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Three Essays in Labor Economics and Public Finance

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Three Essays in Labor Economics and Public Finance

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Dedicated to my dear husband, Amilcar.

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Three Essays in Labor Economics and Public Finance

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This dissertation consists of three essays. The first one brings together the areas of public and labor economics by developing a hypothesis that relates optimal taxation and time use. Using Mexican data on household time use and consumption, we find significant substitution between goods and time in home production and different elasticities of substitution for different household commodities. Adding these findings to the optimal tax problem, we show it is optimal to impose higher taxes on market goods used in the production of commodities with a lower elasticity of substitution between goods and time. This is an analog of the classical Corlett and Hague (1953) result, differing in that we allow for the possibility of substitution between goods and time in the production of commodities.

The second chapter is about international migration, in the area of labor economics. On one hand, surveillance of the border between Mexico

and the United States by the U.S. government has increased dramatically over the last two decades. On the other hand, undocumented Mexican migrants often make multiple trips between the two countries. Thus, my hypothesis is that these migrants respond to heightened surveillance by increasing the length of stay of the current trip. I estimate a semi-parametric hazard model following Meyer (1990). Using data from the Mexican Migration Project I find no evidence that border enforcement affects the hazard of leaving the U.S. by undocumented Mexican Immigrants.

The last essay is about mother's time and children related expenditures. Using data from the Mexican Time Use Survey and the National Household Survey of Income and Expenditure from 2002, I examine the time Mexican mothers dedicate to taking care of their children and the amount of money spent by the household in raising children. The main contribution of this paper is that it analyzes child care time use and child care expenditures simultaneously. The age of the youngest child is the most important determinant of both child care time and money expenditures. It is the case that more educated mothers spend more money on their children. With respect to child care time use, more educated mothers spend more or less time with their children depending on whether they are working or non-working mothers. At all levels of non-mother's income, working mothers spend significantly more money relative to time in child care than non-working mothers. For both groups the ratio of money over time increases at a decreasing rate; however, for non-working mothers the income expansion path is much flatter.

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Chapter 1

The Optimal Tax Rule in the Presence of Time Use

1.1 Introduction[1]

Following Becker (1965), we assume that individuals combine market goods and time to produce commodities which ultimately yield utility. For example, consider a household that wants to change their car's engine oil. In order to get this commodity, the household needs to combine both market goods and time. Having only the engine oil does not give any utility, it has to be put in the car's engine, which requires time. Then we allow for the possibility of substitution between market goods and time to produce commodities. In the case of changing the car's engine oil, one way to get the commodity is to stop by Firestone and pay someone to do the job. This solution saves the household's time but requires payment, including taxes, for the service. Alternatively, members of the household can perform the maintenance themselves. This solution can save money and avoid taxation, but requires more time, assuming the professional working at Firestone has an absolute advantage in production, which is likely true in most cases. Take another example given by Burda

[1]This chapter was written in collaboration with Jean Lim.

et al. (2008). An American couple has to choose between goods-intensive and time-intensive summer vacations facing a limited budget constraint. The goods-intensive solution is to spend their time flying to the Côte d'Azur for a one-week holiday. On the other hand, the time-intensive solution is to take a two-week caravan trip to the Great Smoky Mountains National Park.

How do taxes on market goods affect the household's decision of how many market goods and how much time to use in home production? These two examples show that taxes on market goods can affect the choice of the household between goods-intensive and time-intensive solutions. Specially, an increase in taxes on market goods encourages households to substitute away from the market goods input in favor of the untaxed non-market time input. Therefore, if the government decides to change the tax rate on a specific market good, the government has to take the possibility of substitution into account.

In this paper, we first state theoretically how taxes on market good relate to the elasticities of substitution assuming that each commodity production function has a constant elasticity of substitution functional form, and solve the optimal commodity tax problem for the benevolent government. Within the framework of a three-commodity economy proposed by Corlett and Hague (1953-1954) and the assumption of a Cobb-Douglas utility function, we find that the optimal tax rule is to impose a higher tax rate on market goods used in the production of commodities with a lower elasticity of substitution between goods and time.

Then we check how this optimal tax rule compares to what we see in reality. To this purpose, we need to calculate the elasticities of substitution between market goods and time for different commodities. We use the Mexican time use data which is the only data set for which we observe disaggregated market good expenditures and time uses for the same household and for various different commodities. We find that 'Eating' has the lowest elasticity of substitution and 'Recreation' has the highest elasticity of substitution. According to our theory, these results imply that 'Eating' should be taxed at a very high rate and 'Recreation' at a very low rate. The optimal value added tax system for Mexico would impose 7.0% tax rate on food and 5.5% on market goods used in the production of 'Lodging, Appearance, and Recreation'. This optimal tax structure is more regressive compared to the actual Mexican tax system in which the government gives more weight to equity considerations than to economic efficiency.

The paper proceeds as follows. The next section provides a theoretical model of the optimal taxation problem. Section 1.3 describes our data set and summarizes key variables. The econometric framework and estimation results are presented in section 1.4. Section 1.5 provides policy implications, and section 1.6 concludes.

1.2 Theoretical Model

1.2.1 Background

Since Becker's (1965) pioneering idea of household production as a combination of goods and time, a substantial amount of theoretical and empirical work on the household production has been done in a variety of areas in economics (Hamermesh (2007)). However, relatively little work has been conducted in public finance (see, e.g., Zhang et al. (2008)). The exception is the topic of optimal tax theory and the relevant literature includes Sandmo (1990), Gahvari and Yang (1993), Kleven (2000, 2004), and Boadway and Gahvari (2006).

Sandmo (1990) introduced the home production approach into the optimal taxation problem and found that the income tax creates distortions, giving an incentive to use too much time in home production. However, even though time spent preparing meals may be qualitatively different from time spent listening to music, Sandmo (1990) did not deal with the possibility that different household activities can give different utilities. Gahvari and Yang (1993) first related optimal commodity taxes to the Becker's (1965) idea of home production. They assumed that households consume a bundle of goods, each of which requires time in fixed, but different, proportions to yield utility. Then they found that optimal commodity tax rates depend on time spent consuming each good. Using the same formulation as Gahvari and Yang (1993), Kleven (2004) proposed that the optimal commodity taxation is governed by factor shares in household activities. That is, any market good which requires little time should carry a relatively low tax rate. Boadway and Gahvari (2006) studied the optimal commodity taxation problem under two assumptions: that consumption time is either a perfect substitute for labor or a perfect substitute for leisure and that time spent consuming any particular good is taken to be a fixed proportion of the quantity of the good. They showed that while labor substitutability affects the optimal tax structure, leisure substitutability leaves the classical optimal tax results intact.

Although these studies that have followed the original contribution of Gahvari and Yang (1993) give us useful insights into what the optimal commodity tax system looks like when households combine goods and time to produce commodities, they rule out the possibility of substitution between goods purchases and time use in the production of commodity. Both studies make use of a Leontief home production function, assuming that the amount of time devoted to the consumption of goods is fixed. Introducing a Leontief home production function has a great advantage, it simplifies the optimal commodity taxation problem by reducing it to the classical optimal commodity tax problem without home production. Allowing the possibility of substitution between market goods and time use complicates the problem.[2]

It is true that the assumption of a Leontief home production function does not completely rule out the possibility of substitution in household production. Kleven (2004) takes dish-washing as an example. Dish-washing may be carried out by the use of a brush or a machine and these two production processes involve fixed, but different ratios between market goods and time. So Kleven (2004) argues that washing up with a brush or a machine are two

[2] Under the Leontief production function ($Z_j = \min\left(\frac{X_j}{a_j}, T_j\right)$ where X_j and T_j represent market goods and time use, respectively), the optimal commodity taxation problem becomes the classical optimal tax problem without home production, that is, $U(Z_0, Z_1, ..., Z_n) = U(X_0/a_0, X_1/a_1, X_2/a_2, ..., X_n/a_n)$.

different commodities. Nevertheless, the problem is that the assumption of Leontief home production function requires too many commodities since there are numerous ways to wash dishes other than using a brush and a machine. For example, you can hire a maid. In contrast, if we explicitly allow the possibility of substitution between goods input and time input in home production, we can think of dish-washing as a composite commodity incorporating many different combinations of goods and time. So the aggregation of commodities can reduce the number of tax rates. This reduction is important in practical point of view, since it is impossible in real world to implement the Leontief-based optimal tax system; many different commodities should be taxed at different rates. As Belan et al. (2008) pointed out, the grouping of commodities should be done when there is a constraint on the number of tax rates.

Kleven (2000) provided a more general approach than Kleven (2004). Kleven (2000) showed that the optimal tax is related to factor shares and elasticities of substitution. However, the relationship is not clear without specific functional forms of home production, since household will optimally change factor shares in response to the change in tax rate. The relationship between the optimal tax and elasticities of substitution in household production varies depending on the functional forms of home production. While Kleven (2004) circumvents this problem by assuming Leontief production function,[3] we use a Constant Elasticity of Substitution (CES) function that has better advantages

[3]In case of Leontief production function factor shares do not change in respond to the change in tax rates. Factor shares are determined by parameters of the Leontief production function.

over Leontief function.

Our contribution is to allow explicitly the possibility of substitution between goods and time in home production by assuming a CES production function. In the theory section, we emphasize the importance of elasticity of substitution between goods and time uses in designing optimal tax system and derive the optimal tax rule under this possibility. The empirical analysis is based on Gronau and Hamermesh's (2006) commodity classifications and we estimate the elasticity of substitution between market goods and time for each commodity. From an optimal tax perspective, the magnitude of elasticity of substitution is important. So we test the hypothesis that these elasticities are equal and derive the corresponding policy implications. This new example shows that the restrictive Leontief assumption can be relaxed to allow for estimation of elasticities that are directly useful for policy.

1.2.2 Household Maximization Problem

1.2.2.1 Utility Maximization

Households combine market goods and time to produce commodities that directly enter their utility function. Assume that $q_j = p_j + s_j$ where q_j is the consumer price of market good X_j, p_j is the producer price of X_j, and s_j is the tax on X_j. We also assume that w and T represent the wage rate and total time available, respectively, and M is non-labor income. Then we can write the household utility maximization problem in the following way. If there are $n+1$ commodities and we take $q_1, q_2, ..., q_n, w, T$, and M as given, then the household's problem is:

$$\max_{\{X_j\}_{j=1}^n,\{T_j\}_{j=0}^n} U\left(Z_0, Z_1, ..., Z_n\right) \text{ such that } \sum_{j=1}^n q_j X_j = w\left(T - \sum_{j=0}^n T_j\right) + M$$

$$\text{where } Z_j = \begin{cases} T_0 & if \quad j=0 \\ \left(X_j^{\theta_j} + T_j^{\theta_j}\right)^{\frac{1}{\theta_j}} & if \quad j = 1...n, \text{ and } \theta_j < 1. \end{cases}$$

Z_0 is pure leisure that does not need market goods, but needs time. However, other commodities $Z_{j\neq 0}$ are produced with both goods X_j and time T_j and with specific technology having constant elasticity of substitution between X_j and T_j. Let σ be the elasticity of substitution between market goods and time. So σ is equal to $\frac{1}{1-\theta}$. This optimization problem is not easy to solve, so we circumvent the difficulty with two steps. At the first stage, the household determines the optimal amount of goods and time input for each commodity by solving the cost minimization problem for given $\bar{Z}_j$. Then, in the second stage, the household makes a decision on the amount of consumption of each commodity.

First Step Note that the price of X_j is $q_j \,(= p_j + s_j)$ and the price of T_j is w. The household cost minimization problem is the following. Given $\bar{Z}_j$, q_j, and w,

$$\min_{X_j,T_j} q_j X_j + wT_j \qquad \text{such that} \quad \bar{Z}_j = \left(X_j^{\theta_j} + T_j^{\theta_j}\right)^{\frac{1}{\theta_j}}.$$

Taking first order conditions yields:

$$\left(\frac{X_j}{T_j}\right) = \left(\frac{w}{q_j}\right)^{\frac{1}{1-\theta_j}}. \tag{1.1}$$

To measure how goods and time are combined to produce a commodity let the goods intensity of commodity j be X_j/T_j. Then equation (1.1) tells us how the goods intensity is related to w, q, and θ. Taking the derivative of X_j/T_j with respect to w and s_j we know that:

$$\frac{\partial}{\partial w}\left(\frac{X_j}{T_j}\right) > 0 \qquad \frac{\partial}{\partial s_j}\left(\frac{X_j}{T_j}\right) < 0 \qquad \frac{\partial^2}{\partial w \partial s_j}\left(\frac{X_j}{T_j}\right) < 0.$$

First, an increase in the wage, w, raises the goods intensity. This suggests that the goods intensity is increasing in household income,[4] which is consistent with empirical evidence.[5] Hamermesh (2007) calculates the goods intensity of eating at various percentiles of the income distribution for 1985 and 2003 and shows that the goods intensity increases when you move to the upper end of the income distribution.[6] Second, the increase in tax s_j reduces the goods intensity, but the magnitude of the effect depends on w. The effect becomes larger as wage decreases, which means that lower-income households are likely to be more sensitive to the tax change. Third, the goods intensity of commodity j depends on w, q_j, and θ_j, but does not depend on taxes on other goods $s_{j \neq k}$.

The solution to the cost minimization problem is:

$$X_j^* = \alpha_j \bar{Z}_j, \quad T_j^* = \beta_j \bar{Z}_j \tag{1.2}$$

[4]This is true as long as wage is a proxy for household income.

[5]It might be interesting to compare goods intensities across countries. We expect that the goods intensity will be higher in countries with a higher real wage (w/q).

[6]See Table 5 in Hamermesh (2007).

$$\text{where } \alpha_j \equiv \left(1+\left(\frac{q_j}{w}\right)^{-\frac{\theta_j}{\theta_j-1}}\right)^{-\frac{1}{\theta_j}} \text{ and } \beta_j \equiv \left(1+\left(\frac{q_j}{w}\right)^{\frac{\theta_j}{\theta_j-1}}\right)^{-\frac{1}{\theta_j}}.$$

This result looks like the assumption of Kleven (2004). However, the difference is that coefficients α_j and β_j depend on the tax rate s_j. Kleven (2004) assumes that these coefficients are fixed regardless of the tax rate s_j. Our result shows that when government increases the tax rate s_j on good X_j, households optimally respond by using less of the good and more time in the production of commodity $\bar{Z}_j$.

Second Step This step solves the utility maximization problem of the household. Given q_j for $j = 1, ..., n$, w, and the solution from the first step, the problem becomes:

$$\max_{Z_0, Z_1, \cdots, Z_n} U\left(Z_0, Z_1, \cdots, Z_n\right) \text{ such that } \quad \sum_{j=1}^{n} q_j X_j = w\left(T - \sum_{j=0}^{n} T_j\right) + M.$$

By using (1.2), we can rewrite the budget constraint as:

$$\sum_{j=0}^{n} \gamma_j Z_j = wT + M$$

$$\text{where } \gamma_j = \begin{cases} w & if \quad j = 0 \\ q_j \alpha_j + w \beta_j & if \quad j = 1, ..., n. \end{cases}$$

This relation tells us that the price of Z_j is γ_j which is the weighted sum of the price of good X_j, q_j, and the price of time, w. The price of Z_0 is only w since it does not require market goods for its production. From the first order conditions, we obtain $U_j = \lambda \gamma_j$ for $j = 0, 1, ..., n$.

1.2.3 Optimal Government Policy

The benevolent government's optimal tax problem is to choose s_1,...,s_n to maximize the indirect utility of the representative household subject to the requirement that taxes yield an exogeneous amount of revenue $\bar{R}$. If the government changes the tax rate on market goods, the household responds by changing both market purchases and time use. The social planner has to consider the effect of the tax change on both goods and time spent by the household. The government problem is:

$$\max_{s_1,\dots,s_n} V\left(q_1,..,q_n,w\right) \text{ such that } \quad \sum_{j=1}^{n} s_j X_j = \bar{R}$$

$$\text{where } q_j = p_j + s_j \text{ for } j = 1,...,n.$$

The first-order conditions are:

$$\frac{\partial V}{\partial q_k} + \mu\left(X_k + \sum_{j=1}^{n} s_j \frac{\partial X_j}{\partial q_k}\right) = 0 \text{ for } k = 1,..,n.$$

By the envelope theorem, we can rewrite first order conditions as follows:

$$\frac{\lambda - \mu}{\mu} = \sum_{j=1}^{n} \frac{s_j}{X_k}\frac{\partial X_j}{\partial q_k}.$$

Then, using the Slutsky equation and Slutsky symmetry,[7] we can rewrite these conditions as:

$$\frac{\lambda - \mu}{\mu} + \sum_{j=1}^{n} s_j \frac{\partial X_j}{\partial M} = \sum_{j=1}^{n} \frac{s_j}{q_j}\varepsilon_{kj}^{c}, \tag{1.3}$$

[7] For detailed derivations of these equations, please refer to the Appendix A.1.

where $\varepsilon^c_{kj} \equiv \frac{q_j}{X_k}\frac{\partial X^c_k}{\partial q_j}$ is the compensated elasticity of X_k with respect to the change in the price of X_j. Note that the left hand side of equation (1.3) does not depend on $k \neq j$. Therefore it is constant. Let $-\Phi \equiv \frac{\lambda-\mu}{\mu} + \sum_{j=1}^n s_j \frac{\partial X_j}{\partial M}$. Then we can derive the Ramsey Rule as follows:

$$-\Phi = \sum_{j=1}^{n} \frac{s_j}{q_j}\varepsilon^c_{kj} \text{ for k =1,...,n.} \tag{1.4}$$

This Ramsey rule has the standard form of the optimal commodity tax expression which emphasizes the importance of compensated price responses. (Diamond and Mirrlees (1971), Sandmo (1987), Sandmo (1990)).[8]

Three-commodity Economy

Next, we examine a three-commodity economy first proposed by Corlett and Hague (1953-1954), and then used by Kleven (2004) and Boadway and Gahvari (2006). In this case, there are one untaxable commodity (Z_0) and two taxable commodities (Z_1, Z_2) with different elasticities of substitution between goods and time. The Ramsey rule in the elasticity form becomes:

$$\begin{aligned} -\Phi &= \frac{s_1}{q_1}\varepsilon^c_{11} + \frac{s_2}{q_2}\varepsilon^c_{12} \text{ and} \\ -\Phi &= \frac{s_1}{q_1}\varepsilon^c_{21} + \frac{s_2}{q_2}\varepsilon^c_{22}. \end{aligned}$$

[8] A detailed explanation of the Ramsey rule can be found in Diamond and Mirrlees (1971, p.262) and Sandmo (1990, p.92).

If we use the homogeneity property of compensated demand functions,[9] we can solve for the tax rates as:

$$\begin{pmatrix} \frac{s_1}{q_1} \\ \frac{s_2}{q_2} \end{pmatrix} = -\frac{\Phi}{\Pi} \begin{pmatrix} \varepsilon^c_{11} + \varepsilon^c_{22} + 3\varepsilon^c_{10} \\ \varepsilon^c_{11} + \varepsilon^c_{22} + 3\varepsilon^c_{20} \end{pmatrix}$$

where $\Pi \equiv \varepsilon^c_{11}\varepsilon^c_{22} - \varepsilon^c_{21}\varepsilon^c_{12}$. This result suggests that if the compensated elasticity of X_1 with respect to the price of leisure is lower than the compensated elasticity of X_2 with respect to the price of leisure then a higher tax should be imposed on X_1. Symbolically, $\varepsilon^c_{10} < \varepsilon^c_{20} \rightarrow s_1/q_1 > s_2/q_2$.[10] This result is the analog of standard Corlett-Hague rule: the highest tax rate ought to be levied on the commodity with the highest degree of complementarity with leisure. This result, however, differs from the standard Corlett-Hague rule, because of the last term on the right-hand side of each equation. In case of the standard Corlett-Hague rule, the last term on the right-hand side of the equation is ε^c_{10}, not $3\varepsilon^c_{10}$. This difference can be easily understood from the fact that the price of time is the same whether the time is used for the production of Z_0, Z_1, or Z_2.

Ramsey rule is hard to apply in practice because little is known about the magnitudes of the compensated elasticities (Kleven (2004)). However, the elasticities of substitution can be estimated easily. This is why we study the

[9]For the detailed derivation of the property of compensated elasticity, please refer to the Appendix A.2.

[10]Diamond and Mirrlees (1971, p.262) prove that Φ is positive. Π is also positive, which can be proved using the determinant of the matrix of substitution effects (Sandmo (1987, p.93)).

relationship between the compensated elasticity and the elasticity of substitution between goods and time. To do this, we assume a specific functional form for the utility function. Specifically, we assume the following log utility function:

$$u\left(Z_0, Z_1, Z_2\right) = \delta_0 \ln Z_0 + \delta_1 \ln Z_1 + \delta_2 \ln Z_2 \tag{1.5}$$

$$\text{where} \qquad Z_j = \begin{cases} T_0 & if \quad j = 0 \\ \left(X_j^{\theta_j} + T_j^{\theta_j}\right)^{\frac{1}{\theta_j}} & if \quad j = 1, 2 \text{ and } \theta_1 < \theta_2 < 1, \end{cases}$$

and $\delta_0 + \delta_1 + \delta_2 = 1$.

Conventional wisdom contends that the price of a necessity is lower than the price of a luxury. If this is the case, we can show that the smaller the elasticity of substitution between goods and time, the smaller the compensated elasticity in a three-commodity economy with the logarithmic preferences stipulated by equation (5).[11] Symbolically, $\sigma_1 < \sigma_2 \rightarrow \varepsilon_{10}^c < \varepsilon_{20}^c$. Even in case that the price of a necessity is higher than the price of a luxury, if a necessity tends to have a lower elasticity of substitution than a luxury which is shown empirically in Section 1.4, the smaller the elasticity of substitution between goods and time, the smaller the compensated elasticity. This relationship has a quite important implication. The elasticity of substitution between goods and time is determined by the technology of home production, but the compensated elasticity represents the market. So the relationship shows us how the home production technology is related to the market response. In response to the

[11] For the detailed derivations, please refer to the technical Appendix A.2.

change in the wage rate, goods with higher elasticity of substitution between goods and time have larger compensated elasticity.

Proposition *In a three-commodity economy with logarithmic preferences, the optimal tax policy requires that a higher tax should be placed on goods with a lower elasticity of substitution between goods and time. Symbolically,* $\sigma_1 < \sigma_2 \rightarrow s_1/q_1 > s_2/q_2$.

1.3 Data

To demonstrate the applicability of these results we use the National Time Use Survey 2002[12] (ENUT) from Mexico. This is a nationally representative sample including urban and rural communities. It surveys all individuals[13] who were aged 12 years or older at the time of the survey. The total sample includes 4,783 households and 20,342 individuals. The objective of the survey is to measure the activities undertaken by men and women within the household.

One disadvantage of the ENUT data set is that the questionnaire is not based on time use diaries where individuals are asked to report the activities undertaken on a given day. Instead, individuals are only asked to report how many hours in the week were spent doing a finite number of activities listed

[12] Encuesta Nacional del Uso del Tiempo 2002, http://www.inegi.gob.mx.

[13] By all individuals we mean residents and non-residents. The latter group includes personnel who help with household activities and individuals staying there temporarily.

in the questionnaire. Hence, the total time use for each individual does not add up to 168 hours, the total number of hours in a week. In fact, total time use averages 163.15 hours for our analysis sample. Although it is well known that diary time use questionnaires are more detailed and more reliable for research, the majority of time use surveys, including ENUT, instead use recall questionnaires for major activities due to the cost and complexity of the survey design.

This disadvantage is compensated by a very important advantage. The ENUT is a sub-sample of the National Household Survey of Income and Expenditure 2002[14] (ENIGH), the Mexican national income and expenditure data set. Therefore, we can match the time use data with the expenditure data by household. To our knowledge, only Mexican data provides information (for the same household) on both time uses and goods expenditures for a large number of commodities, although statistical agencies in a number of countries are moving to generate combined time use and expenditure files.

1.3.1 Definitions of Commodities

A household engages in numerous activities every day, for example, having breakfast and dinner, or taking a shower and watching television. All these activities need both market goods and time as inputs. To simplify the analysis we implicitly allocate activities into ten mutually exclusive categories, which are called commodities. The commodities are 'Sleep', 'Eating', 'Lodging', 'Ap-

[14]Encuesta Nacional de Ingreso y Gasto de los Hogares 2002, http://www.inegi.gob.mx.

pearance', 'Recreation', 'Health', 'Child-care', 'Travel', 'Miscellaneous' and 'Work'. Classification of time uses and goods expenditures is not straightforward because any classification is somewhat arbitrary. In order to be consistent with previous literature and to avoid as much subjectivity on our part, we use Gronau and Hamermesh's (2006) definition of commodities. Tables 1.1 and 1.2 define the time use and goods expenditure categories, respectively. In both tables we exhaust all reported time uses and expenditures from the data.

Table 1.1: Time Use Categories[a]

Commodity	Category
Sleep	Night sleep and .5(rest or recovery from an illness).
Eating	Eating at home and away, meal preparation, clean-up, grocery shopping, raising corral animals, collecting fruits, hunting, fishing, and taking care of orchard.
Lodging	House cleaning, outdoor chores, home and car repairs, gardening and animal care, durable goods shopping, misc. household duties, and, .5(make furniture, ornament or traditional craft for the house).
Appearance	Laundry and clothes care, personal and beauty care, and personal hygiene.
Recreation	Sex, nonreligious organizations, entertainment, culture, visits, social events, sports, hobbies, crafts, games, reading, writing,TV and radio, conversing, thinking, .5(make furniture, ornament or traditional craft), and non-travel educational activities if no children and individual is aged $>$ 59.
Health	.5(Rest or recovery from illness), taking care of a family member that is temporarily ill, and personal health care.
Child-care	All infant and child-care non-travel activities if children.
Travel	Accompany any member of the family to somewhere, take or pick up any member of the family to somewhere and travel to education-related activities if no children.
Miscellaneous	Taking care of family documents, helping other households voluntarily, taking care of other members of the family with a physical or mental limitation, volunteering, religious activities, making payments, personal proceedings, taking food to another member of the family to school or work, attending funeral services, non-travel education-related activities if no children and individual is aged $<$60, and all infant and child-care non-travel activities if no children.
Work	Working at a paid job, job search time, and work commuting time.

[a] We exhaust all time uses reported in the ENUT 2002 into these ten mutually exclusive categories which we called commodities. Note that 'Health' does not include medical care at hospitals. Also, 'Travel' does not include all non-working travel time.

The classifications are not exactly the same as in Gronau and Hamermesh (2006). There are three minor variations in the time use categories

Table 1.2: Goods Expenditure Categories[a]

Commodity	Category
Sleep	None
Eating	Food+.5(beverages)+.33(appliances).
Lodging	Housing+.33(appliances)+.5(communications)+ materials and services to repair, maintain or extend the house.
Appearance	Apparel and services+.33(appliances)+personal care.
Recreation	Entertainment+tobacco+.5(beverages)+.5(communications)+ education expenses if no children and individual is aged > 60.
Health	If no children: Hospital care, doctor care, medicine expenses without prescription. If children: Health*(1-number of children/size of the family)
Child-care	boys' and girls' apparel+ education+ Health*(number of children/size of the family) if children.
Travel	Private and public transportation prorated by nonwork travel divided by total travel time.
Miscellaneous	Other expenditures and transfers+education expenses if no children and individual is aged < 60+boys' and girls' apparel if no children.
Work	None

[a] We exhaust all goods expenditures reported in the ENIGH 2002 into these ten mutually exclusive categories which we called commodities. We assume that 'Sleep' have no goods expenditures related to it. Any expenditures seemingly related to 'Sleep' were included either in 'Lodging' or 'Appearance' .

due to differences in the questionnaire structure between their data sets and ours. In our case, time use for 'Eating' includes not only eating at home and away, meal preparation, clean-up, and grocery shopping, but also raising corral animals, collecting fruits, hunting, fishing, and taking care of the orchard. Also, in our classification, 'Health' does not include medical care at hospitals. Given the available data, 'Health' only includes time spent recovering from an illness, taking care of a family member that is temporarily ill, and personal health care. Finally, the other difference is in the 'Travel' time use category. In our data set, this only includes time spent accompanying a member of the family to go somewhere and taking or picking up any member of the family to go somewhere, so it does not includes all non-working travel time. With respect to goods expenditures categories, there are essentially no differences between our classification and that in Gronau and Hamermesh (2006). The only minor discrepancy is that 'Lodging' includes materials and services to repair, maintain, or extend the dwelling besides housing, a fraction of appliances expenditures, and a fraction of communication expenditures. In both classifications, 'Sleep' and 'Work' are assumed to have no expenditures related to them.

1.3.2 Households

The unit of analysis is the household, not individuals, because in the ENIGH only household expenditures are reported. In the sample we only include nuclear households (only one family within the dwelling) to keep the sample as homogeneous as possible, because different types of families have different time use patterns.[15] For instance, we expect married couples to be more efficient in home production than single individuals due to specialization by husband and wife in certain activities. In fact, single men spend on average 16 hours on the 'Eating', while husbands spend on average 12 hours per week on the same commodity. On the other hand, wives spend on average 34 hours per week on 'Eating', whereas single women spend only 22 hours. In the case of extended families (more than one family within the dwelling) it is easy to imagine that these families are different from nuclear families in terms of household expenditures and time uses. It could be the case that families within the extended household do not pool their incomes. Even in those cases, it is possible that such families share time uses. For example, a member of one of the families takes care of all the children within the dwelling, making all other members of the extended household more efficient in their allocation of time. Because of these differences we eliminated 1,286 households from the sample. In addition, 500 observations were dropped because only one spouse was present at the time of the survey. Finally, 57 households were removed because they had no income or were missing other variables. The total number of households in our sample is 2,940.

In Table 1.3, we summarize the demographic characteristics of husbands and wives as well as their time uses. In this table and throughout the paper,

[15]Nuclear households represents 70% of the sample. The other 30% is composed of one-person households (7%) and extended households (23%).

we define earnings as all labor earnings, specifically, salaries, wages, overtime payments, and self-employment income.

Table 1.3: Demographic Characteristics and Time Uses of Husbands and Wives[b]

	Husbands		Wives	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	42.70	13.66	39.11	12.91
Years of Schooling	6.73	4.92	6.31	4.37
Labor Force Participation	.907	.290	.388	.487
Earnings[a]	928.14	1249.96	207.47	578.21
Firm size[c]	50.46	303.09	7.55	66.34
Unionized worker[d]	.074	.262	.028	.165
Time Uses[e] (hrs/week)				
Sleep	56.04	16.40	57.81	11.38
Eating	11.68	9.74	33.63	15.78
Lodging	4.15	6.01	16.41	10.18
Appearance	4.36	3.07	13.85	6.95
Health	3.34	5.69	2.77	5.09
Recreation	16.98	14.19	16.04	13.26
Child-care	1.59	6.21	6.32	18.00
Miscellaneous	4.64	9.47	12.90	22.78
Travel	.42	1.67	.94	2.30
Work	50.10	24.29	12.14	21.28

[a] In Mexican pesos as of 2002, per week. We define earnings as all labor earnings, specifically, salaries, wages, overtime payments, and self-employment income.
[b] Number of observations: 2,940.
[c] Firm size refers to the number of workers in the firm where the husband or the wife works.
[d] Unionized worker is a indicator variable equal to one if the firm is unionized and zero otherwise.
[e] The use of time for each individual does not add up to 168 hours, the total number of hours in a week, because the ENUT 2002 is based on recall questionnaires on major activities and not on time use diaries.

Based on the summary statistics in Table 1.3, we know that husbands are on average 4 years older than wives in the sample. In terms of years of schooling, both spouses are very similar, averaging about 7 years of education. It is also worth noting that wives' earnings are significantly lower than their husbands. This is directly related to the labor force participation decision of both husbands and wives. A total of 91 percent of husbands participate in the labor force, whereas only 39 percent of wives do.

Husbands and wives have different time use patterns as a result of specialization. Husbands report 50 hours of work on average, while wives only work, on average, 12 hours a week in a paid job. However, wives dedicate 34 hours of the week, on average, to 'Eating' and 16 hours to 'Lodging', while men spend only 12 and 4 hours, respectively. Also wives dedicate more time to 'Appearance', 'Child-care' and 'Miscellaneous' commodities than husbands. With respect to 'Sleep' and 'Recreation', both husbands and wives devote similar amounts of time, around 56 and 16 hours a week, respectively.

1.3.3 Time Use and Goods Expenditure

1.3.3.1 Time Use

In Table 1.4, we summarize both expenditures and time use of the household.[16] We define household time use as the sum of the husband's and wife's time use. The household allocates 62 hours for 'Work' a week, on average. A total of 45 hours a week are devoted to 'Eating' and 21 hours are

[16]For the time use variables the week of reference was the week from Monday to Sunday before the day of the survey. For the non-time variables the unit of time was daily, monthly, quarterly, or every six months depending on the type of expenditure. All variables were converted into a weekly basis.

used on ‘Lodging’. The household sleeps an average of 114 hours a week and 33 hours are used for ‘Recreation’per week. Notice that average time spent on ‘Travel’ is about 2 hours per week. This reflects that the measure we have for ‘Travel’ time use is poor. The household allocates only 8 hours per week to ‘Child-care’, on average.[17]

Table 1.4: Summary Statistics of the Households[c]

	Expenditures[a]		Time Use[b]	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Sleep	–	–	113.85	22.96
Eating	389.77	321.10	45.31	20.86
Lodging	204.18	270.70	20.56	11.99
Appearance	156.89	187.47	18.21	7.95
Health	36.09	157.79	6.11	9.35
Recreation	104.22	201.23	33.02	23.70
Child-care	124.26	348.85	7.91	22.02
Miscellaneous	62.26	254.83	17.54	29.24
Travel	5.45	54.82	1.36	3.25
Work	–	–	62.24	33.17

[a] In Mexican pesos as of 2002, per week.
[b] The time use of the household is defined as the sum of the time use of the husband and the wife, per week.
[c] Number of observations: 2,940.

In principle we could also add the time use of other members of the family to the household time use. However, most of the other members are children whose opportunity cost of time is not determined by the labor market. In fact, we could argue that there is no opportunity cost for their time. Nonetheless, in an attempt to capture any effect children could have on the

[17] Around 40% of households do not have children.

allocation of goods or time in the household production of commodities, we control for the number of children in our estimation.

1.3.3.2 Market Goods Expenditure

Household expenditures are summarized in Table 1.4. 'Sleep' is assumed to have no expenditures related to it. Although almost negligible, any expenditures seemingly related to 'Sleep' were included either in 'Lodging' or 'Appearance'. On average, families in this sample spent 400 pesos per week on 'Eating', 200 pesos per week on 'Lodging', 150 pesos per week on 'Appearance' and 124 pesos per week on 'Child-care'. These four categories comprise the four largest components of the household total expenditures.

Households can hire workers such as maids, nannies, or drivers to produce household commodities. The employees carry out activities that are included in 'Eating', 'Lodging', 'Appearance', 'Travel' or 'Child-care' commodities. Therefore, we include the monetary payments the workers receive as household good expenditures because they represent market goods used to produce household commodities. However, we do not observe the salary these employees actually receive for their services, so we use the hourly minimum wage[18] to construct the market value of their hours of work. For example, if the employee dedicated 10 hours a week to the production of the 'eating' commodity and 25 hours to the 'Lodging' commodity then we include 10*minimum wage in the 'Eating' expenditure category and 25*minimum wage in

[18] The average minimum wage in Mexico for 2002 was 4.96 pesos per hour.

the 'Lodging' expenditure category.

1.4 Estimation

We only estimate the elasticity of substitution for the 'Eating', 'Lodging', 'Appearance', and 'Recreation' commodities. 'Health' and 'Travel' are not included in the estimation because, as explained in Section 1.3.1, we have poor measures of time use for these categories. We also ignore 'Child-care'. Significant proportion of families do not have children, and for most families with children, child-care is most probably a secondary activity. That is, parents take care of their children under 13 while doing something else as the main activity.

1.4.1 Estimation Specification

Assuming the household production function for commodity j is CES, the relative demand function for the ratio of market goods expenditure Y_j, defined as $p_j X_j$, and time expenditure T_j is:

$$ln(Y_j/T_j) = constant + \sigma_j ln(\rho_j w_m + (1 - \rho_j) w_f) \tag{1.6}$$

where w_m and w_f are the wage rate of the husband and wife respectively, ρ_j is the weight on the husband's price of time, and σ_j is the elasticity of substitution between market goods and time.[19]

[19] The coefficient σ_j is defined as $1/(1-\theta_j)$ where θ_j is the parameter of the CES function for commodity j.

Table 1.5: NLLS Equation by Equation[a, b]

	N	*constant*	$\hat{\sigma}$	$\hat{\rho}$
Eating	2727	-.273	.344	.327
		(.114)	(.015)	(.031)
Lodging	2738	-.620	.447	.283
		(.148)	(.019)	(.027)
Appearance	2733	-.852	.462	.289
		(.138)	(.018)	(.025)
Recreation	2367	-2.691	.573	.359
		(.222)	(.029)	(.036)

[a] Standard errors in parenthesis.

[b] $\hat{\rho}$ is the weight on the husband's price of time, and $\hat{\sigma}$ is the elasticity of substitution between market goods and time. N refers to the number of observations used in each estimation. Control variables are urban dummy, state dummies, number of children less than 12 years old, number of daughters over 12 years old and number of sons over 12 years old.

We use nonlinear least squares to estimate equation (1.6). The resulting parameter estimates for 'Eating', 'Lodging', 'Appearance' and 'Recreation' are reported in Table 1.5. The control variables included when estimating equation (1.6) are an urban dummy, state dummies, number of children less than 12 years old, number of daughters over 12 years old, and number of sons over 12 years old. Our main interest centers on the estimates of the elasticity of substitution, $\hat{\sigma}$.

Once we control for other characteristics of the household, we find that 'Eating' has the lowest elasticity of substitution between market goods and time. This is very intuitive given that food can not be substituted with anything else, not even time. Also, the most important activity in this commodity is actually eating which is very time intensive and, in contrast to other activities like meal preparation or dish washing, cannot be paid to be done by someone else.

'Lodging' has the second lowest elasticity of substitution. In the city, activities such as house-cleaning, outdoor chores, and home repairs are very easy to buy in the market by paying someone to do such works for you. However, in rural areas this substitution between the household's time and the corresponding market goods is very rare, and these activities are in most cases performed by the members of the household. Once we consider this difference, 'Lodging' has a very low elasticity of substitution. In the Mexican case, the majority of these activities are responsibility of the wife and such activities absorb most of her time.

'Appearance' has the next to largest estimate of the elasticity of substitution between market goods and time. Although it is true that activities such as personal hygiene are very time-intensive, you can certainly spend a lot of money, relative to time, on such activities. Also, activities like laundry and clothes care could be done in various ways that range from the very time-intensive to the very goods-intensive.

Finally, 'Recreation' has the highest elasticity of substitution. It is not difficult to find examples of recreational activities in which the substitution between market goods and time is very easy. Moreover, this commodity includes very time-intensive activities such as reading, writing, conversing and thinking, as well as very market-good intensive activities such as social events, sports or some hobbies.

Given that ρ_j does not play any role in our analysis we can simplify our estimation by writing equation (1.6) as:

$$ln(Y_j/T_j) = constant + \sigma_j ln(wage_{HH}) \tag{1.7}$$

where $wage_{HH}$ is the sum of the husband's and wife's wage rates.

The benefit of this simplification is that equation (1.7) is now linear. In Table 1.6 we compare estimates of the elasticity of substitution for 'Eating ' , 'Lodging', 'Appearance', and 'Recreation' using equations (1.6) and (1.7). Comparing OLS and NLLS columns, we conclude there is no statistically significant difference in the estimates of σ regardless of whether we use equation (1.6) or (1.7).

By defining $wage_{HH}$ as the sum of the wages of the spouses, we are implicitly assuming that the wages of the husband and wife have the same weight. However, estimates of ρ_j using non-linear least squares are significantly different from 0.5. Thus to check whether implicitly assuming equal weights makes a difference in the estimates of σ_j we estimate the following equation:

$$ln(Y_j/T_j) = constant + \sigma_j ln(\hat{\rho}_j w_m + (1 - \hat{\rho}_j) w_f) \tag{1.8}$$

where $\hat{\rho}_j$ comes from the estimates of ρ_j in Table 1.5. When comparing the estimates of the elasticities from this equation with the OLS estimates from equation (1.7), it turns out that the estimates of the elasticities under equation

Table 1.6: OLS and NLLS Equation by Equation[a, b]

	N	OLS	NLLS
Eating	2727	.345	.344
		(.015)	(.015)
Lodging	2738	.449	.447
		(.019)	(.019)
Appearance	2733	.465	.462
		(.018)	(.018)
Recreation	2367	.576	.573
		(.029)	(.029)

[a] Standard errors in parenthesis.

[b] Estimates in this table refer to $\hat{\sigma}$, the elasticity of substitution between market goods and time. Control variables are urban dummy, state dummies, number of children less than 12 years old, number of daughters over 12 years old and number of sons over 12 years old.

(1.8) are very similar to the estimates under equation (1.7).[20] Hence, assuming equal weights or using the optimal weights from equation (1.6) makes little difference in the estimates of the elasticities of substitution between market goods and time. Therefore, the remainder of the study will use the estimation based on equation (1.7).

To test whether the coefficients are the same across commodity equations we estimate the four commodity equations as a system.[21] We test and reject the hypothesis that all coefficients are equal using a Wald test. We also test the same hypothesis and reject the null for all different pairs of coefficients, except for the case when we compare 'Lodging' and 'Appearance' commodities.

1.4.2 Instrumental Variables Estimation

We suspect $wage_{HH}$ is endogenous in equation (1.7). There are unobservable characteristics, such as diligence or attitude toward planning, that are highly valued both in the labor market and in home production. Therefore, households which are efficient at home production are usually also efficient in the labor market, which translates into higher salaries. Without correcting the omitted variables problem the estimates of the elasticity of substitution will be inconsistent. To obtain consistent estimates of the elasticity we need instruments, variables correlated with family labor earnings but not directly

[20] Estimates are available upon request.

[21] Estimates of the system of equations using SUR and the values of all Wald tests are available upon request.

with household production.

The set of instruments for the household labor earnings that we are using are: whether the firm in which the husband works is unionized and the size of the firm in which the husband and the wife are employed (measured by the number of workers). All our instruments are valid. The union dummy and size of the firm variables are clearly not related to the household decision of how much market goods and how much time to use in the production of a certain commodity, but certainly explain a lot of the wages of the husband and the wife, and therefore the household earnings. The prices that households pay for the market goods (implicit in the dependent variable) are clearly not correlated with our instrumental variables. Such prices are taken as given by the household and are not influenced by whether the spouse is a unionized worker or not, or whether he or his wife works in a big or a small company.

To test whether the coefficients are significantly different across the four commodities we estimate a system of equations using GMM. We estimate system GMM using the set of instruments described above. For the first iteration, we used the estimates from GMM equation by equation. The system includes the household labor earnings equation as well as the four commodity equations. The regressors in the household labor earnings equation are years of education of both spouses, age and age squared of both spouses, firm size for both spouses, and a union dummy for the husband. Estimates of the elasticities of substitution are in Table 1.7. All coefficients in the table are significantly different from zero.

Table 1.7: System GMM with Four Commodities: Elasticity of Substitution[a]

Eating	Lodging	Appearance	Recreation
.343	.526	.576	.742
(.085)	(.099)	(.086)	(.117)

[a] Standard errors in parenthesis. Estimates in this table refer to $\hat{\sigma}$, the elasticity of substitution between market goods and time. Control variables are urban dummy, state dummies, number of children less than 12 years old, number of daughters over 12 years old and number of sons over 12 years old. N=2,354.

Similar to the previous estimates, it is the case that 'Eating' has the lowest elasticity of substitution and 'Recreation' has the highest elasticity of substitution. In between we have 'Lodging' and 'Appearance', in that order.

One important difference between the estimates in Table 1.6, without taking care of the endogeneity problem, and the estimates in Table 1.7, when the endogeneity problem is appropriately solved, is the value of the estimates. For all commodities except 'Eating', the elasticities of substitution between market goods and time are higher. This suggests that estimation without controlling for possible endogeneity problem is likely to underestimate the true effect of household earnings on the decision between market goods and time.

Using the results in Table 1.7 we test the hypothesis that the four elasticities of substitution are equal. P-Values of the corresponding Wald tests are reported in Table 1.8. In the first row we test the hypothesis that all

Table 1.8: Wald Tests for System GMM Results

Hypothesis	P-Values
$\hat{\sigma}_{\text{Eating}} = \hat{\sigma}_{\text{Lodging}} = \hat{\sigma}_{\text{Appearance}} = \hat{\sigma}_{\text{Recreation}}$	0.016
$\hat{\sigma}_{\text{Lodging}} = \hat{\sigma}_{\text{Appearance}} = \hat{\sigma}_{\text{Recreation}}$	0.305
$\hat{\sigma}_{\text{Eating}} = \hat{\sigma}_{\text{Lodging}}$	0.091
$\hat{\sigma}_{\text{Eating}} = \hat{\sigma}_{\text{Appearance}}$	0.022
$\hat{\sigma}_{\text{Eating}} = \hat{\sigma}_{\text{Recreation}}$	0.002
$\hat{\sigma}_{\text{Lodging}} = \hat{\sigma}_{\text{Appearance}}$	0.639
$\hat{\sigma}_{\text{Lodging}} = \hat{\sigma}_{\text{Recreation}}$	0.131
$\hat{\sigma}_{\text{Appearance}} = \hat{\sigma}_{\text{Recreation}}$	0.204

elasticities are the same and we reject it. However, according to the second row, we cannot reject the null that the elasticities for 'Lodging' , 'Appearance', and 'Recreation' are the same. This result is supported by the corresponding p-values in the last three rows where we test the hypothesis that each pair of these commodities' elasticities are the same.

For this reason, we calculated the elasticities of substitution using system GMM with instrumental variables for the commodities defined as 'Eating', and the composite commodity 'Lodging-Appearance-Recreation'. The results are in Table 1.9.

Based on Table 1.9, it is again the case that the 'Eating' elasticity of substitution is the smallest. These results are used to analyze the policy implications of our theoretical model. The elasticity of substitution for 'Eating' is 0.440 and 0.681 for 'Lodging-Appearance-Recreation'.

Table 1.9: System GMM with Two Commodities: Elasticity of Substitution[a]

Eating	Lodging + Appearance + Recreation
.440	.681
(.029)	(.028)

[a] Standard errors in parenthesis. Estimates in this table refer to $\hat{\sigma}$, the elasticity of substitution between market goods and time. Control variables are urban dummy, state dummies,number of children less than 12 years old, number of daughters over 12 years old and number of sons over 12 years old. N = 2,354.

1.5 Policy Implications

The differences in the goods-time substitution of each commodity suggest the importance of setting differential goods taxes. This section calculates the optimal goods taxes in Mexico. Based on the results in Table 1.8, we denote Z_0, Z_1, and Z_2 as 'Sleeping', 'Eating', and 'Lodging-Appearance-Recreation'. Table 1.4 shows that Mexican households spend on average 389.77 pesos and 465.29 pesos on Z_1 and Z_2, respectively. They also spend 113.87 hours a week on T_0, 45.33 hours on T_1, and 71.80 hours on T_2, and they work 62.18 hours per week. In addition, the elasticities of substitution between goods and time for Z_1 and Z_2 are 0.440 and 0.681 in that order. We assume these observed goods expenditures and time use patterns are the outcome of the optimal choice made by Mexican consumers under the current tax system in Mexico. We simplify the actual Mexican tax system by setting tax rates on Z_1 equal to 0% and Z_2 equal to 15%.[22]

For policy analysis we use the same log-utility function in equation (1.5). We have to recover values for the underlying parameters from our data set. Note that we need values for the following 10 parameters: θ_1, θ_2, w, T, p_1, p_2, δ_0, δ_1, δ_2, and M. The system GMM estimation in Table 1.9 gives the values for θ_1 and θ_2. We set $w = T = 1$.[23] From the solution of the utility optimization problem we can solve for X_1^*, X_2^*, T_0^* T_1^*, and T_2^*. Then we have six equations[24] and six parameters. Solving the system, we get $p_1 = 0.24$, $p_2 = 0.44$, $\delta_0 = 0.19$, $\delta_1 = 0.31$, $\delta_2 = 0.49$, and $M = 0.97$.[25]

Table 1.10: Optimal Tax Rate[a]

		Current(A)	Optimal(B)	$(B)-(A)$
Tax rate	Eating	0.0%	7.0%	
	Lodging + Appearance + Recreation	15.0%	5.5%	
Expenditure[a]	Eating	389.77	288.76	-101.01
	Lodging + Appearance + Recreation	465.29	599.39	134.10
Time spending[b]	Sleeping	113.87	113.87	
	Eating	45.33	52.22	6.89
	Lodging + Appearance + Recreation	71.80	53.80	-18.00
	Work	62.18	73.30	11.11

[a] Mexican pesos.
[b] Hours per week.

Now we have all the values we need to calculate the optimal tax rates.

[22] In reality, appliances and eating outside are taxed, but the expenditures on these goods are small.

[23] Think of p_1 and p_2 as the prices of goods relative to the wage rate. T_j for j=0,1,2 is the ratio of hours to the total time spending, that is $T_0 = 38.8\%$, $T_1 = 17.8\%$, $T_2 = 18.4\%$, and $L = 25.0\%$.

[24] Five equations from the solution of utility optimization problem and one equation from the parameter restriction; $\delta_0+\delta_1+\delta_2 = 1$. For detailed solutions to this system of equations, please refer to Technical Appendix A.3

[25] We used the $fsolve$ function built in MATLAB to solve the six equations simultaneously. The initial vector is $[p_1\ p_2\ \delta_0\ \delta_1\ \delta_2\ M] = [1\ 1\ 0.33\ 0.33\ 0.33\ 1]$.

From the $10,201\ (=101^2)$ possible tax rate combinations (s_1, s_2),[26] we pick all combinations that satisfy the government budget constraint, $\bar{R} = s_1 X_1 + s_2 X_2$. $\bar{R}$ is equal to 0.183. For each combination that satisfies the government budget constraint, we calculate the corresponding indirect utility value $V(s_1, s_2)$. The pair (7.0%, 5.5%) gives the highest possible indirect utility, therefore this vector is the optimal tax combination.

Table 1.10 shows the household's behavior under the optimal tax system. Under the optimal tax rates, our model predicts Mexican household spends 288.76 pesos and 52.22 hours on Z_1 weekly on average. They also spend 599.39 pesos and use 53.80 hours on Z_2 a week on average. They work 73.30 hours a week. Compared with the current tax rates, the optimal tax system requires government to increase the tax rate on Z_1 by 7 percentage points (from 0% to 7.0%) and reduce the tax rate on Z_2 by 9.5 percentage points (from 15% to 5.5%).

1.6 Conclusions

We relax the usual assumption that individuals get utility directly from market goods. Instead, following Becker (1965), we assume that individuals combine market goods and time to produce commodities which ultimately yield utility. Previous research has incorporated Becker's idea that goods have to be combined with time to yield utility, but it simplifies the analysis by

[26] For each $s_j \in \{0.000, 0.005, 0.010, ..., 0.490, 0.495, 0.500\}$ for j=1,2.

assuming a Leontief commodity production function. Thus, our contribution consists of allowing substitution between market goods and time in the production of commodities by assuming a CES commodity production function. By incorporating these assumptions into the optimal tax problem we show it is optimal to impose lower taxes on goods used in the production of commodities with a higher elasticity of substitution because these goods are easily substitutable for time. Likewise, goods used to produce a commodity in which it is difficult to substitute away from market goods toward time should be taxed at a higher rate. The goal is to minimize the distortionary effects of taxes over household utility maximization. This is an analog of the classical Corlett and Hague (1953-1954) result, differing in that we allow for substitution between time and goods expenditures.

Using the Mexican time use data set from 2002, we estimate the elasticity of substitution between goods expenditures and time in the production of four different commodities: 'Eating', 'Lodging', 'Appearance', and 'Recreation'. For these four commodities, we find that the elasticity is significantly different from zero and 'Eating' has a significantly different elasticity from 'Lodging', 'Appearance', and 'Recreation'. The elasticity of substitution for 'Recreation' is highest. However, we cannot reject the hypothesis that the elasticity of substitution for 'Lodging' is equal to the elasticity of substitution for 'Appearance' and 'Recreation'.

Combining these estimates of the elasticity of substitution with our theoretical results, we conclude that higher taxes should be imposed on the market goods, like food, used in the production of 'Eating'. Along the same lines, lower taxes should be imposed on the market goods used in the production of 'Lodging', 'Appearance', and 'Recreation'. Unfortunately, the optimal tax structure is regressive, in that it goes against the common practice of exempting necessities such as food from sales tax bases. Comparing this optimal tax system to the actual one, we can argue that the Mexican government has traded off efficiency for equity. The actual system in Mexico has a zero tax rate on food and a 15 percent value added tax on all other goods except medicines. Households are very heterogeneous in their earning ability, so by exempting food the government may be attempting to make sales taxes less regressive. This regressivity suggests that future research needs to address the efficiency-equity trade-off of commodity taxation.

Chapter 2

An Unintended Consequence of Border Enforcement

2.1 Introduction

U.S. surveillance of the border between Mexico and the United States has increased dramatically over the last two decades. From 1984 to 2004 the number of line watch hours by the Border Patrol along the Mexico-U.S. border has increased more than fivefold, from 1.8 million to 9.7 million hours. The previous two decades, 1964 to 1984, only saw a doubling of the hours from 0.9 to 1.8 million.[1] The main purpose of securing the border is to capture and deter undocumented immigrants from entering the U.S. Thus, one could be tempted to conclude that once undocumented immigrants succeed in crossing the border they are no longer affected by border enforcement. This would be true if immigrants only make one trip to the host country. My hypothesis is that this statement is not true for circular Mexican immigrants. In the case of undocumented circular migration, as border enforcement increases, undocumented immigrants in the United States realize that re-entering the country will be more difficult in the future: the probability of apprehension

[1] Data from Mexican Migration Project NATLHIST file.

increases, the risk of injury or death while crossing the border rises, and the monetary costs of crossing the border escalate.[2] Therefore, undocumented circular migrants respond by increasing the length of stay of the current trip as a way to counteract the effects of higher border vigilance.

In this paper my hypothesis is that the increase in border enforcement in the last decades has had an unintended consequence: Mexican circular undocumented immigrants already in the United States stay longer. I estimate a semi-parametric hazard model similar to Meyer (1990). The model estimates the impact of line watch hours by the U.S. Customs and Border Protection on the probability that a Mexican undocumented immigrant leaves the U.S. between years t and $t+1$ given survival up through year t while controlling for other variables that could also influence the hazard of leaving the host country. I use the Mexican Migration Project data for the empirical estimation in the paper. I find that there is no effect of border enforcement on the probability of leaving the United States by Mexican immigrants at period $t+1$, given that they have survived t periods.

The rest of the paper is structured as follows. The next section contains a review of existing literature. Section 2.3 summarizes the sample used for the estimation, Section 2.4 presents the methodology, Section 2.5 contains the estimation results, Section 2.6 calculates the expected duration of the last trip for the average immigrant, and Section 2.7 concludes and discusses possible

[2] Massey et al. (2002).

future research.

2.2 Literature Review

It has been long recognized that a large fraction of undocumented Mexican migration to the United States is temporary and repetitive. Using data from 1966 to 1994 from the Mexican Migration Project, Cerruti and Massey (2004) concluded that having made an undocumented trip increases the probability of a second undocumented trip. Therefore, circular migrants in the U.S. are affected by border enforcement since there is a higher probability they will make more trips between Mexico and the U.S. in the future. Also, researchers have long ago recognized the failure of the post-1986 U.S. immigration system and its consequences. Massey et al. (2002) agreed that the border buildup makes immigrants to have longer U.S. trip duration, lower probabilities of return migration, and more likely to stay permanently in the U.S.

Arguments to explain the decision of how long to stay in the host country that are not related to border enforcement are based on the investment opportunities in the place of origin (Lindstrom (1996) and Reyes (2001)), the economic opportunities for immigrants in the United States (Reyes (2001)), or the household resources before migration (Reyes (2001)). Intuitively, if investment opportunities in Mexico are good enough, then migrants will stay longer in the United States to maximize the benefits from migration. More economic opportunities in the United States will cause the immigrant to stay longer in the host country. Lastly, relatively high pre-migration resources of the household tend to make the immigrant stay longer. This is because in this case the principal motive to migrate is either personal reasons or long term investments, instead of short term economic needs.

Only three studies jointly examine border enforcement and the trip duration decision. First, Kossoudji (1992) related length of stay with a direct consequence of border enforcement: the number of apprehensions experienced. Results of this paper suggests that when the costs of migration increase due to an apprehension, undocumented migrants stay in the United States longer than if they had not been apprehended. Next, Reyes (2004) studied which factors are the most important in explaining the changes in patterns of trip duration among undocumented Mexican migrants to the United States. Her analysis found no statistically significant effect of border enforcement (measured by line watch hours) on the probability of return for undocumented immigrants. Furthermore, she found the effect of border enforcement on the probability of return of legal immigrants was negative and statistically significant.

The last study is a recent discussion paper by Angelucci (2005). She studied the effect of U.S. border enforcement on the net flow of Mexican undocumented migration. Her results indicate that border enforcement has a negative effect on the probability of returning to Mexico from an illegal trip. There are some important differences between the present investigation and Angelucci (2005). The present study focuses on the last migration spell, whereas Angelucci (2005) used the information of all migration spells. She restricted her sample to migration decisions starting in 1972 through 1993 due to missing variables and lack of data. Also, she focused only on undocumented migrants and she relied on a 15 year recall window prior to the interview. In comparison, the only exclusions in my sample are the migration spells starting in 2005, 2006, or 2007 because border enforcement is missing for those years. She estimates the probability that someone returns to Mexico relative to the number of immigrants that she observes in the United States at a specific year. In contrast, I estimate the probability that an individual returns at period t, given that he or she has survived up to period $t-1$.

Finally, Hill (1987) argues that when border enforcement increases people certainly make fewer trips to the host country, but whether the length of stay increases or not depends on whether the number of trips and length of stay are complements or substitutes. Although Hill's paper makes a unique contribution by providing a theoretical model to explain duration of stay and migratory frequency, it lacks an empirical framework to test the implications of the model. The present paper is an attempt to fill this niche.

2.3 Data

I use data from Mexican Migration Project 118[3] (MMP118), a research project conducted by Princeton University and the *Universidad de Guadalajara*. This project focuses on heads of households who have migrated at least once. The main advantage of this data set is that it contains complete mi-

[3] http://mmp.opr.princeton.edu/

gration histories for the household heads, detailed information about the first and last trip to the United States, and information about undocumented trips to the United States. It also contains demographic characteristics, characteristics of the origin communities, and border enforcement measures collected from the U.S. Department of Homeland Security.

The main disadvantage of the data set is that it is not a nationally representative sample. Most of the information comes from interviews conducted in Mexican communities with a high propensity to migrate. Only in recent years has the Mexican Migration Project started to include communities in Mexican states with lower propensities to migrate. Therefore, to the extent that responses might differ in other communities, the results cannot be generalized.

Another disadvantage is that Mexican migrants who had not returned to the community of origin by the survey year are missing in the data. To solve this problem, the Mexican Migration Project conducted interviews in the United States of migrants from the same communities sampled in Mexico. This group represents only 5% of the sample, and it does not contain samples from all Mexican communities. Also, when comparing immigrants interviewed in Mexico with those interviewed in United States, the latter group does not just capture average migrants while in the United States, but also migrants who self-select to stay in the United States longer. For this reason and because the population of interest is Mexican undocumented, temporary, and repetitive migrants, I dropped these individuals from the sample.

According to the LIFE data file, the MMP118 has information on 18,539 Mexican households from 118 different Mexican communities. Of the total, only 6,849 have household heads with migration experience to the U.S. I focus on immigrants between 16 and 65 years old. Individuals with missing information and with discrepancies in the duration variables were eliminated from the sample, leaving 5,064 household heads with U.S. migration experience. Both the data and my sample come from surveys administered from 1982 to 2007, but it goes back to 1926 with respect to the migration histories of some individuals.

2.3.1 Summary Statistics

Descriptive statistics for the whole sample are given in Table 2.1. The same table also presents summary statistics for undocumented migrants only, just for reference.

Summary statistics and estimation results are based on the last trip to the United States for two reasons. First, MMP focuses on first and last trip, therefore there is more information about these trips than any others. Second, focusing on the last trip to the United States rather than the first trip minimizes recall bias.

Table 2.1: Summary Statistics

Variables	All Migrants	Undocumented
Demographics		
Male	0.959	0.963
	(0.199)	(0.190)
16-24 years old at the start of the last trip[a]	0.234	0.262
	(0.424)	(0.440)
25-34 years old at the start of the last trip[a]	0.366	0.365
	(0.482)	(0.482)
35-44 years old at the start of the last trip[a]	0.233	0.231
	(0.423)	(0.421)
45-54 years old at the start of the last trip[a]	0.117	0.106
	(0.322)	(0.308)
55-65 years old at the start of the last trip[a]	0.049	0.036
	(0.216)	(0.186)
State of origin in central Mexico	0.461	0.484
	(0.498)	(0.500)
State of origin in the pacific coast Mexico	0.267	0.282
	(0.442)	(0.450)
State of origin in south Mexico	0.026	0.039
	(0.159)	(0.194)
State of origin in north Mexico	0.246	0.194
	(0.431)	(0.395)
Urban area	0.410	0.399
	(0.492)	(0.490)
Zero years of schooling	0.143	0.132
	(0.350)	(0.339)
1-6 years of schooling	0.627	0.641
	(0.483)	(0.480)
7-9 years of schooling	0.193	0.203
	(0.395)	(0.402)
10-12 years of schooling	0.016	0.013
	(0.125)	(0.112)
Sample size	5064	3213

[a]In the empirical analysis this variable varies over time.
Standard deviation in parenthesis.

Table 2.1 – Continued

Variables	All Migrants	Undocumented
More than 13 years of schooling	0.020	0.011
	(0.141)	(0.105)
Attachment to Mexico		
Married	0.728	0.709
	(0.445)	(0.454)
Either mother, father, brother or sister		
in the U.S. at the start of the last trip[a]	0.496	0.492
	(0.500)	(0.500)
No children less than 18 years old	0.281	0.267
	(0.450)	(0.442)
One child less than 18 years old	0.147	0.142
	(0.355)	(0.349)
Two children less than 18 years old	0.163	0.164
	(0.370)	(0.370)
Three children less than 18 years old	0.132	0.130
	(0.339)	(0.337)
More than 3 children less than 18 years old	0.275	0.297
	(0.446)	(0.457)
No children 18 years or older	0.729	0.756
	(0.444)	(0.430)
One child 18 years or older	0.080	0.080
	(0.271)	(0.271)
Two children 18 years or older	0.051	0.047
	(0.219)	(0.212)
Three children 18 years or older	0.033	0.028
	(0.339)	(0.166)
More than 3 children 18 years or older	0.107	0.089
	(0.309)	(0.285)
Immigration related		
Not in the U.S. labor		
force at the start of the last trip[a]	0.022	0.013
	(0.148)	(0.114)
Sample size	5064	3213

[a]In the empirical analysis this variable varies over time.
Standard deviation in parenthesis.

Table 2.1 – Continued

Variables	All Migrants	Undocumented
Unemployed in the U.S.		
at the start of the last trip[a]	0.016	0.020
	(0.125)	(0.139)
Skilled worker in the		
U.S. at the start of the last trip[a]	0.212	0.234
	(0.409)	(0.423)
Agricultural worker in the		
U.S. at the start of the last trip[a]	0.422	0.355
	(0.494)	(0.478)
Unskilled worker in the		
U.S. at the start of the last trip[a]	0.327	0.378
	(0.469)	(0.485)
Undocumented migrant at the		
start of the last trip[a]	0.651	1.000
	(0.477)	(0.000)
Resident/citizen at the		
start of the last trip[a]	0.217	0.000
	(.412)	(0.000)
Temporary documented migrant at		
the start of the last trip[a]	0.132	0.000
	(0.339)	(0.000)
Stayed in a northeast U.S. state	0.033	0.036
	(0.178)	(0.186)
Stayed in a midwest U.S. state	0.111	0.125
	(0.314)	(0.331)
Stayed in a south U.S. state	0.249	0.125
	(0.432)	(0.331)
Stayed in a west U.S. state	0.608	0.599
	(0.488)	(0.490)
Last trip to U.S. before or in the 1940's	0.030	0.019
	(0.171)	(0.136)
Last trip to U.S. in the 1950's	0.078	0.030
Sample size	5064	3213

[a]In the empirical analysis this variable varies over time.
Standard deviation in parenthesis.

Table 2.1 – Continued

Variables	All Migrants	Undocumented
	(0.267)	(0.172)
Last trip to U.S. in the 1960's	0.095	0.055
	(0.293)	(0.228)
Last trip to U.S. in the 1970's	0.165	0.213
	(0.371)	(0.410)
Last trip to U.S. in the 1980's	0.265	0.308
	(0.441)	(0.462)
Last trip to U.S. in the 1990's	0.306	0.300
	(0.461)	(0.458)
Last trip to U.S. in the 2000's	0.062	0.074
	(0.240)	(0.261)
Sample size	5064	3213

[a]In the empirical analysis this variable varies over time.
Standard deviation in parenthesis.

The vast majority of migrants are male; only 4% of the sample are female. 37% of migrants are between 25 and 34 years old. More than half of the migrants in my sample have between 1 and 6 years of schooling. Almost half of the sample comes from a state in central Mexico: Aguascalientes, Guanajuato, Hidalgo, Mexico, Michoacan, San Luis Potosi, Puebla, and Tlaxcala. With respect to the place of the survey, 41% are in urban areas.

In reference to the variables that measure attachment to Mexico, 73% of the migrants are married. Only 28% have no children less than 18 years old, and another 27% have more than three children less than 18 years old. 73% of the sample have no children 18 years old or older. For 50% of the sample it is the case that either their mother, father or sibling(s) were in the U.S. at the start of the last trip.

Relative to the variables about the migration experience, 42% of the migrants were working in the agricultural sector at the start of their last trip, and 32% were unskilled workers. Also, 65% of the sample are undocumented migrants. Of the 35% left, 22% were either permanent legal U.S. resident, U.S. citizens, refugees, or asylums. The other 13% were temporary documented migrants who entered the U.S. using a worker visa or a tourist visa. 61% of the sample stayed in a west U.S. state during the last trip. Finally, 56% of the total migrants I am using in the analysis started their last trip between 1980 and 1999.

In Table 2.2 I summarize the variables that characterize the migration spells. The risk set is the number of observations with spells that have not ended or been censored. Failures refer to the number of spells which end during the interval. Censored observations are those with migration spells that lasted more than 20 years or that ended after 2004. Although the maximum number of years spent by an immigrant in the U.S. is 61, I establish 20 years as the censoring point because only 1.60% of the sample have spell durations greater or equal to 20. The reason I also censored those observations that ended after 2004 is because border enforcement data is missing after this year. Around 98% of the sample is not censored. The hazard is the number of failures divided by the risk set. The average duration of the last trip is around 24 months with a standard deviation of 50 months.

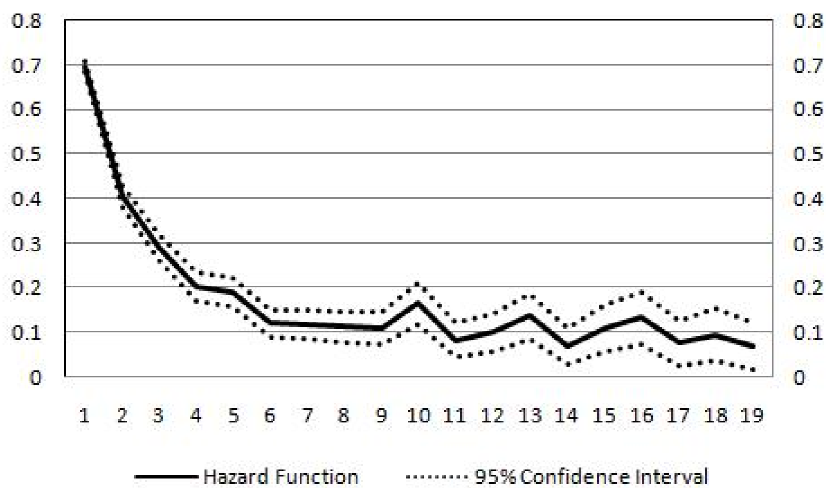
Table 2.2: Failures, Censoring and the Kaplan-Meier Empirical Hazard

Interval	Risk Set	Failures	Censorings	Hazard	Std. Error
$[1, 2)$	5064	3509	10	0.693	0.006
$[2, 3)$	1549	622	6	0.401	0.012
$[3, 4)$	926	270	1	0.291	0.015
$[4, 5)$	653	128	3	0.196	0.016
$[5, 6)$	522	97	3	0.186	0.017
$[6, 7)$	421	48	4	0.114	0.016
$[7, 8)$	372	45	1	0.121	0.017
$[8, 9)$	326	35	1	0.107	0.018
$[9, 10)$	291	31	0	0.106	0.018
$[10, 11)$	259	40	1	0.154	0.023
$[11, 12)$	219	18	0	0.082	0.019
$[12, 13)$	199	17	2	0.085	0.022
$[13, 14)$	182	25	0	0.137	0.026
$[14, 15)$	157	10	0	0.064	0.021
$[15, 16)$	147	15	0	0.102	0.027
$[16, 17)$	132	16	0	0.121	0.031
$[17, 18)$	114	6	2	0.053	0.026
$[18, 19)$	108	11	0	0.102	0.030
$[19, 20)$	97	6	0	0.062	0.027

To obtain a general idea about the pattern of length of stay in the United States by Mexican migrants, Figure 2.1 presents the Kaplan-Meier empirical hazard for the whole sample. The empirical hazard is the fraction of spells ongoing at the start of a year which end during the year.

Figure 2.1 shows that the probability of going back to Mexico given survival up to a given year is decreasing in the time of stay in the host country.

Figure 2.1: Kaplan-Meier Empirical Hazard

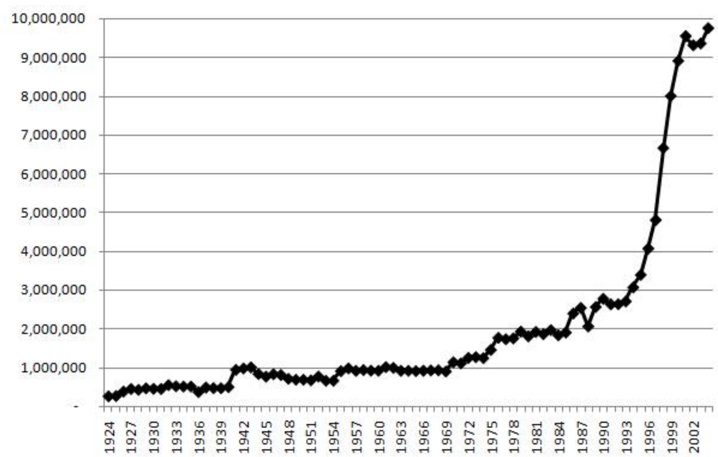


The hazard is defined as the probability of leaving the United States at year t, given survival up to year $t-1$. The Kaplan-Meier empirical hazard is the fraction of spells ongoing at the start of the year t which end during the year and it is equivalent to the flexible hazard when no covariates are included.

The probability of leaving the country before the second year after migration is 69%. Moreover, the hazard of leaving the U.S. before the third year in the United States is 40%. In fact, the probability of leaving the United Sates continues to decrease over time up to 6 years after migration. After six years in the country, the probability of leaving the U.S. is very small, approximately 10%, with no statistically significant changes. This pattern suggest that the probability of going back to Mexico decreases the longer migrants stay in the United States. More experience in the United States harms the links with the home country and leads to greater assimilation of immigrants to the host country. However, the negative duration dependence could be also related to the heterogeneity across individuals. If individuals who stay longer in the United States are different from those who leave in the very first years in terms of unobservable characteristics, I cannot tell whether the decline in the hazard over time is due to assimilation effects or due to heterogeneity among individuals.

Finally, Figure 2.2 graphs the total officer-hours devoted by the border patrol to securing the border between Mexico and the United States from 1924 to 2004. This is the measurement of border enforcement I am use in this paper. From the graph it is clear that vigilance of the border has increased dramatically in the last two decades. If migrants in the United States are planning to go back to Mexico, I expect them to internalize the level of border enforcement in their decision of whether to leave at each point in time.

Figure 2.2: Number of Line-watch Hours by the Border Patrol in the Border with Mexico



The number of line-watch hours are the total number of officer-hours devoted to patrol the border at a certain year.

2.4 Method

I estimate a flexible hazard model for the length of stay by Mexican immigrants in the United States. With this, I infer the effect of the number of line watch hours by the border patrol on the probability that a Mexican immigrant already in the U.S. leaves the country between year t and $t+1$, given survival up to year t. The approach I take here is the same as in Meyer (1990). To apply this method, I construct a panel where each observation is a vector of covariates and binary responses that determine whether the individual has exited the United States and whether it is censored. In this paper, a spell is censored if it ends after 2004 because the border enforcement data are not available for 2005, 2006 and 2007, or because it lasted 20 years or more.

The main advantage of estimating a flexible duration model is that no assumptions about the distribution of the duration of the migration spells are necessary. Also, this method is intended for the cases where the duration data are only known to fall into a certain time interval, as with this data set. Under this model, the hazard function can be different over each time interval. Although time is discrete, the estimates are functions of the continuous time hazard model and thus retain an easy interpretation. Another benefit of using a flexible hazard model is that it naturally allows for time dependent covariates. In my estimation age, whether mother, father or a sibling is in the U.S., occupation in the U.S., immigration status, and border enforcement vary over time and across observations.

Let T_i be the migration spell of individual i in the United States, that is, the duration of the last stay in the United States by Mexican immigrant i. Then, the hazard in this case is defined as the probability that individual i leaves the United States between year t and year $t+1$, given that individual i has stayed in the United States up through year t. With this definition, I parameterized the hazard using a proportional hazard form in the following way.

Let $\lambda_o(t)$ be the baseline hazard at time t, $\mathbf{x}_i(t)$ be the vector of possibly time varying explanatory variables for individual i, and β be the vector of parameters. Then the hazard function for individual i is:

$$\lambda_i(t) = \lambda_o(t) exp\{\mathbf{x}_i(t)'\beta\}. \tag{2.1}$$

Using equation (2.1) we can write down the probability that a duration spell lasts until time $t+1$ given that it has lasted until t.

Using the fact that $\mathbf{x}_i(t)$ is constant in the interval $[t, t+1)$ and the following definition from Meyer (1990),

$$\gamma(t) = log \int_t^{t+1} \lambda_o(u) du, \tag{2.2}$$

I can write the probability of remaining in the United States for the first $k_i - 1$ intervals as:

$$\prod_{t=1}^{k_i-1} exp\{exp[\gamma(t) + \mathbf{x}_i(t)'\beta]\}. \tag{2.3}$$

Moreover the probability that duration T_i falls into interval k_i, is given by:

$$1 - exp\{-exp[\gamma(k_i) + \mathbf{x}_i(k_i)'\beta]\}. \tag{2.4}$$

Using the probabilities defined in equations (2.3) and (2.4), the log-likelihood function for a sample of N individuals is:

$$L(\gamma, \beta) = \sum_{i=1}^{N} \{\delta_i log[1 - exp(-exp[\gamma(k_i) + \mathbf{x}_i(k_i)'\beta])] - \sum_{t=1}^{k_i - 1} exp[\gamma(t) + \mathbf{x}_i(t)'\beta]\} \tag{2.5}$$

where $\gamma = [\gamma(1), ..., \gamma(T-1)]'$, C_i is the censoring time for individual i, $\delta_i = 1$ if $T_i \leq C_i$, i.e. the observation is censored, and 0 otherwise, and $k_i = min\{int(T_i), C_i\}$.

Since observations lasting 20 periods or more are censored at 20, the log-likelihood function is maximized through standard techniques with respect to the 19 elements of γ and the vector β.

2.5 Results

In column A of Table 2.3 are the results from the specification when only the border enforcement measure is included as explanatory variable. The effect of border enforcement on the hazard of leaving the United States is measured by the logarithm of the number of officer-hours assigned to secure the border between Mexico and United States each year. High levels of border enforcement are expected to decrease the hazard because it increases the expected costs of future trips to the United States. According to these results, a one percent increase in border enforcement decreases the probability of going back to Mexico by 0.05%. The coefficient is significant at 5% level.

The results in column B of Table 2.3 correspond to the specification where all exogenous variables are included. These variables are assumed to control for demographic characteristics, variables that measure attachment to Mexico, variables related to the migration experience, and time indicators. In this case, border enforcement is no longer statistically significant. However the sign is still negative. It implies that a 1% increases in border enforcement decreases the probability of leaving the United States by 0.02%.

That the coefficient corresponding to line watch hours is not significant is related to the inclusion of the decade indicators, the immigrant status indicators, and the education indicators. When the decade indicators are excluded but all other regressors are included, the coefficient for border enforcement is -0.007 with p-value=0.80. In contrast, when only the migrant status indicators are omitted the coefficient for border enforcement is -0.06 with p-value=0.29. Years of schooling indicators are also very important in determining the insignificance of border enforcement. When these indicators are excluded, the coefficient of the border enforcement measure is -0.05 with p-value=0.40. When excluding either the decade and status indicators, or the decade and education indicators, an increase of 1% of the border enforcement coefficient implies a 0.05% decrease in the hazard of leaving the United States. In both cases, the coefficient is significant at 5% level.[4]

One concern with the results in column B of Table 2.3 is that some regressors are probably not exogenous. Hence, I estimate the hazard model

[4]Results are available upon request.

with only the following regressors: male indicator, Mexican region indicators, urban indicator, decade indicator, age indicator, and focusing only on undocumented immigrants. In this case, the coefficient for line watch hours is -0.071 with p-value=0.34: the coefficient is negative but still insignificant.[5]

Going back to column B of Table 2.3, with respect to demographic characteristics, male migrants are more likely to go back to Mexico. In fact, the hazard for them is 16% higher than the corresponding hazard for women at 10% level of significance. For the age indicators, the omitted group corresponds to individuals who are more than 54 years old but less than 66 years old. None of the indicators for age is significant at 10%. All of the coefficients have negative sign except for the indicator for age between 35 and 44 years old. Perhaps age is not significant because most immigrants stay less than two periods in the U.S.

I also include indicators for the region in Mexico where the migrants come from. The omitted region is northern Mexico. All indicators are significant at 1% level in this case. The indicator for central Mexico is positive: that is, immigrants whose home state is in central Mexico are 10% more likely to leave the United States relative to the comparison group. Immigrants whose communities of origin are in the Pacific coast have 20% higher hazard of leaving the United States relative to those from northern Mexico. In contrast, immigrant with origins in the south are 42% less likely to go back to Mexico

[5]Results are available upon request.

than people from the north. This last result is in accordance with the hypothesis that migrants who come from farther regions experience higher costs of migration, which make them less likely to go back to their places of origin.

Table 2.3: Flexible Hazard Estimated Coefficients

Variables	Whole Sample (A)	Whole Sample (B)	Undocumented Only (C)	Permanent Documented (D)	Started in 1924-1985 (E)	Started in 1986-2004 (F)
Log-number of line watch hours[a]	-0.052*	-0.024	-0.047	-0.007	-0.032	0.007
	(0.022)	(0.064)	(0.078)	(.135)	(0.163)	(0.074)
Demographics						
Male	-	0.158†	0.059	0.043	0.261*	-0.056
	-	(0.083)	(0.108)	(0.138)	(0.118)	(0.122)
16-24 years old[a]	-	-0.105	-0.021	-0.325	-0.266†	0.022
	-	(0.097)	(0.130)	(0.200)	(0.144)	(0.137)
25-34 years old[a]	-	-0.026	0.029	-0.261	-0.243†	0.167
	-	(0.090)	(0.124)	(0.165)	(0.136)	(0.125)
35-44 years old[a]	-	0.010	0.003	-0.100	-0.167	0.137
	-	(0.088)	(0.121)	(0.154)	(0.133)	(0.120)
45-54 years old[a]	-	-0.120	-0.095	-0.108	-0.314**	0.049
	-	(0.080)	(0.112)	(.126)	(0.125)	(0.106)
State of origin in Central Mexico	-	0.105**	0.038	0.163†	0.245**	-0.049
	-	(.041)	(0.053)	(0.087)	(0.059)	(0.059)
State of origin in the Pacific Coast	-	0.199**	0.096†	0.283**	0.272**	-0.042
	-	(0.045)	(0.058)	(0.095)	(0.064)	(0.068)
State of origin in South Mexico	-	-0.417**	-0.451**	0.111	0.412	-0.578**
	-	(0.104)	(0.112)	(0.618)	(0.411)	(0.118)
Urban area	-	-0.038	-0.019	-0.096	-0.061	-0.058
	-	(0.033)	(0.041)	(0.075)	(.047)	(0.048)
Zero years of schooling	-	-0.366**	-0.192	-0.888**	-0.512**	-0.506**
	-	(0.120)	(0.185)	(0.206)	(0.199)	(0.165)
1-6 years of schooling	-	-0.389**	-0.268	-0.808**	-0.562**	-0.363**
	-	(0.110)	(.176)	(0.167)	(0.191)	(0.139)

Standard errors in parenthesis. **Significant at 1% level. *Significant at 5% level. † Significant at 10% level.
Estimated vector γ not included in this table, but is available upon request.
[a]Time variant.

Table 2.3 – Continued

Variables	Whole Sample (A)	Whole Sample (B)	Undocumented Only (C)	Permanent Documented (D)	Started in 1924-1985 (E)	Started in 1986-2004 (F)
7-9 years of schooling	-	-0.512**	-0.413*	-0.719**	-0.582	-0.492**
	-	(0.113)	(0.178)	(0.164)	(0.198)	(.140)
10-12 years of schooling	-	-0.335*	-0.285	-0.555*	-0.227	0.361†
	-	(0.161)	(0.242)	(0.254)	(0.266)	(0.207)
Attachment to Mexico						
Direct family relatives in the U.S. at the start of the last trip[a]	-	0.104**	0.105	0.152	0.019	0.210**
	-	(0.032)	(0.039)	(.073)	(.047)	(0.045)
Married	-	0.092*	0.061	0.072	0.047	0.143*
	-	(0.044)	(0.053)	(0.098)	(0.066)	(.061)
No children less than 18 years old	-	-0.121*	-0.260**	-0.132	-0.116	-0.289**
	-	(0.055)	(0.071)	(.113)	(0.081)	(0.081)
One child less than 18 years old	-	-0.054	-0.137*	-0.102	-0.022	-0.182*
	-	(0.054)	(0.068)	(0.117)	(0.085)	(0.074)
Two children less than 18 years old	-	0.005	-0.047	0.059	0.034	-0.101
	-	(0.051)	(0.063)	(0.111)	(0.082)	(0.069)
Three children less than 18 years old	-	0.064	0.013	0.140	0.077	-0.018
	-	(0.053)	(0.066)	(0.114)	(0.083)	(0.072)
No children 18 years or older	-	-0.102	-0.050	-0.034	0.006	-0.263*
	-	(0.073)	(0.096)	(0.143)	(0.108)	(0.102)
One child 18 years or older	-	-0.103	0.075	-0.297†	0.066	-0.341**
	-	(0.084)	(0.110)	(0.170)	(0.124)	(0.118)
Two children 18 years or older	-	-0.035	-0.017	0.260	-0.012	-0.028
	-	(0.091)	(0.117)	(0.184)	(0.132)	(0.127)
Three children 18 years or older	-	-0.167†	-0.215†	-0.077	0.161	-0.238†
	-	(0.099)	(0.131)	(0.182)	(0.147)	(0.134)

Standard errors in parenthesis. **Significant at 1% level. *Significant at 5% level. † Significant at 10% level.
Estimated vector γ not included in this table, but is available upon request.
[a]Time variant.

Table 2.3 – Continued

Variables	Whole Sample (A)	Whole Sample (B)	Undocumented Only (C)	Permanent Documented (D)	Started in 1924-1985 (E)	Started in 1986-2004 (F)
Immigration Related						
Not in the U.S. labor force[a]	-	0.540**	0.075	0.867**	0.490**	0.732**
	-	(0.112)	(0.172)	(0.170)	(0.165)	(0.160)
Unemployed in the U.S.[a]	-	0.906**	0.986**	0.720*	1.168**	0.805**
	-	(0.140)	(.162)	(0.302)	(0.244)	(0.180)
Skilled worker in the U.S.[a]	-	-0.087*	-0.088**	-0.083	-0.167*	-0.061
	-	(.042)	(0.050)	(0.087)	(0.069)	(0.054)
Agricultural worker in the U.S.[a]	-	0.441**	0.330**	0.479**	0.359*	0.456*
	-	(0.039)	(0.047)	(0.089)	(0.057)	(0.056)
Undocumented[a]	-	-0.403**	-	-	-0.452**	0.038
	-	(0.060)	-	-	(0.072)	(0.130)
Resident/citizen[a]	-	-0.700**	-	-	-1.149**	-0.113
	-	(0.066)	-	-	(0.095)	(0.133)
Stayed in a northeast U.S. state	-	-0.265**	-0.246*	-0.200	-0.256	-0.175†
	-	(0.088)	(0.103)	(0.206)	(0.206)	(0.100)
Stayed in a midwest U.S. state	-	-0.201**	-0.215**	-0.209†	-0.163*	-0.261**
	-	(0.050)	(0.059)	(0.116)	(0.077)	(0.068)
Stayed in a south U.S. state	-	0.112**	0.089†	0.093	0.173**	0.067
	-	(0.039)	(0.048)	(0.087)	(0.054)	(0.054)
Last trip to U.S. before or in the 1940's	-	-0.453*	-0.297	-1.373*	-0.307	-
	-	(0.200)	(0.253)	(0.600)	(0.194)	-
Last trip to U.S. in the 1950's	-	-0.430*	-0.302	-1.701**	-0.266	-
	-	(0.182)	(0.232)	(0.483)	(0.163)	-
Last trip to U.S. in the 1960's	-	-0.425*	-0.324	-1.307**	-0.171	-
	-	(0.168)	(0.207)	(0.389)	(0.136)	-
Last trip to U.S. in the 1970's	-	-0.357**	-0.179	-1.048**	-0.112†	-

Standard errors in parenthesis. **Significant at 1% level. *Significant at 5% level. † Significant at 10% level.
Estimated vector γ not included in this table, but is available upon request.
[a]Time variant.

Table 2.3 – Continued

Variables	Whole Sample (A)	Whole Sample (B)	Undocumented Only (C)	Permanent Documented (D)	Started in 1924-1985 (E)	Started in 1986-2004 (F)
	-	(0.135)	(0.159)	(0.332)	(0.066)	-
Last trip to U.S. in the 1980's	-	-0.159	-0.042	-0.534*	-	-0.214
	-	(0.116)	(0.139)	(0.268)	-	(0.124)
Last trip to U.S. in the 1990's	-	0.101	0.108	0.009	-	0.007
	-	(0.089)	(0.104)	(0.228)	-	(0.094)
Log-likelihood	-6280.580	-5894.795	-3805.876	-1514.856	-2963.315	-2805.126
Sample size	5064	5064	3213	1174	2540	2524

Standard errors in parenthesis. **Significant at 1% level. *Significant at 5% level. † Significant at 10% level.
Estimated vector γ not included in this table, but is available upon request.
[a]Time variant.

However, that is not also true for immigrants who come from the Pacific coast or from central Mexico, regions that are still far from the U.S. compared to northern Mexican states. Given that I control for occupation in the U.S., the legal status in the U.S., and the year when the last trip started, these results are probably related to unobserved characteristics of the migrants from these regions that make them more likely to go back to Mexico. An urban indicator was also included, but it is not significant. Its negative sign implies that immigrants from urban areas are less likely to leave the United States than migrants from rural areas.

Finally, I include indicators for years of schooling, where the omitted group is having more than 12 years of education. The first three coefficients are significant at 1% level, the other two are significant at 5% level. Having no formal education at all makes immigrants 37% less likely to go back to Mexico than the comparison group. Migrants with at least one year of schooling, but less than 7 years of schooling have a hazard 39% lower of going back to Mexico than the comparison group. Migrants with more than 6 years of education but less than 10 are 51% less likely to leave the United States. Those with education between 9 and 12 years of education are 33% less likely to go back to Mexico. These results imply that less educated immigrants stay longer in the U.S. relative to more educated immigrants. One explanation could be that for less educated immigrants the benefits from working in the U.S. are greater than for highly educated immigrants.

Relative to the variables that measure attachment to Mexico, if the migrant's mother, father, or sibling(s) are in the United States at the start of the last trip, the Mexican migrant is 10% more likely to return to Mexico and the coefficient is significant at 1% level. Also, being married increases the probability of going back to Mexico by 9% and the coefficient is significant at 5% level. This is probably related to the fact that migrants' spouses stay in Mexico while they are in the United States. This is a very good indicator that for migrants family ties are very important and a motive to return to Mexico. The last set of variables in this category are indicators for total number of children at the time the last trip starts. Only two indicators are significant. First, not having children less than 18 years old make immigrants 12% less likely to go back to Mexico relative to having 4 or more children less than 18 years old; this coefficient is significant at 5% level. Second, having three children more than 18 years old make immigrants less likely to go back to Mexico than immigrants with more than three adult children, however the coefficient is just marginally significant (p=0.09). Thus, having no young children or having adult children allow immigrants to stay longer in the U.S.

The variables related to the migration experience are the most interesting. Compared to immigrants who are unskilled workers in the U.S., immigrants who are not in the labor force are 54% more likely to go back to Mexico. The same is true for immigrants who were unemployed while in the United States, in fact, they are 91% more likely to go back to Mexico. In contrast, skilled workers are 8% less likely to return to their places of origin. These results imply that immigrants who are lucky enough to have a job, or better yet, to have a skilled job, are less likely to go back to Mexico. As expected, agricultural workers are 44% more likely than unskilled workers to leave the United States because most agricultural jobs are seasonal. All the coefficients related to occupation are significant at 1% level, except for skilled workers which is significant at 5%.

Compared to temporary migrants, undocumented migrants are 40% less likely to go back to Mexico and the coefficient is significant at 1% level. The most likely reason is that for undocumented migrants the cost of making another trip between the two countries is very high. Therefore, they stay longer to get the most benefits from the trip. Mexican immigrants who are legal U.S. residents or U.S. citizens are also less likely to leave the United States than Mexican migrants who have only temporary permission to stay in the country. Permanent immigrants are 70% less likely to go back to Mexico and the significance level is 1%. Permanent documented migrants are able to cross the border without restrictions; however, their attachment to U.S. is much stronger than their attachment to Mexico, making them more likely to stay in the U.S.

I also include indicators for the regions in the United States where migrants stay longer. The omitted region is the West. The coefficients for the three other regions are significant at 1% level. Migrants who reside in northeast states are 26% less likely than west migrants to return to Mexico. Again, the reason could be that for migrants living in the northeast is more costly than for migrants in the west to travel between the two countries. In line with this argument, immigrants in the midwest have a hazard 20% lower of leaving the U.S. than migrants in the west. Immigrants established in the south during the last trip have a 11% greater hazard of going back to Mexico than immigrants established in the West. The cost of migration is higher the farther from Mexico, thus making immigrants less likely to leave the United States.

Finally, most of the time indicators are significant. Immigrants who started the trip before the 1950 decade are 45% less likely to leave the U.S. than migrants who started the trip in the first half of the 2000 decade. Relative also to the latter, immigrants who started the trip in the 1950's, 1960's, and 1970's, have a hazard of returning to Mexico 43%, 42% and 36% lower, respectively. Immigrants who started the trip in the 1980 decade are less likely to go back to Mexico but the coefficient is not statistically significant. Lastly, immigrants who started the trip in the 1990's are more likely to leave the U.S. relative to the comparison group, although the coefficient is not significant. This pattern is explained by the way the Mexican Project data is collected. For an immigrant to be surveyed he has to be in Mexico. Therefore, immigrants who started their trip in recent years have shorter trips than immigrants who started their trips decades before. Also, immigrants who started their trips in earlier decades, have longer migration spells. To see if these patterns are affecting the significance and magnitude of the line watch hours variable, I estimate the hazard model restricting the sample according to the year each immigrant started his last trip. All immigrants who started the trip before 1960 or after 1999 were excluded. The results indicate that border enforcement is still insignificant, although of the same magnitude as in column B.[6]

2.5.1 Comparing Undocumented and Permanent Documented Migrants

In column C of Table 2.3 I restrict the sample to those who entered the U.S. as undocumented immigrants, whereas in column D of Table 2.3 I restricted the sample to those who entered as residents, citizens, refugees, or asylums of U.S. The coefficient for border enforcement in the case of documented immigrants is much closer to zero than the coefficient for the same variable when the sample is restricted to undocumented immigrants, just as expected. However, the border enforcement measure is not significant in either case.

There are very important differences between undocumented and documented migrants. When I restrict the sample to permanent legal migrants, it is still the case that the male indicator and the indicators for age are not significant as in the case of undocumented. However, when comparing the coefficients for the indicators for education, all of them are significant in the case of documented migrants and only one for undocumented immigrants (the 7 to 9 years of schooling indicator). Moreover, the coefficients are greater in magnitude for permanent documented immigrants. Less educated immigrants are

[6]The results are available upon request.

much more likely to stay in the host country if they are residents. This is probably a reflection of the benefit of staying in the U.S. for more disadvantaged immigrants in terms of human capital.

Another important difference arises according to the region of origin. For undocumented immigrants, coming from a southern Mexico state decreases the probability of going back to Mexico significantly. In comparison, for documented permanent migrants the south Mexican region indicator is not significant anymore. In fact, for this group it is the case that the central and Pacific Mexico indicators are significant and with positive sign. This implies that most documented migrants are from these two regions.

For undocumented immigrants, having no children or having one child makes their hazard of going back to Mexico lower. However, neither number of children nor age significantly affect the hazard of going back to Mexico by permanent documented immigrants. This is most likely because their children are also in the United States with them. Along the same lines, the U.S. region where they stayed during the last trip affects the hazard of leaving for undocumented immigrants, but not for documented ones. For documented immigrants the cost of migration is more or less the same, no matter where they are established. However, for undocumented immigrants, the farther from the border the greater the cost of migration.

With respect to the occupation of immigrants while in the United States, the coefficients for both groups are very similar in terms of sign, magnitude, and significance, with only one important difference. Undocumented

Mexican immigrants are 7% more likely to leave the United States if they are not in the labor force relative to unskilled undocumented immigrants. However, in the same conditions, permanent documented immigrants are 87% more likely to leave the U.S.

Finally, the decade indicators for documented immigrants are all significant except for the 1990 decade. This compares with the case of undocumented immigrants where none of the indicators for when they started the trip to the U.S. are significant. Moreover, the coefficients are much bigger for the permanent legal immigrants. For documented immigrants, those who started the trip more recently are less likely to stay in the U.S. In the case of undocumented immigrants, I still observe that immigrants who arrive to the U.S. in earlier decades are less likely to leave the United States; however the coefficients are not significant and not very different for different decades.

2.5.2 Comparing Immigrants According to the Year They Started the Last Trip to the United States

Looking at the durations, there is a clear difference between those who started the last trip before the 1980 decade and those who started the last trip after the 1970 decade. Based on this, I divided the sample in two parts, leaving 20 years for the second part. The results in column E of Table 2.3 refer to the period 1926-1985 and the results in column F of the same table refer to the period 1985-2004.

The first difference is that for the period 1926-1985, the border enforcement coefficient is negative; in contrast, the coefficient in the period 1986-2004 is positive. However, in both cases the coefficient is not significant. Another important difference is that the male indicator is positive and significant in the first period, but negative and insignificant for the second period. Interestingly, age indicators are negative and marginally significant for the 1926-1985 period, whereas in 1986-2004, the coefficients are positive and not significant. With respect to education there are basically no differences in any sense. Differences arise again relative to the region of origin in Mexico. Immigrants who migrated in earlier years are more likely to come from the central and Pacific regions for which the coefficients are positive and significant. In contrast, immigrants who started the last trip in more recent years are more likely to come from south Mexico, the coefficient is significant and has negative sign.

With respect to children, having no children affects negatively the hazard of recent migrants and does not affect the hazard of earlier migrants. Also, having no adult children affects negatively the hazard of migrants who started the trip in 1986-2004 negatively. However, for the first period, the coefficient of this indicator is not significant and it is positive. Relative to the occupation in the U.S. indicators, there are no huge differences. Finally, being undocumented or permanent documented migrant has a negative and significant effect on the hazard of leaving the U.S. for immigrants who migrated before 1986. But for immigrants who migrated after 1985, although both coefficients are not significant, the coefficient is positive for undocumented immigrants and negative for resident immigrants.

2.5.3 Using Border Enforcement that Varies Across Border Regions

The measure of border enforcement I have used so far is the yearly total number of hours that Border Patrol officers spent securing the Mexico-U.S. border. Perhaps one reason the border enforcement measure is not significant is because yearly variation is not enough to identify the effect of the enforcement in the individual decision of how long to stay. One way to improve my identification strategy is to have variation over time and across border regions. Vigilance is not uniform along the 1,969 miles of the Mexico-United States border. The U.S. Border Patrol has divided the border in 11 sectors: San Diego, CA; El Centro, CA; Yuma, AZ; Tucson, AZ; El Paso, TX; Marfa, TX; Del Rio, TX; Laredo, TX; and McAllen, TX. Across these sectors, the number of hours that the Border Patrol officers guard the border are different. Using data collected by Dr. Gordon Hanson available at on website[7], I run the same specification as in column C. The way I assign the level of border enforcement to each individual is as follows. Looking at the data, I noticed that undocumented immigrants cross the border by the region closest to their destination, unless their destination is the northeast or the midwest. For example, undocumented migrants staying in Texas crossed by Texas. In contrast, undocumented immigrants staying in New York during their last trip crossed by either Arizona, or Texas, and the vast majority through California. Undocumented immigrants living in the state of Washington crossed through

[7]http://irps.ucsd.edu/faculty/faculty-directory/gordon-hanson.htm

California, too. If their destination is a state in the south, say Florida, they cross by Texas. Therefore I assigned the border enforcement measure corresponding to the region closest to their destination, except for undocumented immigrants whose destinations were located in the northeast and midwest. In those cases, they were assigned the total of line-watch hours in the eleven sectors. The data are monthly and although I know the duration in months, I don't know which month they started the trip, so I calculated the yearly average and use it for the estimation. The disaggregated data only cover from 1977 to 2004, so I restrict the sample to those years.[8]

The results are not different from those when I restrict the sample to undocumented immigrants who started the trip between 1977 and 2004 and use the border enforcement measure that only varies over time. The border enforcement measure using line watch hours that vary across region and across years has negative coefficient and, as before, is not significant.

2.6 Expected Duration of the Last Trip

In this section I calculate the expected duration of a trip to the United States by an average Mexican immigrant to see how different characteristics affect the expected migration spell, in terms of months.

To construct the expected value of the migration spell, T, using the estimated hazard model, recall the definition of the hazard function as follows:

[8]Results are available upon request.

$$\lambda_t = P(t \leq T < t+1 \mid T \geq t). \tag{2.6}$$

It is possible to rewrite equation (2.6) as:

$$\lambda_t = \frac{P(t \leq T \leq t+1)}{P(T \geq t+1)} \tag{2.7}$$

$$\lambda_t = \frac{P(T \leq t+1) - P(T \leq t)}{P(T \geq t+1)}. \tag{2.8}$$

Since the hazard was assumed to be constant for intervals of size one, then the hazard is:

$$\lambda_t = \frac{\sum_{r=1}^{t+1} P(r-1 \leq T \leq r) - \sum_{r=1}^{t} P(r-1 \leq T \leq r)}{1 - \sum_{r=1}^{t} P(r-1 \leq T \leq r)} \tag{2.9}$$

$$\lambda_t = \frac{P(t \leq T \leq t+1)}{1 - \sum_{r=1}^{t} P(r-1 \leq T \leq r)}. \tag{2.10}$$

I can use equation (2.10) to solve for $P(t \leq T \leq t+1)$ as follows:

$$P(t \leq T \leq t+1) = \lambda_t (1 - \sum_{r=1}^{t} P(r-1 \leq T \leq r)). \tag{2.11}$$

I know λ_t, for $t = 1, ...19$ by substituting the estimates for γ and β in equation (2.1). Then,

$$P(t \leq T \leq t+1) = \lambda_t \prod_{r=0}^{t-1} (1 - \lambda_{r-1}) \text{ for } 1 \leq t \leq 19 \tag{2.12}$$

Since I censored observations at 20, $P(20 \leq T \leq \infty)$ is just one minus the sum of the nineteen probabilities defined by equation (2.12).

I plug these probabilities into the definition of the expected value which yields:

$$E(T) = \sum_{t=1}^{20} tP(t \leq T \leq t+1). \tag{2.13}$$

This is the expected duration of a trip to the United States by Mexican immigrants. To evaluate the probabilities I picked the characteristics of an average immigrant. That is, a Mexican male undocumented immigrant who comes from a rural community in the Pacific coast. He has less than 6 years of schooling. He is married and has more than three children less than 18 years old and no adult children. He made his last trip to California in 1980, when he was 33 years old. He had a brother living in the United States during that last trip. His job in that occasion was in the agricultural sector. The expected duration in the United States for an immigrant with these characteristics is 15 months.

I predicted the log-line watch hours for the following 20 years after 2004 using a polynomial order 2 trend line using the observed border enforcement. If everything else stays the same, the expected duration for an average Mexican immigrant would still be 15 months. Now, suppose border enforcement stays at the minimum level between 1924 and 2004. In this case the the expected duration decreases by one month. Hence, even if border enforcement were significant, the effect on the expected duration is small.

If instead of being an undocumented immigrant, the average immigrant is a legal permanent resident, then the expected duration of a trip is 19 months: 4 months greater than the average immigrant. Now, consider the case in which this average immigrant does not start the last trip to the U.S. in 1980 but in 1940. In that case, the average duration is also 19 months. The region from which migrants have their origins is very important. If the average Mexican immigrant comes from southern Mexico, the average duration in the United States is then 26 months: 11 months longer. Moreover, the region in the U.S. where migrants establish is also very important determining the hazard. Someone who stayed in a northeast state has an expected duration of 18 months, whereas someone established in Texas has an expected duration of 14 months everything else the same. If the average immigrant was unemployed, the expected duration would be only 13 months. In contrast, if he had a skilled job, the expected duration of the trip is 24 months.

2.7 Conclusions and Future Work

In the case of circular Mexican migration to the United States using the Mexican Migration Project data, I find that there is no effect of border enforcement on the probability of leaving the United States by Mexican immigrants at period $t+1$, given that they have survived t periods.

I find that undocumented immigrants have longer migration spells than temporary documented migrants, but shorter spells than permanent documented migrants. The hazard is 40% lower for undocumented and 70% lower for permanent documented immigrants, relative to immigrants with temporary status.

Also, I find that the Mexican region from which these immigrants come from is very important in determining the hazard of leaving the United States. Moreover, the region in the United States where these immigrants live during that last trip is also very important. Both variables are related to the cost of migration: the greater the cost, the longer they will stay in U.S.

The occupation they had in the United States during the last trip is very important. If immigrants worked in the agricultural sector, they are 44% more likely to return to Mexico than unskilled migrant workers. Immigrants who were unemployed in the United States, had a hazard 90% greater of going back to Mexico than unskilled migrant workers.

There are some important issues I will continue working on in the future. First, immigrants are clustered based on the year they started their trip to the United States since they face the same level of line-watch hours. Therefore, I need to compute the corresponding robust standard errors. Second, it is important that I control for economic conditions in Mexico and in the United States that could be systematically related to border enforcement. I also need to test my hypothesis using other measures of border enforcement such as apprehensions and dollars spend by the border patrol in securing the border. Following Meyer (1990), it is also possible to control for unobserved heterogeneity when estimating a flexible hazard. This could be very important in understanding the hazard of leaving the United States. Moreover, one characteristic of the data that I had not exploited yet and can also easily address with a flexible hazard, is the fact that I observe multiple migration spells for the same individual.

Chapter 3

Time and Money Costs Related to Child Care

3.1 Introduction

This study uses 2002 data from the Mexican Time Use Survey and the National Household Survey of Income and Expenditure to examine the time Mexican mothers dedicate to take care of their children and the amount of money spent by the household in raising children. The main contribution of this essay is that it analyzes child care time use and child care monetary expenditures simultaneously, in contrast to most of the previous literature. First, I estimate a reduced form model for weekly mother's child care time use and weekly household child care expenditures. I distinguish between working and non-working mothers, test whether there are differences overall, and analyze what is the role of income without counting mother's income in the allocation of time and money in child care for both groups. Second, I estimate the effect of the wage rate, i.e. the opportunity cost of time, in the mother's child care expenses in terms of time and money.

The main results are the following. According to the structural model, mothers significantly increase child care monetary expenditures as their wage rate increases. In contrast, the predicted log-wage rate is not significant in the child care time use equation. With respect to the reduced form model, the age of the youngest child is the most important determinant of both child care time and money expenditures. This holds for both working and non-working mothers. The effect of mother's years of schooling is positive and significant on child care monetary expenses for both working and non-working mothers. Mother's education is also significant in the mother's child care time use equation. However, it has positive sign for working mothers and negative sign for non-working mothers. This implies that more educated mothers spend more money on their children, but more or less time depending on whether they work or not.

Household income without counting mother's income positively affects child care related expenditures for both groups and such effects are statistically significant. Such measures of income also positively affects a mother's child care time use but the coefficient is only significant for non-working mothers. In fact, the coefficient is almost 21 times greater for non-working mothers than for working mothers.

The paper is structured as follows. In section 3.2 I briefly summarize the literature related to this study. Section 3.3 I describe the data, the population of interest, and summarize the variables used through out the analysis. The next section contains the econometric model and the results obtained from its estimation. Section 3.5 concludes.

3.2 Literature Review

The literature related to the present investigation is divided in two categories: those papers that study child care expenditures and those that study child care time use, both related to the women's labor supply. Given that I have information both on time use and monetary expenses related to children for the same family, I will study the relationship between the two when different individual or household characteristics change, including the wage rate.

There are a few studies that focus on child care time use and its relationship with the mother's labor supply. The most recent paper is by Kalenkoski et al. (2009) which focuses on the effect of parents' wages on parents' child care time use and labor supply. Using the 2000 United Kingdom Time Use Survey, they estimated gender-specific multivariate models of the time each parent spends in child care and market work. Given the characteristics of the data, they could distinguish between primary child-care activities, and passive child-care activities. They could also distinguish between weekdays and weekends, allowing them to control for the timing of activities. Since men and especially women self-select into labor force participation and wages are probably endogenous, the authors predict wages for men and women. They controlled for two sources of selectivity: nonemployment and misreporting. To identify the selection components, the non-labor income indicator and the number of other adults in the household were excluded from the log-wage equation. To identify the effects of wages on time use, they excluded information on own and partner's education and potential experience, the local unemployment rate, and the region of residence from the time-use equations. The relevant results are that women work more when their wages increase and less when the wages of their partners increases. Also, mothers dedicate more time to child care as their partners' wages increase. However, women's child care time does not change with changes in their own wages. The methodology in the present paper is close to that used in this paper with the difference that I incorporate children-care expenses into the analysis.

In another recent paper, Friedberg and Webb (2005) concluded that for two-earner households, as the wage rate of the mother increases, she spends significantly more time in leisure activities. Also, they had evidence that mothers spend more time with children as their relative wages rise and that these effects vary substantially with the age of the child. For this analysis the authors used the first year of the American Time Use Survey. Similar evidence was presented by Hallberg and Klevmarken (2003). For women, an increase in labor supply has a negative effect on child care related time, but the effect is not significant. Their data comes from the Swedish household panel study conducted in 1984 and 1993, when time surveys were included. Using data from a survey conducted in Netherlands during 1992, Brink and Groot (1997) found that mother's labor supply responds positively to increases in the hourly wage, although the increase is very small. Furthermore, they found that a mother's child care time also rises. In fact, an increase in time spent on child care by women with young children does not reduce labor supply.

Finally, Kooreman and Kapteyn (1987) found that female time use is more elastic with respect to her wage rate and the wage rate of her husband than male time use. In particular, as the female wage increases, mothers spend less time in child care, and less time in the labor market. However, their results were not statistically significant, probably because of the small sample size. The data come from a survey conducted by the University of Michigan during 1975 and 1976.

There is abundant literature that studies child care expenditures and women's labor supply: Ribar (1995), Ribar (1992), Blau and Robins (1988) and Connelly (1992) are some of the most important papers, just to mention a few. In this literature child care costs refer only to paid child care arrangements: baby sitting or day care services. In my paper, however, child care expenditures also include all other goods expenditures exclusively for children: diapers, children's apparel, children's shoes, baby's accessories, baby food, etc. From a strict point of view, all these goods could be produced at home using very time intensive production processes. Therefore, they play the same role as child care arrangements. Moreover, for Mexican families in my sample paid child care is a very rare practice. Only 64 of the 1330 families have nonzero child care arrangements expenditures. One possible reason is the traditional gender role ideology which promotes that children have to be cared by their mothers. Another explanation is that families are less likely to buy such services from the market if family members or relatives help with child care at little or no direct cost.

To my knowledge, there are only two papers that put together money and time child care related expenditures in a particular way. The first one is the seminal work by Cogan (1977, 1981) that developed a theory in which child care represents a fixed cost of labor market entry. The theory is very general and it easily applies to costs related to child rearing. Cogan started by discussing the implications of fixed time and fixed money costs of labor market entry. Then he relaxed the assumption that such costs are fixed and derived the corresponding comparative statics. Although he did not have all the data necessary to test his theory, he provided an empirical analysis by using the National Longitudinal Survey of Mature Women corresponding to 1967. The most important result is that entry costs are of prime importance in determining the labor supply behavior of married women. The other paper is an application of the theory in Cogan (1981) by Tan (1997).

3.3 Data

The data used in this paper come from the National Time Use Survey 2002[1] from Mexico (ENUT) and the National Household Survey of Income and Expenditure[2] (ENIGH). These are nationally representative surveys which includes both urban and rural households. The time use survey interviews all individuals who were aged 12 years or older at the time of the survey. The total sample includes 4,783 households and 20,342 individuals. The objective

[1] Encuesta Nacional del Uso del Tiempo 2002, http://www.inegi.gob.mx.
[2] Encuesta Nacional de Ingreso y Gasto de los Hogares, http://www.inegi.gob.mx.

of the survey is to measure the activities undertaken by men and women within the household.[3]

With respect to the objective of this paper, the main advantage of this data set is that I observe both weekly child care time use by mothers, as well as weekly child care expenditures by the household.[4] The definitions for child care time use and expenditures are shown in Table 3.1. Notice that my definition of child-related expenditures not only refer to baby-sitting expenses or day care costs. It refers to all costs incurred by the household when children are present, especially little children.

3.3.1 Population of Interest

I am focusing on mothers less than 65 years old whose children are less than 18 years old. In the whole sample there are only 4054 families in which the wife is 65 years old or less. Of these families, only 3520 survived because there were children present. If the mother was a labor force participant but did not receive a monetary payment, the household was not included because I do not know the value of the non-monetary compensation she received instead. I eliminate outliers in terms of child care time use and wage rates. Also, I exclude observations with missing non-mother's labor income. The final sample includes 2696 households. Only 28% of the mothers in this sample participated in the labor market. Based on official Mexican data, 35% of all

[3]For a more complete description of the data please refer to Section 1.3.

[4]I also observe the child care time use of all other members of the household, including household personnel, but I have not yet used this information in the analysis.

Table 3.1: Child Care Time and Child Care Expenditures

Child Care	Definition
Mother's weekly hours dedicated to:	Help a household child to eat; bathe and dress a household child; play and talk with a household child; apply a special therapy to a household child; take care of a household child; help a household child with homework; attend school related meetings, festivals, etc.; and, take or pick up a family member to any place.
Household's weekly expenditures on:	Diapers; baby shampoo, baby soap, etc.; day care; additional learning classes; baby-sitter; children's apparel; children's shoes; baby's accessories; toys, games; and, baby food.

women 14 years or older participated in the labor market in 2002. The labor force participation in my sample is smaller because I restricted the sample to women with children.

In this sample I am including mothers who reported to be self-employed. Of the 28% who reported to be labor force participants, only 37% of them are self-employed. To construct the wage rate for this group, I divided the weekly income by the weekly hours of work.

3.3.2 Summary Statistics

Summary statistics of the variables used in the empirical analysis are in Table 3.2. The average age among mothers is 38. The mean mother's years of schooling is six, that is, the equivalent to completed primary school. In this sample, only 28% of mothers worked during the week before the interview. If they worked, they dedicated on average 36 hours in a week to the labor market. On average, mothers dedicate 17 hours in the week to child care activities. The log-wage rate for those mothers who work has a mean of 3.7, that is, 40 pesos per hour as of 2002. The household income without counting the mother's income is on average 2414 pesos a week. The average expenditures on child care are 51 pesos per week.[5] There is a 38% chance that the age of the youngest child is less than five years old, 11% chance that it is either five or six years

[5]Compared to the time mothers spent with their children, this is a very small. This average is also smaller than the weekly child care expenditures in Table 1.4. The reason is that in that definition child care expenditures included education expenses, which are excluded in this case.

old, and 24% probability that it is between 7 and 12 years old. On average, there are around two children less than 18 years old in the household. Finally, 70% of the households are located in urban areas.

Table 3.2: Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Mother's age	38.193	11.039	17	65	2696
Mother's years of schooling	6.416	4.294	0	23	2696
Mother's labor force participation	0.285	0.452	0	1	2696
Youngest child age 0-4	0.376	0.484	0	1	2696
Youngest child age 5-6	0.107	0.309	0	1	2696
Youngest child age 7-12	0.240	0.427	0	1	2696
Number of children age 0-11	1.384	1.256	0	7	2696
Number of children age 12-17	0.633	0.858	0	5	2696
Urban indicator	0.704	0.456	0	1	2696
Non-mother's log-weekly income[a]	7.789	0.985	2.657	11.451	2696
Mother's weekly child-care hours	16.895	24.545	0	148.5	2696
Household's weekly child care expenditures[a]/100	0.513	0.695	0	8.965	2696
Mother's log-wage rate[a]	3.740	1.093	0.223	9.360	769
Mother's weekly working hours	36.334	17.404	0.5	88	769

[a]In Mexican pesos as of 2002.

The most important characteristic of the sample is that a great proportion of these women do not participate in the labor market. For this reason, I expect non-mother's log-weekly income to play an important role not only in child care expenditures, but also in mother's child care time use.

3.4 Econometric Model

I am interested in estimating the effect of the wage rate (Y_1), i.e. the opportunity cost of time, in the mother's child care expenses in terms of time

(Y_2) and money (Y_3).

$$Y_1 = Z_1\beta_1 + u_1 \tag{3.1}$$

Let Y_1 denote the mother's log-wage rate determined by Z_1, a vector of exogenous and observable characteristics and an error term denoted u_1.

$$Y_2 = \alpha_2 Y_1 + Z_2\beta_2 + u_2 \tag{3.2}$$

Let Y_2 specifically refer to the mother's weekly child care time use. This time use is determined by the wage rate, a vector of exogenous characteristics denoted by Z_2, and the error term u_2.

$$Y_3 = \alpha_3 Y_1 + Z_2\beta_3 + u_3 \tag{3.3}$$

Similarly to previous equation, let Y_3, the household's weekly child care expenditures, be determined by the vector of demographic and household characteristics Z_2, as well as an error term denoted u_3.

The model is complicated because the wage rate appears as a regressor in the last two equations of the system and it is not always observed. Even though hours of work, child care time use, and child care related expenditures are always observed, the wage rate is only observed for those mothers with positive labor supply.

3.4.1 Reduced Form Model

The simplest way to estimate this model is by transforming the system above into a system of unrelated regressions (SUR) model by substituting the wage rate equation into the other two equations, that is, plug equation (3.1) into equations (3.2) and (3.3). By doing this, I obtain the following system.

$$Y_2 = Z_1\gamma_2 + Z_2\beta_2 + \varepsilon_2 \tag{3.4}$$

$$Y_3 = Z_1\gamma_3 + Z_2\beta_3 + \varepsilon_3 \tag{3.5}$$

I estimate this system by OLS equation by equation. Recall that system OLS estimation of a SUR model is equivalent to OLS equation by equation. All equations include state indicators. Table 3.3 has the results for the whole sample. Column A of that table displays the results for the mother's child care time use equation. I have that the variable related to the age of the mother, the indicators for the age of the youngest child, the number of children age 12-17, and the non-mother's log weekly household income are the variables with coefficients significantly different from zero. The effect of the mother's age in the child care time use is decreasing at an increasing rate. Most probably, this is related to the fact that as mothers get older, children also get older, therefore child care time decreases at an increasing rate.

Based on the indicators for the age of the youngest kid in the household, it is the case that mothers spend more time with their children when the last child is younger. Compared to the case where the youngest child is 13 years or older, mothers dedicate 25 more hours per week if their youngest child is less than five years old. If the youngest child is 5 or 6 years old, the mother spends 13 more hours to child care, relative to the comparison group. And if the child is between 7 and 12 years old, the increase in child care time use is 6 hours per week. This results are consistent with those obtained in Kalenkoski et al. (2009) and Kooreman and Kapteyn (1987).

Education is not significant although it has the expected sign. This means that more educated mothers, who perhaps earn higher wages and therefore have a higher opportunity cost of time, spend less time with their children. One more year of education decreases child care time use by less than half an hour. The number of children less than 12 years old is not significant but has the expected positive sign. More young children in the household require more time by the mother to take care of them. In contrast, a greater number of children between the ages of 12 and 17 decreases the mother's weekly time dedicated to child care, although the coefficient is only significant at 10% level. This is consistent with the idea that children in this range of ages require less care time from their mothers, or perhaps that they help their mothers to take care of younger children. The weekly non-mother's household income is significant at 1% level, and has a positive sign as expected. In fact, a ten peso increase in non-labor weekly income increases child care time use by 0.12%. This is consistent with the hypothesis that as the household income increases, the mother is less likely to work outside the home and will spend more time

Table 3.3: Child Care Time Use and Expenditures: Whole Sample

Variables	Time Use (A)	Expenditures (B)
Mother's age	-0.839**	0.0003
	(0.295)	(0.009)
Mother's age squared	0.008*	0.00002
	(0.003)	(0.0001)
Mother's years of schooling	-0.109	0.035**
	(0.115)	(0.003)
Urban indicator	-0.642	0.077*
	(1.029)	(0.031)
Youngest child age 0-4	24.645**	0.231**
	(1.978)	(0.059)
Youngest child age 5-6	13.424**	0.188**
	(2.044)	(0.060)
Youngest child age 7-12	6.292**	0.173**
	(1.492)	(0.045)
Number of children age 0-11	0.124	0.047**
	(0.513)	(0.015)
Number of children age 12-17	-1.002†	0.071**
	(0.552)	(0.016)
Non-mother's log-weekly income	1.289**	0.146**
	(0.488)	(0.015)
Intercept	21.488**	-1.029**
	(7.108)	(0.213)
State dummies	Yes	Yes
R^2	0.293	0.210
N	2696	2696

Significance levels : † : 10% $*$: 5% $**$: 1%. Standard errors in parenthesis. Column A: Corresponds to the mother's weekly child care time use equation estimated by OLS. Column B: Corresponds to the household's weekly child care expenditures equation estimated by OLS.

taking care of their children.

In Table 3.3 column B you will find the estimated coefficients for the household's weekly child care related expenditures. The variables with statistically significant coefficients are years of schooling, urban indicator, indicators for the age of the youngest child, number of children less than 12 years old, number of children between 12 and 17 years old, and the non-mother's income of the household. One more year of schooling by the mother increases child care expenditures in the household, but only by 4 pesos per week. This is most likely explained by the fact that more educated mothers earn higher salaries. If market goods related to child care are normal goods, then the household spends more money on them as income increases. Another possible explanation is that more educated mothers, have higher opportunity cost of time and substitute time with money in the production of child care. However, the coefficient for education in column A is not statistically different from zero. The urban indicator coefficient is positive and significant, but small in magnitude.

Child care expenditures are 23 pesos per week higher if the age of the youngest kid is less than 5 years old compared to the case where the youngest child is 13 years or older. If the youngest kid is five or six years old, or between 7 and 12 years old, the children expenditures are 19 and 17 pesos higher relative to the case in which the youngest kid is 13 years or older, respectively. The main reason the expenditures for younger children are higher is because most of the expenses included in the definition for child care related expenditures correspond to very young children.

If the number of children less than 12 years old increases by one, then expenditures related to children increases by 5 pesos; the coefficient is only significant, however, at the 10% level. For the variable number of children less than 18 years old but older than 11, the coefficient is significant at the 1% level, has positive sign, and is equal to 0.071. This is just as expected, the presence of children increases household expenditures and of course expenditures related to children, too.

As the non-mother's income increases, the child care related expenditures increase also. The coefficient is significant and it implies that a 10 pesos increase in such income augments child care expenditures around 1.5%. This is consistent with the perception that child care related market goods are normal goods, thus, expenses related to children increases when this income increases. Lastly, the variables related to the age of the mother are not significant in equation (3.3).

Recall that only 28% of the mothers in my sample participated in the labor market in the reference week, therefore, it is important to see whether there are differences between working and non-working mothers regarding time and money spent in child care. I estimate both the child care time and child care expenditure equations for working mothers and non-working mothers separately. The results are in Tables 3.4 and 3.5. A natural starting point is to test the coefficients between the two tables.[6] In general, the coefficients are

[6]The p-values for corresponding Wald tests using a pooled regression with complete set of interaction terms are available upon request.

not significantly different for working and non-working mothers. With respect to the child care time use, the only two coefficients that are significantly different between each other are those corresponding to mother's education and the urban indicator. Relative to child care expenditures, only the urban indicator coefficient is different between the two groups.

The results in Table 3.4 correspond to estimates of equations (3.4) and (3.5) for working women only. In the case of column A, which refers to mother's child care time use equation, the only insignificant coefficients are the variable relative to the number of children and the non-mother's log-weekly income. The effect of mother's age in the child care time use equation for the case of working mothers is negative at an increasing rate. However, it is only significant at 10%.

The variable years of schooling is significant at 5% level. The sign of the coefficient is positive, in contrast to the results for the whole sample. Working women increase the time dedicated to child care as they increase their years of schooling. The positive sign is explained by the hypothesis that more educated mothers are both more productive in the labor market and in home production, including child care. Then, mothers do not reduce the time dedicated to children as they increase their years of schooling. Working mothers in urban areas spend almost four hours less to child care than working mothers in rural areas.

With respect to the indicators for the age of the youngest child, the comparison group is again the indicator when the youngest child is 13 years

Table 3.4: Child Care Time Use and Expenditures: Only Working Mothers

Variables	Time Use (A)	Expenditures (B)
Mother's age	-1.080†	0.0007
	(0.596)	(0.027)
Mother's age squared	0.012†	0.000001
	(0.007)	(0.0003)
Mother's years of schooling	0.352	0.031**
	(0.166)	(0.007)
Urban indicator	-3.708†	0.195*
	(1.919)	(0.087)
Youngest child age 0-4	20.694**	0.308*
	(3.042)	(0.139)
Youngest child age 5-6	13.192**	0.176
	(3.058)	(0.139)
Youngest child age 7-12	5.179*	0.227*
	(2.304)	(0.105)
Number of children age 0-11	0.344	0.0096*
	(0.966)	(0.044)
Number of children age 12-17	-0.367	-0.053
	(0.923)	(0.042)
Non-mother's log-weekly income	0.080	0.182**
	(0.705)	(0.032)
Intercept	34.839**	-0.875
	(13.339)	(0.608)
State dummies	Yes	Yes
R^2	0.308	0.283
N	769	769

Significance levels : $\dagger$: 10% $*$: 5% $**$: 1%. Standard errors in parenthesis. Column A: Corresponds to the mother's weekly child care time use equation estimated by OLS. Column B: Corresponds to the household's weekly child care expenditures equation estimated by OLS.

or older. As before, mothers dedicate more time to children when they are younger. If the youngest child is young enough so that he or she is not required to go to school (less than 4 years old), the mother dedicates 21 hours per week to take care of children. If the child is either 5 or 6 years old, that is, he or she is required to attend pre-primary school, then the mother dedicates 13 hours per week to child care. The last indicator for the age of the youngest child is significant at 5% level. It is positive and smaller than the other two coefficients, indication that children in primary school age require less time than younger children.

For working women, household income excluding her own income is not significant, but the sign is positive as expected. Increases in income that has nothing to do with how many hours the mother works increases the hours dedicated to children. The other not significant variables are the two related to number of children.

In column B of Table 3.4 are the results relative to child care expenditures for working mothers only. The effect of years of schooling in child care expenditures for working mothers is positive and significant at 1% level. That is, mothers who work spend three more pesos in child care when years of schooling increase by one. The urban indicator is positive and statistically different from zero at the 1% level. That is, working mothers in urban areas spend 20 more pesos per week than working mothers in rural areas. With respect to the indicators for the age of the youngest child, working mothers also spend more money the younger the child.

Relative to the number of children less than 12 years old, the coefficient is positive and significant at 5% level. It means that child care expenditures increase in 10 peso when there is one more children less than 12 years old at home. The coefficient that corresponds to the number of children age 12 to 17 is also positive, but not significant. Finally, the measure of income without including mother's income is again positive and significant: an increase of 10 peso in non-mother's labor income increments child care expenditures by 1.8%. This is just as expected if child care related expenditures are normal goods.

In Table 3.5 I estimate the same OLS regressions as before, but restrict the sample to non-working mothers. With respect to child care time use (column A) age is decreasing at an increasing rate. If the mother is 35 years old, the child care time use per week decreases by 50 minutes. Again, this is probably related to the fact that older mothers have older children, and mothers spend less and less time with children as they get older.

It is the case that years of schooling has negative sign and it is significant at 10% level. That is, mothers who do not work spend less time in child care as they become more educated. For these mothers their opportunity cost of time is still high enough to not participate in the labor market currently, one more year of schooling increases the probability of participating in the labor market, which would make mothers spend less time in child care.

For non-working women, the non-mother's weekly income is equivalent to the household income. Therefore, the coefficient indicates that as income in the household increases, mothers also spend more time with their children. The

Table 3.5: Child Care Time Use and Expenditures: Only Non-Working Mothers

Variables	Time Use (A)	Expenditures (B)
Mother's age	-0.576†	-0.011
	(0.349)	(0.008)
Mother's age squared	0.005	0.0002†
	(0.004)	(0.0001)
Mother's years of schooling	-0.265†	0.022**
	(0.158)	(0.003)
Urban indicator	0.505	0.128
	(1.255)	(0.028)
Youngest child age 0-4	26.187**	0.177**
	(2.543)	(0.057)
Youngest child age 5-6	13.477**	0.131*
	(2.603)	(0.058)
Youngest child age 7-12	6.449**	0.116**
	(1.929)	(0.043)
Number of children age 0-11	-0.016	0.048**
	(0.614)	(0.014)
Number of children age 12-17	-1.219†	0.085**
	(0.687)	(0.015)
Non-mother's log-weekly income	1.702**	0.159**
	(0.661)	(0.015)
Intercept	13.095	-1.870**
	(8.688)	(0.195)
State dummies	Yes	Yes
R^2	0.295	0.198
N	1927	1927

Significance levels : $\dagger$: 10% $*$: 5% $**$: 1%. Standard errors in parenthesis.
Column A: Corresponds to the mother's weekly child care time use equation estimated by OLS. Column B: Corresponds to the household's weekly child care expenditures equation estimated by OLS.

result indicates that a ten peso increase in household income increases child care time use by 0.26%. Although the coefficient is greater for non-working mothers than for working mothers, the two coefficients are not significantly different from each other.

Just as in all previous results, the indicators for the age of the youngest child are positive, statistically significant, and the magnitude of the coefficient is smaller the older the youngest child. Comparing these coefficients with the corresponding ones for working mothers, it is the case that the coefficients are very similar in magnitude.[7] Even though working mothers have presumably less time to dedicate to children than non-working mothers, both groups increase child care time about the same number of hours according to the age of the youngest child.

Relative to child care related expenditures for non-working mothers, column B of Table 3.5, education is positive and significant. This implies that more educated non-working mothers spend more money in their children, although the coefficient is very small: one more year of schooling increases expenditures related to children by two pesos per week. Since these mothers are not labor force participants, the fact that they spend more money in children expenditures is related to the view that more educated mothers care more for their children and therefore spend significantly more monetary resources on them. With respect to the age of children, if the youngest child is less than

[7] In fact, they are not significantly different between each other.

5 years old, then non-working mothers spend 17 pesos per week more than mothers whose youngest child is 13 years or older. The coefficient is significant at 1% level. If the youngest child is either 5 or 6 years old, non-working mothers spend 13 pesos in child care than the comparison group. For the last category, child care expenditures increase in 12 peso and the coefficient is also significant at 1%. In comparison, in families where the mother participates in the labor market, the coefficients in the child care expenditures equation for the indicators of the age of the youngest child are much bigger than for non-working mothers.

It is also the case that non-working mothers spend more money on children as their non-labor income increases. The coefficient is in fact significant at 1% level. A 10 peso increase in such income augments child care expenditures by 1.6%. When comparing this effect to the corresponding effect for working mothers, it turns out that working mothers spend more money than non-working mothers as the non-mother's log-weekly income increases. However, the coefficients are not statistically different between each other.

Around 33% of the sample reported zero child care time use by mothers during the week of reference. Also, 19% reported zero expenditures related to children in the week of reference. Therefore, a Tobit model is more appropriate for equations (3.4) and (3.5). The resulting estimates are very similar to the ones reported here. The corresponding tables are available upon request.

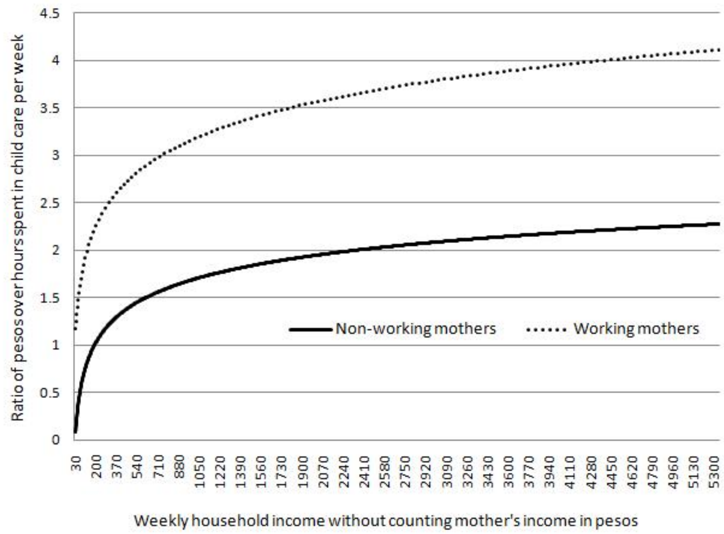
In summary, more educated mothers spend more money in child related expenditures.With respect to child care time use, working mothers spend more time with their children as their years of schooling increase. For non-working mothers, the effect is the opposite: more educated mothers spend less time with their children. As the household income without including mother's income increases, both time and expenditures dedicated to children increase. The only case the coefficient is not significant is in the case of the working mothers' child care time use equation. Regardless of whether women work or not, the age of the youngest child is very important in determining both time and monetary expenses related to child care.

3.4.1.1 Income Expansion Paths

Given that 71% of my sample of mothers do not participate in the labor market, non-mother's log-weekly income is a very important determinant of both child care time and money expenditures. It is interesting to see how time and money spent in child care varies as the household income without counting mother's income changes. Using the estimated equation from Tables 3.4 and 3.5 in Figure 3.1, I graph the predicted ratio of pesos over hours spent in child care per week at each possible level of non-mother's weekly household income both for working and non-working mothers.

The graphs indicate that for all levels of income, working mothers spend more money relative to time in child care. For example, if the non-mother's income is 2000 pesos per week, working mothers spent on average 3.5 times more money than hours in child care. For non-working mothers the ratio is equal to two if the household income is 2000 pesos per week.

Figure 3.1: Income Expansion Paths



According to the graph, the ratio of monetary expenditures over time expenditures increases as income increases but at an logarithmic rate. The income expansion path for non-working women is flatter than the corresponding path for working women. That is, at higher levels of household income, non-working mothers spend more time than money in child care than working mothers. This is just as expected because working mothers have less time to spend with their children than non-working mothers.

3.4.2 Tobit Selection Equation with Missing Explanatory Variable

Although the reduced form model results are very informative and useful as a first approximation to the data, one would like to estimate the system of equations (3.1)-(3.3) directly. In particular, I am interested in estimating the effect of the mother's wage rate on the mother's child care time use and household's expenditures in child care.

The problem is that wages are not observed for the entire sample. These women, one would expect, self-select into the labor force; in other words, only women with offered wage rates greater than their reservation wages will participate in the labor market.

In order to get consistent and $\sqrt{N}$-asymptotically normal estimates of the coefficients on equations (3.1)-(3.3), I use the econometric procedure described by Wooldridge (2002) in Section 17.5.2. The idea is to estimate a system of four equations. The first two are the structural equations of interest: equations (3.2) and (3.3). The third equation is a linear projection of the missing variable, which here corresponds to equation (3.1), and the fourth equation is the Tobit selection equation. In this case, this is the mother's labor supply equation.

First, I estimate the reduced form equation for the labor supply decision using a Tobit model for all observations. I then obtain the Tobit residuals for the selected sub-sample, that is only those women who participated in the labor force. The second step is to estimate the linear projection of the log-wage on all exogenous variables and the corresponding Tobit residuals for the selected sub-sample. Third, I estimate equations (3.2) and (3.3) by OLS with the predicted log-wage and the Tobit residuals as regressors, with years of schooling as the exclusion restriction, and using only the selected sub-sample.[8] To identify the effects of wages on time and goods expenditures, I exclude the mother's education from equations (3.2) and (3.3).

The coefficients for the reduced form labor supply using a Tobit model, the first step of this procedure, are in Table 3.6. Just as expected, the older the mother, the more hours she devotes to the labor market but at a decreasing rate. Mother's age effect reaches its maximum at 40 years. The mother's years of schooling is positive and significant. This is in accordance to the hypothesis that more educated women earn higher wages because their productivity in the labor market is higher, therefore they work more. The urban indicator is marginally significant and has positive sign. This implies that women living in urban areas work more hours in the labor market. In contrast to all previous results, the indicators for age of the youngest child are not significant in this case. It is well known that the presence of young children is expected to increase the reservation wage, lowering the probability of labor force participation; however I do not observe this effect in this table. This implies that Mexican mothers stay out of the labor market not because they have little children to take care of, but because perhaps their levels of schooling and experience do not permit them to participate in the labor market.

Notice that the coefficient for the youngest child being less than 5 years

[8] Usually the sample selection equation and the structural equation are the same. In such cases, the whole sample is used to estimate the equation of interest. In my paper this is not the case. Hence, to correctly estimate the structural equation I need to focus on the selected sub-sample for which the Tobit residuals are calculated.

Table 3.6: First Step: Tobit Selection Equation

Variables	Coefficient
Mother's age	6.242**
	(0.914)
Mother's age squared	-0.077**
	(0.011)
Mother's years of schooling	2.747**
	(0.310)
Urban indicator	17.531**
	(3.044)
Youngest child age 0-4	-6.436
	(5.394)
Youngest child age 5-6	2.208
	(5.404)
Youngest child age 7-12	-1.419
	(4.021)
Number of children age 0-11	-5.741**
	(1.527)
Number of children age 12-17	-0.546
	(1.531)
Non-mother's log-weekly income	-11.130**
	(1.324)
Intercept	-78.703**
	(21.126)
State dummies	Yes
Log-likelihood	-4855.903
N	2696

Significance levels : † : 10% $*$: 5% $**$: 1%.
Standard errors in parenthesis.

old indicator has negative sign and it is significant at 5% level. When children are very young and especially if they don't go to school yet, mothers dedicate less time to the labor market. This result is consistent with the negative and significant coefficient for the number of children less than 12 years old. One more child in age group decreases the hours dedicated to the labor market by mothers. With respect to the measure of income other than mother's income, the coefficient is negative and significant at 1% level. This is consistent with the idea that the reservation wage rises as non-labor income increases, making the mother less likely to participate in the labor market.

Table 3.7 shows the results for the linear projection of the log-wage on all exogenous variables and the Tobit residuals for the selected sub-sample. The variables that are statistically significant in this case are the variables related to age, mother's years of schooling, the non-mother's log-weekly income, and the residual. The effect of the mother's age in the log-wage equation is negative at an increasing rate. The linear effect is significant at 10% level, whereas the quadratic term is significant at 5% level. The mother's years of schooling coefficient implies that one more year of education increases the wage rate by 4%. The coefficient is significant at 1% level. When the non-mother's log weekly income increases by 10 peso, the mother's wage rate increases by 2.58%. This coefficient is significant at 1% level. The most important result here is that the coefficient for the Tobit residual coefficient is significant. Although the coefficient is negative, contrary to what I expected, it is very small. This means that the unobserved characteristics that motivate mothers to work

Table 3.7: Second Step: Log-wage Equation

Variables	Coefficient
Mother's age	-0.063†
	(0.033)
Mother's age squared	0.0001*
	(0.0004)
Mother's years of schooling	0.041**
	(0.011)
Urban indicator	-0.150
	(0.118)
Youngest child age 0-4	0.106
	(0.194)
Youngest child age 5-6	0.042
	(0.172)
Youngest child age 7-12	-0.123
	(0.139)
Number of children age 0-11	0.076
	(0.060)
Number of children age 12-17	-0.016
	(0.056)
Non-mother's log-weekly income	0.258**
	(0.049)
Residual	-0.020**
	(0.002)
Intercept	3.644**
	(0.776)
State dummies	Yes
R^2	0.387
N	769

Significance levels : $\dagger$: 10% $*$: 5% $**$: 1%.
Standard errors in parenthesis.

Table 3.8: Third Step: Structural Child Care Time Use and Expenditures

Variables	Time Use (A)	Expenditures (B)
Predicted mother's log-wage rate	4.362	0.932†
	(4.991)	(0.520)
Mother's age	-1.139	0.065
	(0.742)	(0.057)
Mother's age squared	0.012	-0.001
	(0.009)	(0.0007)
Mother years of schooling	-	-
	-	-
Urban indicator	-3.571†	0.356*
	(2.060)	(0.160)
Youngest child age 0-4	20.774**	0.187
	(3.245)	(0.265)
Youngest child age 5-6	13.017**	0.136
	(3.146)	(0.220)
Youngest child age 7-12	6.067*	0.328†
	(2.383)	(0.184)
Number of children age 0-11	0.192	0.018
	(1.058)	(0.094)
Number of children age 12-17	-0.304	0.068
	(0.961)	(0.075)
Non-mother's log-weekly income	-0.304	-0.083
	(0.961)	(0.197)
Residuals	0.025	0.021
	(0.129)	(0.013)
Intercept	25.007	-4.513*
	(23.551)	(2.085)
State dummies	Yes	Yes
R^2	0.275	-
N	769	769

Significance levels : $\dagger$: 10% $*$: 5% $**$: 1%. Standard errors in parenthesis. Column A: Corresponds to the mother's weekly child care time use equation estimated by OLS. Column B: Corresponds to the household's weekly child care expenditures equation estimated by OLS.

in the labor market decrease their wage rate.

The results for the third step of the procedure are in Table 3.8, that is, OLS estimates for the child care time use and expenditures using only the selected sub-sample and including the predicted mother's log-wage rate as an explanatory variable.[9] The identification strategy consists in excluding the years of schooling variable from the child care time use and expenditures equations, but including it in the log-wage linear prediction. Also, the Tobit residuals are included in both equations. Many regressors are not statistically significant. In the case of child care time use the indicators for the age of the youngest child are positive and significant. These contrast with the results for child care expenditures where only one indicator for the age of the youngest child is significant and at 10% level. In both cases, the coefficients are just as expected in terms of magnitude and sign. The urban indicator is significant in both columns, however the sign is negative in the time use equation and positive in the expenditure equation. They imply that mothers in urban areas spend less time and more monetary resources in child care than mother in rural areas. With respect to the predicted mother's log wage rate, the coefficient is positive and significant at 10% level. In the child care expenditures equation, a one peso increase in the wage rate increases child care expenditures by 0.93%. In the child care time use equation this variable is not significant and has positive sign.

[9] The standard errors in the log-wage and child care expenditure equation were corrected using bootstrap methods because the residuals were significant in both cases.

A natural fourth step would be to estimate the labor supply equation with the predicted wage as regressor. Following Wooldridge (2002), the correct way to do this is by estimating a Tobit model for hours of work where the predicted log-wage rate is included as regressor and years of schooling is excluded as the exclusion restriction. Such model is estimated using the whole sample. The results are just as expected, but the corrected standard errors are big for all variables. The results are available upon request.

3.5 Conclusions and Future Work

The main contribution of this paper is that it analyzes child care time use and child care expenditures simultaneously. This is possible because the 2002 Mexican time use survey is a sub-sample of the Mexican household survey which contains detailed information about household expenditures. The main results are the following. The age of the youngest child is the most important determinant of both child care time and money expenditures. It is the case that more educated mothers spend more money on their children: three and two pesos per week as years of schooling increases in one unit for working and non-working mothers respectively. With respect to child care time use, the results differ between the two groups. Working mothers increase the time they dedicate to children as they become more educated. In contrast, non-working mothers decrease the time they dedicate to children as they increase their years of schooling. At all levels of non-mother's income, working mothers spend significantly more money relative to time in child care than non-working mothers. For both groups the ratio of money over time increases at a decreasing rate; however, for non-working mothers the income expansion path is much flatter.

As a future extension to this paper, I will include the husband's child care time use and labor supply into the analysis. This can be easily incorporated because different uses of time are observed in the data and, in contrast to women, the wage rate is always observed for men in this sample. By doing this I can see the differences in changes of the opportunity cost of time for each spouse in labor supply, but more importantly in child care related time use for both husband and wife, and in child care related monetary expenditures. Another possible extension is to include other uses of time that are also available in the data set. For example, I can incorporate housework time and time dedicated to leisure activities.

Appendix

Appendix 1

Appendix to Chapter 1

A.1 Household Utility Maximization Problem

A.1.1 Step One

Given $\bar{Z}_j, q_j$, and w,

$$\min_{X_j, T_j} q_j X_j + wT_j \quad \text{such that } \bar{Z}_j = \left(X_j^{\theta_j} + T_j^{\theta_j}\right)^{\frac{1}{\theta_j}}.$$

The lagrangian is:

$$L = q_j X_j + wT_j + \eta_j \left(\bar{Z}_j - \left(X_j^{\theta_j} + T_j^{\theta_j}\right)^{\frac{1}{\theta_j}}\right).$$

Differentiate with respect to X_j, and T_j, we get first-order conditions:

$$q_j = \eta_j \left(\frac{1}{\theta_j}\left(X_j^{\theta_j} + T_j^{\theta_j}\right)^{\frac{1}{\theta_j}-1}\right)\theta_j X_j^{\theta_j - 1}, \quad w = \eta_j \left(\frac{1}{\theta_j}\left(X_j^{\theta_j} + T_j^{\theta_j}\right)^{\frac{1}{\theta_j}-1}\right)\theta_j T_j^{\theta_j - 1}.$$

Using the first-order conditions, we can get

$$\frac{X_j}{T_j} = \left(\frac{w}{q_j}\right)^{\frac{1}{1-\theta_j}}. \tag{1.1}$$

From the home production function $\left(\bar{Z}_j = \left(X_j^{\theta_j} + T_j^{\theta_j}\right)^{\frac{1}{\theta_j}}\right)$ and equation (1.1), we have:

$$X_j = \alpha_j \bar{Z}_j \tag{1.2}$$

$$T_j = \beta_j \bar{Z}_j \tag{1.3}$$

where $\alpha_j \equiv \left(1 + \left(\frac{p_j + s_j}{w}\right)^{-\frac{\theta_j}{\theta_j - 1}}\right)^{-\frac{1}{\theta_j}}$, $\beta_j \equiv \left(1 + \left(\frac{p_j + s_j}{w}\right)^{\frac{\theta_j}{\theta_j - 1}}\right)^{-\frac{1}{\theta_j}}$.

A.1.2 Step Two

$$\begin{aligned}&\max_{Z_0,Z_1,\cdots,Z_n} U\left(Z_0, Z_1, \cdots, Z_n\right)\\ &\text{such that } q_1X_1 + ... + q_nX_n = w\left(T - T_1 - ... - T_n - T_0\right) + M\end{aligned}$$

We can rewrite the budget constraint by using (1.2) and (1.3).

$$\begin{aligned}&q_1X_1 + ... + q_nX_n = w\left(T - T_1 - ... - T_n - T_0\right) + M\\ &\gamma_0Z_0 + \gamma_1Z_1 + ... + \gamma_nZ_n = wT + M\\ &\text{where } \gamma_j = \begin{cases} w & j = 0\\ q_j\alpha_j + w\beta_j & j = 1,..,n\end{cases}\end{aligned}$$

So the maximization problem is:

$$\max_{Z_0,Z_1,\cdots,Z_n} U\left(Z_0, Z_1, \cdots, Z_n\right) \text{ such that } \gamma_0Z_0 + \gamma_1Z_1 + ... + \gamma_nZ_n = wT + M.$$

Then solutions are $U_j = \lambda\gamma_j \quad$ for $j = 0, 1, .., n$ where λ is the lagrangian multiplier.

A.2 Optimal Government Policy Problem

A.2.1 Optimal Government Policy Problem

The Government problem is

$$\max_{s_1,\ldots,s_n} V\left(q_0, q_1, \cdots, q_n, w\right) \text{ such that } s_1X_1 + \cdots + s_nX_n = \bar{R}.$$

The lagrangian is:

$$L = V\left(q_0, q_1, \cdots, q_n, w\right) + \mu\left(s_1X_1 + \cdots + s_nX_n - R\right)$$

where μ is the lagrangian multiplier. Differentiate the Lagrangian with respect to $s_1, ..., s_n$. we get:

$$\frac{dL}{ds_k} = \frac{\partial V}{\partial q_k}\frac{dq_k}{ds_k} + \mu\left(X_k + \sum_{j=1}^{n} s_j\frac{\partial X_j}{\partial q_k}\frac{dq_k}{ds_k}\right) = 0 \text{ for } k = 1, ..., n.$$

Using $dq_k/ds_k = 1$, we get

$$\begin{aligned}\lambda\left(\frac{1}{\alpha_k}X_k\right)\frac{\partial\gamma_k}{\partial q_k} &= \mu\left(X_k + \sum_{j=1}^{n} s_j\frac{\partial X_j}{\partial q_k}\right)\\ \frac{\lambda\left(\frac{1}{\alpha_k}\frac{\partial\gamma_k}{\partial q_k}\right) - \mu}{\mu} &= \sum_{j=1}^{n}\frac{s_j}{X_k}\frac{\partial X_j}{\partial q_k}.\end{aligned}$$

Then using $\partial\gamma_k/\partial q_k = \alpha_k$, we have

$$\frac{\lambda-\mu}{\mu} = \sum_{j=1}^{n} \frac{s_j}{X_k}\frac{\partial X_j}{\partial q_k}. \tag{1.4}$$

With the property of slutsky equation and slutsky symmetry, equation (1.4) becomes

$$\frac{\lambda-\mu}{\mu} + \sum_{j=1}^{n} s_j \frac{\partial X_j}{\partial M} = \sum_{j=1}^{n} \frac{s_j}{X_k}\frac{\partial X_k^c}{\partial q_j}. \tag{1.5}$$

And the left hand side of equation (1.5) does not depend on k. So let $-\Theta \equiv \frac{\lambda-\mu}{\mu} + \sum_{j=1}^{n} s_j \frac{\partial X_j}{\partial M}$, then equation (1.5) is:

$$-\Phi = \sum_{j=1}^{n} \frac{s_j}{q_j}\varepsilon_{ki}^c \quad \text{where } \varepsilon_{ki}^c \equiv \frac{q_j}{X_k}\frac{\partial X_k^c}{\partial q_j} \tag{1.6}$$

A.2.2 Three-commodity Economy

To derive the property of compensated elasticity, we differentiate $\bar{U} = U\left(T_0, X_1, T_1, X_2, T_2\right)$ with respect to q_1. Then by using the envelope theorem and slutsky symmetry, we derive

$$\begin{aligned}
0 &= U_{T_0}\frac{\partial T_0^c}{\partial q_1} + U_{X_1}\frac{\partial X_1^c}{\partial q_1} + U_{T_1}\frac{\partial T_1^c}{\partial q_1} + U_{X_2}\frac{\partial X_2^c}{\partial q_1} + U_{T_2}\frac{\partial T_2^c}{\partial q_1} \\
&= \lambda w\frac{\partial T_0^c}{\partial q_1} + \lambda q_1\frac{\partial X_1^c}{\partial q_1} + \lambda w\frac{\partial T_1^c}{\partial q_1} + \lambda q_2\frac{\partial X_2^c}{\partial q_1} + \lambda w\frac{\partial T_2^c}{\partial q_1} \\
&= \frac{w}{X_1}\frac{\partial X_1^c}{\partial w} + \frac{q_1}{X_1}\frac{\partial X_1^c}{\partial q_1} + \frac{w}{X_1}\frac{\partial X_1^c}{\partial w} + \frac{q_2}{X_1}\frac{\partial X_1^c}{\partial q_2} + \frac{w}{X_1}\frac{\partial X_1^c}{\partial w} \\
&= \varepsilon_{11}^c + \varepsilon_{12}^c + 3\varepsilon_{10}^c.
\end{aligned}$$

Using $u\left(Z_0, Z_1, Z_2\right) = \delta_0 \ln Z_0 + \delta_1 \ln Z_1 + \delta_2 \ln Z_2$, let's calculate compensated demand.

$$\min \gamma_0 Z_0 + \gamma_1 Z_1 + \gamma_2 Z_2 \;\; s.t \;\; \bar{U} = \delta_0 \ln Z_0 + \delta_1 \ln Z_1 + \delta_2 \ln Z_2$$

Then we can obtain the following compensated demand function for X_1 and X_2:

$$X_1^c = \alpha_1 \bar{U} \left(\frac{\delta_1}{\delta_0}\frac{\gamma_1}{\gamma_0}\right)^{\delta_0} \left(\frac{\delta_1}{\delta_2}\frac{\gamma_2}{\gamma_1}\right)^{\delta_2}, \quad X_2^c = \alpha_2 \bar{U} \left(\frac{\delta_1}{\delta_0}\frac{\gamma_1}{\gamma_0}\right)^{\delta_0} \left(\frac{\delta_1}{\delta_2}\frac{\gamma_2}{\gamma_1}\right)^{\delta_2 - 1}$$

where $\alpha_j \equiv \left(1 + \left(\frac{q_j}{w}\right)^{-\frac{\theta_j}{\theta_j - 1}}\right)^{-\frac{1}{\theta_j}}$ for $j = 1, 2$. Then

$$\frac{w}{X_1^c}\frac{dX_1^c}{dw} = \frac{w}{\alpha_1}\frac{d\alpha_1}{dw} - \delta_0 \frac{w}{\gamma_0}\frac{d\gamma_0}{dw} + (\delta_0 - \delta_2)\frac{w}{\gamma_1}\frac{d\gamma_1}{dw} + \delta_2 \frac{w}{\gamma_2}\frac{d\gamma_2}{dw} \tag{1.7}$$

$$\begin{aligned} \frac{w}{X_2^c}\frac{dX_2^c}{dw} = {} & \frac{w}{\alpha_2}\frac{d\alpha_2}{dw} + \delta_0 \frac{w}{\gamma_1}\frac{d\gamma_1}{dw} - \delta_0 \frac{w}{\gamma_0}\frac{d\gamma_0}{dw} + (\delta_2 - 1)\frac{w}{\gamma_2}\frac{d\gamma_2}{dw} \\ & - (\delta_2 - 1)\frac{w}{\gamma_1}\frac{d\gamma_1}{dw} \end{aligned} \tag{1.8}$$

From equation (1.7) and (1.8),

$$\begin{aligned} \frac{w}{X_2^c}\frac{dX_2^c}{dw} - \frac{w}{X_1^c}\frac{dX_1^c}{dw} &= \left(\frac{w}{\alpha_2}\frac{d\alpha_2}{dw} - \frac{w}{\gamma_2}\frac{d\gamma_2}{dw}\right) - \left(\frac{w}{\alpha_1}\frac{d\alpha_1}{dw} - \frac{w}{\gamma_1}\frac{d\gamma_1}{dw}\right) \\ &= \frac{\frac{\theta_2}{1-\theta_2}}{1 + \left(\frac{w}{q_2}\right)^{\frac{\theta_2}{1-\theta_2}}} - \frac{\frac{\theta_1}{1-\theta_1}}{1 + \left(\frac{w}{q_1}\right)^{\frac{\theta_1}{1-\theta_1}}} \end{aligned}$$

This does not immediately translate into $\sigma_1 < \sigma_2 \rightarrow \varepsilon_{10}^c < \varepsilon_{20}^c$. However this result always holds if the price of the necessity (q_1) is lower than the price of the luxury (q_2). Even if the price of the necessity is higher than the price of the luxury, the result holds as long as the elasticity of substitution of Z_2 is sufficiently larger than that of Z_1. Conventional wisdom contends that a necessity tends to have a lower elasticity of substitution than a luxury. As shown empirically in Section 1.4, the elasticity of substitution for a necessity is significantly lower than that of a luxury.

A.3 Policy Implication

A.3.1 The Solution to The Household Maximization Problem

$$X_j^* = \alpha_j \tfrac{\delta_j}{\gamma_j} (wT + M), \;\; T_j^* = \beta_j \tfrac{\delta_j}{\gamma_j} (wT + M)$$

where $\alpha_j \equiv \left(1 + \left(\frac{q_j}{w}\right)^{-\frac{\theta_j}{\theta_j - 1}}\right)^{-\frac{1}{\theta_j}}$, $\beta_j \equiv \left(1 + \left(\frac{q_j}{w}\right)^{\frac{\theta_j}{\theta_j - 1}}\right)^{-\frac{1}{\theta_j}}$

and $\gamma_j = \begin{cases} w & if \quad i = 0 \\ q_j\alpha_j + w\beta_j & if \quad i = 1, 2. \end{cases}$

A.3.2 Six Equations and Six Unknown Parameters

We solved 6 equations simultaneously to get values of 6 unknown parameters. The six unknown parameters are $p_1, p_2, \delta_0, \delta_1, \delta_2, M$, and the six equations are: $T_0^* = 0.389$, $T_1^* = 0.178$, $T_2^* = 0.184$, $\frac{p_1 X_1^*}{p_2 X_2^*} = 0.838 \left(= \frac{389.77}{465.29}\right)$, $\sum_{i=0}^{2} \delta_i = 1$, $\sum_{i=1}^{2} q_i X_i^* = w \left(T - \sum_{i=1}^{2} T_i^*\right) + M$. Solving the system, we get $p_1 = 0.2493$, $p_2 = 0.4489$, $\delta_0 = 0.1962$, $\delta_1 = 0.3103$, $\delta_2 = 0.4936$, and $M = 0.9797$.

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