly budget on energy consumption, $35.07 out of total weekly expenditures of $761.78. In addition, 72.04% of single households have no children, while only 38.99% own a home and slightly more than half, 51.83%, own one car. Married households with one working spouse spend approximately 6.32% of their weekly budget on energy consumption while married households with two working spouses spend only 4.72%. The number of hours worked between the earner in the one working spouse sample and the male earner in the married with two working spouses sample, are very similar – 43.17 hours for the former and 44.10 for the latter, while the former earner earns $1 more per hour. The earner in the married households with one working spouse sample earns $11.57 per hour while the male earner in the married households with two working spouses sample earns $10.47.

Home ownership rates are approximately the same for the two married household samples – 71.80% for those with one working spouse and 79.43%

from non-taxable work with the data available. Non-taxable work is therefore assumed to be zero.

[8]Appendix 3, Chapter 17 of the BLS Handbook of Methods lists the components of various aggregate price indices. The "energy" price index is comprised of gasoline, electricity, natural gas and home heating fuels and oils.

for those with two working spouses. The former households are more likely to have three or more children – 20.50% for married households with one working spouse and 12.06% for married households with two working spouses. In the case where only one spouse works, the earner is the husband in 75.67% of the sample. Married households with one working spouse are more likely to own either zero cars, 19.52% versus 15.14%, or own only one car, 45.09% versus 42.11%.

2.3 Almost Ideal Demand System

2.3.1 Almost Ideal Demand System Model

Stone's (1954) linear expenditure system was the first demand system model derived from demand theory.[9] Previous models estimated demand for goods equation by equation in order to calculate price elasticities. This allowed for demand equations to be tailored to specific items, however it did not allow for demand theory to be tested. The motivation behind incorporating demand theory was one of degrees of freedom, there were more parameters to be estimated than observations. Stone imposed demand theory restrictions – additivity, homogeneity and symmetry – in order to reduce the number of parameters that needed to be estimated. Since the demand restrictions are needed to estimate the equations, it was not possible for Stone to test demand theory with his linear expenditure model. The Rotterdam model of Theil (1965) is the model most often used to test demand theory. The model is very similar to Stone's linear expenditure system. The main difference is that the model does not have to impose the assumptions of homogeneity and symmetry in order to be estimated, and therefore these two assumptions can be tested.

Diewert (1971) began a new approach to demand estimation, the use of "flexible functional forms." The idea is to specify an equation with enough parameters so that it can approximate the true direct or indirect utility function or the cost function. Christensen, Jorgenson and Lau (1975) develop the "transcendental logarithmic" model, or trans-log model, to be a second-order

[9] A more detailed summary of the major demand system models is found in chapter 3, Deaton and Muellbauer (1980b)

Table 2.1: Summary Statistics

Variable	Single Households Mean	Single Households Std. Dev.	Married, 1 Worker Mean	Married, 1 Worker Std. Dev
Clean Good Exp ($)	492.29	394.41	703.81	583.21
Energy Good Exp ($)	35.07	23.83	55.33	28.26
Leisure Exp ($)	234.42	188.85	303.33	249.98
Total Expenditures ($)	761.78	469.89	1,062.48	707.85
Clean Good Share (%)	61.95	15.73	64.08	13.97
Energy Good Share (%)	5.26	3.49	6.32	3.68
Leisure Share (%)	32.79	15.95	29.59	13.88
Clean Good Price ($)	1.69	0.04	1.69	0.04
Energy Good Price ($)	1.07	0.04	1.07	0.04
Hourly Gross Wage ($)	12.92	8.93	18.02	13.42
Marginal Tax Rate (%)	33.35	18.04	32.24	16.09
Hourly Net Wage (%)	7.94	5.08	11.57	8.09
Hours Worked (Wkly)	40.05	10.30	43.17	9.29
Hours Leisure (Wkly)	29.95	10.30	26.83	9.29
Ln(Clean Price) ($)	0.52	0.03	0.52	0.03
Ln(Energy Price) ($)	0.07	0.04	0.07	0.04
Ln(Net Wage) ($)	1.89	0.67	2.22	0.74
Ln(Real Income ($)	5.51	0.55	5.77	0.55
Age	37.00	11.80	43.21	10.90
No HS Diploma (%)	9.22	–	19.13	–
HS Diploma (%)	27.05	–	29.70	–
Some College (%)	36.47	–	24.54	–
Bachelor's Degree (%)	19.07	–	16.43	–
Graduate Degree (%)	8.19	–	10.20	–
Male (%)	42.06	–	75.67	–
White (%)	80.07	–	87.58	–
Black (%)	15.32	–	6.39	–
Asian (%)	3.49	–	3.93	–
Other (%)	1.12	–	2.10	–
No Children (%)	72.04	–	35.42	–
One Child (%)	13.85	–	19.31	–
Two Children (%)	9.00	–	24.76	–
Three or More (%)	5.11	–	20.50	–
Own Home (%)	38.99	–	71.80	–
No Cars (%)	30.32	–	19.52	–
One Car (%)	51.83	–	45.09	–
Two Cars (%)	13.51	–	25.39	–
Three or More (%)	4.33	–	10.00	–
# of Observations	19,881	–	6,482	–

*Data is from the 1996 – 1999 CES data set. The energy good is gasoline, electricity, natural gas and home heating fuels and oils. The clean good is remaining household expenditures.

Table 2.2: Summary Statistics Married Households, 2 Workers

	Male		Female	
Variable	Mean	Std. Dev.	Mean	Std. Dev
Clean Good Exp ($)	866.0903	565.01	–	–
Energy Good Exp ($)	60.11	27.88	–	–
Leisure Exp ($)	270.88	188.86	256.98	210.36
Total Expenditures ($)	1,454.06	713.65	–	–
Clean Good Share (%)	57.76	12.94	–	–
Energy Good Share (%)	4.72	2.50	–	–
Leisure Share (%)	19.37	9.83	18.15	9.85
Clean Good Price ($)	1.69	0.04	–	–
Energy Good Price ($)	1.07	0.04	–	–
Hourly Gross Wage ($)	17.72	10.52	13.36	8.89
Marginal Tax Rate (%)	39.30	9.29	–	–
Hourly Net Wage (%)	10.47	5.98	7.85	4.95
Hours Worked (Wkly)	44.10	8.46	37.27	10.30
Hours Leisure (Wkly)	25.90	8.46	32.73	10.30
Ln(Clean Price) ($)	0.52	0.03	–	–
Ln(Energy Price) ($)	0.07	0.04	–	–
Ln(Net Wage) ($)	2.18	0.65	1.87	0.70
Ln(Real Income ($)	6.04	0.47	–	–
Age	41.07	9.85	39.19	9.47
No HS Diploma (%)	9.22	–	7.61	–
HS Diploma (%)	28.83	–	29.23	–
Some College (%)	29.02	–	32.67	–
Bachelor's Degree (%)	20.84	–	20.82	–
Graduate Degree (%)	12.08	–	9.66	–
White (%)	87.67	–	87.72	–
Black (%)	7.30	–	6.81	–
Asian (%)	3.55	–	1.42	–
Other (%)	1.48	–	4.05	–
No Children (%)	38.75	–	–	–
One Child (%)	24.65	–	–	–
Two Children (%)	24.54	–	–	–
Three or More (%)	12.06	–	–	–
Own Home (%)	79.43	–	–	–
No Cars (%)	15.14	–	–	–
One Car (%)	42.11	–	–	–
Two Cars (%)	30.45	–	–	–
Three or More (%)	12.29	–	–	–
# of Observations	15,893	–	–	–

*Data is from the 1996 – 1999 CES data set. The energy good is gasoline, electricity, natural gas and home heating fuels and oils. The clean good is remaining household expenditures.

approximation to any utility function. The benefit of this model is that it is derived from a class of utility functions that does not assume additivity and homotheticity. Additive and homothetic utility functions imply consistent and identical elasticities of substitution between any two commodities.

The Almost Ideal Demand System model of Deaton and Muellbauer is used to estimate demand. The AIDS model follows the "flexible functional form" tradition of Diewert and can be considered a first-order approximation to any demand system. The foundation of the AIDS model is the PIGLOG, "price-independent generalized logarithmic" class of preferences. Demand system estimation faces two different aggregation problems. The first is how to aggregate over commodities and the second is consistent aggregation over consumers. Muellbauer (1975, 1976) considers the latter problem and finds the most general conditions for which consistency holds, which he labels "generalized linearity." The consistency problem of aggregating over consumers is to find some representative level of income, such that the budget share for the ith commodity, based on prices p and this representative level of income, is equivalent to the average budget share for commodity i.[10] However if this representative level of income is to be independent of prices, then the PIGL, "price-independent generalized linearity" class of preferences is required. PIGLOG is the logarithmic version of PIGL. Therefore the AIDS model exactly aggregates over all consumers. In addition, the AIDS model satisfies the axioms of choice and can be used to test the demand theory restrictions of homogeneity and symmetry. The AIDS model also does not impose separability, which is the primary benefit of the estimation procedure for optimal taxation purposes.

The AIDS cost function is the following:

$$\ln(c(u,p)) = (1-u) \times \ln(a(P)) + u \times \ln(b(P)) \tag{2.1}$$

[10]According to Muellbauer (1975), define y_0 to be some representative level of income and p to be the vector of prices. If $\bar{s_i}$ is the average budget share for good i, then consistent aggregation occurs when

$$\bar{s_i} = s_i(y_0, p)$$

where

$$\ln(a(P)) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \times \ln(p_i) + \frac{1}{2} \times \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{i,j} \times \ln(p_i) \times \ln(p_j) \quad (2.2)$$

$$\ln(b(P)) = \ln(a(P)) + \beta_0 \times \prod_{i=1}^{n} p_i^{\beta_i} \quad (2.3)$$

$\ln(a(P))$ and $\ln(b(P))$ are two different price indices and u is utility. Deaton and Muellbauer suggest that $\ln(a(P))$ be interpreted as the cost of subsistence and $\ln(b(P))$ be the cost of bliss. The functional forms for $\ln(a(P))$ and $\ln(b(P))$ are determined by the conditions needed for exact aggregation over consumers to hold. Muellbauer finds that the cost function, in the PIGLOG and PIGL models, consists of two different price indices. In addition, one of the price indices must be homogeneous of degree zero, $\ln(a(P))$, and the other must be homogeneous of degree one, $\ln(b(P))$.

Deaton and Muellbauer derive the following AIDS demand function for good i from the cost function.

$$s_i \equiv \frac{p_i \times x_i}{M} = \alpha_i + \sum_{j=1}^{n} \gamma_{i,j} \times \ln(p_j) + \beta_i \times \ln \frac{M}{a(P)} \quad (2.4)$$

for $i = 1, ..., n$. In the model, n is either 3 or 4 depending on the number of workers in the household. s_i is the budget share for good i, p_i is the price of good i, x_i is demand for good i. M is total income and is defined as

$$M = \omega + m \quad (2.5)$$

where ω is earnings ability, or value of the time endowment, and m is virtual income. Earnings ability is calculated as the average household net wage rate $\times$ time endowment. The tax structure is non-linear, however in the model tax rates are assumed to be linear. Virtual income is the lump-sum transfer amount needed to ensure that tax payments are equivalent between the true non-linear tax regime and the assumed linear tax regime. α_i, β_i and $\gamma_{i,j}$ are parameters to be estimated.

If the actual price index, $\ln(a(P))$, is substituted into the demand function, then non-linear estimation is required. Deaton and Muellbauer suggest approximating this price index with Stone's Index in order to keep the estimated equation linear in parameters.[11] Stone's Index is defined as follows:

$$\ln(P^*) = \sum_{i=1}^{n} s_i \times \ln(p_i) \tag{2.6}$$

The following restrictions are imposed:

$$\sum_{i=1}^{n} \alpha_i = 1; \qquad \sum_{i=1}^{n} \gamma_{i,j} = 0; \qquad \sum_{i=1}^{n} \beta_i = 0 \tag{2.7}$$

$$\sum_{j=1}^{n} \gamma_{i,j} = 0 \tag{2.8}$$

$$\gamma_{i,j} = \gamma_{j,i} \tag{2.9}$$

The first set of restrictions ensures adding up of the budget constraint. The second restriction, eq. (2.8), ensures homogeneity of degree zero and the last restriction imposes Slutsky symmetry.

2.3.2 Almost Ideal Demand System Estimation Procedure

The model suffers from two primary sources of endogeneity. The first is that the net wage rate is endogenous. The marginal tax rate, which is used to calculate the net wage rate, is based on household income. The second source of endogeneity is the real income term, $\frac{M}{a(P)}$. Stone's Index, which is used to approximate $\ln(a(P))$, is a function of budget shares. Therefore the real income term is now a function of the dependent variable.

The econometric procedure of West and Williams (2004, 2007) is followed. They use the 1996-1998 CES data set and the AIDS model to estimate the cross-price elasticity of leisure with respect to gasoline as well as calculate the optimal gasoline tax. Instruments for the net wage rate and the real

[11] West and Williams use a slightly different version of Stone's Index, which uses $\ln(\frac{p_i}{\bar{p_i}})$ in place of $\ln(p_i)$, where $\bar{p_i}$ is the sample average price for good i. Moschini (1995) raises the concern that if prices are not unit-invariant, then Stone's Index is not a satisfactory approximation for the $\ln(a(P))$ price index. Moschini suggests using a "corrected" Stone's Index, such as one where "prices are scaled by their mean," which is what West and Williams do. However, Moschini makes the point that if prices are indices, then it is equivalent to using a "corrected" Stone's Index. In this analysis, the clean good and energy good prices are price indices. Nevertheless, the analysis is repeated using prices scaled by their means, however the results are less robust and thus the original Stone's Index is used.

income term are created. The instrument for the net wage rate is a sample average net wage rate based on occupation–, state–, gender-specific sample cells. The instrument for Stone's Index is an alternative version calculated using sample average budget share values for each good in place of individual budget share values.

Error terms are potentially correlated across equations since the right-hand side variables are identical. Therefore a three-stage least squares procedure is used to estimate the model. The procedure combines 2SLS with a seemingly unrelated regression model. The SUR model controls for the endogenous error term by taking into account the correlated error structure and also allows the imposition of the cross-equation restrictions. The 2SLS component allows for the use of instruments in controlling for endogeneity. The demographic variables included are age, age squared, education dummy variables, ethnicity dummy variables, marital status, dummy variables for the number of children, a dummy variable for home ownership, dummy variables for the number of cars owned and state and month fixed effects.

The energy good is a combination of gasoline consumption and home energy consumption. Dummy variables for home ownership and the number of cars are included to control for energy consumption differences based on owning versus renting and whether one drives. State fixed effects are included to control for differences in energy consumption across states. Public transportation is used regularly in New York City and Washington D.C., while driving is essential in the West. Cities such as Denver and Seattle have strong bicycling cultures. Weather also differs by region. Month fixed effects are included to control for seasonal variation in energy consumption – heating and air-conditioning increase energy consumption in the winter and summer months, while families may drive more during the summer for family vacations. Cross-sectional wage variation, within each state, is used to estimate the cross-price elasticity of labor supply and variation in prices over time is used to estimate the cross-price elasticity of the energy good.

The clean good equation is dropped in the estimation procedure and the parameters are calculated from the cross-equation restrictions. The estimated parameters for single households are reported in Table 2.3, married households with one working spouse are reported in Table 2.4 and married households with two working spouses are reported in Table 2.5. The standard errors are calculating using a bootstrap procedure, 1,500 replications.

Since the same household may appear in up to four consecutive quarters, the bootstrap procedure takes into account potential correlation of households across quarters. The coefficient on the real income term, β_i, is positive for luxuries and negative for necessities since the demand is measured in budget shares and not quantity. The clean good is the only luxury good – β_c is 0.1632 for single households, 0.1474 for married households with one working spouse and 0.1731 for married households with two working spouses. β_i is negative for the energy good and leisure for all three samples.

The law of demand indicates that as price increases, the quantity demanded should decrease. Although the own-price parameter estimates for each equation are always positive for all three samples, this does not necessarily contradict the law of demand again because the dependent variable is budget shares. For instance the clean good price parameter for the clean good equation in Table 2.3 is 0.0565, which means that the share of clean good consumption rises when the clean good price increases. This implies that the price increase dominates the quantity decrease. If the share of clean good consumption rises then the shares of the other two goods have to decrease and this is what the parameters indicate. For single households, the clean good price parameter is –0.0218 for the energy good equation and –0.0347 for the leisure equation.

A similar effect is found for the prices of the other goods in the other samples. For married households with one working spouse (Table 2.4), the energy good price parameter is 0.0473 for the energy good equation, so the share of the energy good consumed increases. Similarly the energy good price parameter is –0.0258 for the clean good and –0.0214 for leisure, so the share of the other goods falls. Deaton and Muellbauer suggest the following interpretation for the price parameters:

> "each $\gamma_{i,j}$ represents 10^2 times the effect on the ith budget share of a 1% increase in the jth price."

Consider the parameter estimates for married households with two working spouses in Table 2.5, the own-price parameter for male net wage is 0.0689, which means that a 1% increase in net wage for husbands leads to a 0.000689 increase in the share of leisure consumed by the husband. This creates a 0.000150 decrease in the share consumed of the clean good, a 0.000079 decrease in the share consumed of the energy good and a 0.000460 decrease in

Table 2.3: Three-Stage Least Squares Estimates For Single Households (AIDS)

	Clean Good		Energy Good		Leisure	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Constant	–0.3469‡	(0.0216)	0.1719‡	(0.0071)	1.1750‡	(0.0222)
Ln(Clean Price)	0.0565‡	(0.0107)	–0.0218‡	(0.0057)	–0.0347‡	(0.0092)
Ln(Energy Price)	–0.0218‡	(0.0057)	0.0358‡	(0.0049)	–0.0140‡	(0.0028)
Ln(Net Wage)	–0.0347‡	(0.0092)	–0.0140‡	(0.0028)	0.0487‡	(0.0097)
Ln(Real Income)	0.1632‡	(0.0032)	–0.0204‡	(0.0010)	–0.1428‡	(0.0033)
Age	0.0055‡	(0.0008)	0.0020‡	(0.0002)	-0.0075‡	(0.0008)
Age Sq	–0.0001‡	(0.00001)	–0.00002‡	(0.000003)	0.0001‡	(0.00001)
No HS Diploma	–0.0058	(0.0041)	–0.0012	(0.0014)	0.0070	(0.0043)
Some College	–0.0063†	(0.0028)	–0.0048‡	(0.0009)	0.0111‡	(0.0029)
Bachelor's Deg	0.0028	(0.0039)	–0.0064‡	(0.0012)	0.0036	(0.0040)
Graduate Deg	0.0050	(0.0054)	–0.0095‡	(0.0016)	0.0045	(0.0057)
Male	0.0078‡	(0.0025)	0.0046‡	(0.0008)	–0.0124‡	(0.0027)
Black	–0.0063†	(0.0029)	–0.0006	(0.0010)	0.0070†	(0.0030)
Asian	–0.0022	(0.0066)	–0.0044‡	(0.0014)	0.0066	(0.0069)
Other	–0.0167	(0.0109)	–0.0029	(0.0039)	0.0196	(0.0103)
Own Home	–0.0195‡	(0.0028)	0.0167‡	(0.0009)	0.0028	(0.0030)
No Children	0.0006	(0.0029)	–0.0084‡	(0.0010)	0.0078†	(0.0031)
Two Children	–0.0093†	(0.0042)	0.0008	(0.0013)	0.0084	(0.0045)
Three or More	–0.0158‡	(0.0055)	0.0071‡	(0.0018)	0.0086	(0.0057)
No Car	–0.0025	(0.0025)	–0.0066‡	(0.0007)	0.0092‡	(0.0026)
Two Cars	0.0049	(0.0027)	0.0093‡	(0.0009)	–0.0142‡	(0.0029)
Three or More	0.0090†	(0.0044)	0.0139‡	(0.0015)	–0.0229‡	(0.0046)

*System of 3 demand equations, the clean good equation is dropped. Parameters for the clean good are calculated based on cross-equation restrictions. Standard errors are calculated using a bootstrap procedure (1,500 replications). † significance at 5% level. ‡ significance at 1% level.

the share consumed of leisure by the wife.

The rationale for separating married households into a sample of households with only one working spouse and a separate household with two working spouses is the belief that household behavior, especially the labor/leisure response differs. The clean good own-price parameter is 0.0779 for households with one working spouse and 0.0700 for households with two working spouses. The energy good own-price parameter is 0.0473 for households with one working spouse and 0.0390 for households with two working spouses. The leisure own-price parameter is 0.0735 for households with one working spouse and 0.0689 for male leisure and 0.0769 for female leisure, in the case of households with two working spouses. Except for female leisure, the own-price parameters are larger for households with one working spouse than households with two working spouses. The relationship for the cross-price parameters is less clear.

Table 2.4: Three-Stage Least Squares Estimates For Married Households, 1 Worker (AIDS)

	Clean Good		Energy Good		Leisure	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Constant	-0.0066	(0.1074)	0.1784‡	(0.0234)	0.8282‡	(0.1018)
Ln(Clean Price)	0.0779‡	(0.0135)	–0.0258†	(0.0102)	-0.0521‡	(0.0089)
Ln(Energy Price)	–0.0258†	(0.0102)	0.0473‡	(0.0100)	-0.0214‡	(0.0031)
Ln(Net Wage)	–0.0521‡	(0.0089)	–0.0214‡	(0.0031)	0.0735‡	(0.0096)
Ln(Real Income)	0.1474‡	(0.0053)	–0.0235‡	(0.0017)	–0.1239‡	(0.0056)
Age	–0.0012	(0.0016)	0.0032‡	(0.0005)	–0.0020	(0.0017)
Age Sq	0.000001	(0.00002)	–0.00003‡	(0.00001)	0.00003†	(0.00002)
No HS Diploma	-0.0030	(0.0055)	–0.0020	(0.0023)	0.0051	(0.0058)
Some College	0.0078	(0.0053)	–0.0038†	(0.0018)	–0.0040	(0.0057)
Bachelor's Deg	0.0173†	(0.0071)	–0.0030	(0.0024)	–0.0143	(0.0076)
Graduate Deg	0.0164	(0.0085)	–0.0055	(0.0029)	–0.0109	(0.0094)
Male	-0.0750	(0.0987)	0.0086	(0.0178)	0.0664	(0.0914)
Black	-0.0075	(0.0088)	–0.0033	(0.0033)	0.0108	(0.0092)
Asian	-0.0028	(0.0098)	–0.0117‡	(0.0030)	0.0144	(0.0106)
Other	0.0008	(0.0190)	-0.0087	(0.0051)	0.0080	(0.0190)
Own Home	-0.0154‡	(0.0049)	0.0162‡	(0.0019)	–0.0008	(0.0052)
No Children	-0.0061	(0.0059)	–0.0034	(0.0022)	0.0095	(0.0063)
Two Children	0.0087	(0.0051)	–0.0003	(0.0018)	–0.0085	(0.0055)
Three or More	-0.0044	(0.0058)	0.0006	(0.0020)	0.0037	(0.0061)
No Car	0.0051	(0.0051)	–0.0039‡	(0.0018)	–0.0012	(0.0053)
Two Cars	0.0025	(0.0043)	0.0061‡	(0.0016)	–0.0086	(0.0046)
Three or More	0.0035	(0.0059)	0.0083‡	(0.0020)	–0.0118	(0.0064)

*System of 3 demand equations, the clean good equation is dropped. Parameters for the clean good are calculated based on cross-equation restrictions. Standard errors are calculated using a bootstrap procedure (1,500 replications). † significance at 5% level. ‡ significance at 1% level.

Table 2.5: Three-Stage Least Squares Estimates For Married Households, 2 Workers (AIDS)

	Clean Good		Energy Good		Male Leisure		Female Leisure	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Constant	-0.4309‡	(0.0248)	0.1821‡	(0.0072)	0.6231‡	(0.0236)	0.6257‡	(0.0234)
Ln(Clean Price)	0.0700‡	(0.0102)	–0.0275‡	(0.0046)	–0.0150†	(0.0075)	–0.0274‡	(0.0055)
Ln(Energy Price)	–0.0275‡	(0.0046)	0.0390‡	(0.0037)	–0.0079‡	(0.0022)	–0.0035†	(0.0018)
Ln(Net Wage) (M)	–0.0150†	(0.0075)	–0.0079‡	(0.0022)	0.0689‡	(0.0081)	–0.0460‡	(0.0047)
Ln(Net Wage) (F)	–0.0274‡	(0.0055)	–0.0035†	(0.0018)	–0.0460‡	(0.0047)	0.0769‡	(0.0061)
Ln(Real Income)	0.1731‡	(0.0036)	–0.0230‡	(0.0010)	–0.0828‡	(0.0036)	–0.0674‡	(0.0034)
Age (M)	0.0004	(0.0013)	0.0001	(0.0004)	0.0015	(0.0012)	–0.0020†	(0.0010)
Age Sq (M)	-0.00001	(0.00001)	–0.000001	(0.000004)	–0.00001	(0.00001)	0.00002‡	(0.00001)
Age (F)	0.0013	(0.0013)	0.0016‡	(0.0004)	-0.0020	(0.0012)	–0.0010	(0.0010)
Age Sq (F)	-0.00003	(0.00002)	–0.00002	(0.000004)	0.00002	(0.00001)	0.00002	(0.00001)†
No HS Diploma (M)	0.0032	(0.0041)	–0.00006	(0.0014)	0.00004	(0.0038)	–0.0032	(0.0036)
Some College (M)	0.0056†	(0.0025)	–0.0009	(0.0007)	–0.0001	(0.0022)	–0.0037	(0.0022)
Bachelor's Deg (M)	–0.0028	(0.0032)	-0.0052‡	(0.0009)	0.0032	(0.0031)	0.0048	(0.0027)
Graduate Deg (M)	–0.0034	(0.0045)	–0.0047‡	(0.0012)	0.0041	(0.0045)	0.0040	(0.0036)
No HS Diploma (F)	0.0037	(0.0045)	–0.0024	(0.0015)	–0.0010	(0.0040)	–0.0004	(0.0038)
Some College (F)	–0.00002	(0.0026)	–0.0008	(0.0008)	0.0006	(0.0025)	0.0002	(0.0022)
Bachelor's Deg (F)	0.0036	(0.0033)	–0.0014	(0.0010)	0.0002	(0.0033)	–0.0025	(0.0032)
Graduate Deg (F)	0.0064	(0.0047)	–0.0023	(0.0013)	0.0028	(0.0045)	–0.0069	(0.0050)
Black (M)	–0.0022	(0.0075)	–0.0005	(0.0020)	–0.0011	(0.0075)	0.0038	(0.0066)
Asian (M)	0.0134	(0.0077)	–0.0010	(0.0020)	–0.0032	(0.0091)	–0.0091	(0.0064)
Other (M)	0.0071	(0.0078)	–0.0031	(0.0025)	–0.0057	(0.0071)	0.0017	(0.0072)
Black (F)	–0.0016	(0.0079)	–0.0006	(0.0021)	0.0142	(0.0078)	–0.0119	(0.0068)
Asian (F)	–0.0107	(0.0090)	0.0012	(0.0028)	0.0078	(0.0071)	0.0017	(0.0091)
Other (F)	–0.0055	(0.0068)	–0.0019	(0.0019)	0.0079	(0.0082)	–0.0005	(0.0058)
Own Home	–0.0153‡	(0.0032)	0.0085‡	(0.0009)	0.0038	(0.0028)	0.0030	(0.0024)
No Children	0.0081‡	(0.0023)	–0.0014†	(0.0007)	0.0026	(0.0022)	–0.0094‡	(0.0019)
Two Children	–0.0053†	(0.0025)	0.0011	(0.0007)	–0.0021	(0.0022)	0.0063‡	(0.0024)
Three or More	–0.0109‡	(0.0033)	0.0041	(0.0010)	–0.0072†	(0.0031)	0.0141‡	(0.0030)
No Car	0.0010	(0.0028)	–0.0013	(0.0007)	–0.0008	(0.0024)	0.0010	(0.0023)
Two Cars	0.0046†	(0.0021)	0.0012†	(0.0006)	–0.0017	(0.0019)	–0.0041†	(0.0019)
Three or More	0.0075‡	(0.0029)	0.0067‡	(0.0008)	–0.0036	(0.0029)	–0.0107‡	(0.0024)

*System of 4 demand equations, the clean good equation is dropped. Parameters for the clean good are calculated based on cross-equation restrictions. Standard errors are calculated using a bootstrap procedure (1,500 replications). † significance at 5% level. ‡ significance at 1% level.

2.3.3 Almost Ideal Demand System Elasticity Calculations

The AIDS model does not directly estimate elasticities. The elasticity formulas are derived by taking the derivative of the budget share equation with respect to prices and then algebraically manipulated. Note that the elasticity formulas are derived from equation 2.2 where the AIDS equation includes the true price index, $\ln(a(P))$. However the parameters are estimated with Stone's Index as a proxy for $\ln(a(P))$. This raises the issue of whether estimation with Stone's Index yields parameters consistent with the true AIDS model. Green and Alston (1990) derive an alternative elasticity formula based on estimating the AIDS equation with Stone's Index. They find that as the error from using Stone's Index approaches zero, the estimated parameters will converge to the true parameters except for the α_i intercept terms. This is consistent with the finding of Buse (1994); parameters estimated using Stone's Index may be combined with the AIDS elasticity formulas as long as α_i is corrected. Moschini (1995) examines whether or not Stone's Index is an adequate approximation to $\ln(a(P))$. If prices are not unit-invariant then Stone's Index is a poor approximation. Therefore Moschini suggests alternative specifications which are unit-invariant. Alternatively if prices are already indices then Stone's Index is sufficient.[12] Therefore the elasticity formulas based on $\ln(a(P))$ are used. The benefit is that this keeps the elasticity formulas consistent with the tax incidence calculations, since the indirect utility function is based on the $\ln(a(P))$ formula.

The uncompensated AIDS elasticity formula is:

$$\epsilon_{i,j} = \frac{1}{w_i}[\gamma_{i,j} - \beta_i \times (\alpha_j + \sum_{k=1}^{n} \gamma_{k,j} \times \ln(p_k))] - \delta_{i,j} \tag{2.10}$$

where $\delta_{i,j}$ is the Kronecker delta. Labor supply is assumed to be endogenous and this affects the cross-price elasticities with respect to the net wage rate.

$$\epsilon_{i,l} = \frac{1}{w_i}[\gamma_{i,l} + \beta_i \times \frac{\omega}{M} - \beta_i \times (\alpha_l + \sum_{k=1}^{n} \gamma_{k,l} \times \ln(p_k))] + \frac{\omega}{M} - \delta_{i,l} \tag{2.11}$$

In the four good model where male and female leisure are separate, ω is spouse-specific earnings ability.

[12] Green and Alston's elasticity formulas are used to calculate elasticity values. However the formula yields a positive compensated own-price elasticity for leisure which is incorrect.

Since the elasticity formulas are derived using the $\ln(a(P))$ price index, but Stone's Index is used in the estimation process, the α_i's need to be adjusted. An iterative procedure is used to calculate the α_i's. The estimated α_i values are used to calculate $\ln(a(P))$. Given a value for the price index, an estimated budget share value can then be found. The α_i values are calibrated so that this estimated budget share value matches the sample average budget share value for each good.[13]

Table 2.6 reports elasticities for single households, Table 2.7 reports elasticities for married households with one working spouse and Table 2.8 reports elasticities for married households with two working spouses. The income elasticities are similar across all three samples. The income elasticity estimates for the clean good are 1.2634 for single households, 1.2300 for married households with one working spouse and 1.3000 for married households with two working spouses, which correspond to the parameter estimates for β indicating that the clean good is a luxury good. The energy good and labor are found to be inelastic across all three samples. The compensated own-price elasticities indicate that all of the goods have the correct inverse price-quantity demanded relationship. For single households, the clean good own-price elasticity is –0.2110 and the energy good own-price elasticity is –0.2519. The compensated own-price elasticity for labor supply is supposed to be positive, 0.3154. As the net wage rate increases, leisure should decrease and therefore hours worked will increase.

The compensated cross-price elasticities for the single household sample are greater in magnitude relative to the corresponding compensated cross-price elasticities for both married household samples, except for the cross-price elasticity between the clean good and the energy good. The compensated cross-price elasticity of the clean good with respect to the energy good price is 0.0075 for single households, 0.0140 for married households with one working spouse and –0.0097 for married households with two working spouses. The compensated cross-price elasticity of the energy good with respect to the clean price is 0.0889 for single households, 0.1414 for married households with

[13] Asche and Wessells (1997) examine the effect of price normalization on the AIDS model. If prices are normalized to unity then $\ln(a(P)) = \alpha_0$. They use this relationship to derive an alternative elasticity formula. The Asche and Wessells elasticity formula is used to calculate compensated cross-price elasticity values for the clean good, energy good and labor supply. These elasticity estimates do not differ from the elasticities found by the iterative procedure.

one working spouse and –0.1184 for married households with two working spouses. These two are also the only insignificant cross-price elasticities for the single household sample.

If the tax regime includes commodity taxation, it is important to include leisure as one of the consumption goods. However since it is not possible to measure leisure consumption, and therefore to tax it, an alternative is to tax complements to leisure. Thus it is necessary to calculate the cross-price elasticity of leisure, or alternatively labor supply. The compensated cross-price elasticity of the energy good with respect to the net wage, for single households, is 0.1507 and the cross-price elasticity of labor supply with respect to the energy good price is –0.0195. Both of these estimates imply that the energy good and leisure are substitutes. For instance, if the energy good price increases by 1%, the amount of labor decreases by 1.95%. This implies leisure will increase, but the quantity consumed of the energy good decreases due to the price increase and thus leisure and the energy good are substitutes.

The compensated cross-price elasticities are similar between the married households with one working spouse sample and the married households with two working spouses sample. The compensated own-price elasticity for the energy good is –0.1748 for households with one working spouse and –0.1111 for households with two working spouses, but both estimates are insignificant. Similar to the single household sample the compensated cross-price elasticity of the clean good with respect to the energy good price, and vice versa, is insignificant for both married samples. The main difference between the two married samples is in the compensated cross-price elasticity of the energy good with respect to the net wage. The elasticity is 0.0268 but insignificant for married households with one working spouse. It is 0.1475 and significant for the female net wage rate in married households with two working spouses. The compensated cross-price elasticity of labor supply with respect to the energy good price is insignificant for both married samples.

West and Williams estimate a similar AIDS demand model on a similar data set, they also use the CES data set but have a different sample size. In their demand model gasoline is the only energy good. They estimate a demand model for single households and a demand model for married households. Their estimate of the compensated cross-price elasticity of labor supply with respect to the price of gasoline is –0.009 for single households which is similar to the estimate of –0.0195 found here. Both estimates are significant.

There is a difference in the estimate for the compensated cross-price elasticity of male labor supply with respect to the energy good price. West and Williams calculate an elasticity of 0.007, while the elasticity calculated here is –0.0114; both values are insignificant. One important distinction is that West and Williams estimate the compensated own-price elasticity of gasoline for single households to be –0.750, while here it is the compensated own-price elasticity of the energy good which is –0.2819; both of which are significant. In addition their estimate for married households is –0.269, which is significant while here the estimate for married households with two working spouses is –0.1111, but it is insignificant. Therefore West and Williams find the compensated own-price elasticity of gasoline to be more responsive than the compensated own-price elasticity of the energy good. The difference could arise from the definition of the energy good. There are alternatives to driving, however it may be more difficult to lower overall home energy use. This may especially be true if energy consumption is predominantly used for home heating purposes and cooking.

2.4 Quadratic Almost Ideal Demand System

2.4.1 Quadratic Almost Ideal Demand System Model

The AIDS model assumes demand equations are linear in log income. Banks, Blundell and Lewbel (1997) test this Working-Leser Engel curve specification and find that it holds for some, but not all goods. If Engel curves are indeed non-linear, then it is important for any demand system to be able to incorporate the differing income effects from households having different incomes. Banks, Blundell and Lewbel develop the Quadratic Almost Ideal Demand System (QUAIDS) as an extension to AIDS with this goal in mind.

Banks, Blundell and Lewbel find that the linear in log income specification is valid for some goods but not all. They develop their QUAIDS model to be flexible enough so that a higher-order log income term need not be imposed on all goods. Banks, Blundell, and Lewbel find that if the Engel curve

Table 2.6: Elasticity Estimates For The AIDS Model

	Estimates For Single Households		
	Clean Price	Energy Price	Net Wage
Compensated Elasticities			
Clean Good	–0.2110	0.0075	0.1779
	(–0.2482, –0.1738)	(–0.0109, 0.0259)	(0.1450, 0.2108)
Energy Good	0.0889	–0.2519	0.1507
	(–0.1285, 0.3063)	(–0.4344, –0.0694)	(0.0427, 0.2587)
Labor	–0.2873	–0.0195	0.3154
	(–0.3336, –0.2410)	(–0.0324, –0.0066)	(0.2668, 0.3640)
Uncompensated Price Elasticities			
Clean Good	–0.9937	–0.0589	0.7104
	(–1.0276, –0.9598)	(–0.0773, –0.0405)	(0.6802, 0.7406)
Energy Good	–0.2905	–0.2841	0.4088
	(–0.4998, –0.0812)	(–0.4668, –0.1014)	(0.3096, 0.5080)
Labor	–0.0259	0.0026	0.1375
	(–0.0667, 0.0149)	(–0.0101, 0.0153)	(0.0930, 0.1820)
Income Elasticities			
Clean Good	1.2634		
	(1.2534, 1.2734)		
Energy Good	0.6124		
	(0.5748, 0.6501)		
Labor	–0.4221		
	(–0.4368, –0.4073)		

*95% confidence intervals are calculated using a bootstrapping procedure (1,500 replications).

Table 2.7: Elasticity Estimates For The AIDS Model

	Estimates For Married Households, 1 Worker		
	Clean Price	Energy Price	Net Wage
Compensated Elasticities			
Clean Good	–0.1813	0.0140	0.1545
	(–0.2260, –0.1366)	(–0.0174, 0.0454)	(0.1229, 0.1861)
Energy Good	0.1414	–0.1748	0.0268
	(–0.1767, 0.4595)	(–0.4856, 0.1360)	(–0.0745, 0.1281)
Labor	–0.2252	–0.0044	0.2334
	(–0.2675, –0.1829)	(–0.0178, 0.0090)	(0.1882, 0.2786)
Uncompensated Price Elasticities			
Clean Good	–0.9695	–0.0638	0.7411
	(–1.0101, –0.9289)	(–0.0953, –0.0323)	(0.7140, 0.7682)
Energy Good	–0.2614	–0.2145	0.3265
	(–0.5756, 0.0528)	(–0.5252, 0.0962)	(0.2387, 0.4143)
Labor	0.0063	0.0184	0.0611
	(–0.0286, 0.0412)	(0.0051, 0.0317)	(0.0221, 0.1001)
Income Elasticities			
Clean Good	1.2300		
	(1.2140, 1.2461)		
Energy Good	0.6285		
	(0.5772, 0.6798)		
Labor	–0.3612		
	(–0.3843, –0.3381)		

*95% confidence intervals are calculated using a bootstrapping procedure (1,500 replications).

Table 2.8: Elasticity Estimates For The AIDS Model

	Estimates For Married Households, 2 Workers			
	Clean Price	Energy Price	Net Wage Male	Net Wage Female
Compensated Elasticities				
Clean Good	–0.2324	–0.0097	0.1252	0.1011
	(–0.2707, –0.1941)	(–0.0257, 0.0063)	(0.0971, 0.1533)	(0.0808, 0.1214)
Energy Good	–0.1184	–0.1111	0.0758	0.1475
	(–0.3141, 0.0773)	(–0.2645, 0.0423)	(–0.0183, 0.1699)	(0.0725, 0.2225)
Male Labor	–0.2360	–0.0114	0.2395	0.0120
	(–0.2850, –0.1870)	(–0.0248, 0.0020)	(0.1885, 0.2905)	(–0.0170, 0.0410)
Female Labor	–0.1800	–0.0076	0.0206	0.3203
	(–0.2443, –0.1157)	(–0.0249, 0.0097)	(–0.0259, 0.0671)	(0.2622, 0.3784)
Uncompensated Price Elasticities				
Clean Good	–0.9832	–0.0710	0.5380	0.3624
	(–1.0171, –0.9493)	(–0.0870, –0.0550)	(0.5125, 0.5635)	(0.3430, 0.3818)
Energy Good	–0.4147	–0.1353	0.2387	0.2507
	(–0.6011, –0.2283)	(–0.2888, 0.0182)	(0.1528, 0.3246)	(0.1775, 0.3239)
Male Labor	–0.0417	0.0045	0.1327	–0.0557
	(–0.0838, 0.0004)	(–0.0088, 0.0178)	(0.0861, 0.1793)	(–0.0851, –0.0263)
Female Labor	0.1390	0.0184	–0.1548	0.2092
	(0.0842, 0.1938)	(0.0013, 0.0355)	(–0.1980, –0.1116)	(0.1518, 0.2666)
Income Elasticities				
Clean Good	1.3000			
	(1.2874, 1.3120)			
Energy Good	0.5129			
	(0.4703, 0.5555)			
Male Labor	–0.3363			
	(–0.3579, –0.3148)			
Female Labor	–0.5523			
	(–0.5850, –0.5196)			

*95% confidence intervals are calculated using a bootstrapping procedure (1,500 replications).

coefficient matrix is of rank three[14] and exactly aggregable then any higher-order log income term must be quadratic, i.e. $\ln M^2$. They also find that if they do not want to impose the non-linear specification on all goods then either the log income or $\ln M^2$ coefficient must be price-dependent, i.e. the value of λ_i varies with the price index $b(P)$. The estimated budget share equation is:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{i,j} \times \ln(p_j) + \beta_i \times \ln \frac{M}{a(P)} + \frac{\lambda_i}{b(P)} \times [\ln \frac{M}{a(P)}]^2 \qquad (2.12)$$

for the non-linear good only. Although Banks, Blundell and Lewbel specify the $\ln(a(P))$ price index to be the same as the Deaton and Muellbauer version, equation 2.2, they specify the $b(P)$ index slightly differently.

$$b(P) = \prod_{i=1}^{n} p_i^{\beta_i} \qquad (2.13)$$

The estimation procedure is identical to the AIDS procedure. The only change is the $\ln M^2$ term also needs to be instrumented for, using the same procedure that created the log income instrument. The QUAIDS model adds one more restriction to the list of cross-equation restrictions from before,

$$\sum_{i=1}^{n} \lambda_i = 0 \qquad (2.14)$$

Tables 2.9-2.11 report the regression results from estimating both the Working-Leser, linear in log income, Engel curve specification and the quadratic log income specification on each good. The regression results indicate that the quadratic log income term is significant for all goods in all three samples. Therefore the QUAIDS model is estimated for all three goods.

[14] Banks, Blundell and Lewbel assume a general Engel curve specification of the form

$$s_i = A_i(P) + B_i(P) \times \ln(M) + C_i(P) \times g(M)$$

where $g(M)$ is some non-linear function of income. This coefficient matrix has maximum rank of 3, depending on the relationship between $B_i(P)$ and $C_i(P)$

Table 2.9: Quadratic Polynomial Regression Results

	Single Households					
	Clean Good		Energy Good		Leisure	
	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic
$\ln M$	0.0841‡	–0.1492‡	–0.0210‡	0.0115‡	–0.063‡	0.1376‡
	(0.0020)	(0.0310)	(0.0004)	(0.0068)	(0.0021)	(0.0321)
$\ln M^2$	–	0.0179‡	–	–0.0025‡	–	–0.0154‡
	–	(0.0024)	–	(0.0005)	–	(0.0024)

*Regression results test the Working-Leser Engel curve specification versus a quadratic log income specification. † significance at 5% level. ‡ significance at 1% level.

Table 2.10: Quadratic Polynomial Regression Results

	Married Households, 1 Worker					
	Clean Good		Energy Good		Leisure	
	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic
$\ln M$	0.0551‡	–0.2265‡	–0.0337‡	–0.0761‡	–0.0214‡	0.3027‡
	(0.0030)	(0.0523)	(0.0007)	(0.0121)	(0.0030)	(0.0531)
$\ln M^2$	–	0.0205‡	–	0.0031‡	–	–0.0236‡
	–	(0.0038)	–	(0.0009)	–	(0.0038)

*Regression results test the Working-Leser Engel curve specification versus a quadratic log income specification. † significance at 5% level. ‡ significance at 1% level.

Table 2.11: Quadratic Polynomial Regression Results

	Married Households, 2 Workers							
	Clean Good		Energy Good		Leisure (M)		Leisure (F)	
	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic
$\ln M$	0.0756‡	–0.5790‡	–0.0284‡	–0.0792‡	–0.0280‡	0.4556‡	–0.0192‡	0.2026‡
	(0.0022)	(0.0473)	(0.0004)	(0.0081)	(0.0017)	(0.0369)	(0.0017)	(0.0373)
$\ln M^2$	–	0.0455‡	–	0.0035‡	–	–0.0336‡	–	–0.0154‡
	–	(0.0033)	–	(0.0006)	–	(0.0026)	–	(0.0026)

*Regression results test the Working-Leser Engel curve specification versus a quadratic log income specification. † significance at 5% level. ‡ significance at 1% level.

2.4.2 Quadratic Almost Ideal Demand System Estimation Results

Table 2.12 reports the parameter estimates for the single household QUAIDS sample, Table 2.13 reports the parameter estimates for the married households with one working spouse QUAIDS sample and Table 2.14 reports the parameter estimates for the married household with two working spouses QUAIDS sample. First, for all three samples the AIDS and QUAIDS cross-price parameter estimates are similar. The single household clean good own-price parameter estimate is 0.0565 for the AIDS model (Table 2.3) and 0.0552 for the QUAIDS model (Table 2.12). The energy good own-price estimate for the married household with one working spouse sample is 0.0473 for the AIDS model (Table 2.4) and 0.0470 for the QUAIDS model (Table 2.13). The clean good, male net wage cross-price parameter is –0.0150 for the AIDS model (Table 2.5) and –0.0127 for the QUAIDS model (Table 2.14), this is for the married households with two working spouses sample.

The difference between the AIDS and QUAIDS model is found in the coefficient for the real income term. Consider the single household sample. For the clean good equation the AIDS parameter estimate, 0.1632 (Table 2.3), is similar to the QUAIDS parameter estimate, 0.1845 (Table 2.12). The estimates are different for the energy good equation. The AIDS estimate is –0.0204 and the QUAIDS estimate is 0.0771. The difference in the leisure equation estimate is one of magnitude. The AIDS estimate is –0.1428 and the QUAIDS estimate is –0.2616. For the married household with one working spouse sample, again the main difference is in the energy good equation. However now the QUAIDS estimate is insignificant; the AIDS estimate is – 0.0235 (Table 2.4) and the QUAIDS estimate is 0.0049 (Table 2.13). For the married household with two working spouses sample (Table 2.14), all of the real income coefficients are insignificant for the QUAIDS model. As for the quadratic income term, it is only significant for the energy good and leisure and only for single households (Table 2.12). For both married household samples, the quadratic income coefficient is insignificant for all goods.

Banks, Blundell and Lewbel developed the QUAIDS model to be flexible enough so that the quadratic log income term does not have to be applied to each demand equation. Therefore a mixed-QUAIDS specification is applied to the single household sample only. In this mixed-QUAIDS model, the

Table 2.12: Three-Stage Least Squares Estimates For Single Households (QUAIDS)

	Clean Good		Energy Good		Leisure	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Constant	–0.4059†	(0.1836)	–0.1015	(0.0667)	1.5074‡	(0.1970)
Ln(Clean Price)	0.0552‡	(0.0117)	–0.0204‡	(0.0059)	–0.0348‡	(0.0100)
Ln(Energy Price)	–0.0204‡	(0.0059)	0.0356‡	(0.0049)	–0.0152‡	(0.0029)
Ln(Net Wage)	–0.0348‡	(0.0100)	–0.0152‡	(0.0029)	0.0500‡	(0.0104)
Ln(Real Income)	0.1845‡	(0.0640)	0.0771‡	(0.0237)	–0.2616‡	(0.0691)
Ln(Real Income^2)	-0.0018	(0.0054)	–0.0084‡	(0.0020)	0.0103	(0.0058)

*QUAIDS specification includes a quadratic log income term on all demand equations. System of 3 demand equations, the clean good equation is dropped. Parameters for the clean good are calculated based on cross-equation restrictions. Standard errors are calculated using a bootstrapping procedure (1,500 replications). † significance at 5% level. ‡ significance at 1% level.

Table 2.13: Three-Stage Least Squares Estimates For Married Households, 1 Worker (QUAIDS)

	Clean Good		Energy Good		Leisure	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Constant	–0.1198	(0.2336)	0.0935	(0.0687)	1.0263‡	(0.2449)
Ln(Clean Price)	0.0778‡	(0.0137)	–0.0253†	(0.0103)	–0.0525‡	(0.0090)
Ln(Energy Price)	–0.0253†	(0.0103)	0.0470‡	(0.0100)	–0.0217‡	(0.0031)
Ln(Net Wage)	–0.0525‡	(0.0090)	–0.0217‡	(0.0031)	0.0741‡	(0.0097)
Ln(Real Income)	0.1854‡	(0.0642)	0.0049	(0.0220)	–0.1904‡	(0.0695)
Ln(Real Income^2)	–0.0031	(0.0050)	–0.0023	(0.0017)	0.0055	(0.0055)

*QUAIDS specification includes a quadratic log income term on all demand equations. System of 3 demand equations, the clean good equation is dropped. Parameters for the clean good are calculated based on cross-equation restrictions. Standard errors are calculated using a bootstrapping procedure (1,500 replications). † significance at 5% level. ‡ significance at 1% level.

clean good equation is estimated according to the AIDS specification and the energy good and leisure are estimated according to the QUAIDS specification. The results are reported in Table 2.15. Again the cross-price parameter estimates are very similar between the AIDS and the mix-QUAIDS model. The real income coefficient for the energy good is –0.0204 in the AIDS model (Table 2.3) and 0.0779 in the mix-QUAIDS model (Table 2.15). The real income coefficient for leisure is –0.1428 for the AIDS model and –0.2406 for the mix-QUAIDS model.

2.4.3 Quadratic Almost Ideal Demand System Elasticity Calculations

The QUAIDS elasticity formulas are:

$$\epsilon_{i,j} = \frac{1}{w_i}[\gamma_{i,j} - [(\beta_i + \frac{2\lambda_i}{b(P)} \times \ln\frac{M}{a(P)}) \times (\alpha_j + \sum_{k=1}^{n} \gamma_{k,j} \times \ln(p_k))]$$

Table 2.14: Three-Stage Least Squares Estimates For Married Households, 2 Workers (QUAIDS)

	Clean Good		Energy Good	
	Estimate	Std. Error	Estimate	Std. Error
Constant	0.0368	(0.2697)	0.1748†	(0.0734)
Ln(Clean Price)	0.0664‡	(0.0114)	–0.0271‡	(0.0048)
Ln(Energy Price)	–0.0271‡	(0.0048)	0.0388‡	(0.0037)
Ln(Net Wage) (M)	–0.0127	(0.0084)	–0.0081‡	(0.0024)
Ln(Net Wage) (F)	–0.0266‡	(0.0059)	–0.0036†	(0.0018)
Ln(Real Income)	0.0219	(0.0859)	–0.0206	(0.0233)
Ln(Real Income^2)	0.0119	(0.0066)	–0.0002	(0.0018)
	Male Leisure		Female Leisure	
	Estimate	Std. Error	Estimate	Std. Error
Constant	0.3163	(0.2614)	0.4721	(0.2454)
Ln(Clean Price)	–0.0127	(0.0084)	–0.0266‡	(0.0059)
Ln(Energy Price)	–0.0081‡	(0.0024)	–0.0036†	(0.0018)
Ln(Net Wage) (M)	0.0674‡	(0.0087)	–0.0465‡	(0.0049)
Ln(Net Wage) (F)	–0.0465‡	(0.0049)	0.0768‡	(0.0061)
Ln(Real Income)	0.0165	(0.0842)	–0.0177	(0.0798)
Ln(Real Income^2)	–0.0078	(0.0066)	–0.0040	(0.0063)

*QUAIDS specification includes a quadratic log income term on all demand equations. System of 4 demand equations, the clean good equation is dropped. Parameters for the clean good are calculated based on cross-equation restrictions. Standard errors are calculated using a bootstrap procedure (1,500 replications). † significance at 5% level. ‡ significance at 1% level.

Table 2.15: Three-Stage Least Squares Estimates For Single Households (Mix-QUAIDS Model)

	Clean Good		Energy Good		Leisure	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Constant	-0.3440‡	(0.0196)	–0.1038	(0.0683)	1.4478‡	(0.0691)
Ln(Clean Price)	0.0522‡	(0.0078)	–0.0202‡	(0.0059)	–0.0320‡	(0.0050)
Ln(Energy Price)	–0.0202‡	(0.0059)	0.0355‡	(0.0049)	–0.0153‡	(0.0030)
Ln(Net Wage)	–0.0320‡	(0.0050)	–0.0153‡	(0.0030)	0.0473‡	(0.0058)
Ln(Real Income)	0.1627‡	(0.0024)	0.0779‡	(0.0242)	–0.2406‡	(0.0243)
Ln(Real Income^2)	–	–	–0.0085‡	(0.0021)	0.0085‡	(0.0021)
Age	0.0053‡	(0.0007)	0.0017‡	(0.0002)	–0.0071‡	(0.0007)
Age Sq	–0.00007‡	(0.00001)	–0.00002	(0.000003)	0.00009‡	(0.00001)
No HS Diploma	–0.0057	(0.0041)	–0.0007	(0.0013)	0.0064	(0.0042)
Some College	–0.0065†	(0.0027)	–0.0047‡	(0.0009)	0.0112‡	(0.0028)
Bachelor's Deg	0.0020	(0.0034)	–0.0066‡	(0.0012)	0.0047	(0.0035)
Graduate Deg	0.0039	(0.0046)	–0.0093‡	(0.0016)	0.0054	(0.0048)
Male	0.0075‡	(0.0024)	0.0047‡	(0.0008)	–0.0122‡	(0.0025)
Black	–0.0062†	(0.0029)	–0.0007	(0.0010)	0.0070†	(0.0030)
Asian	–0.0022	(0.0067)	–0.0048‡	(0.0014)	0.0069	(0.0068)
Other	–0.0168	(0.0110)	–0.0023	(0.0039)	0.0191	(0.0101)
Own Home	–0.0200‡	(0.0025)	0.0167‡	(0.0009)	0.0033	(0.0026)
No Children	0.0003	(0.0029)	–0.0078‡	(0.0010)	0.0075†	(0.0030)
Two Children	–0.0093†	(0.0043)	0.0008	(0.0013)	0.0085	(0.0044)
Three or More	–0.0158‡	(0.0055)	0.0071‡	(0.0018)	0.0087	(0.0056)
No Car	–0.0025	(0.0025)	–0.0059‡	(0.0007)	0.0084‡	(0.0026)
Two Cars	0.0050	(0.0026)	0.0093‡	(0.0009)	–0.0143‡	(0.0028)
Three or More	0.0094‡	(0.0042)	0.0150‡	(0.0015)	–0.0244‡	(0.0044)

*QUAIDS specification includes a quadratic log income term for energy and leisure only. System of 3 demand equations, the clean good equation is dropped. Parameters for the clean good are calculated based on cross-equation restrictions. Standard errors are calculated using a bootstrapping procedure (1,500 replications). † significance at 5% level. ‡ significance at 1% level.

$$-\frac{\lambda_i \beta_j}{b(P)} \times (\ln(\frac{M}{a(P)}))^2] - \delta_{i,j} \tag{2.15}$$

$$\epsilon_{i,l} = \frac{1}{w_i}[\gamma_{i,l} + [(\beta_i + \frac{2\lambda_i}{b(P)}(\ln \frac{M}{a(P)})) \times (\frac{\omega}{M} - (\alpha_l + \sum_{k=1}^{n} \gamma_{k,l} \times \ln(p_k)))]$$

$$-\frac{\lambda_i \beta_l}{b(P)} \times (\ln(\frac{M}{a(P)}))^2] + \frac{\omega}{M} - \delta_{i,l} \tag{2.16}$$

Since we have a mixed AIDS/QUAIDS model the QUAIDS elasticity formulas are only applied to the energy good equation and the leisure equation.

Table 2.16 reports the elasticity estimates for the mix-QUAIDS model. There are several differences between the AIDS elasticity estimates in Table 6 and these estimates. The first is that the compensated own-price elasticity for the energy good is insignificant in the mix-QUAIDS model. Next is the pair of compensated cross-price elasticity estimates between the energy good and the clean good. The AIDS estimate is insignificant for both elasticities. For the QUAIDS model both are significant. The compensated cross-price elasticity of the clean good with respect to the energy good price is 0.0479 and the compensated cross-price elasticity of the energy good with respect to the clean price is 0.5649, so the clean good and the energy good are substitutes. Another difference is the compensated cross-price elasticity of labor supply with respect to the energy price. In the AIDS model this elasticity is –0.0195 and significant. Now the mix-QUAIDS estimate is 0.0514 and insignificant. Therefore changes in the energy price have very little effect on the consumption of leisure, since there is no significant effect on the amount of labor supplied. The last difference is in the income elasticity estimate. The AIDS model finds the income elasticity for the energy good to be 0.6124, while for the QUAIDS model it is 1.9559.

2.5 Equivalent Variation

The importance of calculating elasticities under the AIDS versus QUAIDS specifications is best seen by examining the difference in the welfare implications of a price change. Consider the impact of a tax that increases the price of the energy good by 25%. The welfare impact is measured by calculating

Table 2.16: Elasticity Estimates For Mix-QUAIDS Model

	Estimates For Single Households		
	Clean Price	Energy Price	Net Wage
Compensated Elasticities			
Clean Good	–0.2246	0.0479	0.1511
	(–0.2508, –0.1984)	(0.0183, 0.0775)	(0.1282, 0.1740)
Energy Good	0.5649	–0.1361	–0.4683
	(0.2154, 0.9144)	(–0.4036, 0.1314)	(–0.9629, 0.0263)
Labor	–0.2495	0.0514	0.2034
	(–0.2818, –0.2172)	(–0.0062, 0.1090)	(0.1198, 0.2870)
Uncompensated Price Elasticities			
Clean Good	–1.0067	–0.0184	0.6833
	(–1.0321, –0.9813)	(–0.0480, 0.0112)	(0.6612, 0.7054)
Energy Good	–0.6468	–0.2389	0.3561
	(–0.8995, –0.3941)	(–0.4817, 0.0039)	(0.1439, 0.5683)
Labor	–0.0870	0.0652	0.0929
	(–0.1255, –0.0485)	(0.0119, 0.1185)	(0.0418, 0.1440)
Income Elasticities			
Clean Good	1.2626		
	(1.2549, 1.2703)		
Energy Good	1.9559		
	(1.2634, 2.6484)		
Labor	–0.2623		
	(–0.3461, –0.1785)		

*95% confidence intervals are calculated using a bootstrapping procedure (1,500 replications).

the equivalent variation associated with the price change. The equivalent variation is the amount of wealth needed to be given to the household to make the household indifferent between facing the new prices or accepting this money and staying at the original prices.

$$EV(p^0, p^1, w) = e(p^0, u^1) - e(p^0, u^0) \tag{2.17}$$

$$= e(p^0, u^1) - w$$

where $e(p, w)$ is the expenditure function. p^0 is the original prices, u^0 is the utility level that can be achieved with wealth level w and the original prices, p^0. $e(p^0, u^0)$ is the expenditure level required to achieve utility u^0 at prices p^0, which is equal to w. p^1 is the new price regime and u^1 is the utility level that can be achieved with the new prices and wealth level w. However $e(p^0, u^1)$ is the amount of wealth needed to achieve utility level u^1, but under the original prices p^0.

The equivalent variation is negative because the price increase reduces utility. Since households are worse off under the new prices, money must be taken away if the household is facing the original prices. The indirect utility function for the AIDS model[15] is:

$$\ln(v) = \frac{\ln(M) - \ln(a(P))}{b(P)} \tag{2.18}$$

and the indirect utility function for the QUAIDS model is:

$$\ln(v) = [[\frac{\ln(M) - \ln(a(P))}{b(P)}]^{-1} + \lambda(P)]^{-1} \tag{2.19}$$

Table 2.17 reports the equivalent variation under the AIDS model, the QUAIDS model and also the "bias." The bias is the percentage difference in the equivalent variation estimates relative to the QUAIDS estimate. The results indicate that the AIDS model overestimates welfare loss for low-income households. For households in the 10th income percentile, the average welfare loss is –\$4.57 under the AIDS model and –\$2.57 under the QUAIDS model.

[15] α_0 in the ln(a(P)) formula is not directly estimated. Deaton and Muellbauer however suggest a way to assign a value. α_0 can be considered the minimal level of income needed to live. Therefore the minimum value of real income is used. This is also the procedure Banks, Blundell and Lewbel use, although they choose a value just below the minimum sample value.

Table 2.17: Equivalent Variation Income Distribution

	Single Households Only		
Income Percentiles	AIDS EV ($)	QUAIDS EV ($)	Bias (%)
Tenth	–4.57	–2.57	77.43
Twentieth	–5.86	–4.09	43.18
Thirtieth	–6.57	–4.95	32.75
Fortieth	–7.19	–5.81	23.82
Fiftieth	–7.77	–6.74	15.36
Sixtieth	–8.40	–7.90	6.27
Seventieth	–9.05	–9.17	–1.25
Eightieth	–9.89	–11.03	–10.37
Ninetieth	–11.08	–14.44	–23.29
One Hundredth	–13.79	–27.55	–49.95

the opposite occurs for high-income households. For those in the 100th percentile, the welfare loss is –$13.79 under the AIDS model and –$27.55 under the QUAIDS model.

2.6 Conclusion

Two different demand estimation procedures are compared – the Almost Ideal Demand System and the Quadratic Almost Ideal Demand System. The benefit of these models is neither assumes separability between consumption goods and leisure. If commodity taxes are to be used then leisure should be included as a consumption good. Since it is impractical to measure and tax leisure, it is necessary to know the cross-price elasticity of leisure with respect to other goods. The AIDS model assumes linear Engel curves and if income effects are non-linear this biases welfare estimates. The QUAIDS model allows for non-linear income effects by including a quadratic income term.

Both demand systems are estimated using data from the Consumer Expenditure Survey. Households are separated by marital status and also by the number of working spouses for married households. The linear Engel curve assumption is violated only for energy goods and leisure, and only for the single household sample. The benefit of the QUAIDS model is that the quadratic income specification does not have to be applied for all goods. In the AIDS model the energy good and leisure are substitutes. In the

QUAIDS model, the price of the energy good has no significant impact on the amount of labor supplied and therefore no impact on the consumption of leisure. In addition the AIDS model overestimates welfare loss for low-income single households and underestimates welfare loss for high-income single households. Therefore not accounting for non-linear income effects will bias estimates of the welfare impact of environmental taxes.

CHAPTER 3

OPTIMAL TAXATION AND JUNK FOOD

3.1 Introduction

The dual threat of rising health care costs and the obesity crisis has been on the policy radar for some time. This is not only a health issue, but also a fiscal issue since one of the main factors affecting the sustainability of the budget is spending on health care. Some have looked to economics for a solution. More specifically some have looked towards Sandmo's "principle of targeting" as a rationale for using taxation as a means to influence consumer behavior. The principle of targeting suggests using the most direct tax instrument available to influence behavior. This idea has become very popular at the policy level with many suggesting expanding "sin taxes" to include junk food and soft drinks in addition to the more traditional cigarettes and alcohol. This paper estimates a three-good demand model using the Almost Ideal Demand System of Deaton and Muellbauer (1980) to calculate cross-price elasticities and then calculates the incidence of taxing junk food. What is the impact of a tax on junk food? Will a tax on junk food discourage consumption, or is demand for junk food very inelastic? The latter result would indicate the possiblity of raising significant revenue from a junk food tax that may then be used to subsidize healthy food or healthy eating programs.

Engel's Law describes the relationship between food expenditures and income. As income increases, the share of income spent on food decreases. However there has been less work on the cross-price elasticities between different types of food, in this case healthy food versus junk food. Blanciforti, Green and Lane (1981) estimate Engel curves using a Box-Cox transformation to examine how expenditures on more nutritious and less nutritious food varies over the life-cycle. Hawkins (2002) uses the AIDS model to estimate the excess burden of the general sales tax. Although the model includes expenditures on food consumed at home, it is more focused on overall household consumption as opposed to examining food consumption. Non-economists such as Jacobson and Brownell (2000) have argued for taxes on soft drinks and snack foods, however they do not estimate elasticities. Heien and Wessells (1988) use the AIDS model to estimate demand for dairy products, however their focus is on demand for food and not any issues related to the taxation of unhealthy food. Chouinard, Davis, LaFrance and Perloff (2007) estimate a generalized AIDS model on propriety data from Information Resources Incorporated's Infoscan scanner data, however their focus is on dairy products only and taxing the fat that is in dairy products such as cheese, ice cream and butter. They find demand for dairy products to be price inelastic.

Data on household food consumption comes from the Diary Survey portion of the Consumer Expenditure Survey. Data from the 1996 - 1999 surveys are pooled to create a cross-sectional data set. Price data comes from the consumer price index. Households are assumed to consume three composite goods - a healthy food good, an unhealthy food good (junk food) and a nonfood good. The unhealthy food good consists of items such as donuts, cakes, ice cream, soft drinks and fruit juices that are high in sugar and/or fats and also lack nutritional value. The healthy food good consists of items such as bread, meat, fruits and vegetables. The AIDS model of Deaton and Muellbauer is used to estimate household demand. The AIDS model has many benefits. One of which is that it follows the flexible functional form tradition of Diewert which allows it to be a first-order approximation to any demand sytem. In addition it satisfies demand theory while not imposing neither homotheticity nor separability. The AIDS model does not directly estimate elasticities, rather the elasticity formulas are derived from the estimating equation. The compensated own-price elasticities indicate demand for both healthy food and junk food is inelastic. In addition the two goods are found to be subsitutes.

3.2 Data Set

The data is from the Diary Survey component of the Consumer Expenditure Survey (CES) covering the period 1996-1999. Each household is surveyed over a two-week period. During this time, the household records expenditures on small items that would be difficult to recall over a longer time frame. This includes expenditures on food and beverages, housekeeping supplies, nonprescription drugs and personal care products. Household demographic information is also collected, therefore the Diary Survey can be used independently of the Interview Survey component of the CES.[1]

Data from the Diary Survey is released quarterly. The four quarters from each year are pooled together to create a cross-sectional data set. In addition, data from each week of the two-week household survey can be considered to be independent. The unit of observation is the household. In order to maintain a homogeneous population, the sample is restricted to households where at least one spouse works. In addition, the spouses must be between the ages of 18-65. Lastly if the occupation of the working spouse is either armed forces, self-employed or farming, forestry & fishing then the household is dropped from the sample.

Unlike the Interview Survey, the Diary Survey provides detailed information on household food expenditures. Not only is expenditure data available on such aggregate categories such as bakery products, beef, poultry, milk products, fruits, sweets and oils etc., but detailed expenditure data is available on the subcategories. For instance, it is possible to identify the specific food items that comprise bakery products – white bread, other bread, cakes, cookies, donuts, etc. Similarly, expenditures on specific items in the milk & dairy products category may be identified, such as milk, cream, butter, cheese and ice cream. Therefore one may create very specific definitions for the healthy food good and the junk food good. The healthy food good consists primarily of breads, meats and fruits & vegetables. The junk food good consists primarily of desserts & sweets, fats & oils as well as sugary drinks.

The focus is on all types of unhealthy food. Otherwise the tax is merely favoring (or disfavoring in this case) certain types of unhealthy food over other types. A tax placed only on sodas may reduce soda consumption,

[1]The Consumer Expenditure Survey consists of two distinct and separate components. The first is the Diary Survey which focuses on small items and are collected during a two-week interview period. The second is the Interview component, where households are interviewed for five consecutive quarters on large purchases and purchases that occur regularly. The Interview Survey component does have data on aggregate food expenditures. However, only the Diary Survey component has detailed data on individual food expenditures.

however demand theory suggests that consumers will respond by increasing consumption of sugary fruit juices instead. In addition, one of the principles of good tax policy is to have a broad-based tax. Therefore from an optimal tax perspective, one should tax all unhealthy food.[2]

The third good is a composite good that consists of all nonfood expenditures. The Diary Survey does not have data on total household expenditures,[3] however the survey does have wage data so it is possible to calculate household after-tax earnings. An hourly gross wage rate is calculated for each household from the available employment data and the NBER TaxSim program is used to calculate an effective marginal tax rate. This is used to calculate a weekly after-tax earnings variable for each household. Nonfood good expenditures is then calculated as the difference between weekly after-tax earnings and total food expenditures.[4]

Data on prices is available from the Bureau of Labor Statistics. Price indices from the "all-urban-consumers" (current series) database is used. These indices are available monthly on a national basis. The benefit of using these prices is that the list of available prices closely matches the food categories available in the Consumer Expenditure data set. The price indices are normalized to a value of 100. Therefore the price indices are divided by 100 so that their values correspond to actual prices.

[2]The healthy food composite good consists of - cereal & cereal products; bread, white & other; meats, seafood & eggs; fresh milk; fresh fruits & vegetables; processed fruits & vegetables, except fruit juices; coffee & tea. The junk food composite good consists of - bakery products, except bread, white & other; cream; other dairy products; fruit juices from processed fruits; sugar & other sweets; nonalcoholic beverages, except coffee & tea; fats & oils; miscellaneous foods; food away from home.

[3]The Interview Survey does collect data on total household expenditures. However as explained earlier, the two surveys are separate surveys with different samples that consist of different individuals. Therefore one cannot simply merge the two surveys together, rather the data would have to be imputed. To avoid the complications associated with having to impute total household expenditures, household after-tax earnings is used as a proxy.

[4]Note that the household faces a general income tax, whereas in the above method the household faces a linear income tax. Moreover because of the progressive nature of the U.S. tax system, applying the effective marginal tax rate proportionally to all income would lead to an overestimate of taxes paid for most households. Fortunately the Diary Survey also includes information on taxes paid by the household. This data is used to create a "virtual income" variable that allows the linearization of a general income tax.

Table 3.1: Summary Statistics

Variable	Mean	Std. Dev.
Age	39.55	10.92
Percent Male	59.93	–
Percent Married	61.30	–
Family Size	2.61	1.43
Healthy Food Expenditures ($)	38.07	35.65
Junk Food Expenditures	65.66	54.11
Nonfood Expenditures	777.20	573.38
Total Income	880.94	596.79
Health Food Expenditures (%)	6.11	–
Junk Food	9.65	–
Nonfood Good	84.24	–
Healthy Food Price ($)	0.53	0.37
Fatty Food Price	0.86	0.38
Nonfood Price	1.65	0.03
# of Observations	4,527	–

*Data is from the 1996-1999 CES data set.

3.3 Almost Ideal Demand System

3.3.1 AIDS Model

The foundation of demand system estimation is Stone's (1954) linear expenditure system, which is derived from demand theory. In order to estimate the linear expenditure system, it is necesary to assume that several demand theory properties hold – additivity, homogeneity and symmetry. The drawback though is that these assumptions cannot be tested. The Rotterdam model of Theil (1965) is similar to Stone's linear expenditure system. However the Rotterdam model does not impose homogeneity nor symmetry, which allows these two assumptions to be tested. The next significant contribution to demand estimation is Diewert's (1971) "flexible functional forms" approach. This approach is based upon estimating equations with enough parameters so that any direct or indirect utility function may be approximated. It is this school of thought that led to the "transcendental logarithmic," or trans-log, model created by Christensen, Jorgenson and Lau (1975).

The Almost Ideal Demand System model of Deaton and Muellbauer is used to estimate the system of household demand equations. The AIDS model follows the "flexible functional form" approach of Diewert. The AIDS model has several attractive properties. This includes exact aggregation over all consumers, as well as satisfying the axioms of choice. In addition, the AIDS model can be used to test the demand theory restrictions of homogeneity and symmetry. Lastly, the AIDS model does not impose separability.

The AIDS demand function for good i is as follows,

$$s_i \equiv \frac{p_i \times x_i}{M} = \alpha_i + \sum_{j=1}^{n} \gamma_{i,j} \times \ln(p_j) + \beta_i \times \ln \frac{M}{a(P)} \tag{3.1}$$

where $i = 1 \ldots n$, here $n = 3$. Note that s_i is the budget share for good i, p_i is the price of good i, x_i is demand for good i and M is total income. $\ln(a(P))$ is a price index and is defined as follows:

$$\ln(a(P)) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \times \ln(p_i) + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{i,j} \times \ln(p_i) \times \ln(p_j) \tag{3.2}$$

The above demand equation, as written, requires nonlinear estimation because of the $\ln(a(P))$ price index. However to avoid the complications associated with nonlinear estimation and because the AIDS model is only locally optimal, Deaton & Muellbauer suggest approximating the price index with Stone's Index in order to keep the estimated equation linear in parameters.[5] Stone's Index is defined as follows:

$$\ln(P^*) = \sum_{i=1}^{n} s_i \times \ln(p_i) \tag{3.3}$$

In addition the following restrictions are imposed to ensure that the AIDS model satisfies the adding up of the budget constraint as well as homogeneity of degree zero. The last restriction imposes Slutsky symmetry.

$$\sum_{i=1}^{n} \alpha_i = 1; \qquad \sum_{i=1}^{n} \gamma_{i,j} = 0; \qquad \sum_{i=1}^{n} \beta_i = 0 \tag{3.4}$$

[5]Moschini (1995) raises the concern that if prices are not unit-invariant, then Stone's Index is not a satisfactory approximation for the $\ln(a(P))$ price index. Moschini suggests using a "corrected" Stone's Index, such as one where "prices are scaled by their mean." However, Moschini also raises the point that if prices are indices, then it is equivalent to using a "corrected" Stone's Index.

$$\sum_{j=1}^{n} \gamma_{i,j} = 0 \tag{3.5}$$

$$\gamma_{i,j} = \gamma_{j,i} \tag{3.6}$$

3.3.2 AIDS Estimation Procedure

The AIDS model suffers from endogeneity due to the real income term $\ln \frac{M}{a(P)}$. Stone's Index is used in place of the $\ln(a(P))$ price index in order to keep the model linear in parameters. However the equation involves the budget share for each good, which also happens to be the dependent variable. The econometric procedure of West and Williams (2004, 2007) is followed. West and Williams use the CES data set and the AIDS model to estimate the cross-price elasticity of leisure with respect to gasoline, as well as calculate the optimal gasoline tax. The instrument for Stone's Index involves replacing individual budget shares for each good with the sample average value.

A three-stage least squares procedure is used to estimate the AIDS model. The three-stage least squares procedure combines two-stage least squares with a seemingly unrelated regression. The two-stage least squares procedure allows the use of instruments to control for endogeneity. The seemingly unrelated regression component is needed because error terms may be correlated across equations, since the right-hand side variables are identical.

The demographic variables include age, a quadratic age term, the gender of the household reference person, marital status, education dummy variables, ethnicity dummy variables, home ownership dummy variable, a dummy variable for children as well as season and state dummy variables. Seasonal and state fixed effects are included to control for differences in food consumption that may arise due to the time of the year or region. For instance, the fall and winter months include Thanksgiving and the Christmas holidays which is when people tend to indulge a little more. In addition there are regional differences in diet.

Food expenditures is affected by the composition of the household. The larger the household the cheaper groceries can become because of the ability to buy in bulk. Alternatively, two households with the same level of income but different family sizes cannot spend the same amount on a per-person basis. Therefore it is important to incorporate family size into the model.

Let z be the family size variable. Family size is incorporated into the model in two ways – first as a demographic variable and second as an interaction with the real income term, $\ln \frac{M}{a(P)}$. Adjust α_i, β_i as follows:

$$\overline{\alpha}_i = \alpha_i + \phi_i \times z \tag{3.7}$$

$$\overline{\beta}_i = \beta_i + \psi_i \times z \tag{3.8}$$

Then the new AIDS budget share equation that is being estimated is:

$$s_i = \alpha_i + (\phi_i \times z) + \sum_{i=1}^{n} \gamma_{i,j} \times \ln(p_j) + (\beta_i + (\psi_i \times z)) \times \ln \frac{M}{a(P)} \tag{3.9}$$

$$= \overline{\alpha}_i + \sum_{i=1}^{n} \gamma_{i,j} \times \ln(p_j) + \overline{\beta}_i \times \ln \frac{M}{a(P)} \tag{3.10}$$

The nonfood good equation is dropped in the estimation procedure. The parameters for the nonfood good equation are calculated by imposing the cross-equation restrictions. The price for the healthy food good is the meat price index, for the junk food good it is the beverage price index and for the nonfood good it is the 'commodities-less-food-and-beverages' price index. Prices for the healthy food and junk food good are mean-centered, while the nonfood good price is divided by 100 to convert the price index to prices.

These modifications are made because the original prices suffer from multicollinearity. Therefore alternative prices and several different price transformations are compared in an attempt to minimize the impact of multicollinearity on the results. The Consumer Price Index has price indices for a variety of food categories that is consistent with the food expenditure definitions in the Consumer Expenditure Survey. The original healthy food and junk food good prices are composite prices which match the definition of the healthy food good and junk food good. The 'all-items-less-food' price index is originally chosen for the nonfood good. It is these three prices which are highly correlated.

The price indices for the individual food items are considered as alternative prices for the healthy food good and the junk food good. Two alternative composite price indices, 'commodities-less-food-and-beverage' and 'commodities-less-food,' are used for the nonfood good. The meat price index, the beverage price index and the 'commodities-less-food-and-beverages'

Table 3.2: Three Stage Least Squares Estimates

	Healthy Food		Junk Food		Nonfood Good	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Constant	0.2550	0.0166	0.4142	0.0229	0.3308	–
Ln(Healthy)	–0.0021	0.0011	–0.0052	0.0013	0.0073	–
Ln(Junk)	–0.0052	0.0013	–0.0094	0.0032	0.0146	–
Ln(Nonfood)	0.0073	0.0018	0.0146	0.0034	–0.0218	–
Real Income	–0.0454	0.0024	–0.0491	0.0032	0.0946	–
Family Size	0.0256	0.0048	0.0377	0.0065	–0.0633	–
Interaction	–0.0024	0.0007	–0.0049	0.0010	0.0073	–

*System of 3 demand equations, the nonfood good equation is dropped.

price index are found to be the best proxies for the healthy food good, junk food good and nonfood good respectively.

In addition several price transformations are considered – prices are standardized according to the standard normal distribution, prices are mean-centered or prices are standardized according to a normal $(\mu = 0.5, \sigma = 1)$ distribution. Originally prices are scaled by dividing by 100 to convert the price indices to a value similar to actual prices. However now if the prices are transformed, they are not scaled. Several different transformation combinations are tried, such as transforming all three prices or only transforming two. Mean-centering the healthy food price and the junk food price while only scaling the nonfood good price is found to yield the best results.

3.4 AIDS Elasticities

Elasticity values are indirectly estimated by the AIDS model. The relationship between budget shares and quantity demanded is used to link the AIDS equation to the elasticity formula. The income elasticity is derived as follows:

$$\frac{\partial s_i}{\partial \ln M}\bigg|_p = M\frac{\partial s_i}{\partial M}\bigg|_p = M\frac{\partial}{\partial M}\left(\frac{p_i x_i}{M}\right). \tag{3.11}$$

Which after further calculations becomes

$$\frac{1}{s_i}\frac{\partial s_i}{\partial \ln M}\bigg|_p = \frac{M}{x_i}\frac{\partial x_i}{\partial M} = \eta_i - 1. \tag{3.12}$$

Solving for $\frac{1}{s_i}\frac{\partial s_i}{\partial \ln M}$ yields

$$\eta_i = 1 + \frac{\beta_i}{s_i} \tag{3.13}$$

A similar procedure yields the uncompensated cross-price elasticity formula.

$$\frac{\partial s_i}{\partial \ln p_j} = p_j \frac{\partial s_i}{\partial p_j} = p_j \frac{\partial}{\partial p_j}\left(\frac{p_i x_i}{\partial M}\right). \tag{3.14}$$

which after further calculations becomes

$$\frac{\partial s_i}{\partial \ln p_j} = s_i \left(\delta_{i,j} + \epsilon_{i,j}\right). \tag{3.15}$$

Solving for $\frac{\partial s_i}{\partial \ln p_j}$ yields

$$\epsilon_{i,j} = \frac{1}{s_i} \times \left\{\gamma_{i,j} - \overline{\beta}_i \times \left(\overline{\alpha}_j + \sum_{k=1}^{n} \gamma_{k,j} \times \ln(p_k)\right)\right\} - \delta_{i,j} \tag{3.16}$$

where $\delta_{i,j}$ is the Kronecker delta and $\delta_{i,j} = 1$ if i = j and 0 otherwise. Lastly to go from uncompensated price elasticities to compensated price elasticities, the following formula is used:

$$\epsilon^C_{i,j} = \epsilon_{i,j} + s_j \times \eta_i. \tag{3.17}$$

These elasticity formulas are based on estimating the AIDS equation with the $\ln(a(P))$ price index. Estimating the AIDS equation where Stone's Index replaces the $\ln(a(P))$ price index is at times referred to as the LA/AIDS model, or linear-approximate AIDS model. Considerable research has been done on whether the parameter estimates from the two specifications are consistent. The question is when is Stone's Index a good proxy for the true price index, $\ln(a(P))$?

Moschini (1995) finds that if prices do not satisfy the 'commensurability' property, i.e. are not unit-invariant, then the two models are not consistent and this biases estimates of $\gamma_{i,j}$ and β_i. Therefore Moschini suggests alternatives to Stone's Index, price indices that are unit-invariant. However if prices are already price indices then this commensurability property is not a concern.

Even if prices satisfy the 'commensurablity' property, another issue remains and that is the fact that the α_i estimates are inconsistent between the two models. Green and Alston (199) and Alston, Foster and Green (1994) compare the AIDs elasticity formula with several elasticity formulas calculated from the LA/AIDS specification. Green and Alston find that errors do occur when combining the AIDS elasticity formula with parameter estimates from the LA/AIDS model. On the other hand, parameter estimates from the LA/AIDS equation do yield elasticity results that are consistent with the true AIDS formula when combined with the LA/AIDS elasticity formula. Alston, Foster and Green confirm that elasticities calculated with the LA/AIDS formula and LA/AIDS parameters is consistent with the true AIDS elasticities. However Alston, Foster and Green also confirm the result of Buse (1994), which is that it is possible to correct the LA/AIDS estimate of α_i and then use the AIDS elasticity formula.

The welfare calculations require use of the true AIDS model and therefore the second approach is followed, where the α_i estimates are corrected and then the AIDS elasticity formula is used to calculate elasticity values. The α_i estimates are adjusted by means of an iterative procedure. First the $\ln(a(P))$ price index is calculated using the estimated parameters. Next the α_i estimates are calibrated so that the estimated budget shares are similar to the sample average budget shares. This procedure is repeated until there is convergence between estimated and actual sample budget shares.

The compensated own-price elasticity estimates for both the healthy food and junk food are inelastic, although on the high side of inelastic. Therefore it seems that there is the possibility of discouraging junk food consumption with a broad-based tax. Heien and Wessells estimate a demand model for food that is focused on dairy consumption. Their compensated own-price elasticity estimates for twelve different food items is similar to the estimates found here. The most inelastic value they find is the compensated own-price elasticity for margarine, which is –0.25. The own-price elasticity estimates for the remaining goods are all larger in absolute value and range from –1.77 to –0.51. The compensated own-price elasticity value of –1.77 belongs to fruit ades and vegetable juice, while the –0.51 value belongs to meat. Heien and Wessells find the compensated own-price elasticity of fruit to be –0.83 while it is –0.73 for butter and –0.58 for soda.

Table 3.3: Elasticity Estimates For AIDS Model

	Health Food Price	Fatty Food Price	NonFood Good Price
Compensated Elasticities			
Health Food	–0.8170	0.1979	0.6190
Junk Food	0.1236	–0.8625	0.7389
Nonfood Good	0.0426	0.0815	–0.1241
Income Elasticities			
Health Food	0.1167		
Junk Food	0.3375		
Nonfood Good	1.1339		

3.5 Conclusion

The growing concern about obesity, and the associated obesity related health costs, has forced politicans and policy-makers alike to consider various solutions. One such solution that has gained popularity is a tax on junk food. It is important to estimate household demand for not only junk food but healthy food also in order to understand the implications of a junk food tax. The Almost Ideal Demand System of Deaton and Muellbauer is used to estimate the cross-price elasticity between healthy food and junk food as well as the compensated own-price elasticity for both goods and also a non-food good. The results indicate that both healthy food and junk food face inelastic demand while healthy food and junk food are substitutes.

CHAPTER 4

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