HEALTH ECONOMICS
Health Econ. **24**: 1314–1330 (2015)
Published online 18 July 2014 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/hec.3084

HOW DO SMOKERS RESPOND TO CIGARETTE TAXES? EVIDENCE FROM CHINA'S CIGARETTE INDUSTRY

HONG LIU[a], JOHN A. RIZZO[b], QI SUN[c,*] and FANG WU[c]

[a]*China Economics and Management Academy, Central University of Finance and Economics, Beijing, China*
[b]*Department of Economics and Department of Preventive Medicine, Stony Brook University, Stony Brook, USA*
[c]*School of International Business Administration, Shanghai University of Finance and Economics, Shanghai, China*

ABSTRACT

This paper examines how Chinese smokers respond to tax-driven cigarette price increases by estimating a discrete choice model of demand for differentiated products, using annual nationwide brand-level cigarette sales data in China from 2005 to 2010. We allow for substitution between different cigarette brands and also incorporate key features of rational addiction theory into the model. Results show that the average own-price elasticity of demand for cigarettes at the brand level is –0.807, and the overall price elasticity of cigarettes at the market level is –0.488 in China. We find tax-induced substitution toward low-price cigarettes as well as high-tar cigarettes and that tax hikes encourage within-class substitution more than across-class substitution. These results have important policy implications for the potential effects of cigarette taxation. Copyright © 2014 John Wiley & Sons, Ltd.

Received 17 January 2014; Revised 20 May 2014; Accepted 20 June 2014

JEL Classification: D42; H22; I10

KEY WORDS: cigarette demand; discrete choice models; substitution; cigarette tax

1. INTRODUCTION

As the largest producer and consumer of cigarettes in the world, China had an estimated 301 million adult smokers and the smoking prevalence among adult men attained 52.9% in 2010 (Li *et al*., 2011). About two million people in China die from smoking-related diseases each year (CDCC, 2010). To address this critical public health concern, China's government has endeavored to control tobacco use through various channels but with limited success (Hu and Mao, 2002; Kenkel *et al*., 2009). Compared to other countries, cigarette prices are very low in China;[1] moreover, the government has not implemented strong pricing and taxation measures to reduce cigarette smoking. There is considerable uncertainty about the likely success of cigarette taxation in China. First, there is limited evidence on Chinese consumers' sensitivity to cigarette prices and other behavioral responses. Second, the Chinese government has been reluctant to raise cigarette taxes substantially since it may have a large negative impact on employment and tax revenues from the tobacco industry, due to reduced cigarette consumption (Bishop *et al*., 2007; Hu *et al*., 2010).

*Correspondence to: School of International Business Administration, Shanghai University of Finance and Economics 777 Guoding Road, Shanghai 200433, China. E-mail: sun.qi@mail.shufe.edu.cn

[1]The price of a pack of 20 cigarettes is only 5 RMB or less (73 US cents) for the most popular brands in China, which is much lower than the average price $2.53 at the global level (WHO, 2010). As income has been growing more rapidly than cigarette prices in China, cigarettes have become much more affordable during the past two decades (Hu *et al*., 2008).

To shed light on these issues, the present study examines how Chinese smokers respond to tax-driven cigarette price increases by estimating a discrete choice model of demand, using annual nationwide cigarette sales data on more than 75 cigarette brands during 2005 to 2010. Our approach makes several contributions to the literature. First, unlike prior studies, we allow for product differentiation in this market and employ brand-level data. These two features of our empirical model allow for substitution across cigarette brands and help us to quantify smokers' brand-switching behaviors. Second, we adopt a generalized method of moments estimation approach and employ instruments based on exogenous product characteristics and policy changes (we discuss this in further detail in Section 4.2) to address the endogeneity of cigarette prices in the demand estimation model. Third, we estimate own-price and cross-price elasticities of cigarette consumption at the *brand* level as well as the overall price elasticity at the *market* level. Using the estimated parameters from the demand model, we then conduct numerical simulations to investigate the potential impact of proposed tax increases on cigarette sales, government revenue from cigarette taxes, and total tar and nicotine intakes.

There are several reasons to model China's cigarette market as one consisting of differentiated products. There are more than 100 cigarette brands in China which differ significantly in terms of quality and price. Treating cigarettes as differentiated products allows us to examine a richer set of smoker responses to tax-induced cigarette prices increases. First, smokers may try to maintain the number of cigarettes consumed and limit the tax-induced financial burden by switching to less expensive brands of cigarettes (Tsai *et al*., 2005). Second, as cigarette taxes are levied per unit, a tax increase would lead to an increase in the price per unit of tar and nicotine in low-yield brands. Thus, smokers may compensate by switching to cigarettes higher in tar and nicotine content to maintain their current levels of tar or nicotine intake. As health risks of smoking are correlated with average daily tar and nicotine intake (e.g., Stellman and Garfinkel, 1989), such tax-induced compensating behavior may undermine the effectiveness of cigarette taxation with regard to the health of smokers.

Early studies on consumer demand theory demonstrate that consumers respond to per-unit price increases by reducing the quantities as well as increasing the quality purchased (e.g. Houthakker, 1952; Barzel, 1976; Deaton, 1988). Harris (1980) has shown smokers' compensating behavior in response to tax changes in a theoretical model. A number of recent studies find significant empirical evidence of smoker tax-induced changes in smoking patterns using individual-level data from the US or Taiwan (Evans and Farrelly, 1998; Farrelly *et al*., 2004; Tsai *et al*., 2005; Adda and Cornaglia, 2006; Abrevaya and Puzzello, 2012; Adda and Cornaglia, 2012). However, very few studies in the literature on cigarette demand have treated cigarettes as differentiated products. Three notable exceptions are Tan (2006), Cilliberto and Kuminoff (2010), and Qi (2013), which apply differentiated product models to study firms' behaviors in the US cigarette market. In contrast, we focus on the demand side.

By studying cigarette demand in China, this paper is also related to a growing empirical literature on the effects of price on cigarette demand in low-income and middle-income countries, a topic of considerable policy interest given the growth in cigarette consumption in many of these countries. For example, studies report estimated price elasticities at –1.42 in Papua New Guinea (Chapman and Richardson, 1990; Wilkins *et al*., 2004) and at –0.8 in Bulgaria (Sayginsoy *et al*., 2002) considerably higher in magnitude than the average estimates of about –0.4 (with a narrower range –0.3 to –0.5) for the US and other industrialized countries (Warner, 1990; Lance *et al*., 2004; Wilkins *et al*., 2004).

The limited studies focusing on smokers in China report a wide range of price elasticities of cigarette consumption, probably due to the use of different data sets (aggregate time series vs. cross section of households/individuals) as well as different model specifications and estimation approaches (i.e., some studies address endogeneity problems while others do not).

Two studies using annual time series data and ordinary least squares estimation methods estimate the price elasticity of cigarette demand in China at –0.54 (Hu and Mao, 2002) and –0.84 (Bai and Zhang, 2005). Several studies based on cross sections of households or individuals and using a two-part modeling approach report price elasticity estimates that are much smaller in magnitude. For example, Mao *et al*. (2005) estimate price elasticity at –0.15. Focusing on males over the age of 13, Lance *et al*. (2004) report price elasticity estimates in the range of –0.007 to –0.08 in China, while Bishop *et al*. (2007) obtain an elasticity estimate of –0.5 using a sample of urban adult males. However, none of the aforementioned studies directly correct for endogeneity by instrumental variables estimation; thus, their estimated effects of cigarette prices may be biased due to endogeneity and measurement error issues.[2]

A recent study by Chen and Xing (2011), based on household survey data covering eight provinces in northern China, employs the Deaton method (Deaton, 1997) to address endogenous quality changes when unit value (i.e., expenditure divided by quantity) is used to measure cigarette price. They find an overall price elasticity of –0.82 in the two-part model but ranges from –0.35 to –0.70 in the Deaton model. However, they acknowledge that their estimates of the price elasticity of cigarette demand may still suffer from attenuation bias due to measurement error.

Distinct from the above literature that has either treated cigarettes as a homogeneous product or failed to control for cigarette quality, we allow for specific measures of differentiation in cigarette quality and define differentiation in cigarettes at the *brand* level. We address the endogeneity issue using a generalized method of moments with instrumental variables. Therefore, we can obtain consistent and more realistic estimates of price elasticity of demand at the *brand* and *market* levels, respectively, and capture substitution patterns of cigarette demand, thus enhancing the accuracy of our policy simulations.

The remainder of the paper is organized as follows. Section 2 briefly describes the institutional background of China's tobacco industry and cigarette taxation policies. Section 3 describes the data. Section 4 introduces our econometric model and estimation strategy. Section 5 presents our empirical findings, and Section 6 concludes.

2. INDUSTRY BACKGROUND

China's tobacco industry is tightly regulated by the government, with farming, production, distribution, sales, and marketing of all tobacco and tobacco products in China under the control of the China National Tobacco Corporation (CNTC), a state-owned monopoly. The State Tobacco Monopoly Administration (STMA) is the regulatory agency in charge of enforcing related policies for tobacco and cigarette products in China. Although the CNTC and the STMA were intended to be two separate entities in principle, in practice they function as one organization with two name plates, performing both functions of management and regulation.

The monopoly state company, CNTC, has approximately 40 cigarette manufacturers with locations in every province in China except Tibet. These manufacturers are responsible for cigarette production, while the distribution sector of CNTC is in charge of cigarette sales. STMA directly sets and controls the retail price of every cigarette brand in China through its licensing system because only licensed retailers can legally sell cigarettes in China.

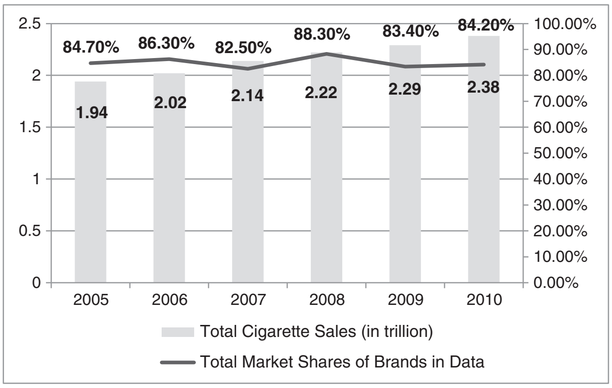
The 40 manufacturers compete on price and product differentiation by producing both national brands and small local brands, with the latter having very small market shares. Our sample includes 49 to 65 national brands each year, accounting for over 80% of all cigarette sales in China (Figure 1).[3] From Figure 2, we can see that the Chinese cigarette market is much less concentrated than those in other developed countries, although the top brands have been gaining market share during 2005–2010.

Within each brand, there are multiple varieties differing in terms of price and quality. According to the quality of tobacco leaves and the price of cigarettes, Chinese cigarettes are classified into five grades (grades 1 to 5, with higher being better) by the CNTC.

The cigarette tax in China consists of a specific excise tax and an *ad valorem* tax. Before May 2009, the specific excise tax that is fixed in nominal terms was 0.06 RMB per pack, the same for all cigarettes. The *ad valorem* tax rate had two tiers: 30% for cigarettes with a producer price less than 5 RMB per pack, called class B cigarettes, which include cigarettes of grades 1 and 2, and 45% for cigarettes with the producer price higher than or equal to 5 RMB per pack, called class A cigarettes, which include cigarettes of grades 3, 4, and 5.

[2]Some studies have attempted to mitigate endogeneity concerns by using cigarette prices aggregated at the community (Lance *et al*., 2004), county, or provincial levels (Bishop *et al*., 2007) and controlling for regional fixed effects (Lance *et al*., 2004; Chen and Xing, 2011).
[3]Foreign brands have only accounted for about 3% of the Chinese market.

DOI: 10.1002/hec



Notes: Total cigarette sales in China are obtained from *Global Market Information Database* and *China Tobacco Year Book 2005-2010*.

Figure 1. Cigarette sales in China 2005–2010

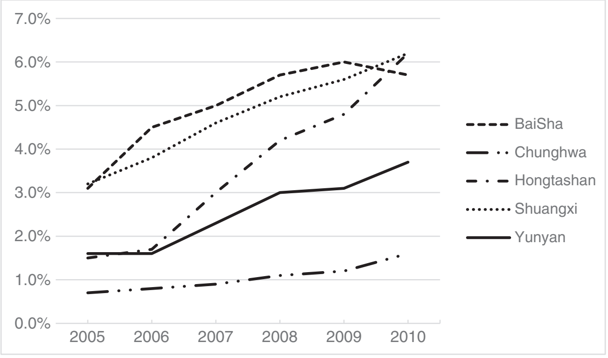


Figure 2. Market shares of popular cigarette brands in China 2005–2010

China adjusted the cigarette tax rate schedule in May of 2009. As shown in Table I, the specific excise tax of 0.06 RMB per pack remained unchanged.[4] But the *ad valorem* tax rates were raised to 36% and 56% in classes B and A, respectively, and the price band separating the two tiers was increased to 7 RMB per pack from 5 RMB per pack. Most cigarettes sold are subject to the 36% *ad valorem* excise. A new 5% excise was added at the wholesale level for all cigarettes. At the same time, the government required the CNTC to absorb all of the tax increase from its profits and not pass it on to consumers. Thus, the 2009 tax adjustment has not served as a tobacco control measure but a transfer from CNTC to the government (Gao *et al*., 2012).

Studies have shown that the total cigarette tax burden in China was about 35–40% of the retail price level under the tax schedule in effect before May 2009 (Sunley, 2008; Hu *et al*., 2010). Even if the 2009 tax increase were translated into higher retail prices, Hu *et al*. (2010) suggest that the new tax rate at the retail price level would be only 43.4%, still far below the world median level of 65–70%.

3. DATA AND VARIABLES

Our data come from multiple sources. This section describes the data sources and how study variables are defined and constructed.

[4]Given the rising inflation rate from 2005 to 2010 in China, the specific excise tax has declined in real terms.

Table I. Cigarette taxation in China before and after May 2009

	Before May 2009	After May 2009
1. Specific excise tax per pack	0.06 RMB	0.06 RMB
2. *Ad valorem* excise tax rate		
Class A cigarettes	Price per pack ≥ 5RMB 45%	Price per pack ≥ 7RMB 56%
Class B cigarettes	Price per pack < 5RMB 30%	Price per pack < 7RMB 36%
3. Wholesale price tax	0%	5%

3.1. Cigarette brand sales

We obtain cigarette sales data from two sources: Global Market Information Database and China Tobacco Year Book 2005–2010. The former tracks sales data of various cigarette brands in China from 2005 to 2010, while the latter mainly collects sales data for the top 50 best-selling cigarette brands in China. We combine these two sources of sales data and exclude small local brands having minute market shares (less than 0.1%). Thus, we obtain 49 to 65 brands each year and 348 brand-year observations from 2005 to 2010.[5]

To incorporate the option of not smoking in our demand model, we need to estimate the potential cigarette market in China, defined as the number of cigarettes that would have been consumed if the entire population aged 15 and above[6] were smokers. First, according to multiple data sources,[7]the smoking prevalence among adults in China was approximately 25% in 2005, 26.5% in 2006, 25.8% in 2007,[8] 25.1% in 2008, 27.5% in 2009, and 28.1% in 2010. Second, we construct our measure of market share for each brand relative to the size of the potential cigarette market as defined above, by dividing its observed market share by the smoking prevalence rate in each year.

3.2. Brand price and characteristics

Data on cigarette prices and characteristics are obtained from STMA. This dataset contains the suggested retail price per pack for each variety within each cigarette brand. However, since we only have brand-level sales data, we use the average price of all the varieties within each cigarette brand as the brand price. All prices are inflated to RMB in 2010. In Table II, the descriptive statistics show that the average retail price for a pack of 20 cigarettes is about 9.06 RMB in our sample but varies substantially by brand, ranging from 2.23 to 48.50 RMB.

For each cigarette brand, we have four variables capturing brand characteristics.[9] The first three variables measure tar, nicotine, and carbon monoxide (CO) yields of each brand, defined as milligrams per cigarette. Tar content influences the taste of cigarettes, while nicotine is the major psychoactive agent in tobacco responsible for the addictive properties of cigarettes. Again, although we have variety-specific data for these three measures, we use the average content across different varieties within each brand as the brand-level yields to match our market share data at the brand level. The last variable measuring brand characteristics is the number

[5]Produced by 22 out of total 40 manufacturers in China, our sample brands are all national brands and account for over 80% of all cigarette sales in China in a given year from 2005 to 2010. It is reasonable to take this sample as representative of Chinese cigarette market.

[6]The prevalence of adult smoking is defined for the Chinese population aged 15 and over in our data sources, including National Health Services Survey 2003, 2008, and Global Adult Tobacco Survey China 2010. Studies on adolescent smoking in China show that the prevalence rates for experimenting were about 6% among boys and 2% among girls by age 10, and the prevalence rates of smoking was 3% among boys and 0.3% among girls by age 15 (Yang *et al*., 2004). Compared to those in developed countries, boys in China have exhibited a similar pattern of smoking initiation, but girls in China have a much lower smoking rate, resulting in an older average age of initiation (Chen *et al*., 2001; Yang *et al*., 2004).

[7]The data sources for smoking prevalence in China include the Analysis Report of National Health Services Survey in China conducted by the Ministry of Health of China in 2003 and 2008, China Health and Nutrition Surveys 2006 and 2009, the Global Adult Tobacco Survey China conducted by the China Center for Disease Control and Prevention in 2010, and data from the Institute for Health Metrics and Evaluation (Qin, 2014).

[8]We impute smoking prevalence rate in 2007 as the average of prevalence rates in 2006 and 2008.

[9]The values for all the four characteristics of not smoking are defined as zero.

DOI: 10.1002/hec

Table II. Descriptive statistics at the brand level

	Full sample				High tier cigarettes (Class A)	Low tier cigarettes (Class B)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	Mean	SD	Min	Max	Mean	Mean	
Observed market share	0.013	0.014	0.001	0.062	0.016	0.010	***
Price per pack (RMB in 2010)	9.064	8.633	2.228	48.497	12.801	4.699	***
Tar (mg/cigarette)	11.657	1.238	5.780	13.580	12.103	11.221	**
Nicotine (mg/cigarette)	1.117	0.131	0.560	1.350	1.094	1.120	
CO (mg/cigarette)	11.830	1.198	7.880	14.00	11.967	12.122	
Num. of varieties within brand	6.875	3.952	2	12	7.024	6.493	
Smoking intensity (a_t)	1.128	0.106	1	1.283	1.128	1.128	
Expected price change (P^e_{t+1})	0.468	0.499	0	1	0.469	0.465	

The last column indicates if column (5) and column (6) are significantly different based on the *t* test.
$*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

of varieties within each brand. Each brand includes 6 to 7 varieties on average, with a minimum two varieties and a maximum 12 varieties.

Compared to class B (lower-tier) cigarette brands, class A (higher-tier) brands have slightly greater market shares and more varieties within the brand class. The tar yield of class A cigarette brands is higher than that of class B brands.

It must be noted that because of data limitations, we define product differentiation at the brand level instead of at the brand-variety level and treat the number of varieties as one of the brand characteristics (Deng and Ma, 2010). This assumption only allows for cross-brand substitution but not for within-brand substitution by variety. As smokers are likely to switch among the varieties within the same brand as well as across brands, smokers' substitution behavior may be underestimated in this study.

3.3. Rational addiction

The rational addiction literature suggests that there is a dependence of smokers' current smoking behavior on their *past* cigarette consumption (Chaloupka, 1991; Becker *et al*., 1994; Becker and Murphy, 1988) and that smokers are forward looking with respect to future prices of cigarettes (Gruber and Köszegi, 2001; Coppejans *et al*., 2007). To capture these features, we construct two variables.

The first variable measures smoking addiction for an average smoker. Ideally, we should have an addiction measure that is brand specific but to our knowledge, there are no data on the number of smokers for each brand in any data source in China. Therefore, we assume that smokers are equally addicted and construct an addiction measure that is year specific but the same for all cigarette brands in a given year as follows. First, we obtain the estimated number of smokers in each year, according to smoking prevalence rate and population data from the *Chinese Population Census*. Then, we calculate the average smoking intensity per person in each year by dividing the annual total cigarette sales by the estimated number of smokers. We use this measure of smoking intensity at year $t-1$ as the measure for addiction at year t. Furthermore, we normalize the addiction measure to 1 in 2005.

The second variable is constructed to measure consumers' expectations about future cigarette prices. As cigarette prices are regulated by STMA in China, the prices of most brands and varieties within each brand changed little over time during our study period.[10] Therefore, we calculate the sales-weighted average price at the manufacturer level[11] and use changes in this measure to reflect consumers' expectations about cigarette

[10]The price of each variety within each cigarette brand is controlled by STMA in China. Despite the tax adjustment in 2009, the retail prices of cigarettes to consumers have been unaffected due to price regulation (Gao *et al*., 2012).
[11]Although it is preferable to use brand-level measures to capture expected future price change, we cannot calculate it as we lack variety-level sales data.

DOI: 10.1002/hec

price trends. Following Ciliberto and Kuminoff (2010), we construct a binary variable that is equal to 1 if, for any particular manufacturer, the sales-weighted average price of all of its cigarette brands in period t is higher than that in period $t-1$ and equal to zero otherwise. It is implicitly assumed here that smokers predict future cigarette prices based on past price changes, which is consistent with Gruber and Köszegi (2001) and Sloan *et al*. (2003).

4. EMPIRICAL METHODS

4.1. Model

Following Berry's (1994) theoretical framework, we use a nested logit model to study consumers' demand for differentiated cigarettes and obtain the demand parameters. We model a consumer's cigarette purchase decision in a sequential fashion. At the top level, a consumer has to decide to smoke cigarettes or not. After deciding to smoke, the consumer's second-level decision is to choose between tiers that differ in cigarettes' quality and price. We group cigarettes into two classes, $g=1,2$, corresponding to class A (higher-tier) and class B (lower-tier) cigarettes, respectively. At the third level, the smoker chooses among brands within the cigarette class that has been chosen. To summarize, each consumer i chooses among $J+1$ alternatives (including not smoking) according to the above decision process, where J denotes the number of brands available in China's cigarette market in a given year.

We assume that the utility of consumer i derived from purchasing the cigarette brand j in period t is determined by

$$u_{ijt} = x_{jt}\beta - \alpha p_{jt} + \varphi a_t + \phi p^e_{j,t+1} + \xi_{jt} + \gamma_{it}(\sigma) + (1-\sigma)\varepsilon_{ijt} \tag{1}$$

where x_{jt} is a vector of the observed characteristics of cigarette brand j at period t, p_{jt} denotes the price of brand j at period t, a_t is our measure of smokers' degree of addiction, proxied by the number of cigarettes an average smoker consumes at period $t-1$, and $p^e_{j,t+1}$ is a binary variable that measures smokers' expectations about the price change at period $t-1$. β, α, φ, and ϕ are structural parameters to be estimated. The parameter α represents consumer i's marginal utility from income. As implied by rational addiction theory, we expect that $\varphi > 0$ and $\phi < 0$.

In equation (1), ξ_{jt} represents the attributes of cigarette brand j that are observed by consumers and firms but unobserved by the econometrician, such as firms' advertising efforts. ε_{ijt} represents consumers' idiosyncratic tastes for brand j. We assume that ε_{ijt} is an identically and independently distributed extreme value over each brand $j=1, 2, \ldots, J$ and period $t=1, 2, \ldots, T$. σ denotes the nested logit parameter which captures the correlation of consumers' tastes between different cigarette brands within the same class. Finally, γ_{it} is a random variable with a unique distribution such that the additive term $[\gamma_{igt}(\sigma)+(1-\sigma)\varepsilon_{ijt}]$ also follows the extreme value distribution.

The utility from the decision not to smoke cigarettes is given by

$$u_{i0t} = \gamma_{i0t}(\sigma) + (1-\sigma)\varepsilon_{i0t} \tag{2}$$

We let $\delta_{jt} \equiv x_{jt}\beta - \alpha p_{jt} + \varphi a_t + \phi p^e_{j,t+1} + \xi_{jt}$, which is the mean utility level of brand j at period t. Consumer i is assumed to choose the alternative j that yields the highest level of utility among all $J+1$ alternatives.[12] As noted by Berry (1994), the market share of brand j at period t, denoted by s_{jt}, is determined by the following equation:

[12]Our specifications of equations (1) and (2) assume that income enters into consumer i's indirect utility function linearly. Therefore, when making choices among all alternatives (i.e., consumers will choose alternative j, $j=0, 1, \cdots, J$, if and only if $u_{ijt} > u_{ikt}, \forall k$), income can be canceled out and does not affect consumer's choices. Nevertheless, we also estimate a version of our model in which we assume that the income enters into the utility function in a nonlinear fashion, using the natural logarithm of income. Employing this specification, we obtain estimates of –0.794 for the average own-price elasticity at the brand level and –0.463 for the price elasticity of overall cigarette demand. These elasticity estimates are very similar to those reported in this paper that assumes a linear income effect.

DOI: 10.1002/hec

$$s_{jt} = \frac{e^{\delta_{jt}/(1-\sigma)}}{D_{gt}^{\sigma}\left[1 + D_{gt}^{1-\sigma}\right]} \quad (3)$$

where

$$D_{gt} = \sum\nolimits_{j \in M_{gt}} e^{\delta_{jt}/(1-\sigma)} \quad (4)$$

and M_{gt} is the set of brands in class g at period t.

Following Berry (1994), the log transformation of relative brand share gives our estimating equation as follows:

$$ln(s_{jt}) - ln(s_{0t}) = x_{jt}\beta - \alpha p_{jt} + \varphi a_t + \phi p^e_{j,t+1} + \sigma ln(s_{jt|gt}) + \xi_{jt} \quad (5)$$

where s_{0t} is the market share of the outside alternative and $s_{jt|gt}$ is the market share of cigarette brand j in the class g at period t.

After obtaining consistent estimates of the demand parameters (discussed more fully in the following subsection), we are able to calculate the own-price elasticity of demand for brand j at period t, which is given by

$$\eta_{j,j,t} = \frac{\partial s_{jt}}{\partial p_{jt}} \frac{p_{jt}}{s_{jt}} = \alpha p_{jt} \left(\frac{\sigma}{1-\sigma} s_{jt|gt} + s_{jt} - \frac{1}{1-\sigma} \right), \quad j \in M_g; g = 1,\ 2 \quad (6)$$

The cross-price elasticity of demand between brands j and k at period t is given by

$$\eta_{j,k,t} = \frac{\partial s_{jt}}{\partial p_{kt}} \frac{p_{kt}}{s_{jt}} = \alpha p_{kt} \left(\frac{\sigma}{1-\sigma} s_{kt|gt} + s_{kt} \right), \ j \neq k,\ j \in M_g,\ k \in M_h,\ g, h = 0, 1, 2 \quad (7)$$

When $g = h$, we obtain the within-class-cross-price elasticity of demand from equation (7). Otherwise, equation (7) becomes $\alpha p_{kt} s_{kt}$, which is the cross-class-cross-price elasticity of demand.[13]

To make further comparisons with previous estimates for price elasticities that treat cigarettes as a homogeneous good,[14] we also calculate the overall market-level cigarette price elasticity, which measures the percentage change in the total cigarette consumption if the price of each cigarette brand increases by 1% at the same time. To do so, after obtaining the parameter estimates of equation (5), we increase the prices of all cigarette brands by 1% and calculate the new market share of every cigarette brand according to equations (3) and (4) using the demand parameter estimates and new prices. Then, we calculate the total demand change based on these new market shares. This approach highlights that market-level elasticity is an *aggregation* of brand-level elasticities.

4.2. Estimation and identification

Inspecting the demand equation (5), if we assume that all regressors are uncorrelated with the brand-specific unobserved attributes ξ_{jt}, we can simply conduct linear OLS estimations with the log of relative brand share as the dependent variable. The individual consumer's smoking decision can then be based on a simple logit model by assuming $\sigma = 0$ or a nested logit model by assuming $\sigma \neq 0$ in equation (5). The significance of the estimate for σ will help shed light on the consumer's decision process.

However, following the literature (e.g., Berry *et al.*, 1995; Petrin, 2002), we can only assume that the observed brand characteristics x_{jt} (including cigarette yields of tar, nicotine and CO, and number of varieties within brand j) are uncorrelated with the brand-specific unobserved attributes ξ_{jt} in equation (5). As the addiction measure a_t is determined at period $t-1$, it can also be treated as exogenous. However, we are confronted

[13]The measures of own-price and cross-price elasticities in equations (6) and (7) are conditional on the total size of the potential cigarette market in China.

[14]Previous studies assume that cigarettes are homogeneous; i.e., there is one representative cigarette brand in the market; therefore, their estimates of price elasticities are both the brand- and market-level elasticities.

DOI: 10.1002/hec

with potential endogeneity, as ξ_{jt} may be correlated with current price p_{jt}, expected future price $p^e_{j,t+1}$, and within-market share $s_{jt|gt}$. For example, if the high quality of a particular cigarette brand is correctly perceived by consumers and the firm, it is able to induce higher willingness to pay so that the firm can charge a higher price and also achieve a greater market share.

To address these endogeneity concerns, we employ an instrumental variables approach. However, traditional two-stage least squares (2SLS) estimation may be subject to bias due to functional misspecification when the linear approximations of endogenous variables on the instruments are not precise (Berry *et al*., 1995; Xiao, 2008). Therefore, we adopt a generalized method of moments (GMM) to obtain consistent estimates of the demand parameters in equation (5). The moment condition is

$$E(\xi|Z) = 0 \tag{8}$$

where Z is the matrix of instrumental variables for the three endogenous variables, p_{jt}, $p^e_{j,t+1}$, and $s_{jt|gt}$. Let θ denote the vector of parameters to be estimated in equation (5) and define $G(\theta) \equiv Z'\xi(\theta)$. Hansen (1982) shows that the optimal GMM estimators are defined by

$$\hat{\theta} = \arg\min_{\theta} G(\theta)' W G(\theta) \tag{9}$$

where W is a symmetric positive definite weighting matrix that may be chosen optimally to minimize the variance of $\hat{\theta}$.

Our instrumental variables approach is similar to that used in Berry *et al*. (1995). For each brand, we have two sets of instruments. The first set of instruments includes the three sums of nicotine, tar, and CO yields, respectively, of other brands produced by the same manufacturer in the same year. The second set of instruments includes the three sums of nicotine, tar, and CO yields, respectively, of all brands produced by other competing manufacturers in the same year. The rationale is that brands facing more similar substitutes tend to have low markups and thus lower prices relative to cost. The similarities between cigarette brands are measured by the similarities in brand yields. Furthermore, in oligopoly models, product markups and therefore product prices respond differently to own and rival products. Thus, to achieve optimality (Berry *et al*., 1995), we use these two sets of instruments to distinguish between the effects on one brand's price from cigarette brands produced by the same multiproduct manufacturer and the effects from cigarette brands produced by competing manufacturers.[15]

We also use an additional instrumental variable for p^e_{t+1}, which is a binary indicator that is equal to 0 before 2009 and 1 after 2009. The underlying idea is that the cigarette tax adjustment in 2009 was an exogenous event that imposed additional producer/wholesale taxes on all cigarette brands, and should be uncorrelated with unobserved brand-specific attributes ξ_{jt}. Although the additional tax increase was required by the government to be absorbed from the firms' profits and has not been passed along to the retail price, it may have affected the way the smokers formed their expectations on *future* cigarette prices. We test the validity of our instruments in section 5.

Another concern about the identification is that the number and composition of cigarette brands may have been changing during the sample period. We follow Ackerberg and Rysman (2005) and address it by controlling for the number of varieties within each brand in each year. This way also helps to address any potential bias due to data limitation that we only have brand-level market share (Deng and Ma, 2010).

A final concern for identification is that there may be strong regional brand differences in terms of distribution and consumption of cigarettes in China (Bai and Zhang, 2005; Zhang and Zou, 2012). In our estimation, we include manufacturer fixed effects and province-specific fixed effects to control for unobserved manufacturer-specific attributes as well as regional differences.[16]

[15]These types of instruments have been widely used in the empirical industrial organization literature to estimate the demand for differentiated products in many markets (Bresnahan, 1987; Berry *et al*., 1995; Nevo, 2000, 2001; Petrin, 2002).

[16]Our study sample has 22 manufacturers located in 22 provinces in China. As most provinces have only one manufacturer, the inclusion of manufacturer fixed effect may also capture regional differences. Although unreported, the results are quite robust to the exclusion of regional fixed effects.

DOI: 10.1002/hec

5. EMPIRICAL RESULTS

5.1. Estimates for demand parameters

Table III presents the estimation results from the cigarette demand equation (5) with the log of relative market shares as the outcome variable.

In columns (1) and (2), the OLS estimates for equation (5), with or without allowing for the correlation of unobserved consumer tastes σ, show that the price coefficients are positive and statistically insignificant, suggesting upward-sloping demand curves. However, the OLS estimates may be subject to positive endogeneity bias due to the correlation between cigarette price and unobserved brand heterogeneity ξ_{jt}in the demand equation. Moreover, the OLS estimate for σ is 0.969 and is significant at the 1% level, indicating that the nested logit model is the preferred specification over the logit model to study individual smoking decisions.

In columns (3) and (4), we adopt traditional 2SLS and GMM estimations, respectively, to control for possible endogeneity in equation (5). The reliability of the IV estimates depends on the validity of the instruments. To test the instruments, we first examine the explanatory power of the instruments for p_{jt}, $p^e_{j,t+1}$, and $s_{jt|gt}$. In the bottom of column (3), the first-stage F statistics suggest that the instruments are strong (significant at the 1% level) for each of three endogenous variables. Second, since we have more instruments than endogenous variables, we also perform tests for overidentification restriction. The Hansen's J-statistics are 5.107 for the 2SLS estimation in column (3) and 5.199 for the GMM estimation in column (4), which suggest that the exogeneity of our instruments cannot be rejected at the 10% level.

In column (3), the traditional 2SLS estimate of coefficient on price is –0.027 and is significant at the 5% level. In column (4), we proceed with the GMM estimation to address the potential bias in 2SLS due to functional form misspecification of the instruments in the linear first-stage estimation, as suggested in Berry *et al.* (1995) and Petrin (2002). The GMM estimate of the price coefficient is –0.022, very similar in magnitude to the 2SLS estimate but has a higher level of statistical significance (at the 1% level). Both the 2SLS and GMM estimates suggest that cigarette demand is a downward-sloping curve after correcting for endogeneity in the demand equation.

Compared to the OLS estimate, the GMM estimate for the constant correlation of unobserved consumer tastes σ is also significant at the 1% level but is smaller in magnitude (0.749), indicating that consumer tastes are positively correlated over different cigarette brands within the same class.

Table III. Parameter estimates for the demand equation (5)

	OLS	OLS	2SLS	GMM
	(1)	(2)	(3)	(4)
Price	0.015 (0.009)	0.007 (0.004)	–0.027** (0.011)	–0.022*** (0.006)
Within-class market share ($\ln(s_{jt\|gt})$)		0.969*** (0.024)	0.672*** (0.109)	0.749*** (0.147)
Expected price change (P^e_{t+1})	–0.017 (0.032)	–0.110*** (0.015)	–0.190*** (0.051)	–0.200*** (0.070)
Smoking intensity (a_t)	1.482*** (0.635)	1.690*** (0.070)	1.090*** (0.315)	1.166*** (0.228)
Tar (mg/cigarette)	0.027 (0.015)	0.064** (0.023)	0.042** (0.020)	0.038*** (0.008)
Nicotine (mg/nicotine)	–0.259 (0.693)	0.065 (0.170)	–0.171 (0.395)	0.105 (0.255)
CO (mg/nicotine)	0.071 (0.085)	–0.140 (0.290)	0.166 (0.476)	0.132 (0.341)
ln(number of varieties)	0.259 (0.482)	0.184 (0.178)	0.263 (0.357)	0.242 (0.405)
Constant	–7.922*** (0.906)	–6.358*** (1.205)	–5.089*** (1.672)	–6.692*** (1.023)
First-stage F statistics for price			6.73 (P = 0.000)	
First-stage F statistics for $\ln(s_{jt\|gt})$			348.15	
First-stage F statistics for P^e_{t+1}			1267.91	
Overidentification test (Hansen's J)			5.107 (P = 0.403)	5.199 (P = 0.393)
R^2	0.865	0.990	0.931	0.907
N	348	348	348	348

The dependent variable is the log of relative market share $\ln(s_{jt}) - \ln(s_{0t})$. All specifications include the full sets of manufacturer, provincial and year dummies. Robust standard errors are in parentheses.
*Statistical significance at 10% level, **Statistical significance at 5% level, ***Statistical significance at 1% level.

Table IV. Own-price and cross-price elasticities by year and class

Year/Class	Class A	Class B	Average	Overall
Panel I. Own-price elasticity by year and class				
2005	–0.835	–0.575	–0.770	–0.486
2006	–0.857	–0.584	–0.769	–0.477
2007	–0.869	–0.611	–0.787	–0.493
2008	–0.900	–0.592	–0.820	–0.502
2009	–0.927	–0.631	–0.817	–0.500
2010	–0.920	–0.623	–0.806	–0.490
Average	–0.899	–0.634	–0.807	–0.488
Panel II. Within-class-cross-price elasticity by year and class				
2005	0.138	0.189	0.152	
2006	0.151	0.200	0.168	
2007	0.110	0.179	0.150	
2008	0.106	0.145	0.130	
2009	0.127	0.158	0.135	
2010	0.125	0.152	0.131	
Average	0.130	0.164	0.149	
Panel III. Cross-class-cross-price elasticity by year and class				
2005	0.020	0.044	0.027	
2006	0.015	0.047	0.025	
2007	0.018	0.037	0.026	
2008	0.019	0.041	0.025	
2009	0.017	0.033	0.022	
2010	0.021	0.041	0.026	
Average	0.018	0.040	0.025	

Elasticities are sales-weighted average. The above estimates are short-run elasticities in that the expectations for future cigarette prices are kept constant. The last column of panel I calculates the percentage change in total demand for cigarette if the price of every cigarette brand increases by 1% at the same time.

Consistent with the addictive nature of cigarette consumption, the smoking intensity of an average person (a_t) has a significant and positive impact on the cigarette sales. The coefficient on expected price increase ($p^e_{j,t+1}$) has the anticipated negative sign and is statistically significant, suggesting that smokers may be forward looking with respect to cigarette pricing (Gruber and Köszegi, 2001).

The estimates on brand characteristics show that the concentration of tar is significantly positively correlated with the relative market share of each brand, after controlling for the effect of price. This suggests that smokers are likely to prefer cigarettes with higher tar concentration. This finding provides some evidence for smokers' compensating behavior in terms of switching from low-tar to high-tar cigarettes when they are forced to consume fewer cigarettes. The coefficient on the nicotine and CO concentrations is statistically insignificant across all specifications in columns (1)–(4). Finally, the estimate for the number of varieties within each brand is also insignificant in each model specification.

5.2. Demand elasticities

Table IV summarizes the own-price and cross-price elasticities of demand by year and class based on the GMM parameter estimates in column (4) of Table III.[17] In panel I of Table IV, we find an average own-price elasticity at the brand level of –0.807, which measures the percentage change in demand for a particular cigarette brand if its price increases by 1% but prices of other brands remain unchanged. This is relatively high compared to previous estimates of price elasticities that assume cigarettes to be homogeneous (e.g., Hu and Mao, 2002; Lance *et al.*, 2004; Bishop *et al.*, 2007; Chen and Xing, 2011), due to consumers' ability to substitute across brands.

[17]The estimates are short-run elasticities in the sense that they are calculated holding the (expected) future prices constant.

DOI: 10.1002/hec

The last column of panel I reports the overall market-level price elasticity of cigarette demand, which measures the percentage change in total cigarette demand if prices of all cigarette brands increase by 1%. Our estimated overall price elasticity in China is –0.488, which is in the middle range of estimated elasticities in the literature on China, and slightly higher in the magnitude than the average estimates of about –0.4 for developed countries. It is consistent with the argument that lower-income smokers are more sensitive to the price of cigarettes than are higher-income smokers (Warner, 1990; Chaloupka and Warner, 2000),

The own-price elasticities for class A cigarettes had an increasing trend in magnitude during 2005 to 2010, while there was no clear pattern for class B cigarettes. The results in Panel I also reveal that the own-price elasticities are greater in magnitude for class A cigarettes than for class B cigarettes in each year as well as on average. This implies that smokers using low-priced cigarettes are less responsive to price changes than smokers using high-priced cigarettes, which is consistent with findings by Cummings *et al*. (1997) in the US and Li *et al*. (2010) in China. The intuition behind these results is twofold. First, smoking is addictive, and therefore, smokers have a tendency to keep the level of cigarette consumption unchanged when cigarette prices increase. Smokers of high-priced cigarettes can opt for low-priced brands when cigarette prices increase, while smokers of low-priced cigarettes cannot. As a result, high-priced cigarette brands may exhibit higher own-price elasticities. Second, because of budget constraints, heavier smokers may tend to consume cigarettes with lower prices, and at the same time, they are also less likely to quit smoking. This may also lead to less price sensitivity among users of low-priced cigarettes.

Panels II and III in Table IV present the within-class and cross-class cross-price elasticities, respectively. The estimated within-class cross-price elasticities have an overall average of 0.149 across all years and classes and range from 0.106 to 0.2, and they are higher for class B cigarettes than for class A cigarettes. These results imply that the substitution effects between different brands are stronger among low-priced (class B) cigarette brands than among high-priced (class A) brands.

In Panel III, the estimated cross-class cross-price elasticities vary from 0.015 to 0.047, with a sales-weighted average of 0.025 across years and classes, which is much smaller in magnitude than the within-class cross-price elasticities. This suggests that smokers are more likely to switch brands within each class than across classes when cigarette prices change. We also find that the cross-class cross-price elasticities are larger in magnitude for class B brands than for class A brands, which suggests that the price change of more expensive (class A) brands has a larger positive impact on the sales of low-priced (class B) brands than the price change of class B brands on class A brands.

5.3. Policy implications

Tobacco taxes have been widely adopted as one of the most effective tobacco control policies in many countries. Studies suggest that if we try to increase the total tax burden on cigarettes in China to meet with the World Bank yardstick of two thirds of the retail price level, the government should raise the specific excise tax to approximately 4 RMB per pack. However, a more feasible approach would be to raise the specific excise tax to 1 RMB per pack from the current level of less than 0.06 RMB per pack and then gradually increase it to 4 RMB per pack, in order to mitigate adverse effects on the cigarette industry (Sunley, 2008; Hu *et al*., 2010; Chen and Xing, 2011). Therefore, in this subsection, we simulate a cigarette tax increase by 1, 2, 3, and 4 RMB per pack, respectively, and discuss their impacts, based on the assumption that the CNTC directly sets the retail prices of cigarettes at levels as directed by the government.

Cigarette sales were approximately 119 billion packs in 2010 and 108.3 billion packs on average during the period 2005–2010. The simulated results in Table V show that cigarette sales would be reduced by 8.85%, a reduction of 7.35 billion packs when a 1 RMB excise tax is levied. Our estimates are smaller in magnitude than those in other studies of Chinese smokers.[18] Moreover, a uniform tax increase per pack may have asymmetric

[18]For example, previous studies show that an additional 1 RMB excise tax would lead to a reduction in cigarette consumption by 9.97 billion packs at a price elasticity of −0.48 (Chen and Xing, 2011) or by 9.90 billion packs at a price elasticity of −0.50 (Hu *et al*., 2010).

DOI: 10.1002/hec

Table V. Simulated effects of cigarette tax increases under different scenarios

	Cigarette excise tax increase			
	1 RMB/pack	2 RMB/pack	3 RMB/pack	4 RMB/pack
I. Cigarette sales				
ΔCigarette sales (billion pack)	–7.35 [–8.05, –6.76]	–10.75 [–14.10, –9.69]	–18.46 [–22.01, –17.13]	–29.28 [–34.35, –27.00]
ΔClass A sales	–1.89 [–2.45, –1.18]	–2.82 [–3.42, –2.28]	–4.92 [–5.58, –3.93]	–6.75 [–9.19, –5.31]
ΔClass B sales	–5.47 [–6.81, –4.50]	–7.93 [–10.27, –6.01]	–13.54 [–16.82, –10.99]	–22.53 [–26.82, –20.11]
%ΔCigarette sales	–8.85% [–9.67%, –8.12%]	–12.77% [–14.42%, –12.58%]	–22.62% [–24.77%, –22.09%]	–32.57% [–35.03%, –30.28%]
%ΔClass A sales	–2.67% [–3.70%, –1.98%]	–5.62% [–7.09%, –4.92%]	–11.33% [–13.64%, –10.05%]	–18.29% [–21.28%, –16.03%]
%ΔClass B sales	–15.17% [–17.89%, –14.51%]	–19.58% [–21.68%, –17.81%]	–31.72% [–34.02%, –28.73%]	–48.89% [–53.01%, –47.08%]
II. Government revenue from cigarette taxes				
ΔTax (billion RMB)	118.24 [109.15, 127.90]	137.21 [127.25, 141.44]	173.68 [161.27, 192.68]	129.05 [117.12, 132.55]
%ΔTax	35.82% [31.94%, 39.52%]	42.73% [39.77%, 45.81%]	50.89% [47.65%, 54.06%]	38.26% [33.94%, 42.57%]
III. Tar and nicotine intake				
%ΔTotal tar	–6.68% [–7.02%, –5.03%]	–9.91% [–11.04%, –8.27%]	–18.76% [–20.05%, –16.83%]	–26.69% [–29.91%, –23.58%]
%ΔAverage tar level per cigarette	2.83% [2.36%, 3.05%]	2.92% [2.17%, 4.01%]	4.02% [2.55%, 6.01%]	5.61% [3.58%, 7.82%]
%ΔTotal nicotine	–8.73% [–5.02%, –11.35%]	–13.06% [–9.02%, –16.77%]	–19.58% [–25.16%, –15.03%]	–35.14% [–41.74%, –30.85%]
%ΔAverage nicotine level per cigarette	0.51% [–0.40%, 1.16%]	–0.78% [–2.28%, 1.23%]	2.09% [–1.22%, 4.49%]	–0.18% [–2.16%, 3.17%]

The simulation is based on the demand estimates in column (4) in Table III. All monetary terms are in 2010 RMB. All percentages are sales weighed. Shown in square brackets are 95% confidence intervals based on 500 parametric bootstraps.

effects on different brands. For the same level of cigarette tax increase per pack, high-priced brands would have a lower percentage price increase, and therefore, their demand would be less affected.[19]

As shown in panel II, an increase in the tax level of 1 RMB per pack would increase total tax revenue from cigarettes by 35.82% (118.24 billion RMB).[20] Compared to previous studies,[21] our simulation results show a larger effect of a cigarette tax increase on government tax revenues. The main reason is that by allowing for brand switching, we find less reduction in cigarette consumption for the same level of cigarette tax increase, which leads to a larger increase in total tax revenue.

In addition, we are also interested in simulating the potential effect of a cigarette tax increase on other risk factors associated with smoking—the intakes of tar and nicotine. Because taxes are independent of tar and nicotine content, smokers may compensate by switching to cigarettes that are higher in tar and nicotine content. As expected, with an additional specific tax of 1 RMB per pack, the decrease in the total intake of tar would be 2–3% less than the total reduction in cigarette sales, and such differences are all statistically significant at the 95% level. The average tar levels per cigarette[22] would rise by 2.83%. However, we do not find such tax-induced compensating patterns for nicotine.

6. CONCLUSIONS

When countries propose increasing cigarette taxes to reduce smoking prevalence, it is vital to understand the behavioral changes of smokers as their responses to tax-induced price increases. To our knowledge, this paper is the first attempt to apply the discrete choice model of differentiated products to study China's cigarette market, and estimate own-price as well as cross-price elasticities of cigarette demand at the brand level as well as at the market level. Based on annual nationwide sales data from 2005 to 2010, we find that the overall price elasticity of cigarettes at the market level is –0.488, and the sales-weighted average own-price elasticity at the brand level is –0.807. High-priced (class A) cigarettes have higher own-price elasticities than low-priced (class B) cigarettes.

This study confirms the importance of brand-switching behavior of smokers as their responses to tax-induced price increases and identifies the substitution patterns in China's cigarette market. We find that substitution is more likely to occur among brands in the same class than across classes when cigarette prices change. The average within-class cross-price elasticity is 0.149, while the average across-class cross-price elasticity is only 0.025. We also demonstrate that Chinese smokers have a preference for cigarettes with higher concentration in tar, providing empirical evidence for smokers' compensatory behavior (Evans and Farrelly, 1998; Farrelly *et al*., 2004; Tsai *et al*., 2005; Adda and Cornaglia, 2006). In other words, smokers may not only switch to low-priced brands but also shift to high-tar cigarettes when cigarette prices increase.

This study is subject to several limitations. First, because we only have brand-level sales data, this study does not allow for within-brand substitution by variety, which may be a plausible type of behavior. Thus, our estimates of smokers' substitution behavior may be underestimated. Second, because of data limitations, we cannot measure smoking addiction at the individual level or at the brand level. Our measure of smoking intensity for an average smoker masks considerable heterogeneity in smoking addiction. However, Ciliberto and Kuminoff (2010) also assume smokers to be equally addicted and use a similar addiction measure in their study on the US cigarette industry.

[19]A uniform increase in the specific cigarette tax as considered in this paper results in a smaller percentage change in prices for high-priced cigarettes than for low-priced cigarettes. Therefore, sales of high-priced cigarettes will be less affected even though they tend to have higher own-price elasticities.

[20]Our simulation results are partial equilibrium, in that we only consider the changes in taxes levied on cigarette consumption but not the changes in profits or tax revenues from cigarette manufacturing firms.

[21]With an additional 1 RMB excise tax, previous studies have shown that total government cigarette tax revenues would increase by 66.09 billion RMB at a price elasticity of −0.48 (Chen and Xing, 2011) or by 101.8 billion RMB at a price elasticity of −0.50 (Hu *et al*., 2010).

[22]To calculate the average tar/nicotine level per cigarette, we divide the total tar or nicotine intake by the total number of cigarette sales in each scenario.

DOI: 10.1002/hec

Despite these limitations, our results have important implications for the potential effects of cigarette taxation in China. Given a tax-induced price hike, previous studies only consider the options of reducing or quitting smoking and may thus overestimate the magnitude of the impact of excise tax policies on cigarette consumption. Incorporating smokers' brand-switching behaviors, our simulation results show that the proposed 1-RMB-per-pack increase in specific tax will decrease on average 7.35 billion packs (about 8.85%) of cigarette consumption and increase annual tax revenue by 118.24 billion RMB (about 35.82%). This suggests that raising taxes alone may not reduce smoking to the degree previously believed, but it will still be an effective policy instrument for controlling tobacco use and raising tax revenue in China.

Studies have shown that tar intake is the primary cancer-causing agent in cigarettes (Stellman and Garfinkel, 1989). According to our estimates, the price elasticity of overall tar intake is –0.379, which is lower in the magnitude than the price elasticity of overall cigarette demand of –0.488 in China.[23] This suggests that smokers' tax-induced compensating behavior may undermine the effectiveness of a uniform tax increase as a policy instrument to promote public health, as current cigarette excise taxes are levied regardless of the tar content per cigarette in most countries. Therefore, to maximize the health benefits of a cigarette tax hike, policymakers should examine not only how many cigarettes are consumed but also the tar content of those cigarettes. It may be appropriate for the government to focus on the price elasticity of tar intake as well and establish differential taxes based on the tar and nicotine content of cigarettes in China.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

ACKNOWLEDGEMENTS

We would like to thank the editor, two anonymous reviewers, seminar participants at Shanghai University of Finance and Economics, Central University of Finance and Economics, Renmin University of China, the 5th CIER/IZA Workshop on Research in Labor Economics, and the 5th International Symposium on Human Capital and the Labor Market for helpful comments. We acknowledge the financial support from the National Natural Science Foundation of China (grant nos 71203244 and 71303148), Humanities and Social Sciences Foundation of Ministry of Education of China (grant no. 13YJC790126), Shanghai Pujiang Program (grant no. 12PJC053), Program for New Century Excellent Talents in University (grant no. NCET-12-0993), and Beijing Higher Education Young Elite Teacher Project (grant no. YETP0989).

REFERENCES

Abrevaya J, Puzzello L. 2012. Taxes, cigarette consumption, and smoking intensity: comment. *American Economic Review* **102**(4): 1751–1763.

Ackerberg DA, Rysman M. 2005. Unobserved product differentiation in discrete-choice models: estimating price elasticities and welfare effects. *RAND Journal of Economics* **36**(4): 771–788.

Adda J, Cornaglia F. 2006. Taxes, cigarette consumption, and smoking intensity. *American Economic Review* **96**(4): 1013–1028.

Adda J, Cornaglia F. 2012. Taxes, cigarette consumption, and smoking intensity: reply. Working Paper, Centre for Economic Performance, London School of Economics.

Bai Y, Zhang Z. 2005. Aggregate cigarette demand and regional differences in China. *Applied Economics* **37**(21): 2523–2528.

Barzel Y. 1976. An alternative approach to the analysis of taxation. *Journal of Political Economy* **84**: 1177–1197.

Becker GS, Murphy KM. 1988. A theory of rational addiction. *Journal of Political Economy* **96**(4): 675–700.

Becker GS, Grossman M, Murphy KM. 1994. An empirical analysis of cigarette addiction. *American Economic Review* **84**(3): 396–418.

Berry S. 1994. Estimating discrete-choice models of product differentiation. *RAND Journal of Economics* **25**(2): 242–262.

Berry S, Levinsohn J, Pakes A. 1995. Automobile prices in market equilibrium. *Econometrica* **63**(4): 841–890.
Bishop J, Liu H, Meng Q. 2007. Are Chinese smokers sensitive to price? *China Economic Review* **18**(2): 113–121.
Bresnahan T. 1987. Competition and collusion in the American automobile industry: The 1955 price war. *Journal of Industrial Economics* **35**(4): 457–482.
Chaloupka F. 1991. Rational addictive behavior and cigarette smoking. *Journal of Political Economy* **99**(4): 722–742.
Chaloupka F, Warner KE. 2000. The economics of smoking. In *Handbook of Health Economics*, vol. **1B**, Culyer A, Newhouse J (eds.). North Holland: Amsterdam; pp. 1539–1627.
Chapman S, Richardson J. 1990. Tobacco excise and declining tobacco consumption: the case of Papua New Guinea. *American Journal of Public Health* **80**(5): 537–540.
Chen Y, Xing W. 2011. Quantity, quality, and regional price variation of cigarettes: demand analysis based on a household survey in China. *China Economic Review* **22**(2): 221–232.
Chen X, Li Y, Unger JB, Gong J, Johnson CA, Guo Q. 2001. Hazard of smoking initiation by age among adolescents in Wuhan, China. *Preventive Medicine* **32**(5): 437–445.
China Center for Disease Control and Prevention (CDCC). 2010. *Global Adult Tobacco Survey (GATS) China 2010 Country Report*. China Sanxia Press: Beijing, China.
Ciliberto F, Kuminoff N. 2010. Public policy and market competition: how the Master Settlement Agreement changed the cigarette industry. *The BE Journal of Economic Analysis & Policy* **10**(1): 1–46.
Coppejans M, Gilleskie D, Sieg H, Strumpf K. 2007. Consumer demand under price uncertainty: empirical evidence from the market for cigarettes. *Review of Economics and Statistics* **89**(3): 510–521.
Cummings K, Hyland A, Lewit E Shopland D. 1997. Discrepancies in cigarette brand sales and adult market share: are new teen smokers filling the gap? *Tobacco Control* **6**(2): S38–S43.
Deaton A. 1988. Quality, quantity, and spatial variation of price. *The American Economic Review* **78**(3): 418−430.
Deaton A. 1997. *The analysis of household surveys: a microeconometric approach to development policy*. The Johns Hopkins University Press: Baltimore and London.
Deng H, Ma AC 2010. Market structure and pricing strategy of China's automobile industry. *Journal of Industrial Economics* **58**(4): 818–845.
Evans W, Farrelly M. 1998. The compensating behavior of smokers: taxes, tar, and nicotine. *RAND Journal of Economics* **29**(3): 578–595.
Farrelly M, Nimsch C, Hyland A, Cummings M. 2004. The effects of higher cigarette prices on tar and nicotine consumption in a cohort of adult smokers. *Health Economics* **13**(1): 49–58.
Gao S, Zheng R, Hu T. 2012. Can increases in the cigarette tax rate be linked to cigarette retail prices? Solving mysteries related to the cigarette pricing mechanism in China. *Tobacco Control* **21**(6): 560–562.
Gruber J, Köszegi B. 2001. Is addiction "rational"? Theory and evidence. *Quarterly Journal of Economics* **116**(4): 1261–1303.
Hansen LP. 1982. Large sample properties of generalized method of moments estimators. *Econometrica* **50**(4): 1029–1054.
Harris JE. 1980. Taxing tar and nicotine. *American Economic Review* **70**(3): 300–311.
Houthakker HS. 1952. Compensated changes in quantities and qualities consumed. *Review of Economic Studies* **19**: 155–164.
Hu TW, Mao Z. 2002. Effects of cigarette tax on cigarette consumption and the Chinese economy. *Tobacco Control* **11**(2): 105–108.
Hu TW, Mao Z, Shi J, Chen W. 2008. Tobacco taxation and its potential impact in China. International Union against Tuberculosis and Lung Disease: Paris.
Hu TW, Mao Z, Shi J. Chen W. 2010. The role of taxation in tobacco control and its potential economic impact in China. *Tobacco Control* **19**(1): 58–64.
Kenkel D, Lillard D, Liu F. 2009. An analysis of life-course smoking behavior in China. *Health Economics* **18**(S2): S147–S156.
Lance P, Akin J, Dow W, Loh C. 2004. Is cigarette smoking in poorer nations highly sensitive to price?: evidence from Russia and China. *Journal of Health Economics* **23**(1): 173–189.
Li Q, Hsia, J, Yang G. 2011. Prevalence of smoking in China in 2010. *New England Journal of Medicine* **364**(25): 2469–2470.
Li Q, Hyland A, Fong GT, Jiang Y, Elton-Marshall T. 2010. Use of less expensive cigarettes in six cities in China: findings from the International Tobacco Control (ITC) China Survey. *Tobacco Control* **19**(Suppl 2): i63–i68.
Mao Z, Hu TW, Yang GH. 2005. Price elasticities and impact of tobacco tax among various income groups (in Chinese). *Chinese Journal of Evidence-Based Medicine* **4**: 291–295.
Nevo A. 2000. Mergers with differentiated products: the case of the ready-to-eat cereal industry. *RAND Journal of Economics* **31**(3): 395–421.
Nevo A. 2001. Measuring market power in the ready-to-eat cereal industry. *Econometrica* **69**(2): 307–342.
Petrin A. 2002. Quantifying the benefits of new products: the case of the minivan. *Journal of Political Economy* **110**(4): 705–729.
Qi S. 2013. The impact of advertising regulation on industry: the cigarette advertising ban of 1971. *RAND Journal of Economics* **44**(2): 215–248.

DOI: 10.1002/hec

Qin A. 2014. Smoking prevalence steady in China, but numbers rise. http://sinosphere.blogs.nytimes.com/2014/01/09/smoking-prevalence-steady-in-china-but-numbers-rise/?_php=true&_type=blogs&_r=0

Sayginsoy O, Yurekli A, de Beyer J. 2002. Cigarette demand, taxation, and the poor: a case study of Bulgaria. Working Paper, World Bank.

Sloan F, Smith V, Taylor D. 2003. *The Smoking Puzzle: Information, Risk Perception, and Choice*. Harvard University Press: Cambridge.

Stellman S, Garfinkel L. 1989. Lung cancer risk is proportional to cigarette tar yield: evidence from a prospective study. *Preventive Medicine* **18**(4): 518–525.

Sunley E. 2008. Taxation of cigarettes in the Bloomberg Initiative countries: overview of policy issues and proposals for reform. Working Paper, World Health Organization.

Tan W. 2006. The effects of taxes and advertising restrictions on the market structure of the US cigarette market. *Review of Industrial Organization* **28**(3): 231–251.

Tsai Y, Yang C, Chen C, Liu T, Chen P. 2005. The effect of Taiwan's tax-induced increases in cigarette prices on brand-switching and the consumption of cigarettes. *Health Economics* **14**(6): 627–641.

Warner KE. 1990. Tobacco taxation as health policy in the Third World. *American Journal of Public Health* **80**(5): 529–531.

Wilkins N, Yurekli A, Hu T. 2004. Economic analysis of tobacco demand. In *Economics of Tobacco Toolkit*, Ayda Y, de Beyer J (eds). World Bank: Washington D. C.

World Health Organization. 2010. WHO Technical Manual on Tobacco Tax Administration, http://www.who.int/tobacco/publications/tax_administration/en/ [accessed on 17 January 2014]

Xiao J. 2008. Technological advances in digital cameras: welfare analysis on easy-to-use characteristics. *Marketing Letters* **19**(2): 171–181.

Yang G, Ma J, Chen AP, Brown S, Taylor CE, Samet JM. 2004. Smoking among adolescents in China: 1998 survey findings. *International Journal of Epidemiology* **33**(5): 1103–1110.

Zhang Q, Zou H. 2012. Regional inequality in contemporary China. *Annals of Economics and Finance* **13**(1): 113–137.