9-2015

Essays in Health Economics of Cigarette Consumption

Yan Song
Graduate Center, City University of New York

ESSAYS IN HEALTH ECONOMICS OF CIGARETTE CONSUMPTION

by

Yan Song

A dissertation submitted to the Graduate Faculty in Economics in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2015

This manuscript has been read and accepted for the Graduate Faculty in Economics in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

Dr. Michael Grossman

Date — Chair of Examining Committee

Dr. Wim Vijverberg

Date — Executive Officer

Dr. Michael Grossman

Dr. Wim Vijverberg

Dr. Inas R. Kelly

Supervisory Committee

The City University of New York

Abstract

Three Essays on the Demand for Cigarettes

by

Yan Song

Adviser: Professor Michael Grossman

This dissertation mainly consists of three essays of original research.

Therefore, Chapter 1, the primary focus of this essay is to use a long time series of state cross sections for the 1955-2009 time period in the United States in order to predict cigarette consumption. This essay updates estimates of the rational addiction model of cigarette consumption obtained by Gary Becker, Michael Grossman, and Kevin Murphy in their seminal 1994 American Economic Review paper. By using two types of prices, the cigarette price and the cigarette tax, and employing a cigarette demand function, I verify that smoking is a rationally addictive form of behavior. This is based on the theory that current smoking behavior is affected by both past and future smoking behaviors. Furthermore, I estimate long-run and short-run elasticities and find that the long-run elasticity is larger than that in the short run.

Chapter 2, the primary focus of this essay is to obtain new estimates of the price sensitivity of cigarette consumption and related outcomes using the 1979 cohort of the National Longitudinal Survey of Youth (NLSY79). This work expands on the existing literature on the topic by taking into account measures of time preference in the NLSY79 to examine interactions between these measures and price in the demand function for cigarettes. My specific hypothesis is that those who discount the future consequences of their current actions heavily are likely to be more sensitive to price than those who do not. I find that the people who discount the future heavily are more sensitive to price change.

Chapter 3, in this essay I explore the smoking behavior of pregnant women using the 1979 cohort of the National Longitudinal Survey of Youth (NLSY79). A key aspect of this research is the availability of smoking participation data before and during pregnancy. Thus, I consider the probabilities of quitting while pregnant as outcomes. I find that pregnant women who are cigarette consumers are less responsive to price changes because they are a future oriented group. Individuals who are more present-oriented are more likely to smoke and to consume more cigarettes given that they do smoke than those who are more future-oriented. Moreover, those who discount the future more heavily will be more sensitive to the money price of cigarettes than those who are more future-oriented. I find that a one percent change in the money price of

cigarettes represents a larger percentage change in the full price for the former group. I focus on the role of time preference and the interaction between time preference and price in determining these outcomes.

Acknowledgments

I feel very lucky that I can have the opportunity to study the economic knowledge from the excellent professors in the economics department.

I would like to thank my supervisor, Dr. Grossman, for his kindness, brilliance and guideness to lead me on the road of my research and my life. His excellent knowledge in the economics have always made me respect him so much.

I would like to thank my dissertation committee members, Dr. Wim Vijverberg, I appreciate him to teach all the econometrics details to me with all his patience.

I would like to thank my dissertation committee members, Dr. Inas R. Kelly, for her always being great helpful to my academic research and kind support.

I am very grateful to my family who give me the full support all the time.

Contents

List of Tables

List of Figures

Chapter 1

Rational Behavior in Cigarette Consumption: Evidence from the United States

1.1 Introduction

Despite overwhelming research on its damaging effects to human health, increased taxes and pricing, and an active societal campaign against it, people continue to smoke cigarettes and smoking endures as a social issue. Although some would attempt to explain this phenomenon through a myopic model of behavior which implies that current consumption is only affected by past consumption. However, I will argue that a rational behavior model, which emphasizes that both the future price and past consumption will affect current consumption, better accounts for this human activity.

In one of the more acclaimed studies, Becker et al. (1994), an empirical analysis related to cigarette demand, marshal empirical evidence from 1955 to 1985 to show that cigarette demand rises as prices decline. This study concludes that cigarette smoking is explained best by the rational behavior model. In this paper, I examine whether their results can be verified by extending the data from 1954 to 2009 (Tax Burden on Tobacco). At the same time, I will apply smoking participation–Behavioral Risk Factor Surveillance System (BRFSS)–as another type of consumption, seeking to verify the rational behavior model.

Instead of the myopic theory that addictive current consumption is affected only by past consumption, Becker and M.Murphy (1988) suggest that addictive current consumption is affected by past and future consumption. The empirical estimation implemented by Becker et al. (1994) uses a rational model and a myopic model with OLS and 2 SLS methods of estimation. These two papers represent the standard model for later rational behavior research.

In the 1970s, researchers suggested that, for addictive products, the influence of past consumption on current consumption is greater than that of future consumption on current consumption. In contrast, by using cigarette consumption data, citetBecker:1994 found that consumers behave in a rational additive manner, with past and future consumption affecting current consumption. Their paper demonstrated that higher future prices lead to lower current consumption, indicating forward-looking behavior.

However, Gruber and Koszegi (2001) assert that the addictive rational model is valid when time preference is held constant. If time preference varies, the "policy" of addictive cigarette consumption will change. Gruber and Koszegi develop an alternative model, in which they embed in the Becker-Murphy framework the hyperbolic discounting preferences provided by Laibson (1997). Becker et al. (1994) can be a special case of the Gruber and Koszegi (2001) model. In order to achieve better estimation, Becker et al. (1994) put proper restrictions on the discount factor (from 0.7 to 0.95). In contrast, instead of calibrate the discount factor, Gruber and Gruber and Koszegi (2001) estimate the value from the empirical data. While Gruber and Koszegi (2001) also used high frequency monthly data on cigarette consumption, they found that the new model and new data indicated that future prices have an effect on current consumption. The results are similar to those of Becker et al. (1994).

In order to test the applicability of the rational addictive and myopic models, researchers have employed various data. Instead of the state aggregate sales data used by Becker et al. (1994), Levy (2010) applies the individual-level annual data in the National Vitality Statistics Natality Data (NHIS). He finds that while young smokers only respond to the current cigarette price, mature smokers respond to both current and expected future prices. Labeaga et al. (1999) also applies the individual-level data to the Becker et al. (1994) model. Kim (2005) applies three measurements of consumption to myopic and rational models: the proportion of smokers, per capita consumption, and the average daily cigarette consumption of smokers.Lanoie and Leclair (1998) used Canadian data at the state level for the period from 1954 to 2009; Hu et al. (1994) analyzed data from 11 western states over the period 1967-1990; and in order to provide more intuitive explanations for addictive behavior, Suranovic et al. (1999) added quitting cost ("frustrated or anxious or restless") and the negative effects of smoking (later appearing in an individual's life) to the model. All of these studies support the rational addictive model and reject the myopic model.

Scholars have also employed different estimation models. Because individual level data yield a distribution for disturbance exhibiting non-constant variance, economists have resorted to a two-part model: first, a logit or probit specification and, second, an ordinary least squares (OLS) model. In practice, people subject the dependent variable of the OLS regression model to a logarithmic transformation in order to stabilize non-constant error variances. Mullaphy (1998), Manning (1998), Manning and Mullaphy (2001) and Tauras (2005) have each investigated the bias associated with using log-transformed dependent variables and conclude that the price coefficients obtained from a conditional demand equation are biased when using a traditional log-transformed dependent variable.

In sum, the literature suggests that cigarettes are addictive and, furthermore, that cigarette addiction follows the rational behavior model. In this study, I use a broader data set to verify this result, extending the Becker et al. (1994) data to include the years 1954 to 2009. I employ both the myopic and the rational behavior model and include two measures of consumption: (i) per capita cigarette consumption (in millions of packages) from state level annual data from 1954 to 2009 (Tax Burden on Tobacco); and (ii), annual smoking participation (current smoking status) data from 1984 to 2009 (BRFSS). The results show that a) smoking consumption is a rational addictive behavior and that b) as prices decrease, consumption increases significantly, but smoking participation does not change much. The results verify that cigarette consumption follows rational addictive behavior.

1.2 Empirical Work

1.2.1 Model

Following Becker et al. (1994), we assume a concave utility function as:

$$U(Y_t, C_t, C_{t-1}, e_t) \tag{1.1}$$

Consumers maximize their infinite life time utility:

$$Max \sum_{t=1}^{\infty} \beta^{t-1} U(Y_t, C_t, C_{t-1}, e_t) \tag{1.2}$$

subject to a lifecycle budget constraint

$$\sum_{t=1}^{\infty} \beta^{t-1} (Y_t + P_t C_t) = A^0$$

where: Y_t is the consumption of a composite commodity in period t; $C_t$is the number of packages of cigarettes consumed; β is the discount factor. e_t represents unobserved variables affecting utility (Becker et al., 1994). These unobserved variables cause an endogenous consumption problem, the reason the two stage least square estimate method is used later. A^0 represents the current wealth. By maximizing utility, we get the first order condition.

$$U_y(C_t, C_{t-1}, Y_t, e_t) = \lambda$$

$$U_1(C_t, C_{t-1}, Y_t, e_t) + \beta U_2(C_{t+1}, C_t, Y_{t+1}, e_{t+1}) = \lambda P_t \tag{1.3}$$

Rearranging the first order utility, results in the consumption equation, which is the regression equation:

$$C_t = \theta C_{t-1} + \beta \theta C_{t+1} + \theta_1 P_t + \theta_2 e_t + \theta_3 e_{t+1} \tag{1.4}$$

where: P_t is the current price of cigarettes, and $e_t$and e_{t+1} are "shift variables". This equation determines current cigarette consumption.

Equation (1.4) is the regression of rational addictive cigarette consumption. Equation (1.3) represents that marginal utility of current cigarette consumption (U_1), plus the discounted marginal effect on the next period utility of today's consumption (U_2), which is equal to the current price multiplied by the marginal utility of wealth (Becker et al., 1994). By concavity of U we know that θ_1 is negative. Equation (1.4) implies that increases in the current price decrease current consumption. If θ is positive, increases in past consumption and future consumption raise current consumption. So as past or future cigarette prices decrease, current consumption increases. In the myopic model, first-order condition does not include future utility (βU_2), so there is no future consumption term in equation (1.4). Therefore, the difference between rational and myopic models is that rational addictive individuals increase their current consumption as future prices are expected to fall, but myopic addictive individuals do not (Becker et al., 1994).

By following Becker et al. (1994) the effect of price in long-run on consumption is:

$$\frac{\partial C_\infty}{\partial P} = \frac{\theta_1}{\theta(1-\phi_1)(\phi_2-\phi_1)}$$

the short-run price effect is:

$$\frac{\partial C_t}{\partial P_t} = \frac{\theta_1}{\theta(1-\phi_1)\phi_2}$$

where

$$\phi_1 = \frac{1-(1-4\theta^2\beta)^{1/2}}{2\theta}$$

$$\phi_1 = \frac{1+(1-4\theta^2\beta)^{1/2}}{2\theta}$$

with $4\theta^2\beta < 1$ for stability.

1.2.2 Estimation Method

Following Becker et al. (1994), I use the myopic and rational addiction models. First, I perform an OLS regression to estimate normal results. However, due to missing observations, past consumption and future consumption may be correlated to the error term. Because all of the consumption data for the regression cannot be collected, unobserved consumption included in the error term is correlated to the independent variable "past and future consumption". This endogeneity problem requires the use of two-stage least square (2SLS) estimation. Because current consumption is unrelated to past and future prices when other variables are held constant, past and future prices can be used as instruments. Moreover, since excise taxes imposed on cigarettes are important exogenous factors determining cigarette prices, excise tax rates may also be used as instruments.

Following Becker et al. (1994), the same instruments for consumption will be applied in both the myopic and rational model price equations. In this case, tax refers only to state tax. For all other equations, tax includes federal and state tax.

1.2.3 Data

Data for prices, taxes and consumption come from Tax Burden on Tobacco (Volume 44, 2009). Data is at the state level for the period from 1954 to 2009. The tax instrument for consumption in the myopic and rational model price equations is state tax (Table 1, 2). For all others the tax instrument is (federal + state) tax. Price and tax have been adjusted for CPI increases (1967=100).

Fiscal years ending June 30 are used for prices, taxes and consumption. Price data are collected in November of each year. As taxes may vary by month and year, tax is matched to price by first subtracting tax from the November price, using data from Tax Burden on Tobacco (Volume44, 2009), then adding the change in tax for month and year to the corresponding monthly price. After getting the right monthly price (including tax), we collapse it into an annual price again.

Consumption is per capita annual sales (in millions of packs) of state tax-paid cigarettes from 1954 to 2009. The base period of CPI is 1967=100. Real Tax = (Federal + state) tax. Consumption is state Tax-paid Cigarette Sales (in millions of packs).

Data for smoking participation comes from the Behavioral Risk Factor Surveillance System (BRFSS). Smoking participation (current smoking status) is annual from 1984 to 2009. Smoking participation represents current smoking status. I refer to those people who smoke every day and those who smoke on some days as "current smokers"; people no longer smoking and people who never smoked are referred to as "nonsmokers".

Data for state level per capita income come from the Statistical Abstract of the United States and data are available from 1955 to 2009, so this income variable is used as an exogenous variable in the regression. The data constitute a panel of the 50 states of the U.S. over time.

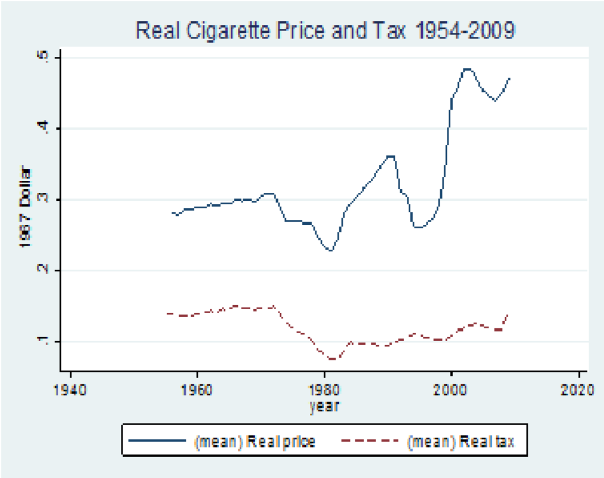

Figure 1.1: Real Price and Tax Data Distribution. Note:the base period of CPI is 1967=100; Real Tax = (Federal + state+county) tax.

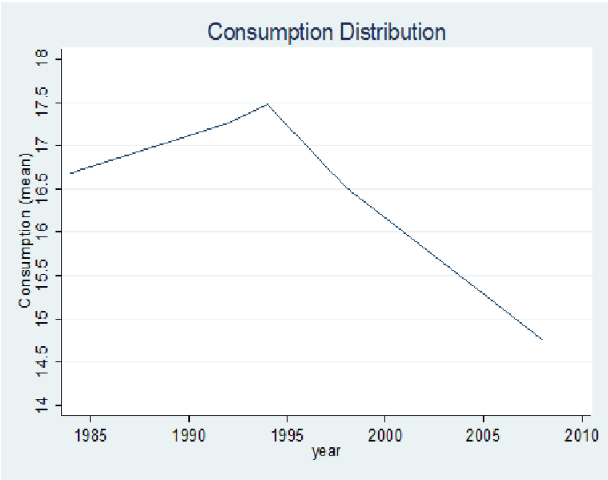

Figure 1.2: Daily Cigarette Consumption Distribution.1984 to 2008.

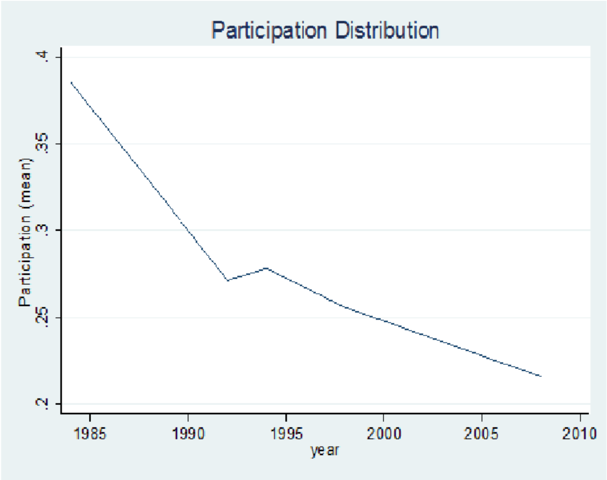

Figure 1.3: Participation Distribution.Note: In 1984, "smoked 100 cigarettes in lifetime" was not part of the questionnaire, which may affect the measure of participation for 1984.

1.2.4 Empirical results

According to Becker et al. (1994), if a positive past consumption coefficient is significant, holding other variables constant, then this consumption follows addictive behavior. Larger values of the past consumption coefficient (θ) mean greater degrees of addiction. From the consumption regression (Table 1.1), one can see that the past consumption, real cigarette price and income coefficients are significant. Therefore, cigarettes are addictive both in terms of consumption and smoking participation in the myopic model.

In Table (1.1), there are fewer observations in column (4) than in column (2) and (3) because the instruments in column (4) include additional second lag taxes and second lag prices. The more lags used, the more observations are lost and, therefore, there are fewer observations in the results.

Elasticity shows that, as current prices increase by 10 percent, cigarette consumption decreases by 3.5 percent in the short-run and 12 percent in the long-run; cigarette participation decreases by 0.1 percent in the short-run and 0.5 percent in the long-run.

The coefficient of past participation is greater than that of consumption, indicating that smoking participation is more addictive than consumption. Insignificant elasticity suggests that price does not have a significant effect on smoking participation. This result is similar to the finding of Kim (2005) (page 56)

In the consumption equation (Table 1.2), past and future consumption, real cigarette price,

Table 1.1: Myopic Models (Price).

	Consumption Equation				Participation Equation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Past Consumption	0.92***	0.64***	0.72***	0.77***	-	-	-	-
	(0.01)	(0.056)	(0.078)	(0.058)				
Past Participation	-	-	-	-	0.29***	0.82 ***	0.90 ***	0.70 ***
					(0.043)	(0.13)	(0.112)	(0.116)
Real price	- 0.54 ***	-1.435***	1.18***	-1.00 ***	-0.00013	-0.00005	-0.00005	-0.0009
	(0.092)	(8.211)	(0.25)	(0.209)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
Income	- 0.06	-0.434***	-0.328***	-0.26***	5.49e-06	-0.00007	-0.00008	-0.0002
	(0.051)	(0.187)	(0.172)	(0.150)	(0.0002)	(0.0012)	(0.0001)	(0.0002)
R^2	0.98	0.96	0.97	0.97	0.85	0.80	0.78	0.80
F_{IV}	-	51.19	23.81	15.18	-	4.47	3.40	2.69
(P-value)		0.00	0.00	0.00		0.039	0.04	0.041
Wu-F(endog)	-	39.94	39.95	26.74	-	2.64	4.30	3.80
(P-value)		0.00	0.00	0.00		0.11	0.043	0.057
χ^2(overid)	-	-	94.02	127.82	-	-	0.53	4.00
(Sargan P-val)			0.00	0.00			0.46	0.26
LR elasticity	-1.87***	-1.154***	-1.215***	-1.261***	-0.304	-0.052	-0.074	-0.049
	(0.338)	(0.22)	(0.25)	(0.259)	(0.068)	(0.156)	(0.27)	(0.098)
SR elasticity	-0.16***	-0.425***	-0.349***	-0.298***	-0.022	-0.009	-0.007	-0.015
	(0.027)	(0.067)	(0.074)	(0.062)	(0.050)	(0.028)	(0.028)	(0.028)
Regression	OLS	2sls	2sls	2sls	OLS	2sls	2sls	2sls
State Year Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2688	2645	2645	2600	1071	1071	1071	969

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Significant level at 5 %: F(1,50)=4.03: F(2,50)=3.18; F(3,50)=2.79; F(4,50)=2.56; $\chi^2(1)$=3.84; $\chi^2(2)$=5.99; $\chi^2(3)$=7.81;

In the consumption equation, tax is state tax. In the participation equation tax is (federal + state) tax.

First IV (2) (6) is just identifying restriction, so there is no over identifying test.

In over-identifying tests, the consumption IV (3) (4) equation results show that the null of over-identifying restriction valid is rejected (p-value=0.00), which means over-identifying instrument IV (3) (4) may not be valid. Similar results appear in all the over-identifying instrument tests for consumption (including price and tax, myopic and rational model).

The Instruments: (in the consumption equation) in column (2) past price; in column (3) past price, current state tax, past tax; in column(4) past price, current state tax, past tax, second lag tax, second lag price.

The Instruments: (in the participation equation) in column (6) first lag tax; in column (7) one lag tax, one lead tax; in column (8) one period lag tax, first and second and third period lead tax.

Table 1.2: Rational Models (Price).

	Consumption Equation				Participation Equation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Past Consumption	0.49*** (0.004)	0.579*** (0.087)	0.39*** (0.046)	0.54*** (0.044)	-	-	-	-
Future Consumption	0.49*** (0.003)	0.095*** (0.106)	0.48*** (0.060)	0.309*** (0.074)	-	-	-	-
Past Participation	-	-	-	-	0.20*** (0.033)	0.65 *** (0.213)	0.55 *** (0.217)	0.47 *** (0.201)
Future Participation	-	-	-	-	0.26*** (0.033)	0.25 *** (0.261)	0.33 *** (0.364)	0.43 *** (0.401)
Real price	- 0.24 *** (0.041)	-1.359*** (0.169)	-0.649*** (0.166)	-0.738 *** (0.181)	-0.0001 (0.0003)	-0.0001 (0.0001)	-0.0001 (0.0001	-0.001 (0.0001)
Income	- 0.017 (0.011)	-0.400*** (0.154)	-0.151*** (0.08)	-0.171*** (0.096)	0.00026 (0.0002)	0.0001 (0.0001)	0.00009 (0.0001)	0.0001 (0.0001)
R^2	0.98	0.97	0.98	-0.98	0.85	0.81	0.82	0.82
F_{IV_t-1} (P-value)	-	29.19 0.00	20.78 0.00	15.86 0.00	-	4.30 0.019	2.15 0.088	2.59 0.063
F_{IV_t+1} (P-value)	-	17.20 0.00	11.14 0.00	9.76 0.00	-	3.35 0.043	6.28 0.0004	2.22 0.097
Wu-F(endog) (P-value)	-	29.84 0.00	12.20 0.00	11.40 0.0001	-	1.60 0.21	1.11 0.34	1.11 0.34
χ^2(overid) (Sargan P-value)	-	-	101.48 0.00	174.69 0.00	-	-	1.97 0.37	2.47 0.12
LR elasticity	-4.451*** (1.491)	-1.206*** (0.234)	-1.372*** (0.31)	-1.389*** (0.313)	-0.036 (0.077)	-0.190 (0.38)	-0.149 (0.334)	-0.146 (0.481)
SR elasticity	-0.658*** (0.027)	-0.548*** (0.110)	-0.376*** (0.120)	-0.501*** (0.131)	-0.010 (0.020)	-0.050 (0.062)	-0.050 (0.061)	-0.044 (0.065)
Regression	OLS	2sls	2sls	2sls	OLS	2sls	2sls	2sls
State Year Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2688	2594	2594	2594	1071	1071	1071	966

Significant level at 5 %: F(1,50)=4.03; F(2,50)=3.18; F(3,50)=2.79; F(4,50)=2.56; $\chi^2(1)=3.84$; $\chi^2(2)=5.99$; $\chi^2(3)=7.81$;
Tax is using state tax only for consumption instrument.
In consumption IV (3) (4) equation estimates cannot reject the null of over identifying restriction being valid (p-value = 0.00), which means over identifying instrument may not be valid.
Instruments: (in the consumption equation) in column (2) lag price, lead price; in column(3) lag price, lead price, current tax, lag tax; in column(4) lag price, lead price, current state tax, lag tax, lead tax.
Instruments: (in the participation equation (tax is using federal and state tax)) in column(6) past tax, second lead tax; in column(7) lag tax, second lag tax, one lead tax, second lead tax; in column (8) lag tax, second lag tax, third lead tax.

and income are significant. If past and future consumption positively correlate with current consumption, it indicates that the rational addictive model applies to cigarette smoking. It also indicates that myopic theory does not apply, since this theory suggests that only past consumption "reinforces" current consumption. Even though positive past and future consumption correlate significantly with current consumption, the estimated results are not very robust support for rational theory. Assuming a time preference discount factor equal to the interest rate, the estimated discount factor β (the ratio of the coefficient of future consumption to the coefficient of past consumption) should be equal to 1/(1+r) (r is the estimated interest rate). The purpose of the discount factor is to examine whether the estimatedβ fits the real world or not. A discount factor β between 0.7-0.95 and r between 3-40 percent is good. However, in consumption equations our discount factors range from 0.164 to 1.23, corresponding to r from -18.7 to 509.7 percent. The best discount factor, which comes from column (4), is 0.572 corresponding to an r of 74 percent. The wide range of discount factors suggest that the interest rate is "implausible". According to Becker et al. (1994), this "implausible" phenomenon can be accounted for by future price changes.

In the smoking participation equation the coefficient of future consumption is insignificant. Thus, it does not support the rational theory.

In the consumption equation, elasticity shows that as the current price increases by 10 percent, cigarette consumption decreases by 5 percent in the short-run and by 13 percent in the long-run. In Becker et al. (1994), as the current price increases by 10 percent cigarette consumption decreases by 4 percent in the short-run and by 7 percent in the long-run.

In the participation equation, elasticity shows that as the current price increases by 10 percent cigarette consumption decreases by 0.5 percent in the short-run and by 1.5 percent in the long-run.

Evans et al. (1999) show that by using *The Tax Burden On Tobacco*, the coefficient of nominal tax on average cigarette retail price is 1.01 and the coefficient of real tax on price is 0.92, which implies that a one cent change in taxes will cause approximately same amount change in prices. They also point out that replacing price with taxes can directly capture the variation sourcing from taxes for prices across states excluding other endogenous market factors.

In table 1.3, using tax data, past consumption, future consumption and price are all significant in the consumption equation but not in the participation equation. There is evidence of rational addictive behavior in the tax consumption equation as well as in the smoking participation OLS

Table 1.3: Myopic Models (Tax=federal+state tax).

	Consumption Equation				Participation Equation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Past Consumption	0.93*** (0.01)	0.505*** (0.085)	0.55*** (0.086)	0.55*** (0.058)	-	-	-	-
Past Participation	-	-	-	-	0.28*** (0.045)	1.70 (8.51)	0.50 (0.36)	0.12 (0.23)
Real cigarette tax	- 0.36*** (0.156)	-1.385*** (0.39)	- 1.44*** (0.47)	-1.72 *** (0.587)	-0.0006 (0.0003)	** -0.003 (0.0077)	-0.0004 (0.0004)	-0.0008 ** (0.0004)
Income	- 0.016 (0.051)	-0.471*** (0.279)	-0.446*** (0.276)	-0.48*** (0.279)	0.00005 (0.0003)	-0.00003 (0.0011)	0.0001 (0.0003)	0.0001 (0.0005)
R^2	0.98	0.94	0.95	-0.95	0.85	0.17	0.83	0.83
F_{IV} (P-value)	-	24.187 0.00	11.52 0.0001	8.28 0.00	-	0.087 0.76	1.25 0.30	1.51 0.21
Wu-F(endog) (P-value)	-	57.75 0.00	42.09 0.00	49.43 0.00	-	0.587 0.447	0.358 0.55	0.187 0.67
χ^2(overid) (Sargan P-val)	-	-	27.33 0.00	27.39 0.00	-	-	1.41 0.49	2.65 0.45
LR elasticity	-0.52*** (0.190)	-0.294*** (0.112)	-0.337*** (0.12)	-0.395*** (0.121)	-0.038*** (0.016)	-0.044*** (0.013)	-0.040*** (0.019)	-0.043*** (0.017)
SR elasticity	-0.039*** (0.017)	-0.148*** (0.042)	-0.152*** (0.05)	-0.178*** (0.061)	-0.027 ** (0.012)	-0.119 (0.368)	-0.020 (0.018)	-0.038** (0.016)
Regression	OLS	2sls	2sls	2sls	OLS	2sls	2sls	2sls
State Year Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2689	2688	2637	2600	1071	1071	1020	969

Significant level at 5 %: F(1,50)=4.03; F(2,50)=3.18; F(3,50)=2.79; F(4,50)=2.56; $\chi^2(1)$=3.84;$\chi^2(2)$=5.99; $\chi^2(3)$=7.81;

Instruments: (in consumption equation) in column (2) lag tax; in column (3) lag tax, lead tax; in column (4) lag tax, first , second and third lead tax;

Instruments: (in participation equation) in column (6) second lag tax; in column (7) lag tax, lead tax, second lead tax; in column (8) lag tax , first and second and third lead tax.

Table 1.4: Rational Models (Tax=federal+state tax).

	Consumption Equation				Participation Equation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Past Consumption	0.49*** (0.004)	0.949*** (0.383)	0.35*** (0.081)	0.54*** (0.075)	-	-	-	-
Future Consumption	0.49*** (0.004)	-0.99 (0.738)	0.42*** (0.136)	0.154*** (0.044)	-	-	-	-
Past Participation	-	-	-	-	0.20*** (0.033)	0.44 (0.456)	0.31 (0.34)	0.42 (0.467)
Future Participation	-	-	-	-	0.25*** (0.035)	0.35 (0.33)	0.20 (0.42)	0.15 (0.451)
Real cigratte tax	- 0.213 *** (0.06)	-3.12*** (0.724)	-0.973*** (0.473)	-1.196 *** (0.416)	-0.0005* (0.0003)	-0.0002 (0.0004)	-0.0004* (0.0002)	-0.0003 (0.0003)
Income	- 0.036 * (0.019)	-1.099 (0.888)	-0.21 (0.146)	-0.371 (0.198)	0.00005 (0.0003)	0.00009 (0.0002)	0.00007 (0.0003)	0.00008 (0.0002)
R^2	0.99	0.76	0.98	0.97	0.85	0.84	0.85	0.84
F_{IV_t-1} (P-value)	-	11.52 0.0001	10.55 0.00	10.71 0.00	-	2.32 0.109	1.31 0.28	1.72 0.18
F_{IV_t+1} (P-value)	-	3.79 0.029	12.45 0.00	7.26 0.00	-	1.04 0.36	2.98 0.028	2.25 0.09
Wu-F(endog) (P-value)	-	19.78 0.00	20.16 0.00	31.73 0.0001	-	0.34 0.71	0.056 0.95	0.13 0.88
χ^2(overid) (Sargan P-val)	-	-	53.07 0.00	74.96 0.00	-	-	1.97 0.37	1.21 0.27
LR elasticity	-1.691*** (0.626)	-0.316*** (0.121)	-0.438*** (0.120)	-0.408*** (0.124)	-0.040* (0.023)	-0.040 (0.051)	-0.038 (0.026)	-0.035 (0.028)
SR elasticity	-0.641*** (0.182)	-0.494*** (0.185)	-0.366** (0.23)	-0.493*** (0.199)	-0.010 (0.007)	-0.015 (0.044)	-0.014 (0.021)	-0.016 (0.030)
Regression	OLS	2sls	2sls	2sls	OLS	2sls	2sls	2sls
State Year Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2638	2637	2535	2492	1071	1071	1071	1017

All tests are added robust test (cluster). Tax is using state tax only for consumption instrument.

In consumption IV (3) (4) equation estimates cannot reject the null of over identifying restriction being valid (p-value = 0.00), which means over identifying instrument may not be valid.

Instrument: (in consumption equation) in column (2) lag tax, lead tax; in column (3) lag tax, second and third lead tax; in column (4) lag tax, second lag tax, first and second and third lead tax;

Instrument: (in participation equation) in column (6) lag tax, second lead tax. In column (7) lag tax, second lag tax, first and second lead tax; in column (8) lag tax, second lag tax, second lead tax.

regression. Evidence of addictive behavior in smoking participation was found in the 2sls model, but not in the OLS regression. Thus, the consumption equation supports rational addictive behavior, but the smoking participation data does not. This only occurs in the OLS regression, but because C_{t+1} is endogenous (as is C_{t-1}), OLS estimates are biased and therefore less credible than 2SLS estimates.

Price is significant and negatively correlated to consumption in the consumption equation. However, in the smoking participation equation there was not a significant and negative relationship between price and consumption as there was in the price estimation.

Long-run price elasticity was smaller in both the tax consumption and tax smoking-participation equations than in the price regression.

1.3 Robustness test.

In order to check whether the estimation is correct, the regression results were compared toBecker et al. (1994) results from the same time period. The original data of Becker et al. (1994) were consumption, price and income. It shows that the price coefficient is similar.

Comparing the results to the Becker et al. (1994) data (Table 1.5), the 2sls price coefficient is around 2.7 and the data price coefficient is 2.9, resulting in a price coefficient close to Becker et al. (1994). In my data, the income coefficient is somewhat greater than that of the BGM Becker et al. (1994) data. One possible reason is that the original income data was recently adjusted by an updated measurement, so that the income data collected now is different from that of a few years ago. The above results suggest that the data used here are similar to the data used by Becker et al. (1994) and no bias estimation was caused by the data.

Finally, I compare the real price and income coefficients from the period before (and including) 1985 (the end year for the regression used by Becker et al. (1994)) to the period after 1985. If the coefficients are significantly different, it will suggest that the characteristics of the data before and after 1985 are different. The Wald test shows that the two real price coefficients and the income coefficients are significantly different. Ordinarily, income has a positive effect on consumption, but some later period income coefficient become negative. This difference, however, does not invalidate the conclusions. As more information has become available about the harmful effects of smoking since 1980s, the relationship between income and smoking has switched from positive to negative: instead of a normal good, cigarette consumption has become an inferior good.

Table 1.5: Myopic Models of Addiction (Dependent Variable =Consumption).

	OLS		2SLS (IV=Past price)	
	BGM [1994]	My data	BGM [1994]	My data
Past Consumption	0.824***	0.831***	0.519***	0.516***
	(0.012)	(0.011)	(0.042)	(0.041)
Real Price	- 1.433 ***	-1.500***	-2.698***	-2.920 ***
	(0.101)	(0.105)	(0.206)	(0.218)
Income	0.272 ***	0.197***	0.698 ***	0.378 ***
	(0.098)	(0.082)	(0.132)	(0.107)

Note: standard Error in Parentheses.

Table 1.6: Rational Models of Addiction (Dependent Variable =Consumption.

	OLS		2SLS (IV=Past and Future price, past and current tax)	
	BGM [1994]	My data	BGM [1994]	My data
Past Consumption	0.489***	0.492***	0.388***	0.404***
	(0.014)	(0.013)	(0.050)	(0.049)
Future Consumption	0.468***	0.467***	0.175***	0.162***
	(0.014)	(0.014)	(0.061)	(0.057)
Real Price	- 0.604 ***	-0.651***	-2.413***	-2.600 ***
	(0.080)	(0.083)	(0.230)	(0.233)
Income	0.171 ***	0.102***	0.669 ***	0.346 ***
	(0.098)	(0.062)	(0.122)	(0.095)
Price Elasticity	-	-	0.566 ***	0.578***
			(0.054)	(0.052)

Table 1.7: Myopic Models of Addiction (Wald Test).

	OLS			2SLS (IV=Past price)		
	My data (Year<=1985)	My data (Year>1985)	Wald Test (P-value)	My data (Year<=1985)	My data (Year>1985)	Wald Test (P-value)
Past Consumption	0.898***	0.887***	0.37	0.487***	0.685***	3.13
	(0.012)	(0.018)	(0.545)	(0.062)	(0.121)	(0.077)
Real Price	- 0.837 ***	-0.269***	16.90***	-2.699 ***	-0.368	21.57
	(0.148)	(0.086)	(0.0001)	(0.411)	(0.308)	(0.000)
Income	0.188 **	-0.090*	28.62***	0.568 *	- 0.574 ***	24.02
	(0.072)	(0.048)	(0.000)	(0.299)	(0.191)	(0.000)

Table 1.8: Rational Models of Addiction (Wald Test).

	OLS			2SLS		
	My data (Year<=1985)	My data (Year>1985)	Wald Test (P-value)	My data (Year<=1985)	My data (Year>1985)	Wald Test (P-value)
Past Consumption	0.496*** (0.004)	0.486*** (0.007)	1.85 (0.180)	0.417*** (0.067)	0.327*** (0.121)	0.39 (0.532)
Future Consumption	0.481*** (0.007)	0.493*** (0.004)	2.55 (0.112)	0.239 (0.094)	0.551*** (0.207)	3.04 (0.081)
Real Price	- 0.376 *** (0.062)	-0.125*** (0.039)	18.93 (0.0001)	-2.017 *** (0.304)	-0.092 (0.212)	35.25 (0.000)
Income	0.070*** (0.024)	0.004 (0.015)	8.04 (0.007)	0.297 (0.255)	- 0.376*** (0.125)	6.55 (0.011)

2SLS (IV=Past and Future price,Past and current tax)

1.4 Conclusion

The results suggest two conclusions. First, smoking is a rational addictive behavior in the consumption equation. Smoking participation has a higher degree of addiction than consumption in the myopic model, but not in the rational model. Second, decreasing prices significantly increases consumption in the consumption equation, but not in the smoking participation equation. Long-run elasticity is greater than short run elasticity. The consumption long-run price elasticity (-1.3) is greater than Becker et al. (1994)'s finding (-0.7). This result may be due to the longer period of data. Three other variables used by Becker et al. (1994) were omitted and the Wald test shows that the parameter of price, past and future consumption, and income have been changed since 1985, so the results cannot be compared to Becker et al. (1994). One reason for using tax instead of price is to compare long-run elasticities. Since tax is just a component of price, the long-run elasticity of price is greater than that of tax. Price elasticity is more dominant than that of the tax. From the data, this result can be seen by comparing the long-run elasticities in the table. Another reason is that tax is a more exogenous variable than price. Price is an outcome variable of the supply and demand that drive the cigarette market and, as such, is endogenous. Tax rates are set by policy makers, not in response to demand conditions. Thus, a change in the disturbance does not generate a change in tax rates, but may well generate a change in prices. It can be clearly observed to be a strong instrument for consumption and participation regression. Therefore, price and tax can be used as instruments in price regression, but only tax can be used as an instrument in tax regression.

Two measures of consumption are applied because consumption (from 1954 to 2009, Tax Burden on Tobacco) and smoking participation (BRFSS) have different characteristics. Past participation has a greater influence on current participation than it does on future participation. Since participation has only two discrete choices (smoking or not smoking), past smoking affects current smoking status, but future smoking does not influence current smoking. The data show that participation is more addictive in the myopic model and not addictive in the rational model in 2 SLS (Table 1.1, 1.2). Furthermore, since participation has only two discrete choices, price changes will not affect participation very much. The results clearly show that price has an insignificant effect on participation (Table 1.1, 1.2). There is a discount factor restriction test Becker et al. (1994) and Gruber and Koszegi (2001), which implies that time-preference change might affect the result of rational behavior. In future research I will examine those tests to see how time-preference difference affects rational model consequences.

Chapter 2

The Effect of the Interaction Between Price and Time Preference on Cigarette Consumption

2.1 Introduction

It is common knowledge that when the price of a good rises, the quantity demanded of the good falls. This relationship between price and quantity demanded is true for most goods in the economy, and even though cigarettes are addictive goods, this downward-sloping demand law still fits well (Becker et al., 1994). Because each person has a different time preference with regard to increases in cigarette price, this paper seeks to understand how price affects cigarette consumption when the individual measure of time preference interacts with price in the demand function for cigarettes.

When considering economic problems, one cannot ignore issues of psychology (Mankiw, 2009). In the economic world, everyone faces trade-offs. In order to acquire something one likes, one must give up another thing one likes, and different people have different attitudes about trade-off decisions. In the case of smoking, there is always a trade-off between instant gratification and future harmful consequences.

The primary purpose of this paper is to obtain new estimates of the price sensitivity of cigarette consumption and related outcomes using NLSY79. The point of departure from the existing literature is that I take account of measures of time preference in NLSY79 to examine interactions between these measures and price in the demand function for cigarettes. My specific hypothesis is that those who discount the future consequences of their current actions heavily are likely to be more sensitive to price than those who do not. This hypothesis stems from the conception of the full price of cigarettes as the sum of the money price and the monetary value of the expected future harm due to smoking. A one percent increase in the money price results in a greater percentage increase in the full price for those who discount the future heavily than for other individuals.

Income influences one's time preference. According to Becker et al. (1991), in the case of smoking, teenagers and poorer people are assumed to have lower values of the discount factor (higher discount rates) because they tend to discount the future more heavily. Poorer and younger people may care less about their future health or may lack the financial ability to place higher monetary value on future harm. Also, according to my hypothesis, because they belong to a low-earning group, the money price accounts for a greater proportion of the full price. These groups are, therefore, more sensitive to money prices–they underestimate the monetary value of the harm.

In spite of the case of time consistent preference, the same person may also face time inconsistent preferences. As hyperbolic studies of time preference have shown, the discount factor is much smaller in the short-run than in the long-run. People often plan to diet and quit smoking, but are more likely to delay their actions in the short run (Harris and Laibson, 2000). People are more likely to act on the basis of instant rewards and less likely to act on the basis of future rewards (Laibson, 1997, D.Cohen et al., 2004). The same theory is also demonstrated by the inter-temporal consumption equation: people consume more in the current period and less in the future period.

I will use NLSY quasi-hypothetical reward question to measure personal preference. According to Johnson and Bickel (2002) and Madden et al. (2003), quasi-hypothetical questions have similar results to empirical experiments. I follow Courtemanche et al. (2015) and use the NLSY79 measure of time preference rate, which was only available in 2006. Most of the other control variables are available in more than one year in NLSY79. By assuming that time preference rates do not vary over time, I use a 1979 to 2008 survey to estimate demand functions for cigarettes. Because this is panel data, I also include fixed effects. If I fit an individual fixed effect model, the discount factor of $1/(1 + \text{time preference rate})$ would drop out of that specification because they do not vary over time, but the interaction between each of these variables and price would not drop out. In my results, the interaction term between the discount factor and cigarette price has a positive sign. This supports my hypothesis that patient people are less responsive to price changes, though the results are insignificant at the 10% confidence interval. Pregnant women are less sensitive to price changes than others because they think more about the future.

2.2 Empirical Work

2.2.1 Model

To test my hypothesis, I assume that each individual lives for two periods. The lifetime utility function is

$$V = U(H_0, X, C) + \beta U(H, X_1, C_1). \tag{2.1}$$

Here H_0 is initial health and is exogenous. X is consumption of a good other than cigarettes during period 0, and C is consumption of cigarettes during the period 0. The price of X is $1, and the price of cigarettes is p. The variables H, C_1 and X_1 are health, cigarette consumption, and the other goods in period 1. β is the time discount factor for time. For simplicity, I assume that lending and borrowing are not possible and ignore the selection of X_1 and C_1. Hence, the relevant budget constraint is

$$I = X + pC \tag{2.2}$$

Finally, an increase in C lowers health in period $1(\partial H/\partial C \equiv H_c < 0)$

The Lagrange function is

$$L = U(H_0, X, C) + \beta U(H, X_1, C_1) + \lambda(I - X - pC),$$

where λ is the marginal utility of income.

The first order condition for C is

$$U_c + \beta U_H H_C = \lambda p \tag{2.3}$$

The second term on the right-hand side of the last equation is negative since $U_H > 0$ and $H_C <$

0. The previous equation is rewritten as

$$U_c = \lambda(p - \beta\frac{U_H H_C}{\lambda})$$

Note that $f \equiv -\beta\frac{U_H H_C}{\lambda}$ defines the discounted monetary value of the loss in utility during period 1 due to smoking during period 0. Hence, the full price of cigarettes (π) is

$$\pi \equiv p + f$$

The full price is higher the larger is the value of β.

The way to proceed is to specify a general demand function without assuming anything about the form of the utility function:

$$C = C(I, \pi) \tag{2.4}$$

Then differentiate C with respect to p, with f and I held constant

$$C_p = C_\pi$$

So

$$-C_p\frac{p}{C} \equiv= -C_\pi\frac{\pi}{C}\frac{p}{\pi}$$

Define ϵ as - $C_\pi\frac{\pi}{C}$, and note that ϵ is the elasticity of C with respect to full price π. Hence,

$$e = (p/\pi)\epsilon$$

If ϵ is constant, e rises as β falls because p/π rises as β falls. In other words, people who discount the future heavily have a more elastic demand function than those who do not because a one percent change in money price is a greater percentage change in full price for the former group.

Because I am interested in how time preference affects individual responses to price, I simplify the cigarette demand model, but interact time preference with price:

$$C_{i,t} = \alpha P_{i,t} + \alpha_1 P_{i,t} \beta_i + \epsilon_{i,t} \tag{2.5}$$

where β is the discount factor. The partial price effect is

$$\frac{\partial C_{i,t}}{\partial P_{i,t}} = \alpha + \alpha_1 \beta_i$$

This can be evaluated at different values of β_i. The partial derivative of the price should be negative, since when the price of goods increases, consumption decreases. The coefficient of the interaction term α_1 should be positive because the greater the discount factor (the smaller discount rate), the lesser the negative price effect, which means the negative price effect will decrease as the discount factor increases. When β increases by one percent, the effect of the price decrease by the value of α_1. Therefore, the greater the discount factor (the lesser the time-preference rate) is, the less patient people respond to price changes.

However, the full price of cigarettes includes the monetary price and the expected value of the monetary value of harm. People who discount future harm less think that future health is important. For this group, the expected future monetary value accounts for a greater proportion of the full price of cigarettes and, therefore, they should be less responsive to the current cigarette price. Conversely, impatient people pay more attention to the current cost, as is the case with the poor and with teenagers. Thus, these groups are more sensitive to changes in cigarette prices.

Instead of a constant discount factor overall lifetime, the time-inconsistent case consists of the long-run discount factor δ and the present-bias β. Economists have used the quasi-hyperbolic function: 1, $\beta\delta$, $\beta\delta^2$, ..$\beta\delta^t$, ...When $\beta = 1$, it represents the time-consistent preference case, while $\beta \leq 1$ indicates the time-inconsistent case. In the latter case, δ is constant for all time and β captures the discount rates decrease in time t. For example, according to the empirically quasi-hyperbolic examination, the average value of the present-bias discount factor β is 0.8 and the next period becomes 0.7, diminishing with time (Courtemanche et al., 2015). The short-run time preference rate is greater than the long-run time preference rate, and the best value for the long-run δ is 0.7 (Laibson, 1997). Most individuals have a diminishing impatience.

According to equation (2.5), the partial price effect becomes

$$\frac{\partial C_{i,t}}{\partial p_{i,t}} = \alpha_0 + \alpha_1 \delta_i + \alpha_2 \beta_i$$

Individuals will discount the future less when the long-run discount factor δ is greater or present bias β is greater and, thus, consumption responds to price less when δ or β is greater. Therefore, the interaction term of α_1 and α_2 should be positive. This factor plays a primary role depending on whether patience is determined by the long-run discount factor or by a present-bias.

2.3 Data

All data come from the National Longitudinal Surveys (NLSY79) and are now available from Round 1 (1979 survey year) to Round 25 (2012 survey year). They include NLSY79 parents who were born between 1957-64 and whose ages ranged from 14-22 during the first survey year (1979). The survey was conducted biennially until 2012. The original sample included 12,686 respondents and, at present,9, 964 remain due to withdrawal from the sample. The dependent variable is cigarette usage, which is only available in the years 1984, 1992, 1994, 1998, and 2008. The 1984 consumption and participation data structure are different from 1992, 1994, 1998, and 2008. For example, there was no question regarding "cigarettes smoked in entire lifetime" for the 1984 survey, but it appeared on surveys from later years. Therefore, I estimate the model with and without the 1984 data. Because the results are not so different, I only show the results for 1992, 1994, 1998 and 2008.

There are two types of cigarette measurements: cigarette consumption and cigarette smoking participation. Cigarette consumption refers to the number of cigarettes consumed within the last 30 days. Cigarette participation is the current smoking status: if the person has smoked within 30 days it is 1; otherwise it is 0. After dropping observations and merging data, there were 6,599 observations left for the number of cigarette consumed and 25,635 for the number of cigarette-smoking participants.

Data for prices and taxes come from Tax Burden on Tobacco (Volume 44, 2009). Data are at the county level for the period from 1984 to 2009. Both price and tax data are in real terms. The base period of CPI is 1967=100. Taxes in the real term consist of the sum of federal, state and county taxes.

Time preference variables (DF1, DF2) are calculated from NLSY79 reward question in 2006 wave. First : "Suppose you have won a prize of $1000, which you can claim immediately. However, you have the alternative of waiting one year to claim the prize. If you do wait, you will receive more than $1000. What is the smallest amount of money in addition to the $1000 you would have to receive one year from now to convince you to wait rather than claim the prize now?" Discount factor 1(DF1) is calculated from the answers (amount1) by the following formula:

$$DF1 = \frac{1000}{1000 + amount1}$$

Second: " Suppose you have won a prize of $1000, which you can claim immediately. However, you can choose to wait one month to claim the prize. If you do wait, you will receive more than $1000. What is the smallest amount of money in addition to the $1000 you would have to receive one month from now to convince you to wait rather than claim the prize now?" Discount factor 2 (DF2) is obtained from the answers (amount2) by the following formula:

$$DF1 = (\frac{1000}{1000 + amount2})^{12}$$

For the time inconsistent case, δ and β are calculated as follows

$$\beta\delta^{1/12} = \frac{1000}{1000 + amount2}$$

$$\beta\delta = \frac{1000}{1000 + amount1}$$

DF1 is the annual discount factor; DF2 is the monthly discount factor. According to Laibson (1997), the next period should be discounted, not only by the standard discount factor δ, but also by an extra fraction β. The appropriate rate of β should be around 0.7. For a time-consistent case, δ is constant for each period. For a time-inconsistent case, I assume that impatience is decreasing for a fixed-time gap. This assumption may represent the fact that people are more reactive with instant rewards and less reactive to future rewards (D.Cohen et al., 2004). The same theory is also shown in the inter-temporal consumption equation: people will consume more in the current period, and less in the future period.

In addition to the independent variable, time-preference, I also include demographic variables: Age, Gender, Race, Marital Status, Human Capital, Armed Forces Qualification Test (AFQT)

(1988), and Schooling dummies. For example, college is equal to 1 if the highest grade completed is 16th or over 16th. Labor includes work hours and occupation. I classify occupations as white collar, blue collar and service, according to the scheme introduced by Courtemanche et al. (2015). Finally, I add income, income squared, and net worth as financial variables.

2.4 Empirical analysis

2.4.1 Time consistent discount factor

In order to examine how the discount factor affects consumption, I use the following estimating regression equation:

$$
\begin{aligned}
C_{it} = \alpha_0 + \alpha_1 DF1_i + \alpha_2 DEMO_{it} + \alpha_3 HC_{it} + \alpha_4 LABOR_i + \alpha_5 FIN_{it} \\
+ \epsilon_{it} \qquad (2.6)
\end{aligned}
$$

where i represents individuals. $DF1$ is the annual discount factor: DEMO includes age, gender, race, and marital status; HC (Human Capital) includes the AFQT score and schooling dummies; LABOR includes work hours and occupation (for example, blue collar, white collar and service indicators); and FIN (Financial) includes income, income squared and net worth.

The purpose of equation (2.6) which includes only the discount factor and control variables is to see the pure effect of the discount factor. On the other hand, in order to examine how the discount factor influences the price effect on consumption, I use the following estimation regression equation

$$
\begin{aligned}
C_{it} = \alpha_0 + \alpha_1 \beta_i + \alpha_2 DEMO_{it} + \alpha_3 HC_{it} + \alpha_4 LABOR_i + \alpha_5 FIN_{it} \\
+ \alpha_6 P_{ct} + \alpha_6 \beta_i P_{ct} + \epsilon_{it} \qquad (2.7)
\end{aligned}
$$

where $P_{c,t}$ is the cigarette price varying over time at the county level. In order to examine how the discount factor influences the price effect on consumption, I add price and the interaction term to between price and the discount factor in equation (2.7).

Table 2.3 shows estimates of the equation (2.6) and (2.7). Column (1) is a simple regression without price term for consumption. Here, the measure of consumption is the number of cigarettes an individual consumed last month. It follows the regression in equation (2.6). Columns (2) and (3) are the estimates of the regression in equation (2.7), which includes the price and interaction term with the discount factor. Column (3) is estimated with both year and state fixed-effect but column (2) only with year fixed-effect. Columns (4) and (5), (6) are following equations (2.6) and (2.7) respectively and the dependent variable is smoking participation, for which I set the smoker as 1 and the nonsmoker as 0. The greater the discount factor (the lesser the discount rate) is, the less individuals respond to price. I expect the coefficient of discount factor1 to be negative, and Columns (2), (3), (4), (5) and (6) show that the coefficient of DF1 is negative. Based on these results, I conclude that people who are present-oriented (i.e. do not value the future highly), are more likely to smoke.

In columns (2), (3), (5) and (6), the coefficient of price should be negative because when price goes up, consumption should go down. The coefficient of the interaction term should be positive because a greater discount factor (a smaller discount rate or more patient individual) has a negative effect on consumption through price. Therefore, the negative price effect declines for more patient people. Columns (2), (3), (5) and (6) show reasonable results, even though the coefficients of the interaction term are not significant at the 10% confidence interval, the t-statistic for the interaction (the coefficient divided by its standard error) is 1.33 for participation in column (5), which is weakly significant. Therefore, I conclude that people who are present-oriented are more likely to smoke as cigarette price goes down, even though the results are not significant.

In the estimation, I used a separate year fixed-effect, and a combined year and state fixed-effect. Our assumption is that the effect of the price is negative. From equation (2.7), the partial price effect is

$$\frac{\partial C_{i,t}}{\partial P_{i,t}} = \alpha + \alpha_1 DF1_i.$$

This calculation reveals that only the estimate using year fixed-effect has a negative partial price effect. Therefore, the regression using only year fixed-effect is a more reasonable estimation.

According to the prediction, individuals who are more future-oriented will be less responsive to cigarette price change. This relationship can be examined in terms of the value of price elasticity. As the discount factor increases, price elasticity decreases, indicating that individuals who evaluate the future highly are less responsive to cigarette price change. This is explained well by the full price theory, that a one percent increase in price is associated with a smaller percentage change in the full price for those who are more future-oriented.

2.4.2 Time inconsistent discount factor

In the previous section, I analyzed the discount factor for the time-consistent case. Next, I consider the discount factor for the time-inconsistent case. I use the following estimation regression equation

$$\begin{aligned} C_{it} = \theta_0 + \theta_1\beta_i + \theta_2\delta_i + \theta_3 DEMO_{it} + \theta_4 HCit + \theta_5 LABOR_i \\ + \theta_6 FIN_{it} + \eta_{it} \end{aligned} \tag{2.8}$$

$$\begin{aligned} C_{it} = \theta_0 + \theta_1\beta_i + \theta_2\delta_i + \theta_3 DEMO_{it} + \theta_4 HCit + \theta_5 LABOR_i \\ + \theta_6 FIN_{it} + \theta_7 P_{it} + \theta_8(\beta_i * P_{it}) \\ + \theta_9(\delta_i * P_{it}) + \theta_{10}\eta_{it} \end{aligned} \tag{2.9}$$

where β is present-bias and δ is long-run patience. I assume the discount factor is decreasing as time T progresses. δ is constant throughout an individual's life. β, which captures time variety, is the value weighted to the constant discount factor δ.

Table 2.4 shows the results for the time-inconsistent case. Columns (1) and (2) are the regression results for equations (2.8) and (2.9), respectively. Column (3) is the estimation with year and state fixed-effect for equation (2.9). Columns (4), (5) and (6) show the estimates of the participation regression. In columns (5) and (6), the coefficients of the interaction between price and the discount factor presents positive, which are consistent with the hypothesis that a negative price effect should be smaller for those who are more future-oriented. But they are insignificant at 5% significant interval level.

2.4.3 Full Price Model

The Effect of Logarithm of the Price

One may recall that the full price of cigarettes is $\pi = p + f$, where $f \equiv -\beta\frac{U_H H_C}{\lambda}$ is the discounted monetary value of the loss in utility in period 1 due to smoking in period 0, and β is the discount factor. The point is that a one percent change in p is a greater percentage change in π the smaller is β. For more detail, let the demand function be

$$C = \alpha + \gamma \ln(p + f) = \alpha + \gamma \ln p + \gamma \ln[(p + f)/p] \tag{2.10}$$

Denote b as the coefficient of $\ln p$ in this regression. By the estimated formula, we can get

$$b = k\gamma, k \equiv p/(p + f) \tag{2.11}$$

Since k is larger for individuals who are less future-oriented, the money price elasticity is bigger for individual who have smaller values of β and hence smaller values of f. Equation (2.11) in its constrained form indicates that $\partial C/\partial \ln p = k\gamma$.

I have β but do not have $-(U_H H_c)/\lambda$. Since k rises as β falls, $\partial C/\partial \ln p$ should be bigger in absolute value the smaller is β. I, therefore, regress C on $\ln p$ and $\beta * \ln p$. The coefficient of the interaction should be positive, while the coefficient of price should be negative when participation or consumption is the dependent variable. A one percent increase in price is a smaller percentage change in the full price for those who are more future oriented. So the negative price effect should be smaller for them, which is why the interaction effect should be positive.

For a time-inconsistent case, the discount factor β becomes two factors of δ and β, in which δ is constant over the course of an individual's lifetime, and β rises with time going. The estimation should regress C on $\ln p, \delta * \ln p$ and $\beta * \ln p$. The interaction signs should be positive, and price effect is negative, as it is in the time-consistent case.

Table 2.6 and 2.7 show the results for this model. In Table 2.6, columns (2), (3), (7) and (8), the price effect is negative and the coefficient of the interaction term is negative. In Table 2.7, I add the nonsmoker into observations of consumption. In this way, I reduce the bias caused by unobservable consumption.

Approximated full Price Model

Consider one additional point in which future monetary loss is included. Referring to equation (2.3) we set $g \equiv -(U_H H_C)/\lambda$. $f = \beta g$. I have a measure of β but do not have a measure of g. I will try to regress C on $\ln p$ and $\ln(1+\frac{\beta}{p})$. Alternatively if $\beta g/p$ is less than 1 and also less than 0.2,

$$\ln(1+\frac{\beta g}{p}) \approx \frac{\beta g}{p} \tag{2.12}$$

This approximation is based on the Taylor expansion up to first order. Even if g is substantial, the health costs of smoking might not occur for 20 years or so. Suppose the one period discount factor is $1/1.10 = 0.909$. Then the relevant discount factor is $(0.909)10 = 0.385$. If I use the approximation, $C = \alpha + \gamma \ln p + \gamma g \beta p^{-1}$. If g is a constant, the coefficient of βp^{-1} estimates γg. In either case, the model I am going to estimate includes $\ln p$ and βp^{-1}. Note that the sign of the interaction is the same as the sign of $\ln p$ and is negative. Since with $\ln p$ and hence p held constant, an increase in β raises the full price of smoking (π) and hence lowers the probability of smoking and the amount smoked given positive consumption. It still is the case that the price effect falls as β rises. Here, the price effect of $\ln p$ is negative, but the price term in the interaction is $\frac{1}{p}$, which as a whole has positive effect on consumption. Because an increased β decreases positive price effect on consumption, the interaction term is negative. The following is the simplified estimation equation:

$$C = \alpha + \gamma \ln p + \gamma \ln[(p+f)/p] + \epsilon = \alpha + \gamma \ln p + \gamma \ln[1+f/p] = \alpha + \gamma \ln p + \gamma g \beta p^{-1} + \epsilon \tag{2.13}$$

$$\frac{\partial C}{\partial \ln p} = \gamma - \gamma g \beta p^{-1} \tag{2.14}$$

Consider a fuller Taylor expansion

$$\ln(1+\frac{\beta g}{p}) \approx \frac{\beta g}{p} - \frac{1}{2}(\frac{\beta g}{p})^2$$

The estimate model becomes the form:

$$C = \gamma \ln p + \gamma g \beta p^{-1} - \frac{\gamma g^2 \beta^2}{2} p^{-2}$$

Here the right-hand side variables are $\ln p$, (β/p) and $(1/2) * (\beta/p)^2$. The coefficient of (β/p) estimates γg. The coefficient of $(1/2) * (\beta/p)^2$ estimates$-\gamma g^2$. The ratio of the last coefficient to the penultimate coefficient estimates $-g$.

$$\frac{\partial C}{\partial \ln p} = \gamma - \gamma g \beta p^{-1} - \frac{\gamma g^2 \beta^2}{2} \frac{-2}{p^2} = \gamma - \gamma g \beta p^{-1} + \frac{\gamma g^2 \beta^2}{p^2} = \gamma(1 - g\beta p^{-1} + g^2 \beta^2 p^{-2}) \quad (2.15)$$

Table 2.8 and 2.10 are, respectively, the estimate results from regressing C on $\ln p$, $\frac{\beta}{p}$, and on $\ln p$, $\frac{\beta}{p}$, and $\frac{1}{2}(\frac{\beta}{p})^2$. These results are based on the approximated model as the full price model in equation (2.10). In Table 2.8 column (2) and (6), the coefficient of interaction as well as the price effect are negative. The price effect in the interaction term $\beta\frac{1}{p}$ is positive on consumption, which is consistent with the prediction. This positive price effect should be smaller for those who are more future oriented. Therefore, the interaction term should be negative.

As explained before, by assuming that $\beta g/p$ is less than 1, I can get $\ln(1+\frac{\beta g}{p}) \approx \frac{\beta g}{p} - \frac{1}{2}(\frac{\beta g}{p})^2$. Referring to Table 2.10, column (1), g=108.89, the mean cigarette price is 100 ranging from 71 to 281 with standard deviation 22.94. The mean discount factor is 0.56 ranging from 0.0001 to 1 with standard deviation 0.27. So $\beta g/p$=108.89*0.56/100=0.609, which proves empirically that this term is less than 1. It also verifies that the coefficient of log price is negative. From the calculation of $\beta g/p$, it is evident that the term in parentheses in equation (2.14) is positive, and γ (-0.625), the coefficient of log price in Table 2.10, column (1) is negative. According to equation (2.14), price elasticity is $\gamma(1 - g\beta p^{-1}) = -0.625(1 - 0.069) = -0.244$, which verifies that the price effect is negative.

In the time inconsistent case, Taylor expansion can be approximated as ,

$$\ln(1 + \frac{\delta g}{p} + \frac{\beta g}{p}) \approx \frac{\delta g}{p} + \frac{\beta g}{p}$$

The regression function is

$$C = \gamma \ln p + \gamma g \delta p^{-1} + \gamma g \beta p^{-1} \tag{2.16}$$

It is still the true that the price effect is negative

$$\frac{\partial C}{\partial \ln p} = \gamma - \gamma g \delta p^{-1} - \gamma g \beta p^{-1} \tag{2.17}$$

Applying two discount factor δ, β into the fuller Taylor expansion results in

$$\ln(1 + \frac{\delta g}{p} + \frac{\beta g}{p}) \approx \frac{\delta g}{p} + \frac{\beta g}{p} - \frac{1}{2}(\frac{\delta g}{p})^2 - \frac{1}{2}(\frac{\beta g}{p})^2$$

The regression model form is

$$C = \gamma \ln p + \gamma g \delta p^{-1} + \gamma g \beta p^{-1} - \frac{\gamma g^2 \delta^2}{2} p^{-2} - \frac{\gamma g^2 \beta^2}{2} p^{-2} \tag{2.18}$$

Table 2.8 and 2.10 also report the results for the time-inconsistent regression. In Table 2.8, I experiment an approximation of future value with a Taylor expansion up to the first order level as equation (2.12). Both the coefficients of the interaction term and the price effect are negative in Table 2.8, column (2) and (6), and Table 2.10 column (6), (8) which is consistent with the prediction. Furthermore, the effect of price is negative. To see this, the results from Table 2.8, column (1) are applied to equation (2.16), showing that $-0.448 - 1.832 * \delta/p - 17.1 * \beta/p$ are negative, as $\delta/p < 1$, $\beta/p < 1$ and both nonnegative.

2.4.4 First time quitting smoking

A related issue is defining the initial sample (Wooldridge, 2005, Ce, 2011). In my model, it is not difficult to treat "first-time quitting" as the outcome. I select a sample of smokers from Period 1, defining that period as the first time a given person has smoked. For each individual, Period 1 is potentially a different year. Then I generate a variable for "first-time quitting". The indicator is 0 for those who start smoking for the first time (Period 1) and, if they continue to smoke, it remains 0 until the last period. The indicator is 1 if an individual stops smoking for the first time, after which they drop out of the sample. It must also be noted that year dummies are not the same as period dummies. According to Wooldridge (2005), one should consider the initial time period a parametric nonlinear model. Therefore, I create a period dummy for each "first-time quitting" smoker, and omit period dummies from the basic model (OLS linear model). I also omit initial consumption from the basic model, since Hsiao (1986) argues that one should only be concerned with the initial sample problem in nonlinear models.

Table 2.12 shows good results for the effect of price level on "first-time quitting". The effect of price is positive and the interaction is negative. If I calibrate DF1 (discount factor 1) as 0.6 , the mean of DF1 in the summary table, the price effect is equal to 0.0006-0.000006*0.6=0.0006 (following Table 2.12, column (1)). This is consistent with the theory that when price increases, the probability of quitting increases as well. Also when the discount factor increases, the positive effect of price decreases and, thus, the coefficient of the interaction term presents a negative sign. In the time-inconsistent case, the price effect is still positive. If I calibrate Beta as 0.8 and Delta as 0.75 (shown in Summary Table 2.2), the price effect is equal to -0.0003+0.002*0.8-0.0006*0.75=0.00085 (following Table 2.12, column (3); for column (4) the result is 0.0005), which is a positive price effect . As a result, the estimate of the effect of price on "first-time quitting" verifies the hypothesis that future-oriented people respond less to changes in price level.

2.5 Conclusion

This paper studies the effect of prices on cigarette consumption. This effect varies if an individual's time preference changes. I use a proxy measure of time preference from the NLSY79 (2006) survey to interact with cigarette price. I primarily focus on the interaction term to examine the effect of time preference on cigarette consumption through the price effect. I find that people who discount the future consequences of their current actions heavily are likely to be more sensitive to price than those who do not.

According to the theory, I would expect a negative coefficient for cigarette price when the dependent variable is cigarette consumption or smoking participation. The interaction term between price and the discount factor should have a positive coefficient. As demonstrated, patient people respond less to price because their discount rate is low, which supports my hypothesis that those who discount the future consequences of their current actions heavily are likely to be more sensitive to price than those who do not.

I find substantial proof for my hypothesis. In the time-consistent case, the results show that the coefficient of the price is negative and the coefficient of the interaction between price and the discount factor is positive insignificant at the 10% significance level. In the time-inconsistent case, I have very similar results which show the coefficient of the interaction term is positive. This points to heterogeneity in the impact of price on cigarette consumption. I also find that as the degree of patience increases, cigarette price elasticity decreases in absolute value.

These results suggest an important role for heterogeneous time preference in the price effect while it is insignificant at the 10% significance level. If governments try to reduce cigarette consumption by increasing cigarette taxes, the responsive groups will be limited to those people who discount the future heavily, such as teenagers or lower income individuals.

Table 2.1: Summary for 6599 observations.

Variable Name	Description	Mean (Std. Dev.)
Age	Age in years	36.03 (6.21)
Female	1 if female	0.484 (0.500)
Race:black	1 if race is black	0.137 (0.344)
Race:other	1 if race is neither black nor white	0.0241 (0.153)
Married	1 if married	0.633 (0.482)
AFQT	percentile score on armed forces qualifying test in 1985	49.56 (28.67)
High school	1 if highest grade is completed=12	0.408 (0.492)
Some college	1 if 13 $\leq$highest grade completed $\leq$ 15	0.238 (0.426)
College	1 if highest grade completed 16 $\geq$	0.284 (0.451)
White collar	1 if current occupation is white collar	0.627 (0.452)
Blue collar	1 if current occupation is blue collar	0.255 (0.407)
Service	1 if current occupation is service	0.117 (0.297)
Hours worked	Average hours worked per week in the preceding year	35.66 (19.66)
Income	Total household income(units of $\$10,000$	8.255 (8.201)
Net worth	Household asset minus liabilities in 2004(units of $\$10,000$)	25.86 (46.20)

Table 2.2: Summary for 6599 observations.

Variable Name	Description	Mean (Std. Dev.)
Comsumption	The number of cigarette consumed during last month	501.73 (303.11)
Smoking participation	Smoking or not (Yes is 1, not is 0) during last month	0.254 (0.435)
Discount factor 1	Computed from amount needed to wait a year to receive $1,000	0.586 (0.262)
Discount factor 2	Computed from amount needed to wait a year to receive $1,000	0.284 (0.340)
Delta	Computed using the quasi-hyperbolic discounting specification	0.747 (0.334)
Beta	Computed using quasi-hyperbolic discounting specification	0.794 (0.216)

Table 2.3: Results for time consistent OLS regressions.

	consumption			participation		
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)
Discount factor1	13.83	-10.90	-11.26	-0.028	-0.066	-0.079*
	(18.20)	(49.12)	(48.25)	(0.02)	(0.04)	(0.04)
Cigarette price		-1.647*	-0.515		-0.0005	-0.00004
		(0.69)	(0.43)		(0.0005)	(0.0003)
DF1*price		0.250	0.277		0.0004	0.0004
		(0.406)	(0.401)		(0.0003)	(0.0003)
Age	5.633*	5.722**	6.495**	0.004**	0.004*	0.005**
	(2.23)	(2.21)	(2.13)	(0.002)	(0.002)	(0.002)
Female	-42.89***	-44.01***	-49.43***	-0.011	-0.011	-0.014
	(11.94)	(11.88)	(11.76)	(0.01)	(0.01)	(0.01)
Married	-2.924	-4.083	-9.979	-0.084***	-0.085***	-0.087***
	(10.37)	(10.26)	(9.96)	(0.01)	(0.01)	(0.01)
AFQT	0.544*	0.551*	0.573*	0.00001	0.00001	-0.0002
	(0.25)	(0.25)	(0.24)	(0.0003)	(0.0002)	(0.0002)
High school	-12.32	-13.46	-16.69	-0.118***	-0.118***	-0.123***
	(12.10)	(12.19)	(11.88)	(0.02)	(0.02)	(0.02)
Some college	-30.37*	-30.95*	-29.51*	-0.204***	-0.203***	-0.199***
	(14.66)	(14.63)	(14.39)	(0.02)	(0.02)	(0.02)
College	-131.6***	-132.8***	-137.3***	-0.302***	-0.303***	-0.300***
	(20.32)	(20.48)	(20.23)	(0.02)	(0.02)	(0.02)
White collar	-202.4	-208.8	-169.0	0.003	0.004	-0.006
	(105.4)	(109.3)	(126.3)	(0.05)	(0.06)	(0.06)
Blue collar	-153.1	-161.0	-127.3	0.059	0.059	0.047
	(105.2)	(109.1)	(126.0)	(0.05)	(0.06)	(0.06)
Service	-165.4	-172.5	-130.3	0.038	0.038	0.027
	(105.2)	(109.1)	(126.2)	(0.05)	(0.06)	(0.06)
Work hours	0.198	0.182	0.127	-0.001***	-0.001***	-0.001***
	(0.288)	(0.286)	(0.288)	(0.0002)	(0.0002)	(0.0002)
Networth	0.248	0.231	0.244	-0.0003	-0.0003	-0.0002
	(0.43)	(0.43)	(0.43)	(0.0001)	(0.0002)	(0.0002)
Income	-0.227	0.172	1.821	-0.011***	-0.011***	-0.011***
	(3.49)	(3.48)	(3.40)	(0.003)	(0.002)	(0.002)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Observations	6599	6599	6599	25742	25697	25697
R^2	0.123	0.126	0.152	0.095	0.095	0.110

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Discount factor1 refer to annual discount factor

Table 2.4: Results for time inconsistent OLS regressions.

	consumption			participation		
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)
Delta	6.779	-17.96	-18.96	-0.017	-0.049	-0.054
	(12.14)	(33.23)	(33.09)	(0.011)	(0.029)	(0.029)
Beta	34.80	57.21	61.35	-0.006	-0.007	-0.025
	(22.14)	(63.15)	(62.35)	(0.02)	(0.046)	(0.046)
Cigarette Price		-1.534	-0.379		-0.0006	-0.0002
		(0.83)	(0.62)		(0.001)	(0.0004)
Beta*price		-0.215	-0.250		0.00001	0.0001
		(0.528)	(0.524)		(0.0004)	(0.0004)
Delta*price		0.244	0.272		0.0003	0.0004
		(0.280)	(0.278)		(0.0002)	(0.0002)
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Human capital	Yes	Yes	Yes	Yes	Yes	Yes
Labor	Yes	Yes	Yes	Yes	Yes	Yes
Financial	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Observations	6599	6599	6599	25635	25635	25635
R^2	0.123	0.127	0.153	0.095	0.095	0.108

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

"Demographic" includes age, gender ,race, and marital status.

"Human capital" includes AFQT score and the high school, some collage,collage indicators.

"Labor" includes work hours and white collar, blue collar, service dummies.

"Financial" includes income, income^2 , net worth, variables .

Table 2.5: Results for consumption including all nonsmoker .

	(1)	(2)	(3)	(4)	(5)	(6)
DF1	-9.150	-36.69	-44.27			
	(10.57)	(26.15)	(25.86)			
Cigarette price		-0.726	-0.206		-0.713	-0.249
		(0.396)	(0.196)		(0.422)	(0.259)
DF1*price		0.268	0.305			
		(0.188)	(0.188)			
Delta				-5.844	-30.03	-33.25
				(7.308)	(19.42)	(19.23)
Beta				9.349	14.45	2.695
				(12.56)	(29.41)	(29.16)
Beta*price					-0.05	0.039
					(0.216)	(0.214)
Delta*price					0.235	0.249
					(0.153)	(0.151)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Observations	25635	25635	25635	25635	25635	25635
R^2	0.086	0.086	0.102	0.086	0.086	0.102

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.6: Results for time consistent and time inconsistent, regressor being ln(price) and discount factor*ln(price).

	time consistent				time inconsistent			
	consumption		participation		consumption		participation	
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DF1	0.049	-0.013	-0.233	-0.264				
	(0.527)	(0.529)	(0.169)	(0.169)				
ln(price)	-0.566**	-0.050	-0.145	0.0003	-0.564**	-0.042	-0.151	-0.014
	(0.177)	(0.132)	(0.081)	(0.045)	(0.213)	(0.176)	(0.087)	(0.058)
DF*ln(price)	-0.005	0.010	0.0443	0.050				
	(0.114)	(0.114)	(0.036)	(0.036)				
Delta					-0.140	-0.176	-0.192	-0.199
					(0.363)	(0.365)	(0.137)	(0.136)
Beta					0.242	0.266	-0.016	-0.090
					(0.657)	(0.657)	(0.222)	(0.221)
Beta*ln(price)					-0.041	-0.046	0.002	0.017
					(0.142)	(0.142)	(0.047)	(0.047)
Delta*ln(price)					0.034	0.042	0.039	0.040
					(0.078)	(0.078)	(0.029)	(0.029)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	6599	6599	25697	25697	6599	6599	25697	25697
R^2	0.130	0.157	0.096	0.110	0.130	0.157	0.096	0.109

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.7: Results for consumption including nonsmoker with regression on ln(price) and discount factor*ln(p).

	time consistent			time inconsistent		
	consumption					
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)
DF1	-8.934	-157.6	-174.9			
	(10.52)	(118.0)	(117.7)			
ln(price)		-148.6**	-26.02		-146.2*	-29.43
		(55.62)	(30.10)		(60.16)	(37.59)
DF*ln(price)		32.25	35.21			
		(24.50)	(24.46)			
Delta				-5.649	-129.5	-134.3
				(7.304)	(91.20)	(90.30)
Beta				10.01	35.70	-9.786
				(12.48)	(135.0)	(134.0)
Beta*ln(price)					-5.572	3.729
					(28.27)	(28.00)
Delta*ln(price)					26.85	27.53
					(19.21)	(19.00)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Observations	25635	25635	25635	25635	25635	25635
R^2	0.085	0.087	0.102	0.085	0.087	0.102

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.8: Results for time consistent and time inconsistent, regressor being ln(price) and discount factor/p (approximated by Taylor expantion up to order 1).

	time consistent				time inconsistent			
	ln(consumption)		participation		ln(consumption)		participation	
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DF1	-0.057	0.072	-0.050	0.011				
	(0.131)	(0.132)	(0.040)	(0.038)				
ln(price)	-0.532**	-0.060	-0.110	0.010	-0.448*	-0.091	-0.034	0.009
	(0.185)	(0.129)	(0.082)	(0.044)	(0.228)	(0.155)	(0.083)	(0.051)
$\frac{DF1}{price}$	7.948	-3.878	2.132	-4.542				
	(12.28)	(12.43)	(4.177)	(3.893)				
Delta					-0.005	0.087	-0.027	0.017
					(0.090)	(0.086)	(0.035)	(0.032)
Beta					-0.123	0.0747	-0.130*	-0.007
					(0.174)	(0.161)	(0.057)	(0.052)
$\frac{Delta}{price}$					1.832	-6.559	1.252	-3.296
					(8.539)	(8.334)	(3.332)	(3.082)
$\frac{Beta}{price}$					17.10	-1.974	12.12*	-0.273
					(16.24)	(14.95)	(5.649)	(5.064)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	6599	6599	25697	25697	6599	6599	25697	25697
R^2	0.130	0.157	0.096	0.110	0.131	0.157	0.096	0.109

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.9: Results for consumption including nonsmoker with regressor being ln(price) and discount factor/p (approximated by Taylor expantion up to order 1).

	time consistent			time inconsistent		
			consumption			
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)
DF1	-8.934	-19.01	21.96			
	(10.52)	(26.84)	(25.25)			
ln(price)		-125.6*	-19.94		-74.42	-19.29
		(56.59)	(30.26)		(58.61)	(35.35)
$\frac{DF1}{price}$		972.6	-3395.9			
		(2928.0)	(2737.6)			
Delta				-5.649	-10.88	18.54
				(7.304)	(21.91)	(19.76)
Beta				10.01	-74.02*	6.480
				(12.48)	(34.64)	(30.44)
$\frac{Delta}{price}$					492.6	-2550.4
					(2238.4)	(2052.5)
$\frac{Beta}{price}$					8220.3*	89.98
					(3571.5)	(3121.8)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Observations	25635	25635	25635	25635	25635	25635
R^2	0.085	0.087	0.102	0.085	0.087	0.102

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.10: Results for time consistent and time inconsistent, regressor being $ln(price), discountfactor/p$ and $\frac{1}{2} * (discountfactor/p)^2$ (approximated by Taylor expantion up to order 2).

	time consistent				time inconsistent			
	ln(consumption)		participation		ln(consumption)		participation	
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DF1	0.190	0.325	-0.013	0.053				
	(0.173)	(0.170)	(0.057)	(0.055)				
ln(price)	-0.625**	-0.155	-0.125	-0.006	-0.507*	-0.159	-0.070	-0.023
	(0.192)	(0.139)	(0.085)	(0.048)	(0.251)	(0.184)	(0.10)	(0.067)
$\frac{DF1}{price}$	-43.74	-57.26*	-5.866	-13.45				
	(27.32)	(26.97)	(9.770)	(9.463)				
$\frac{1}{2} * (\frac{DF1}{price})^2$	4753.9*	4915.8*	740.2	825.0				
	(2262.0)	(2239.7)	(805.2)	(798.7)				
Delta					0.099	0.196*	0.009	0.060
					(0.094)	(0.090)	(0.041)	(0.038)
Beta					-0.129	0.081	-0.108	0.002
					(0.272)	(0.259)	(0.094)	(0.088)
$\frac{Delta}{price}$					-19.86	-29.14**	-6.493	-12.57*
					(11.06)	(11.09)	(5.453)	(5.189)
$\frac{Beta}{price}$					18.71	-2.781	7.295	-2.354
					(45.73)	(44.77)	(16.77)	(16.28)
$\frac{1}{2} * (\frac{Delta}{price})^2$					998.5**	1035.6**	384.0	457.2*
					(309.9)	(329.0)	(200.1)	(202.8)
$\frac{1}{2} * (\frac{Beta}{price})^2$					153.3	330.7	465.9	279.5
					(3055.5)	(3053.1)	(1123.2)	(1120.9)
$g_{DF1} \equiv -\frac{U_H H_C}{\lambda}$	108.89	85.85	126.18	61.338				
$g_\delta \equiv -\frac{U_H H_C}{\lambda}$					50.28	35.54	59.17	36.37
$g_\beta \equiv -\frac{U_H H_C}{\lambda}$					- 8.19	118.91	-63.87	118.73
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	6599	6599	25697	25697	6599	6599	25697	25697
R^2	0.131	0.158	0.096	0.110	0.132	0.158	0.096	0.110

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.11: Results for consumption including nonsmoker with regressor being $ln(price), discountfactor/p$ and $\frac{1}{2} * (discountfactor/p)^2$ (approximated by Taylor expantion up to order 2).

	time consistent			time inconsistent		
	consumption					
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)
DF1	-8.934	37.21	81.64*			
	(10.52)	(38.61)	(36.15)			
ln(price)		-148.6*	-43.41		-98.27	-41.51
		(59.72)	(34.15)		(66.27)	(43.34)
$\frac{DF1}{price}$		-11021.1	-16143.2*			
		(6732.5)	(6491.4)			
$\frac{1}{2} * (\frac{DF1}{price})^2$		1109366.7*	1179651.4*			
		(544579.3)	(542920.0)			
Delta				-5.649	26.23	60.24*
				(7.304)	(27.09)	(24.41)
Beta				10.01	-74.25	1.159
				(12.48)	(55.00)	(49.05)
$\frac{Delta}{price}$					-7507.1*	-11490.7**
					(3762.3)	(3526.2)
$\frac{Beta}{price}$					8143.4	1191.8
					(9923.0)	(9367.5)
$\frac{1}{2} * (\frac{Delta}{price})^2$					397841.3**	442217.3***
					(134236.8)	(133902.5)
$\frac{1}{2} * (\frac{Beta}{price})^2$					122717.0	41407.8
					(695069.5)	(691463.8)
$g_{DF1} \equiv -\frac{U_H H_C}{\lambda}$		100.66	73.07			
$g_\delta \equiv -\frac{U_H H_C}{\lambda}$					52.995	38.48
$g_\beta \equiv -\frac{U_H H_C}{\lambda}$					-15.07	- 34.74
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Observations	25635	25635	25635	25635	25635	25635
R^2	0.085	0.087	0.102	0.085	0.088	0.103

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.12: Results for the effect of the price on the first-time quitting smoking.

	time consistent		time inconsistent	
Dependent var:	(1)	(2)	(3)	(4)
DF1	0.032	0.155		
	(0.082)	(0.252)		
Real price	0.0016**	0.001	0.0008	-0.0017
	(0.0005)	(0.002)	(0.0009)	(0.003)
DF1*price	-0.00007	-0.0004		
	(0.0009)	(0.003)		
Delta			0.067	0.251
			(0.0554)	(0.185)
Beta			-0.125	-0.395
			(0.087)	(0.292)
Beta*price			0.0015	0.005
			(0.0009)	(0.002)
Delta*price			-0.0006	-0.002
			(0.0006)	(0.002)
Initial consumption		-0.0009***		-0.0009***
		(0.00007)		(0.00007)
Control Var.	Yes	Yes	Yes	Yes
Period fixed effect	No	Yes	No	Yes
Regression	OLS	Probit	OLS	Probit
Observations	9872	9839	9872	9839
R^2	0.081		0.082	
Pseudo R^2		0.166		0.167

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chapter 3

The Effect of the Interaction Between Price and Time Preference on Cigarette Consumption: The Case of Pregnant Women

3.1 Introduction

Attributable risk is widely used to represent the relationship between smoking and its health risks. It is defined as the maximum proportion of a disease that is attributed by a certain characteristic factor, holding other factors equal for all people (Lilienfeld and Stolley, 1994). Attributable risks are distinguished between the smoking and nonsmoking group. In tobacco prevalent countries, smoking-related circulatory and respiratory diseases account for a remarkable amount of chronic illness. In particular, pregnant women who smoke face more risks than do members of the general public. For example, pregnant women who smoke exhibit lower rates of fertilization, are at greater risk for osteoporosis, and have a greater risk of natural miscarriage than other women. Furthermore, smoking during pregnancy is a risk factor for low birth weight. (Centers for Disease Control and Prevention, 2014)

Expansive health education and recent research have made the harmful consequences of smoking well known to smokers. Nevertheless, due to addiction, it is difficult for people who are willing to give up smoking to successfully quit. For example, a Finnish survey has shown that (N=752) 58 percent of smokers who attempted to stop smoking failed to actually quit (Sosiaali, 1988). Becoming a parent is a great opportunity to stop smoking, especially for women. Pregnant women are a future-oriented group: they care more about their future children's health than the general population. In this paper, I focus on how the probability of pregnant women quitting smoking changes when cigarette price and discounted future extensive cost of smoking change. According to the hypothesis, money price elasticity is smaller for individuals who are more future-oriented.

Recent studies have attempted to identify factors associated with smoking reduction. Godtfredsen et al. (2002), analyzed the relationship between smoking behavior and mortality. The authors suggest that a decline in mortality from smoking-caused diseases did not reduce cigarette smoking. Colman et al. (2003), use the Pregnancy Risk Assessment Monitoring system (PRAMS) survey data to estimate the direct effect of cigarette price on smoking during pregnancy. The PRAMS data include 38,099 observations and were designed in particular to the response to the decline in the rate of low birth weight births. Therefore, PRAMS is a particularly appropriate data set for research on the smoking behavior of pregnant women. Using the PRAMS data, Colman et al. (2003). were able to verify that the financial burden of cigarette smoking has a greater effect on smoking cessation in pregnant women than in other groups.

In this paper, I use a data set from NLSY79 (National Longitudinal Surveys 79) to test whether these same results hold. The NLSY79 data includes the smoking participation status for pregnant women for 15 years and for the general population for 4 years. I will take the smoking participation data from pregnant women as smoking status during the pregnancy and take the same pregnant womenï£¡s previous year smoking participation from drug use for general population as smoking status before pregnancy. Because smoking status for the general population is only available for 4 years, there are far fewer observations available for the estimate of probability of quitting.

The "full price" of cigarettes refers to the sum of the money price and the monetary value of the expected future harm from smoking. To determine the monetary value of expected future harm, I employ the discount rate, which is used to account for the value of risky behaviors. The risk of future outcomes can be discounted today by a discount factor $\mathrm{DF}(\beta) = 1/(1+r)$, where r is the discount rate. The higher the discount rate, the lower the discount factor and the lower the value assigned to the future outcome. As the discount rate rises, people are more likely to prefer instant gratification, resulting in lower monetary value of risky consequences. The point here is that each percentage change in cigarette price represents a greater percentage change in the full price the smaller the discount factor is. In spite of the case of time-consistent preference, the same person may also face time-inconsistent preference. Individuals tend to delay their actions in the short-run (Harris and Laibson, 2000). Individuals tend to act on the basis of instant rewards and not on the basis of future rewards (Laibson, 1997, D.Cohen et al., 2004). Risk outcomes are evaluated by individual preferences, although income level is another important concept for evaluating health risk.

This paper focuses on cause-effect analysis from the vantage point of both health and economics. First, because drug use restricts reproductive ability I want to examine the extent to which pregnant women individually or collectively reduce smoking behavior in response to price and personal preference. Individuals may sacrifice some present happiness to achieve a reduction in the probability of future harmful outcomes. (Laibson, 1997, D.Cohen et al., 2004) Second, same harmful consequences caused by smoking can be interpreted differently by the people who have various future discount rate. Interacting the price with the discount factor can be more precise in interpreting the price effect.

Besides the health risks caused by a smoking mother, the economic consequences of smoking during pregnancy also entail great costs for government sponsored healthcare for mothers and children. This paper also provides evidence of the effect of cigarette tax policy on the smoking behavior of pregnant women and may thereby contribute to a reduction in healthcare expenditure on medical benefits for pregnant women.

I use NLSY quasi-hypothetical reward question to measure personal preference. According Johnson and Bickel (2002) and Madden et al. (2003), quasi-hypothetical questions have similar results to empirical experiments. Following Courtemanche et al. (2015), I use the measure of time-preference rate, which is only available in the 2006 wave of the NLSY79.

.

3.2 Empirical Work

3.2.1 Model

To test my hypothesis, I assume each individual lives for two periods. The lifetime utility function is

$$V = U(H_0, X, C) + \beta U(H.X_1, C_1). \tag{3.1}$$

Here H_0 is initial health and is exogenous. X is the consumption of a good other than cigarettes in period 0, and C is the consumption of cigarettes in period 0. The price of X is \$1, and the price of cigarettes is p. The variables H, C_1 and X_1 are health, cigarette consumption, and the other goods in period 1 respectively. β is the time discount factor for time. For simplicity, I assume that lending and borrowing are not possible and ignore the selection of X_1 and C_1. Hence the relevant budget constraint is

$$I = X + pC \tag{3.2}$$

Finally, an increase in C lowers health in period $1(\partial H/\partial C \equiv H_c < 0)$

The Lagrange function is

$$L = U(H_0, X, C) + \beta U(H, X_1, C_1) + \lambda(I - X - pC),$$

where λ is the marginal utility of income.

The first order condition for C is

$$U_c + \beta U_H H_{Cd} = \lambda p$$

The second term on the right-hand side of the last equation is negative since $U_H > 0$ and $H_C < 0$. The previous equation is rewritten as

$$U_c = \lambda(p - \beta \frac{U_H H_C}{\lambda})$$

Note that $f \equiv -\beta \frac{U_H H_C}{\lambda}$ defines the discounted monetary value of the loss in utility in period 1 due to smoking in period 0. Hence the full price of cigarettes (π) is

$$\pi \equiv p + f$$

The full price is higher the larger is the value of β.

One way to proceed is to specify a general demand function without assuming anything about the form of the utility function:

$$C = C(I, \pi) \tag{3.3}$$

Then differentiate C with respect to p, with f and I held constant

$$C_p = C_\pi$$

So

$$-C_p \frac{p}{C} \equiv = -C_\pi \frac{\pi}{C} \frac{p}{\pi}$$

Define ϵ as - $C_\pi \frac{\pi}{C}$, and note that ϵ is the elasticity of C with respect to full price π. Hence

$$e = (p/\pi)\epsilon$$

If ϵ is constant, e rises as β falls because p/π rises as β falls. In words, people who discount the future heavily have a more elastic demand function than those who do not because as one percent change in money price is a larger percentage change in full price for the former group.

Because I am interested in the effect of cigarette price and the interaction between price and the discount factor, I simplify the cigarette demand model as follows:

$$C_{i,t} = \alpha P_{i,t} + \alpha_1 P_{i,t} \beta_i + \epsilon_{i,t} \tag{3.4}$$

where: β is the discount factor. The partial price effect is

$$\frac{\partial C_{i,t}}{\partial P_{i,t}} = \alpha + \alpha_1 \beta_i.$$

The effect of price should be negative. Since, if the price increases, the consumption of goods will decrease. The coefficient of the discount factor should be negative because the greater the discount factor (the smaller the discount rate), the lesser the amount of consumption. The coefficient of the interaction term should be positive. The bigger the β (smaller time preference rate) is, the less patient people respond to the price. The full price includes monetary price of cigarettes and expected monetary value of future harm. The people who appreciate the future more, have bigger share in larger expected monetary value for the future consequences, therefore should be less responsive to the current cigarette price. While impatient people care more about the current cigarette cost, for instance poor and teenagers, are more sensitive to the cigarette price change.

In the time inconsistent case, instead of the single discount factor, it consists of the long run discount factor δ and the present-bias β. Economists have used the quasi-hyperbolic function: 1, $\beta\delta$, $\beta\delta^2$, ..$\beta\delta^t$, ... When $\beta \leq 1$, δ is constant for all the time and β captures the discount rates decrease in time t. Short run time preference rate is greater than the long run time preference rate. The best value for long run δ is 0.7 (Laibson, 1997). Most people overtime have a diminishing the present-bias β. The quasi-hyperbolic examination shows that the average discount rate of β is 0.8, next period become 0.7 or average 33% per year (Courtemanche et al., 2015).

3.2.2 Probit estimation

According to (Ai and Norton, 2003), assume a Probit model as

$$Pr[y = 1|x_1, x_2, X] = \Phi(\beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + X\beta) \tag{3.5}$$

Where X is a k x 1 vector of independent variables, including control variables, year dummy and state dummy depending on the model. To derive the interaction effect of $x_1 x_2$, first the derivative with respect to x_1 is:

$$\frac{\partial \Phi(\cdot)}{\partial x_1} = \Phi'(\beta_1 + \beta_{12} x_2) \tag{3.6}$$

then with respect to x_2:

$$\frac{\partial^2 \Phi(\cdot)}{\partial x_1 \partial x_2} = \beta_{12}\Phi'(\cdot) + (\beta_1 + \beta_{12} x_2)(\beta_2 + \beta_{12} x_1)\Phi''(\cdot) \tag{3.7}$$

In order to calculate the correct standard error, Ai and Norton (2003) suggests to use the Delta method for the variance, derived from the Taylor expansion (Xu and long, 2005). The normal distribution of the interaction effect is shown as

$$\hat{\mu}_{12} \backsim \mathcal{N}(\mu_{12}, \frac{\partial}{\partial \beta'}[\frac{\partial^2 \Phi(\cdot)}{\partial x_1 \partial x_2}]\hat{\Omega}_\beta \frac{\partial}{\partial \beta}[\frac{\partial^2 \Phi(\cdot)}{\partial x_1 \partial x_2}] \tag{3.8}$$

and estimated variance is

$$\frac{\partial}{\partial \beta'}[\frac{\partial^2 \Phi(\cdot)}{\partial x_1 \partial x_2}]\hat{\Omega}_\beta \frac{\partial}{\partial \beta}[\frac{\partial^2 \Phi(\cdot)}{\partial x_1 \partial x_2}$$

The t statistics is $t = \hat{\mu}_{12}/\hat{\sigma}_{12}$. The hypothesis can be tested by using the t statistics.

To calculate the standard error of the interaction effect, I write the derivative for each estimate as follows. Set $\frac{\partial^2 \Phi(\cdot)}{\partial x_1 \partial x_2}$=$S$

$$\frac{\partial S}{\partial \beta_1} = \beta_{12}\Phi'' x_1 + [(\beta_2 + \beta_{12}x_1)\Phi'' + (\beta_1 + \beta_{12}x_2)(\beta_2 + \beta_{12}x_1)\Phi''' x_1]$$

$$\frac{\partial S}{\partial \beta_2} = \beta_{12}\Phi'' x_2 + [(\beta_1 + \beta_{12}x_2)\Phi'' + (\beta_1 + \beta_{12}x_2)(\beta_2 + \beta_{12}x_1)\Phi''' x_2]$$

$$\frac{\partial S}{\partial \beta_{12}} = (\Phi' + \beta_{12}\Phi'' x_1 x_2) + [(\beta_1 x_1 + \beta_2 x_2 + 2\beta_{12}x_1 x_2)\Phi'' + (\beta_1 + \beta_{12}x_2)(\beta_2 + \beta_{12}x_1)\Phi''' x_1 x_2]$$

$$\frac{\partial S}{\partial \beta_4} = \beta_{12}\Phi'' x_4 + (\beta_1 + \beta_{12}x_2)(\beta_2 + \beta_{12}x_1)\Phi''' x_4$$

$$\vdots$$

$$\frac{\partial S}{\partial \beta_k} = \beta_{12}\Phi'' x_k + (\beta_1 + \beta_{12}x_2)(\beta_2 + \beta_{12}x_1)\Phi''' x_k$$

In the empirical analysis, the related results for the interaction effect are obtained by the above equations. In the data , I will consider x_1 as discount factor 1 and x_2 as cigarette price.

3.3 Data

Excluding for cigarette price, all data are drawn from the National Longitudinal Surveys 1979 (NLSY79). This data is generally available every other year from 1979 to 2010. The dependent variable is generated from pregnant women smoking participation, which was available in 1983, 1984, 1985, 1986, 1988, 1990, 1992, 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008 (15 year periods). The 2010 and 2012 survey data are available now, however, since I only have cigarette price data up to 2009, I used NLSY79 data up to 2008.

The dependent variable is a quitting smoking indicator, which equals 1 when smoking women stop smoking after getting pregnant, and 0 otherwise. The smoking status of pregnant women is available in the original questionnaire, which examines the smoking behavior of pregnant women, whereas smoking status before pregnancy can only be obtained from general drug use answers, which are only available in 1984 ,1992, 1994, 1998, 2008. This means that, in order to satisfy the indicator condition that before- and during-pregnancy smoking participation status is non-missing, many smoking status observations for pregnant women had to be dropped. Participation data in 1984 is structured differently from 1992, 1994, 1998, and 2008. Specifically, there is no question about "100 cigarettes smoked in entire life time" for the 1984 participation survey. In NLSY79 individuals aged between 19 and 27 in 1984. Because, according previous research, smokers are likely to begin smoking during this younger age range, I include the 1984 data in the quitting model. All of the independent variables are time varying data, except for AFQT, being from 1988, and the discount factor from 2006.

I am primarily interested in quitting-smoking behavior. In such cases, quitting refers to the women who smoke before pregnancy and stop smoking after pregnancy. The data sample consists of women who smoked before pregnancy and either continued to smoke or stopped smoking after pregnancy. The quitting proportion of the total is 0.27 (56/205). By year, the proportions are 0.23 (17/73=0.23) in 1984; 0.32 (20/63=0.32) in 1992; 0.29 (14/49=0.29) in 1994; and 0.25 (5/20=0.25) in 1998. These numbers are consistent with the findings of (Colman et al., 2003). I consider both women who became pregnant during one period (31/124=0.25) and those who became pregnant in two consecutive years (25/81=0.31). In the latter case, the women who stop smoking during any pregnancy are categorized as those who stopped smoking.

Data for prices and taxes come from Tax Burden on Tobacco (Volume 44, 2009). Data is at the county level for the period from 1984 to 2009. Both price and tax are in the real term. The base period of CPI is 1967=100. Taxes in the real term includes federal,state and county taxes.

I use monthly data (cigarette interview date) in NLSY79 to merge with cigarette prices to match with state and county tax, which is a more effective way for cigarette price to capture the tax change by month.

For the discount factor variable , one can refer to Chapter 2.

Table 3.1 is the summary list for all the control variables used in the equations. Table 3.2 is the summary list for the all the key variables used in the equations.

3.4 Empirical analysis

3.4.1 Time consistent discount factor model

The estimating regression equation for the time consistent discount factor model is

$$\begin{aligned} C_{it} = {} & \alpha_0 + \alpha_1 DF1_i + \alpha_2 DEMO_{it} + \alpha_3 HC_{it} + \alpha_4 LABOR_{it} + \alpha_5 FIN_{it} \\ & + \epsilon_{it} \end{aligned} \tag{3.9}$$

where C is cigarette consumption or smoking participation; i represents individuals; $DF1$ is the annual discount factor; DEMO includes age, gender, race and marital status; HC (Human Capital) includes AFQT score and schooling dummies; LABOR includes work hours and occupation (for example, workers' blue collar, white collar and service indicators); and FIN (Financial) includes income, income squared and net worth. For consumption regression, I estimate data set both with positive consumption and with consumption including nonsmoker.

$$\begin{aligned} C_{it} = {} & \alpha_0 + \alpha_1 DF1_i + \alpha_2 DEMO_{it} + \alpha_3 HC_{it} + \alpha_4 LABOR_{it} + \alpha_5 FIN_{it} \\ & + \alpha_6 P_{ct} + \alpha_7 DF1_i P_{ct} + \epsilon_{it} \end{aligned} \tag{3.10}$$

where P_{ct} is the cigarette price varying by county level and by time. In contrast to the previous equation which only examines the effect of the discount factor on cigarette consumption, I add cigarette price and the interaction term of price and the discount factor into this equation. If r is bigger than 0 for the future benefit, then $DF1$ is always less than 1. The equation (3.10) includes additional cigarette prices and the interaction of cigarette prices with the discount factor. I want to examine how the discount factor influences the cigarette consumption through prices.

3.4.2 Smoking consumption and participation

Although this paper is interested in the quitting probabilities of pregnant women, first I want to represent the general relationship between cigarette consumption and the discount factor for pregnant women.

Table 3.3 displays the estimated results from equation (3.9). Column (1) is a simple estimation without a price term for consumption. Consumption here indexes the number of cigarettes people consumed during the last 30 days. Columns (2) and (3) are the results from the regression on price and the interaction between price and the discount factor $DF1$, which follows equation (3.10). Column (3) is estimated with both year and state fixed-effect. Columns (4) and (5), (6) are following equation (3.9) and (3.10) respectively. Here, the dependent variable is smoking participation for cigarettes, for which "smoked during last 30 days" is indicated by 1 and "nonsmoker" is indicated by 0. The greater the discount factor (the lower the discount rate) is, the more people are future-oriented, and the less people respond to changes in current price. Columns (2), (3), (5) and (6) show that the coefficient of DF1 is negative which means the discount factor is negatively related to cigarette consumption. The price elasticity of participation for the non-state fixed effect model in Table 3.3, column (1) is -0.56, similar to results obtained by Chaloupka and Warner (2000). There is no price effect on the number of cigarettes smoked in columns (2) and (3), which is consistent with previous findings (Colman et al., 2003).

I am interested in columns (2), (3), (5) and (6). The coefficient of price should be negative because when price goes up, consumption should go down. The coefficient of interaction should be positive, because the negative price effect will decrease when individuals tend to be more future-oriented. Column (2), (3), (5) and (6) show reasonable results. Even though the coefficients of the interaction term are not significant within the 10% confidence interval, the t-statistic for the interaction (the coefficient divided by its standard error) is 1.33 for participation in column (5), which is weakly significant. From these results, I conclude that people who are present-oriented are more likely to smoke as cigarette price goes up, though the results were not significant.

From the coefficients of high school, some college and college. It is easy to see that as the level of education increases, the consumption of the cigarettes decreases (-116.9 shown in Table 3.3 and column (3)). As income increases, people become more concerned about their health, so the coefficient of income is negative (-5.065 shown in Table 3.3 and column (3)). These results have proved the rationale expectation. Compare to the consumption result with Table 5, we get the negative price elasticity and the coefficient of interaction shows positive in Table 3.5. Estimate results are improved a lot when I add the nonsmoker into the pure consumption population.

3.4.3 Quit probabilities

The results shown in Table 3.6 prove the hypothesis of quitting probabilities. First, for the probit model, the interaction effect of probit is calculated from a cross derivative of the expected value of smoking participation and its standard error is the result from the delta method. The hypothesis here is that price increases the probability of quitting smoking. For the quitting indicator, I defined that quitting=1 if a pregnant woman gives up smoking during her pregnancy period and 0 if a pregnant woman keep smoking .The price effect will be smaller for individuals who have higher discount factors. That results in a negative sign for the interaction effect. In table 3.6, column (5) and (6), I find positive price participation elasticity and a negative coefficient for the interaction term, confirming the hypothesis. Second, in the linear probability model in Table 3.6, column (2) and (3), price elasticity is correctly positive, and the interaction effect is negative, consistent with my expectations.

3.4.4 Time inconsistent discount factor model

In the previous section, I analyzed the discount factor for the time consistent case. Next I will consider the discount factor for the time-inconsistent case .

$$\begin{aligned} C_{it} = \theta_0 + \theta_1\beta_i + \theta_2\delta_i + \theta_3 DEMO_{it} + \theta_4 HCit + \theta_5 LABOR_i \\ + \theta_6 FIN_{it} + \eta_{it} \end{aligned} \tag{3.11}$$

$$
\begin{aligned}
C_{it} = \theta_0 + \theta_1\beta_i + \theta_2\delta_i + \theta_3 DEMO_{it} + \theta_4 HCit + \theta_5 LABOR_i \\
+ \theta_6 FIN_{it} + \theta_7 P_{it} + \theta_8(\beta_i * P_{it}) \\
+ \theta_9(\delta_i * P_{it}) + \theta_{10}\eta_{it}
\end{aligned}
\tag{3.12}
$$

where β is present-bias and δ is long-run patience. I assume that the discount factor decreases as time T progresses. δ is constant over the course of an individual's lifetime. β, which captures the variation in time, is the value weighted to constant discount factor δ.

To concentrate the price and interaction effect, I temporarily simplify the demand function in equation (3.12)

$$
C_{i,t} = \alpha P_{i,t} + \alpha_1 P_{i,t}\beta_i + \alpha_2 P_{i,t}\delta_i + \epsilon_{i,t} \tag{3.13}
$$

where: β and δ are the discount factor. The partial price effect is

$$
\frac{\partial C_{i,t}}{\partial P_{i,t}} = \alpha + \alpha_1\beta_i + \alpha_2\delta_i
$$

Table 3.4 shows the results for the time-inconsistent case. Columns (1) and (2) are the regression results for equation (3.11) and (3.12), respectively. Column (3) is the estimation with year and state fixed-effect. The discount factor should be negative since the higher discount factor (the lower discount rate, referring to patient individuals) is less responsive to price change. In columns (4) and (5), the participation regression indicate reasonable results. The interaction between price and the discount factor should be positive, because the negative price effect decreases for individuals who are more future-oriented. In column (6), both coefficients of price interaction are positive, but insignificant.

Table 3.5, column (5) is the result for consumption, which includes observations of nonsmokers without state fixed-effect. It indicates that the price effect is negative and the interaction effect is positive. Both results are consistent with the prediction. When compared to the oddly positive price elasticity indicated in columns (2) and (3) in both Tables 3.3 and 3.4, columns (2) and (5) in Table 3.5 show the negative sign. The reason is that the consumption data that includes nonsmokers tends to be less biased than the data that excludes nonsmokers.

Table 3.5, columns (3) and (6) do not show a negative price sign. This may be because there was little state-to-state variation in price within a given year. The regression including state fixed-effect tends to show a weaker result and, thus, is less reliable.

3.4.5 Full Price Model

The effect of Logarithm of the Price

One may recall that the full price of cigarettes is $\pi = p+f$, where $f \equiv -\beta\frac{U_H H_C}{\lambda}$ is the discounted monetary value of the loss in utility in period 1 due to smoking in period 0, and β is the discount factor. The point is that a one percent change in p is a bigger percentage change in π the smaller is β. To see more detail, let the demand function be

$$C = \alpha + \gamma \ln(p+f) = \alpha + \gamma \ln p + \gamma \ln[(p+f)/p] + \epsilon \tag{3.14}$$

$$\frac{\partial C}{\partial \ln p} = k\gamma, k \equiv p/(p+f) \tag{3.15}$$

I have β but do not have $g \equiv -(U_H H_c)/\lambda$. Since k rises as β falls, $\partial C/\partial \ln p$ should be bigger in absolute value the smaller is β. So I would regress C on $\ln p$ and $\beta * \ln p$. The coefficient of the interaction should be positive, while the coefficient of price should be negative when either participation or consumption is the dependent variable. The regression model is:

$$C = \gamma_0\beta + \gamma_1 \ln p + \gamma_2 \beta * \ln p \tag{3.16}$$

In this model, for the number of cigarettes consumed, ln C is used instead of C , because we want to transform consumption into a small scale consistent with the scale of $\ln p$. Otherwise, the coefficient of $\ln p$ would be too large. For smoking participation, we will use the original data form. The price effect, also the price elasticity is $\frac{\partial C}{\partial \ln p} = \gamma_1 + \gamma_2\beta$. A one percent increase in price is a smaller percentage change in the full price for those who are more future oriented. So the negative price effect should be smaller for them, therefore the interaction effect should be positive.

For time inconsistent case, the discount factor β becomes two factors of δ and β, which δ is constant over the period of lifetime, and β increases as time progresses. The estimation should regress C on $\ln p, \delta * \ln p$ and $\beta * \ln p$. The regression model is:

$$C = \gamma_1 \beta + \gamma_2 \delta + \gamma_3 \ln p + \gamma_4 \beta * \ln p + \gamma_5 \delta * \ln p \tag{3.17}$$

The price elasticity equation is $\frac{\partial C}{\partial \ln p} = \gamma_3 + \gamma_4 \beta + \gamma_5 \delta$. This price effect should be negative when participation or consumption is the dependent variable. When "quitting probability" is the dependent variable, the price effect should be positive and the interaction term should be negative.

Tables 3.8 and 3.9 show the results of regressing consumption and smoking participation on ln p and β*ln p for the time-consistent and time-inconsistent cases. For all results, the price effect is negative and the interaction effect is positive. This is consistent with the theory that individuals who are more future-oriented have less of a response to the price effect. For these individuals, the negative price effect should be smaller and, therefore, the interaction effects should be positive.

Approximated full Price Model

Let consider one additional point in which future monetary loss is included. Set $g \equiv -(U_H H_C)/\lambda$. The $f = \beta g$. I have a measure of β but do not have a measure of g. I will regress C on $\ln p$ and $\ln(1 + \frac{\beta}{p})$. Alternatively if $\beta g/p$ is less than 1

$$\ln(1 + \frac{\beta g}{p}) \approx \frac{\beta g}{p}$$

This approximation is based on the Taylor expansion up to first order. If I use the approximation, $C = \alpha + \gamma \ln p + \gamma g \beta p^{-1}$. If g is a constant, the coefficient of βp^{-1} estimates γg. In either case, the model I am going to estimate includes $\ln p$ and βp^{-1}. Note that the sign of the interaction is the same as the sign of $\ln p$ and is negative. Since with $\ln p$ and hence p held constant, an increase in β raises the full price of smoking (π) and hence lowers the probability of smoking and the amount smoked given positive consumption. It still is the case that the price effect falls as β rises. Here, the price effect of $\ln p$ is negative, but the price term in the interaction is $\frac{1}{p}$, which as a whole has positive effect on consumption. Because an increased β decreases positive price effect on consumption, the interaction term is negative.

$$C = \alpha + \gamma \ln p + \gamma \ln[(p+f)/p] = \alpha + \gamma \ln p + \gamma \ln[1 + f/p] = \alpha + \gamma \ln p + \gamma g \beta p^{-1} \tag{3.18}$$

$$\frac{\partial C}{\partial \ln p} = \gamma - \gamma g \beta p^{-1} \tag{3.19}$$

The second term on the right-hand side of the last equation is positive as long as $g\beta < p$, which is the assumption of the approximation. Given that, the right hand side of the equation falls in absolute value as β rises. The last equation is the price elasticity of this model for smoking participation and logarithm consumption.

Table 3.10 shows the time-consistent and time-inconsistent results for the full-price model approximated by Taylor expansion order 1. In Table 3.11, the dependent variable changes to cigarette consumption including nonsmokers. As predicted, both the price effect and the interaction effect are negative, which proves my hypothesis that as β rises, the positive price effect of $\frac{1}{p}$ on consumption and smoking participation declines. The coefficient of the interaction term in the table 3.11 seems very large, but this is because the independent variable "consumption with nonsmoker" ranges from 0 to 1200. However, the value of $discountfactor/price$ ranges from 1.14e-06 to .0140684 with a mean of .0057, calculated from the mean of the discount factor (0.558) and price (99.71).

Consider a fuller Taylor expansion

$$\ln(1 + \frac{\beta g}{p}) \approx \frac{\beta g}{p} - \frac{1}{2}(\frac{\beta g}{p})^2 \tag{3.20}$$

The estimate model becomes

$$C = \gamma \ln p + \gamma g \beta p^{-1} - \frac{\gamma g^2 \beta^2}{2} p^{-2}$$

$$\frac{\partial C}{\partial \ln p} = \gamma - \gamma g \beta p^{-1} - \frac{\gamma g^2 \beta^2}{2} \frac{-2}{p^2} = \gamma - \gamma g \beta p^{-1} + \frac{\gamma g^2 \beta^2}{p^2} = \gamma(1 - g\beta p^{-1} + g^2 \beta^2 p^{-2}) \tag{3.21}$$

In the time inconsistent case, the Taylor expansion can be approximated as ,

$$\ln(1 + \frac{\delta g}{p} + \frac{\beta g}{p}) \approx \frac{\delta g}{p} + \frac{\beta g}{p}$$

The regression function is

$$C = \gamma \ln p + \gamma g \delta p^{-1} + \gamma g \beta p^{-1} \tag{3.22}$$

It is still true that the price effect is negative

$$\frac{\partial C}{\partial \ln p} = \gamma - \gamma g \delta p^{-1} - \gamma g \beta p^{-1} \tag{3.23}$$

Applying two discount factors δ, β into the fuller Taylor expansion results in

$$\ln(1 + \frac{\beta g}{p}) \approx \frac{\beta g}{p} - \frac{1}{2}(\frac{\beta g}{p})^2 \Rightarrow \frac{\delta g}{p} + \frac{\beta g}{p} - \frac{1}{2}(\frac{\delta g}{p})^2 - \frac{1}{2}(\frac{\beta g}{p})^2$$

The regression model form is

$$C = \gamma \ln p + \gamma g \delta p^{-1} + \gamma g \beta p^{-1} - \frac{\gamma g^2 \delta^2}{2} p^{-2} - \frac{\gamma g^2 \beta^2}{2} p^{-2} \tag{3.24}$$

Table 3.12 shows the results of the full-price model approximated by Taylor expansion up to order 2. In column (1), (2) and (4), the coefficients of the second interaction term show the positive sign, which is consistent with the hypothesis.

Probit estimation for The effect of the Logarithm of the Price

In the probit model, the regression model for the effect of the logarithm of the price is

$$Pr[y = 1 | x_1, x_2, X] = \Phi(\beta_1 \beta + \beta_2 \ln p + \beta_{12} \beta \ln p + X\gamma)$$

where x_1 is applied to β, and x_2 to $\ln p$.g

Similarly the time inconsistent equation is

$$Pr[y = 1|x_1, x_2, x_3, X] = \Phi(\beta_1\beta + \beta_2\delta + \beta_3 \ln p + \beta_{13}\beta \ln p + \beta_{23}\delta \ln p + X\gamma)$$

When the probability of quitting is the dependent variable, the coefficient of price should be positive and the coefficient of the interaction should be negative. The detailed calculation for the coefficient and standard error of the interaction term are shown in Section 2.2., where I can apply x_1 to β, and x_2 to $\ln p$ in the time-consistent case.

Table 3.14 shows the results of the time-consistent and time-inconsistent cases for the quitting probability of pregnant women. I regress quitting index (either 0 or 1) on lnp and $\beta * \ln p$. As explained in Section 4.5.1., the price effect of $\frac{\partial C}{\partial \ln p} = k\gamma$, where $k \equiv p/(p + f)$, should be bigger in absolute value the smaller is β, since k rises as β falls.

In the table, excluding the regression with adding state fixed-effect, the coefficients of price show a positive sign, which is explained by the theory that when price goes up, the probability of quitting smoking also goes up. The coefficients of the interaction term all present a negative sign, which means that the positive price effect decreases when individuals are more future-oriented.

Probit estimation for Approximated full Price Model

I regress quitting index (0 or 1) on lnp and $\frac{\beta}{p}$ which is the approximation of $\ln(1 + \frac{\beta g}{p}) \approx \frac{\beta g}{p}$. Since g is not a variable available in the data, the estimated coefficient of $\frac{\beta}{p}$ includes the value of g. Later I will estimate g by using Taylor expansion up to second order to estimate g.

Recall the Probit model I assumed before

$$Pr[y = 1|x_1, x_2, X] = \Phi(\beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + X\gamma)$$

The estimation equation for the full price model using Taylor expansion up to first order is

$$Pr[y = 1|x_1, x_2, X] = \Phi(\beta_1\beta + \beta_2 \ln p + \beta_{12} g\beta p^{-1} + X\gamma) \tag{3.25}$$

The first derivative with respect to β is:

$$\frac{\partial\Phi(\cdot)}{\partial\beta} = \Phi'(\beta_1 + \beta_{12}p^{-1})$$

then with respect to p^{-1}:

The coefficient of the interaction term should be

$$\frac{\partial^2\Phi(\cdot)}{\partial\beta\partial p^{-1}} = \beta_{12}\Phi'(\cdot) + (\beta_1 + \beta_{12}p^{-1})(\beta_2(-p) + \beta_{12}\beta)\Phi''(\cdot) \tag{3.26}$$

In order to calculate the correct standard error, Ai and Norton (2003) paper suggest using the Delta method for the variance derived from the Taylor expansion (Xu and long, 2005). The normal distribution of the interaction effect is shown as

$$\hat{\mu}_{12} \backsim \mathcal{N}(\mu_{12}, \frac{\partial}{\partial\beta'}[\frac{\partial^2\Phi(\cdot)}{\partial x_1\partial x_2}]\hat{\Omega}_\beta\frac{\partial}{\partial\beta}[\frac{\partial^2\Phi(\cdot)}{\partial x_1\partial x_2}] \tag{3.27}$$

and the estimated variance is

$$\hat{\sigma}_2^2 = \frac{\partial}{\partial\beta'}[\frac{\partial^2\Phi(\cdot)}{\partial x_1\partial x_2}]\hat{\Omega}_\beta\frac{\partial}{\partial\beta}[\frac{\partial^2\Phi(\cdot)}{\partial x_1\partial x_2}]$$

The t statistics is $t = \hat{\mu}_{12}/\hat{\sigma}_2$. It is easy to test the hypothesis by using the t statistics.

To calculate the standard error of the interaction effect, I write the derivative for each estimate as follows. Set $\frac{\partial^2\Phi(\cdot)}{\partial x_1\partial x_2}$ $=S$, which is equation (3.26).

$$\frac{\partial S}{\partial\beta_1} = \beta_{12}\Phi''\beta + (\beta_2 * (-p) + \beta_{12}\beta)\Phi'' + (\beta_1 + \beta_{12}p^{-1})(\beta_2(-p) + \beta_{12}\beta)\Phi'''\beta$$

$$\frac{\partial S}{\partial\beta_2} = \beta_{12}\Phi'' \ln p + (\beta_1 + \beta_{12}p^{-1})\Phi'' * (-p) + (\beta_1 + \beta_{12}p^{-1})(\beta_2(-p) + \beta_{12}\beta)\Phi''' \ln p$$

$$\frac{\partial S}{\partial\beta_{12}} = (\Phi' + \beta_{12}\Phi''\beta p^{-1}) + (p^{-1}\beta_2(-p) + 2\beta_{12}p^{-1}\beta + \beta 1\beta)\Phi'' + (\beta_1 + \beta_{12}p^{-1})(\beta_2(-p) + \beta_{12}\beta)\Phi'''\beta p^{-1}$$

$$\frac{\partial S}{\partial \beta_4} = \beta_{12}\Phi'' x_4 + (\beta_1 + \beta_{12}p^{-1})(\beta_2(-p) + \beta_{12}\beta)\Phi''' x_4$$

$$\vdots$$

$$\frac{\partial S}{\partial \beta_k} = \beta_{12}\Phi'' x_k + (\beta_1 + \beta_{12}p^{-1})(\beta_2(-p) + \beta_{12}\beta)\Phi''' x_k$$

The equation above is used to calculate the standard error in the interaction term in the probit full-price model approximated by Taylor expansion up to order 1.

Table 3.15 shows an empirical result for Taylor expansion order 1 approximation. The effect of price on quitting smoking should be positive. The interaction term of $(discountfactor/price)$ is positive. For this term, the price effect of p^{-1} is negative on quitting smoking. A one percent increase in price is a smaller percentage change in the full price for those individuals who are more future-oriented. The negative price effect in interaction term should be smaller for these individuals and, thus the interaction effect should be positive. The sign of price elasticity and interaction shown in the table 3.15 are all consistent with my prediction, even though results are statistically insignificant.

In the time-inconsistent case, two discount factors that interact with price need to be considered. β and δ are two different discount factors, the demand function for the probit model with the full-price model approximated by Taylor expansion up to first order is

$$Pr[y = 1|x_1, x_2, x_3, X] = \Phi(\beta_1\beta + \beta_2\delta + \beta_3 \ln p + \beta_{13}\beta p^{-1} + \beta_{23}\delta p^{-1} + X\gamma)$$

Where p indicates cigarette price. X is a k x 1 vector of independent variables, including control variables, year dummy and state dummy.

In this case, the effect of price is

$$\frac{\partial \Phi(\cdot)}{\partial \ln p} = \Phi'(\beta_3 - \beta_{13}\beta p^{-1} - \beta_{23}\delta p^{-1})$$

To calculate interaction effect for β, first, the derivative with respect to β is:

$$\frac{\partial\Phi(\cdot)}{\partial\beta} = \Phi'(\beta_1 + \beta_{13}p^{-1})$$

then with respect to p^{-1}

$$\frac{\partial^2\Phi(\cdot)}{\partial\beta\partial p^{-1}} = \beta_{13}\Phi'(\cdot) + (\beta_1 + \beta_{13}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi''(\cdot) \tag{3.28}$$

To calculate the interaction effect for δ, first, the derivative with respect to $g\delta$:

$$\frac{\partial\Phi(\cdot)}{\partial\delta} = \Phi'(\beta_2 + \beta_{23}p^{-1})$$

then with respect to p^{-1}

$$\frac{\partial^2\Phi(\cdot)}{\partial\delta\partial p^{-1}} = \beta_{23}\Phi'(\cdot) + (\beta_2 + \beta_{23}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi''(\cdot) \tag{3.29}$$

As noted in equation (3.27), in the probit model the interaction effect can be shown as a normal distribution with standard error adjusted by the delta method. To construct the matrix for it, I will write few representative derivations, which should be that each coefficient with respect to the interaction effect of β in equation (3.28) and to the interaction effect of δ in equation (3.29).

First, with respect to the interaction equation of β in equation (3.28)

$$\frac{\partial S}{\partial\beta_1} = \beta_{13}\Phi''\beta + (\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'' + (\beta_1 + \beta_{13}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\beta$$

$$\frac{\partial S}{\partial\beta_2} = \beta_{13}\Phi''\delta + (\beta_1 + \beta_{13}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\delta$$

$$\frac{\partial S}{\partial\beta_3} = \beta_{13}\Phi''\ln p + (\beta_1 + \beta_{13}p^{-1})(-p)\Phi'' + (\beta_1 + \beta_{13}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\ln p$$

$$\frac{\partial S}{\partial \beta_{13}} = (\Phi' + \beta_{13}\Phi''\beta p^{-1}) + (p^{-1}\beta_3(-p) + 2\beta_{13}p^{-1}\beta + p^{-1}\beta_{23}\delta + \beta_1\beta)\Phi''$$
$$+(\beta_1 + \beta_{13}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\beta p^{-1}$$

$$\frac{\partial S}{\partial \beta_{23}} = \beta_{13}\Phi''\delta p^{-1} + [\beta_1 + \beta_{13}p^{-1})\delta\Phi'' + (\beta_1 + \beta_{13}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\delta p^{-1}]$$

$$\frac{\partial S}{\partial \beta_4} = \beta_{13}\Phi'' x_4 + (\beta_1 + \beta_{13}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi''' x_4$$

$$\vdots$$

$$\frac{\partial S}{\partial \beta_k} = \beta_{13}\Phi'' x_k + (\beta_1 + \beta_{13}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi''' x_k$$

Secondly, with respect to the interaction of δ in equation (3.29)

$$\frac{\partial S}{\partial \beta_1} = \beta_{23}\Phi''\beta + (\beta_2 + \beta_{23}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\beta$$

$$\frac{\partial S}{\partial \beta_2} = \beta_{23}\Phi''\delta + (\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'' + (\beta_2 + \beta_{23}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\delta$$

$$\frac{\partial S}{\partial \beta_3} = \beta_{23}\Phi''\ln p + (\beta_2 + \beta_{23}p^{-1})(-p)\Phi'' + (\beta_2 + \beta_{23}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\ln p$$

$$\frac{\partial S}{\partial \beta_{13}} = \beta_{23}\Phi''\beta p^{-1} + (\beta_2 + \beta_{23}p^{-1})\beta\Phi'' + (\beta_2 + \beta_{23}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\beta p^{-1}$$

$$\begin{aligned}\frac{\partial S}{\partial \beta_{23}} = (\Phi' + \beta_{23}\Phi''\delta p^{-1}) + (p^{-1}\beta_3(-p) + 2\beta_{23}p^{-1}\delta + p^{-1}\beta_{13}\beta + \beta_2\delta)\Phi'' \\ +(\beta_2 + \beta_{23}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''\delta p^{-1}\end{aligned}$$

$$\frac{\partial S}{\partial \beta_4} = \beta_{23}\Phi''x_4 + (\beta_2 + \beta_{23}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''x_4$$

$$\vdots$$

$$\frac{\partial S}{\partial \beta_k} = \beta_{23}\Phi''x_k + (\beta_2 + \beta_{23}p^{-1})(\beta_3(-p) + \beta_{13}\beta + \beta_{23}\delta)\Phi'''x_k$$

Table 3.15 shows the results.

3.4.6 First differences Model

With regard to the panel data analysis, the traditional way to solve the unobservable individual fixed-effect problem is to take first differences , which individual fixed effect will drop out of the equation. Even though this method leads to some inconsistent estimator problems, which can be improved by the GMM method, I still prefer to use this method to improve my estimate results. The first reason that I prefer to take first differences is that, in spite of including many control variables, the estimate of price effect will be affected by the unobserved individual effect, for example personal taste or the smoking status of a family member. Second, the change in price will have a more direct effect on quitting probability and, thus, the interaction effect will be more explicit.

A discrete time linear probability hazard model, suggested by Margolis et al. (2013) is the first differences from a log smoking-participation model. The log smoking-participation model will be

$$
\begin{aligned}
\ln s_{it} = \alpha_0 - \alpha_1 DF1_i - \alpha_2 DEMO_{it} - \alpha_3 HC_{it} - \alpha_4 LABOR_{it} - \alpha_5 FIN_{it} \\
- \alpha_6 P_{ct} - \alpha_7 DF1_i P_{ct} - \alpha_7 f_i - \epsilon_{it}
\end{aligned} \tag{3.30}
$$

where f_i is the individual fixed effect. After first differences, all time-invariant individual characteristics, such as f_i, $DF1_i$ and schooling level will drop out.

Before making difference for the equation, consider a derivation:

$$S_t \equiv S_{t-1} - Q_t$$

where S_t is the number of smokers in period t and Q is the number of quitters in period t. Then divide by the population

$$\frac{S_t}{N} \equiv \frac{S_{t-1}}{N} - \frac{Q_t}{S_{t-1}} \frac{S_{t-1}}{N}$$

Set $s_t = \frac{S_t}{N}$ and $s_{t-1} = \frac{S_{t-1}}{N}$, then

$$\frac{s_t}{s_{t-1}} \equiv 1 - q_t \Rightarrow \ln \frac{s_t}{s_{t-1}} \equiv \ln(1 - q_t) \simeq -q \tag{3.31}$$

where s_t and s_{t-1} are the smoking participation rates and q_t is the quit rate.

Now taking the first differences, one gets

$$-(\ln s_t - \ln s_{t-1}) \simeq q_t$$

$$q_t = \alpha_2(DEMO_{i,t} - DEMO_{i,t-1}) + \alpha_3(HC_{i,t} - HC_{i,t-1}) + \alpha_4(LABOR_{i,t} + LABOR_{i,t-1})$$
$$+\alpha_5(FIN_{i,t} - FIN_{i,t-1}) + \alpha_6(P_{c,t} - P_{c,(t-1)}) + \alpha_7 DF1_i(P_{c,t} - P_{c,(t-1)}) + \alpha_8(\epsilon_{i,t} - \epsilon_{i,t-1}) \tag{3.32}$$

Equation (31), shows that the regression of the first difference of the log of smoking participation is approximately the same as that of the quit rate with reversed signs. It indicates that we can use the log smoking-participation function to obtain a quit function. The advantage of using this first different log smoking-participation function is that it allows one to drop out individual fixed effects. The regression results are shown in Table 3.17. If the difference in cigarette price between period t and period t-1 increases, the quitting probability of pregnant women also increases. This result can be verified in all the columns by calculating the price effect, which is always positive. The coefficient of interaction is negative because if the discount factor increases, the price effect for those individuals who are more future-oriented will decline. These results tend to suggest that future-oriented individuals have less of a response to changes in price.

3.5 Conclusion

This paper examines the effect of cigarette prices on the quitting probability of pregnant women. I focus on the role of time preference and the interaction between time preference and price in determining these outcomes. I explore an empirical measure of time preference and apply it to a data set of the smoking behavior of pregnant women to test my hypothesis. I find that people who discount the future consequences of their current actions heavily are likely to be more sensitive to price than those who do not.

Most results show that the discount factor is negatively associated with the number of cigarettes consumed and with smoking participation. The higher the discount factor, the lower is consumption and participation; the result is the opposite when the independent variable is quitting probability. I conclude that among pregnant women, those individuals who are present-oriented, i.e. do not value the future highly, are more likely to smoke and more sensitive to price than those who are not .

The coefficient of the interaction term should be positive when the independent variable is consumption or smoking participation (e.g. Table 3.5 and 3.8), but negative given the independent variable is quitting probability (e.g. Table 3.6 and 3.14). Increased price results in a higher quitting probability. This positive price effect becomes smaller as the discount factor increases. Therefore, the coefficient of interaction between price and the discount factor presents a negative sign for quitting probability. In my results, the interaction term correctly shows a negative sign for quitting probability, and shows a positive sign for consumption and smoking participation.

These results suggest an important role for time preference in the smoking behavior of pregnant women. It implies that the price effect on cigarette consumption or quitting probability is influenced by time preference. Therefore, in practice, policymakers should consider both determinants when they try to decrease the consumption of cigarettes or increase the quitting probability of pregnant women.

Table 3.1: Variable Summary for quitting regression (205 observations).

Variable Name	Description	Mean (Std. errors)
Age	Age in years	28.58 (5.08)
Race:black	1 if race is black	0.36 (0.48)
Race:other	1 if race is neither black nor white	0.063 (0.244)
Married	1 if married	0.415 (0.494)
AFQT	percentile score on armed forces qualifying test in 1985	31.79 (22.80)
High school	1 if highest grade is completed=12	0.532 (0.50)
Some college	1 if 13 $\leq$highest grade completed $\leq$ 15	0.215 (0.412)
College	1 if highest grade completed 16 $\geq$	0.063 (0.244)
White collar	1 if current occupation is white collar	0.564 (0.43)
Blue collar	1 if current occupation is blue collar	0.18 (0.305)
Service	1 if current occupation is service	0.256 (0.392)
Hours worked	Average hours worked per week in the preceding year	21.26 (18.75)
Income	Total household income(units of $\$10,000$	2.17 (4.37)
Income2	The square of total household income(units of $\$10,000$	23.73 (249.23)
Net worth	Household asset minus liabilities in 2004(units of $\$10,000$)	3.302 (4.01)

Table 3.2: Variable Summary for quitting regression (205 observation).

Variable Name	Description	Mean (Std. errors)
Quit	Stop smoking during pregnancy	0.273 (0.44)
Cigarette price	Cigarette price including fed and state tax adjusted by year 1960 CPI	91.229 (9.236)
ln(price)	the logarithm of real cigarette price	4.51 (0.104)
Discount factor 1	Computed from amount needed to wait a year to receive $\$1,000$	0.569 (0.279)
Discount factor 2	Computed from amount needed to wait a year to receive $\$1,000$	0.261 (0.373)
Delta	Computed using the quasi-hyperbolic discounting specification	0.765 (0.348)
Beta	Computed using quasi-hyperbolic discounting specification	0.754 (0.225)
pregnant consumption	The number of cigarettes smoked per month (1769 obs)	473.66 (285.32)
Smoking participation	Smoking or not (Smoking is 1, not is 0) during last month (6693 obs)	0.264 (0.441)
pregnant consumption including nonsmoker	add observation of nonsmoker into pregnant consumption (6693 obs)	125.191 (255.224)

Table 3.3: Results for pregnant woman time consistent OLS regressions.

	consumption			participation		
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)
Discount factor (DF1)	19.89	-202.7	-242.2	0.003	-0.078	-0.097
	(28.43)	(196.5)	(199.9)	(0.026)	(0.095)	(0.0962)
real price		-0.972	0.221		-0.002*	-0.0008
		(1.626)	(1.858)		(0.0009)	(0.001)
Discount factor*price		2.266	2.672		0.0008	0.001
		(2.005)	(2.022)		(0.0009)	(0.0009)
Age	9.555*	7.519*	9.456*	0.017***	0.016***	0.017***
	(3.806)	(3.735)	(3.786)	(0.003)	(0.003)	(0.003)
Married	-39.22*	-32.83	-39.58*	-0.128***	-0.137***	-0.128***
	(18.49)	(17.86)	(18.47)	(0.017)	(0.018)	(0.0171)
AFQT_adj1	0.455	0.429	0.463	-0.0003	0.0002	-0.0003
	(0.474)	(0.469)	(0.476)	(0.0004)	(0.0004)	(0.0004)
Highschool	-42.20*	-36.95	-43.57*	-0.118***	-0.108***	-0.117***
	(20.96)	(20.46)	(20.79)	(0.025)	(0.025)	(0.025)
Somecollage	-96.66***	-85.89**	-97.99***	-0.230***	-0.228***	-0.230***
	(28.46)	(28.59)	(28.32)	(0.031)	(0.032)	(0.031)
Collage	-115.7*	-101.2*	-116.9*	-0.326***	-0.327***	-0.326***
	(46.54)	(47.16)	(47.28)	(0.031)	(0.031)	(0.031)
Whitecollar	4798.9	357.3	6918.5	0.10	0.145*	0.118
	(55706.7)	(57426.9)	(58505.3)	(0.108)	(0.0599)	(0.110)
Blucollar	4835.5	397.9	6955.2	0.100	0.143*	0.122
	(55707.2)	(57427.5)	(58505.7)	(0.110)	(0.061)	(0.113)
Service	4832.0	392.4	6949.9	0.157	0.212**	0.179
	(55706.3)	(57426.8)	(58504.6)	(0.113)	(0.065)	(0.116)
hourwork	0.092	0.064	0.070	-0.0005	-0.0006	-0.0005
	(0.591)	(0.605)	(0.592)	(0.0005)	(0.0005)	(0.0005)
Networth	-2.856**	-2.646*	-2.725**	-0.0009*	-0.001*	-0.0009*
	(0.964)	(1.083)	(0.963)	(0.0005)	(0.0005)	(0.0005)
Income	-5.867	-3.724	-5.065	-0.00194	-0.001	-0.002
	(10.58)	(10.33)	(10.68)	(0.004)	(0.004)	(0.004)
$\frac{\partial smokingparticipation}{\partial price}$		.272	1.688		-.0015	-.00026
		(1.126)	(1.580)		(.00075)	(.0008)
Price elasticity		.056	.350		-.562	-.097
		(.233)	(.327)		(.281)	(.299)
Year/State fixed effect	Yes /Yes	Yes / No	Yes /Yes	Yes /Yes	Yes / No	Yes /Yes
Regression	OLS	OLS	OLS	OLS	OLS	OLS
Observations	1769	1769	1769	6702	6702	6702
R^2	0.095	0.058	0.097	0.142	0.115	0.143

Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.4: Results for pregnant woman time inconsistent OLS regressions.

	consumption			participation		
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)
Delta	3.571	-90.16	-94.92	-0.019	-0.118	-0.113
	(24.34)	(146.3)	(139.9)	(0.019)	(0.093)	(0.094)
Beta	14.48	-99.50	-167.7	0.04	-0.016	-0.044
	(46.08)	(206.6)	(211.3)	(0.03)	(0.128)	(0.119)
Real price		-1.318	-0.421		-0.003	-0.002
		(2.689)	(2.408)		(0.002)	(0.002)
Beta*price		1.224	1.868		0.0006	0.0008
		(2.15)	(2.23)		(0.001)	(0.001)
Delta*price		0.938	0.995		0.001	0.001
		(1.507)	(1.431)		(0.0008)	(0.0009)
$\frac{\partial smokingparticipation}{\partial price}$		.295	1.713		-.001	-.0002
		(1.365)	(.0009)		(.0007)	(.001)
Price elasticity		.061	.355		-.0003	-.00005
		(.236)	(.283)		(.0002)	(.0002)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	Yes	No	Yes	Yes	No	Yes
Regression	OLS	OLS	OLS	OLS	OLS	OLS
Observations	1769	1769	1769	6702	6702	6702
R^2	0.094	0.058	0.096	0.143	0.116	0.143

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.5: Results for pregnant women consumption including all nonsmoker.

	(1)	(2)	(3)	(4)	(5)	(6)
Discount factor (DF1)	6.987	-60.09	-70.57			
	(15.02)	(57.36)	(57.03)			
Real price		-1.034	-0.104		-1.389	-0.488
		(0.609)	(0.579)		(1.007)	(1.014)
Discount factor*price		0.712	0.779			
		(0.576)	(0.568)			
Delta				-7.787	-66.42	-62.96
				(9.846)	(44.42)	(43.43)
Beta				24.32	-12.30	-29.95
				(18.77)	(69.35)	(65.48)
Beta*price					0.425	0.547
					(0.673)	(0.654)
Delta*price					0.596	0.558
					(0.424)	(0.413)
$\frac{\partial smokingparticipation}{\partial price}$		-0.636	0.331		-.616	.347
		(0.492)	(0.462)		(.560)	(.546)
Price elasticity		-0.507	0.264		-.491	.276
		(0.392)	(0.368)		(.446)	(.435)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	Yes	No	Yes	Yes	No	Yes
Regression	OLS	OLS	OLS	OLS	OLS	OLS
Observations	6694	6694	6694	6694	6694	6694
R^2	0.128	0.099	0.128	0.129	0.100	0.129

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

DF1=Discount factor 1

Table 3.6: Results for quitting smoking while pregnancy in time consistent case.

Dependent var:	(1) quit	(2) quit	(3) quit	(4) quit	(5) quit	(6) quit
Discount factor (DF1)	0.105	1.226	0.412	0.331	4.555	1.417
	(0.112)	(1.269)	(1.406)	(0.359)	(4.228)	(6.022)
Real price		0.015	0.012		0.053	0.056
		(0.008)	(0.01)		(0.03)	(0.049)
Discount factor*price		-0.012	-0.004		-0.046	-0.016
		(0.014)	(0.016)		(0.046)	(0.065)
$\frac{\partial smokingparticipation}{\partial price}$		.008	.0096		.015	.014
		(0.005)	(.009)		(.008)	(.01)
Price elasticity		2.673	3.207		5.01	4.677
		(1.601)	(2.937)			
Interaction effect of probit					-.019	-.006
					(.040)	(.025)
Year/State fixed effect	Yes/No	Yes/ No	Yes/Yes	Yes / No	Yes/No	Yes/Yes
Regression	OLS	OLS	OLS	Probit	Probit	Probit
R^2	0.126	0.144	0.316			
Pseudo R^2				0.119	0.134	0.264
Observations	205	205	205	205	205	176

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.7: Results for quitting smoking while pregnancy in time inconsistent case.

Dependent var:	(1) quit	(2) quit	(3) quit	(4) quit	(5) quit	(6) quit
Delta	0.062	0.404	0.332	0.219	1.750	2.223
	(0.09)	(1.14)	(1.28)	(0.29)	(3.92)	(4.77)
Beta	0.119	3.468*	1.896	0.301	14.23**	8.723
	(0.16)	(1.36)	(1.52)	(0.50)	(4.90)	(6.39)
Real price		0.041*	0.029		0.165**	0.141
		(0.02)	(0.02)		(0.06)	(0.08)
Delta*price		-0.004	-0.003		-0.016	-0.023
		(0.01)	(0.01)		(0.04)	(0.05)
Beta*price		-0.038*	-0.021		-0.155**	-0.098
		(0.02)	(0.02)		(0.05)	(0.07)
$\frac{\partial smokingparticipation}{\partial price}$		.009	.011		0.046	.035
		(0.005)	(.009)		(.017)	(.021)
Price elasticity		3.136	3.535		15.37	11.69
		(1.553)	(2.855)			
Interaction effect of probit for Beta					-.061	-.039
					(.031)	(1.491)
Interaction effect of probit for Delta					-.007	-.009
					(.093)	(.336)
Year/State fixed effect	Yes/No	Yes/ No	Yes/Yes	Yes / No	Yes/No	Yes/Yes
Regression	OLS	OLS	OLS	Probit	Probit	Probit
R^2	0.127	0.165	0.322			
Pseudo R^2				0.119	0.158	0.271
Observations	205	205	205	205	205	176

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.8: Results for time consistent and inconsistent OLS model, regressor being ln(price) and discount factor*ln(price).

	time consistent				time inconsistent			
	ln(consumption)		participation		ln(consumption)		participation	
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DF1	-1.717	-2.074	-0.475	-0.567				
	(1.682)	(1.687)	(0.485)	(0.493)				
ln(price)	-0.156	-0.161	-0.129	-0.10	-0.139	-0.208	-0.201	-0.176
	(0.235)	(0.232)	(0.07)	(0.07)	(0.404)	(0.407)	(0.141)	(0.142)
DF*ln(price)	0.384	0.462	0.105	0.124				
	(0.368)	(0.369)	(0.106)	(0.107)				
Delta					-0.873	-0.871	-0.535	-0.533
					(1.069)	(1.054)	(0.385)	(0.395)
Beta					-0.296	-0.948	-0.234	-0.333
					(1.907)	(1.944)	(0.678)	(0.673)
Beta*ln(price)					0.072	0.213	0.061	0.080
					(0.416)	(0.425)	(0.147)	(0.146)
Delta*ln(price)					0.192	0.192	0.113	0.112
					(0.233)	(0.229)	(0.084)	(0.086)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Regression	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Observations	1769	1769	6702	6702	1769	1769	6702	6702
R^2	0.051	0.090	0.108	0.135	0.050	0.089	0.109	0.136

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.9: Results for consumption including all nonsmoker with ln(price) and Discount factor*ln(price) .

	consumption					
	(1)	(2)	(3)	(4)	(5)	(6)
DF1	10.44	-387.5	-441.7			
	(15.21)	(299.9)	(297.8)			
ln(price)		-74.62	-54.17		-109.4	-91.14
		(43.98)	(42.19)		(84.56)	(82.06)
DF1*ln(price)		86.70	97.76			
		(65.80)	(65.29)			
Delta				-6.829	-333.2	-329.8
				(10.13)	(201.0)	(201.5)
Beta				27.74	-155.4	-213.8
				(18.54)	(404.5)	(402.6)
Beta*ln(price)					39.90	51.44
					(87.57)	(87.24)
Delta*ln(price)					71.20	70.43
					(44.03)	(44.11)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Regression	OLS	OLS	OLS	OLS	OLS	OLS
Observations	6693	6693	6693	6693	6693	6693
R^2	0.093	0.093	0.122	0.093	0.094	0.122

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.10: Results for time consistent and time inconsistent OLS model, regressor being $ln(price)$, $\frac{DF1}{p}$ and $\frac{\delta}{p}$, $\frac{\beta}{p}$ (Taylor expansion order 1).

	time consistent				time inconsistent			
	ln(consumption)		participation		ln(consumption)		participation	
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DF1	0.492	0.603	0.197	0.226				
	(0.381)	(0.375)	(0.118)	(0.119)				
ln(price)	-0.186	-0.202	-0.171*	-0.149*	-0.194	-0.329	-0.338*	-0.339*
	(0.228)	(0.224)	(0.069)	(0.071)	(0.380)	(0.382)	(0.132)	(0.132)
$\frac{DF1}{price}$	-43.64	-54.31	-18.31	-21.70				
	(35.99)	(35.74)	(11.13)	(11.18)				
Delta					0.255	0.275	0.166	0.178*
					(0.237)	(0.229)	(0.087)	(0.088)
Beta					0.135	0.352	0.234	0.276
					(0.433)	(0.442)	(0.153)	(0.151)
$\frac{Delta}{price}$					-24.06	-25.96	-17.71*	-18.86*
					(22.84)	(22.26)	(8.308)	(8.393)
$\frac{Beta}{price}$					-9.505	-31.24	-18.45	-23.25
					(41.30)	(42.19)	(14.70)	(14.54)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1769	1769	6702	6702	1769	1769	6702	6702
R^2	0.051	0.090	0.108	0.136	0.051	0.089	0.109	0.137

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.11: Results for pregnant women consumption including nonsmoker in time consistent and inconsistent case with regression on $ln(price)$, $\frac{DF1}{p}$ alternatively on $ln(price)$, $\frac{\delta}{p}$, $\frac{\beta}{p}$ (Taylor expansion order 1) .

	consumption					
	(1)	(2)	(3)	(4)	(5)	(6)
DF1	10.44	144.2	165.3*			
	(15.21)	(74.37)	(73.89)			
ln(cigarette price)		-97.63*	-83.13*		-174.9*	-180.2*
		(42.32)	(41.36)		(74.65)	(75.50)
$\frac{DF1}{price}$		-13009.4	-15389.3*			
		(6839.6)	(6824.8)			
Delta				-6.829	101.2*	110.9*
				(10.13)	(47.96)	(46.84)
Beta				27.74	127.7	159.6
				(18.54)	(88.27)	(90.81)
$\frac{Delta}{price}$					-10470.7*	-11417.5**
					(4459.8)	(4364.2)
$\frac{Beta}{price}$					-9689.6	-13318.7
					(8571.1)	(8837.0)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Observations	6694	6694	6694	6694	6694	6694
R^2	0.093	0.094	0.122	0.094	0.094	0.123

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.12: Results for time consistent and time inconsistent OLS model, regressor being $ln(price)$, $\frac{DF1}{p}$, and $\frac{1}{2} * (\frac{DF1}{p})^2$, and $\frac{\delta}{p}$, $\frac{1}{2} * (\frac{\delta}{p})^2$;$\frac{\beta}{p}$, $\frac{1}{2} * (\frac{\beta}{p})^2$. (Taylor expansion order 2).

	time consistent				time inconsistent			
	ln(consumption)		participation		ln(consumption)		participation	
Dependent var:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DF1	0.702	0.797	0.195	0.237				
	(0.419)	(0.415)	(0.141)	(0.142)				
ln(price)	-0.271	-0.284	-0.171*	-0.153*	-0.142	-0.267	-0.294*	-0.284
	(0.241)	(0.239)	(0.075)	(0.077)	(0.411)	(0.408)	(0.149)	(0.149)
$\frac{DF1}{price}$	-86.50	-94.22	-17.96	-23.96				
	(48.89)	(48.90)	(19.37)	(19.34)				
$\frac{1}{2} * (\frac{DF1}{price})^2$	3934.0	3685.0	-31.42	205.2				
	(2829.4)	(2798.3)	(1403.8)	(1399.3)				
Delta					0.279	0.296	0.143	0.169
					(0.244)	(0.237)	(0.093)	(0.094)
Beta					0.030	0.228	0.187	0.195
					(0.525)	(0.526)	(0.207)	(0.208)
$\frac{Delta}{price}$					-36.08	-37.01	-12.96	-17.06
					(25.05)	(24.98)	(10.83)	(10.80)
$\frac{Beta}{price}$					14.02	-4.108	-9.047	-7.131
					(72.05)	(72.99)	(32.02)	(32.10)
$\frac{1}{2} * (\frac{Delta}{price})^2$					976.7	908.0	-222.3	-86.83
					(797.5)	(747.4)	(283.2)	(266.3)
$\frac{1}{2} * (\frac{Beta}{price})^2$					-1583.1	-1841.4	-733.9	-1171.9
					(4113.5)	(4274.5)	(2027.3)	(2025.9)
$g \equiv -\frac{U_H H_C}{\lambda}$	45.48	39.11	-1.77	8.56				
$g_\delta \equiv -\frac{U_H H_C}{\lambda}$					25.962	24.534	-17.15	-5.09
$g_\beta \equiv -\frac{U_H H_C}{\lambda}$					112.92	-448.25	-81.12	-164.34
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1769	1769	6702	6702	1769	1769	6702	6702
R^2	0.052	0.091	0.108	0.136	0.052	0.090	0.110	0.137

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.13: Results for pregnant women consumption including nonsmoker with regression on taylor expansion up to order 2.

	consumption					
	(1)	(2)	(3)	(4)	(5)	(6)
DF1	10.44	176.3	204.0*			
	(15.21)	(91.02)	(90.76)			
ln(cigarette price)		-111.0*	-99.42*		-155.1	-155.2
		(48.04)	(46.74)		(81.22)	(82.20)
$\frac{DF1}{price}$		-19574.3	-23311.4			
		(12084.9)	(12102.3)			
$\frac{1}{2} * (\frac{DF1}{price})^2$		596462.5	721010.5			
		(833674.1)	(835671.8)			
Delta				-6.829	102.3*	119.5*
				(10.13)	(49.75)	(48.76)
Beta				27.74	93.58	108.5
				(18.54)	(112.1)	(115.2)
$\frac{Delta}{price}$					-10682.9	-13163.0*
					(5598.0)	(5495.3)
$\frac{Beta}{price}$					-2887.2	-3106.1
					(16961.3)	(17340.0)
$\frac{1}{2} * (\frac{Delta}{price})^2$					8786.8	79715.9
					(154390.7)	(146746.0)
$\frac{1}{2} * (\frac{Beta}{price})^2$					-480501.0	-704573.3
					(1102426.5)	(1127654.6)
$g_{DF1} \equiv -\frac{U_H H_C}{\lambda}$		30.47	30.93			
$g_{\delta} \equiv -\frac{U_H H_C}{\lambda}$					0.823	0.056
$g_{\beta} \equiv -\frac{U_H H_C}{\lambda}$					-166.42	-226.84
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	No	No	Yes	No	No	Yes
Observations	6694	6694	6694	6694	6694	6694
R^2	0.093	0.094	0.122	0.094	0.094	0.123

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.14: Results for quitting smoking of time consistent and inconsistent case, and regressor being ln(price) and discount factor*ln($price$) and $Delta * ln(price)$ and $Beta * ln(price)$.

Dependent var: quit	time consistent				time inconsistent			
DF1	4.991 (5.458)	2.291 (6.313)	19.24 (18.16)	14.10 (26.54)				
ln(price)	1.012 (0.664)	0.280 (0.898)	3.859 (2.376)	1.227 (3.713)	3.036* (1.369)	1.658 (1.755)	13.22* (5.576)	8.403 (7.524)
DF1*ln(price)	-1.084 (1.212)	-0.500 (1.404)	-4.183 (4.023)	-3.098 (5.861)				
Delta					1.926 (4.962)	2.219 (5.838)	9.411 (16.74)	17.02 (20.69)
Beta					13.76* (5.971)	7.596 (6.878)	58.88** (22.24)	36.35 (29.85)
Delta*ln(price)					-0.414 (1.095)	-0.482 (1.291)	-2.023 (3.688)	-3.718 (4.559)
Beta*ln(price)					-3.046* (1.334)	-1.693 (1.541)	-13.03** (4.943)	-8.085 (6.634)
Price elasticity	.394 (.30)	-.004 (.48)	18.26	5.20	.42 (.302)	.01 (.47)	60.94	31.62
Interaction effect of probit (DF1)			-1.664 13.025	-1.228 2.778				
Inter effect probit (β)							-5.120 (10.403)	-3.223 (4.796)
Inter effect probit (δ)							-.812 (22.624)	-1.479 (9.679)
Year/State fixed effect	Yes/ No	Yes/Yes	Yes/No	Yes/Yes	Yes/ No	Yes/Yes	Yes/No	Yes/Yes
Regression	OLS	OLS	Probit	Probit	OLS	OLS	Probit	Probit
Observations	205	205	205	176	205	205	205	176
R^2	0.138	0.306			0.156	0.312		
Pseudo R^2			0.131	0.245			0.152	0.253

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.15: Results for quitting smoking of time consistent and inconsistent , regressor being $ln(price)$, $\frac{DF1}{p}$ and $\frac{\delta}{p}$, $\frac{\beta}{p}$ (Taylor expansion order 1).

Dep var: quit	time consistent				time inconsistent			
DF1	-0.657	-0.159	-2.669	-2.081				
	(1.192)	(1.356)	(3.809)	(5.582)				
ln(price)	0.846	0.122	3.252	0.813	2.289	0.945	9.656*	5.715
	(0.665)	(0.882)	(2.310)	(3.716)	(1.366)	(1.684)	(4.844)	(7.189)
$\frac{DF1}{price}$	68.24	17.29	273.2	198.2				
	(106.5)	(119.9)	(343.6)	(512.6)				
Delta					0.002	-0.078	-0.157	-2.152
					(1.033)	(1.193)	(3.259)	(4.197)
Beta					-2.314	-1.093	-9.701*	-5.632
					(1.404)	(1.599)	(4.522)	(6.303)
$\frac{\delta}{price}$					4.887	10.45	36.99	213.2
					(95.15)	(108.6)	(302.1)	(389.0)
$\frac{\beta}{price}$					212.0	96.13	883.8*	497.3
					(122.0)	(137.8)	(398.5)	(561.1)
Price elastic	.42	.014	15.41	3.44	.47	.053	44.94	24.08
	(.294)	(.479)			(.299)	(.478)		
Inter effect probit (DF1)			109.038 (149297.97)	78.69 (18941.32)				
Inter effect probit (β)							351.51 (9137.55)	198.40 (22884.65)
Inter effect probit (δ)							16.11 (174687.2)	85.02 (21149.89)
Year/State fixed effect	Yes/ No	Yes/Yes	Yes/No	Yes/Yes	Yes/ No	Yes/Yes	Yes/No	Yes/Yes
Regression	OLS	OLS	Probit	Probit	OLS	OLS	Probit	Probit
Observations	205	205	205	176	205	205	205	176
R^2	0.137	0.306			0.148	0.308		
Pseudo R^2			0.130	0.245			0.144	0.249

The coefficients of interaction are large.
The estimated probit model is $Pr[y = 1|x_1, x_2, X] = \Phi(\beta_1\beta + \beta_2 \ln p + \beta_{12} g\beta p^{-1} + X\gamma)$.
Since the only variable available are the discount factor and price, the the coefficient of interaction that results from the regression is the combination of real coefficent of interaction and g, which is the monetary value of future consequences. Thus, the standard error calculated based on the combined coefficient are not the real one for the interaction term.

Table 3.16: Results for time consistent and time consistent, regressor being $ln(price)$, $\frac{DF1}{p}$, $\frac{1}{2} * (\frac{DF1}{p})^2$; and $\frac{\delta}{p}$, $\frac{1}{2} * (\frac{\delta}{p})^2$;$\frac{\beta}{p}$, $\frac{1}{2} * (\frac{\beta}{p})^2$. (Taylor expansion order 2).

	time consistent				time inconsistent			
Dependent var:	(1) quit	(2) quit	(3) quit	(4) quit	(5) quit	(6) quit	(7) quit	(8) quit
DF1	-0.283	0.192	-1.164	-0.349				
	(1.130)	(1.376)	(3.684)	(5.496)				
ln(price)	0.674	-0.018	2.485	-0.303	1.627	0.327	6.419	1.321
	(0.627)	(0.875)	(2.149)	(3.696)	(1.318)	(1.636)	(4.483)	(7.197)
$\frac{DF1}{price}$	-11.16	-66.94	5.923	-170.6				
	(106.7)	(134.5)	(373.3)	(559.3)				
$\frac{1}{2} * (\frac{DF1}{price})^2$	7415.9	8635.5	20895.9	34654.0				
	(6316.7)	(7514.0)	(19517.3)	(26494.7)				
Delta					0.453	0.351	2.031	0.101
					(0.866)	(1.034)	(2.937)	(3.655)
Beta					-1.701	-0.323	-6.896	-0.462
					(1.350)	(1.554)	(4.439)	(6.486)
$\frac{\delta}{price}$					-69.98	-67.24	-266.7	-129.8
					(82.82)	(99.18)	(295.5)	(360.4)
$\frac{\beta}{price}$					81.50	-67.27	333.5	-454.0
					(137.3)	(156.3)	(520.6)	(729.6)
$\frac{1}{2} * (\frac{\delta}{price})^2$					3582.3	4094.7	10654.6	14410.8
					(2092.7)	(2208.1)	(6711.4)	(7383.1)
$\frac{1}{2} * (\frac{\beta}{price})^2$					10054.5	12536.6	39247.3	63657.2
					(8848.1)	(10282.5)	(30438.2)	(36756.4)
$g_{DF1} \equiv -\frac{U_H H_C}{\lambda}$			-3527.62	203.13				
$g_\delta \equiv -\frac{U_H H_C}{\lambda}$							39.95	31.74
$g_\beta \equiv -\frac{U_H H_C}{\lambda}$							-117.68	140.21
Year/State fixed effect	Yes/ No	Yes/Yes	Yes/No	Yes/Yes	Yes/ No	Yes/Yes	Yes/No	Yes/Yes
Regression	OLS	OLS	Probit	Probit	OLS	OLS	Probit	Probit
Observations	205	205	205	176	205	205	205	176
R^2	0.143	0.312			0.167	0.330		
Pseudo R^2			0.133	0.252			0.159	0.274

Standard errors in parentheses

Table 3.17: Results for first differences of quitting probability.

	time consistent				time inconsistent			
Dependent var:	(1) quit	(2) quit	(3) quit	(4) quit	(5) quit	(6) quit	(7) quit	(8) quit
diff(price)	0.013*	0.012*	0.040*	0.036	0.016	0.013	0.049	0.036
	(0.005)	(0.006)	(0.018)	(0.018)	(0.009)	(0.010)	(0.029)	(0.031)
diff(DF1*price)	-0.006	-0.003	-0.022	-0.009				
	(0.006)	(0.007)	(0.020)	(0.022)				
diff(Beta*price)					-0.002	0.0006	-0.006	0.011
					(0.007)	(0.009)	(0.024)	(0.028)
diff(Delta*price)					-0.007	-0.005	-0.021	-0.016
					(0.005)	(0.006)	(0.017)	(0.017)
Control Vars.	No	Yes	No	Yes	No	Yes	No	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regression	OLS	OLS	Probit	Probit	OLS	OLS	Probit	Probit
Observations	205	205	205	205	205	205	205	205
R^2	0.034	0.092			0.038	0.096		
Pseudo R^2			0.028	0.082			0.032	0.087

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Bibliography

Ai, C. R. and Norton, E. C. (2003), 'Interaction terms in logit and probit models', *Economics letters* **80**(1), 123–129.

Becker, G. S., Grossman, M. and M.Murphy, K. (1991), 'Rational addiction and the effect of price on consumption.', *The American Economic Review* **81**(2), 237–241.

Becker, G. S., Grossman, M. and Murphy, K. M. (1994), 'An empirical analysis of cigarette addiction', *The American Economic Review* **84**(3), pp. 396–418.

Becker, G. S. and M.Murphy, K. (1988), 'A theory of rational addiction.', *Journal of Political Economy* **96**(4), 675–700.

Ce, S. (2011), 'Demand for cigarettes by teenagers and young adults and their smoking transitions.', *The City University of New York* .

Centers for Disease Control and Prevention (2014), 'Tobacco use and pregnancy', *http://www.cdc.gov/reproductivehealth/tobaccousepregnancy/* .

Chaloupka, F. J. and Warner, K. E. (2000), 'The economics of smoking. in: Culyer aj and newhouse jp, eds.', *Handbook of Health Economics, Elsevier Science* **1**, 1539–1627.

Colman, G., Grossman, M. and Joyce, T. (2003), 'The effect of cigarette excise taxes on smoking before, during and after pregnancy.', *Journal of Health Economics* **22**(6), 1053–1072.

Courtemanche, C. J., Heutel, G. and McAlvanah, P. (2015), 'Impatience, incentives, and obesity', *The Economic Journal* **125**(582), 1–31.

D.Cohen, J., David Laibson, G. L. and McClure, S. M. (2004), 'Separete neural systems value immediate and delayed monetary rewards', *Science* **306**.

Evans, W. N., S.Ringel, J. and Stech, D. (1999), 'Tobacco taxes and public policy to discourage smoking', *In J.M. Poterba (ed.), Tax Policy and the Economy* **13**(1-55).

Godtfredsen, N. S., Holst, C., Prescott, E., Vestbo, J. and Osler, M. (2002), 'Smoking reduction, smoking cessation , and mortality: 16-year follow-up of 19,732 men and women from the copenhagen centre for prospective population studies', *American journal of Epidemiology* **156**(11).

Gruber, J. and Koszegi, B. (2001), 'Is addiction rational? theory and evidence.', *Quarterly Journal of Economics* **116**(4), 1261–1303.

Harris, C. and Laibson, D. (2000), 'Dynamic choices of hyperbolic consumers'.

Hsiao, C. (1986), 'Analysis of panel data.', *Cambridge University Press: Cambridge.* .

Hu, T. W., Theodore E, K. and Sung, H. Y. (1994), 'Cigarette taxation and demand: an empirical model.', *Contemporary Economic Policy* **12**(3), 91–101.

Johnson, M. and Bickel, W. (2002), 'Within-subject comparison of real and hypothetical money rewards in delay discounting.', *Journal of the Experimental Analysis of Behavior* **77**, 129–146.

Kim, S. (2005), 'Endogenous time preference and addiction.', *Ph.D. dissertation* .

Labeaga, L. M., Theodore E, K. and Sung, H.-Y. (1999), 'A double-hurdle rational addiction model with heterogeneity: Estimating the demand for tabacco.', *Journal of Econometrics* **93**(1), 49–72.

Laibson, D. (1997), 'Golden eggs and hyperbolic discounting', *Quarterly Journal of Economics* **112**(2), 443–478.

Lanoie, P. and Leclair, P. (1998), 'Golden eggs and hyperbolic discounting,.', *Economics Letters* **58**(1), 85–89.

Levy, M. (2010), 'An empirical analysis of biases in cigarette addiction.', *working paper* **93**(1), 49–72.

Lilienfeld, D. E. and Stolley, P. D. (1994), 'Foundations of epidemiology', *Oxford University Press* .

Madden, G., Begotka, A. and Kastern, L. (2003), 'Delay discounting of real and hypothetical rewards.', *Experimental and Clinical Psychopharmacology* **11**, 139–145.

Mankiw, N. G. (2009), 'Principles of microeconomices.', *Cengage Learning* .

Manning, W. G. (1998), 'The logged dependent variable, heteroscedasticity, and the retransformation problem..', *Journal of Health Economics* **17**(3), 283–295.

Manning, W. G. and Mullaphy, J. (2001), 'Estimating log models; to transformation or not to transform.', *Journal of Health Economics* **20**(4), 461–494.

Margolis, J., Hockenberry, J., Grossman, M. and Chou, S.-Y. (2013), 'Moral hazard and less invasive medical treatment for coronary artery disease:the case of cigarette smoking', *NBER conference* .

Mullaphy, J. (1998), 'Much ado about two: Reconsidering retransformation and the tow-part model in health econometrics.', *Journal of Health Economics* **17**(3), 247–281.

Sosiaali, V. . (1988), 'ja terveysministerion omalaakarikokeilu : tutkirnuksen aineisto, tulokset ja johtopaatokset [personal doctor program: data, results and conclu sion of the finnish study]. helsinki: Laakintohallitus, . (laakintohallituksen tutkimuksia 50.)'.

Suranovic, S. M., Goldfarb, R. S. and Leonard, T. C. (1999), 'An economic theory of cigarette addiction.', *Journal of Health Economics* **18**(1), 1–29.

Tauras, J. A. (2005), 'An empirical analysis of adult cigarette demand.', *Eastern Economic Journal* **31**(3), 361–375.

Wooldridge, J. M. (2005), 'Simple solutions to the initial conditions problem in dynamic, nonlinear panel data models with unobserved heterogeneity.', *Journal of Applied Econometrics* **20**(1), 39–54.

Xu, J. and long, S. J. (2005), 'Confidence intervals for predicted outcomes in regression models for categorical outcomes.', *The Stata Journal* **5**(4), 537–559.