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The impact of tobacco prices on smoking onset: a methodological review

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ABSTRACT

The benefits of preventing smoking onset are well known. Existing reviews clearly demonstrate that increasing the prices of tobacco products reduces smoking prevalence and cigarette consumption. However, only a small number of studies included in existing reviews have examined smoking onset (the transition between never smoking and smoking). Moreover, existing reviews provide limited quality assessment of the data and methods utilised. This paper systematically searches for and critically reviews studies that examine the impact of tobacco prices or taxes on smoking onset. Most studies reviewed have important methodological limitations, including recall bias; a general failure to apply diagnostic tests, to discuss the choice of estimators and distributional assumptions and to conduct sensitivity analysis; and a reliance on empirical approaches that are methodologically weak. On the whole, existing studies do not provide strong evidence that tobacco prices or taxes affect smoking onset.

INTRODUCTION

Decades of research have clearly demonstrated that the single most effective method to reduce smoking prevalence and cigarette consumption is to increase tobacco prices.[1–8]

Existing reviews,[1–8] however, have important methodological limitations and have weaker generalisability to low- and middle-income countries: they provide limited quality assessment of the data and methods used by the studies and include a relatively small number of studies conducted in low-income and middle-income countries (one exception is Rice *et al*,[7] who attempted to assess the quality of studies). Moreover, as only a small number of studies examine the decision to initiate smoking (the transition between never smoking and smoking), they do not provide definitive evidence regarding the impact of tobacco prices on smoking initiation/onset (as compared to smoking participation, smoking intensity or smoking cessation). Examining factors that influence youth smoking may focus on the decision to initiate smoking or the decision to be a current smoker (ie, participation is conditional on having initiated smoking). The distinctions in these approaches are important. Approaches that model participation do not allow one to distinguish between former smokers who have quit smoking and those who have never smoked. The addictive nature of nicotine plays a critical role in the decision to continue smoking.[9] In contrast, the role of addiction in the decision to initiate smoking is of lesser importance. Differences between participation and smoking onset elasticities vary with age—younger individuals are substantially more likely to initiate smoking than older individuals.[10]

Determining the impact of tobacco prices on smoking onset in low-income and middle-income countries is of particular importance, given how young their populations are and given that many low-income and middle-income countries are experiencing a rise in non-communicable diseases associated with tobacco use.[11] With this in mind, to the extent possible, special attention is given to studies conducted in low-income and middle-income countries.

METHODS

In the development and operation of the review, I use the assessment measurement tool developed by Shea *et al* as a methodological guide.[12 13]

Criteria for considering studies for this review

Types of study

I consider all studies that examine the relationship between the prices of or taxes on tobacco products and smoking initiation or onset.

Time period

I include all studies, regardless of date of publication or data collection.

Geographic location and coverage

I include all studies, regardless of the geographic coverage (eg, state, province, municipality).

Language

I include all studies that meet the inclusion criteria, regardless of the language of publication.

Types of 'outcome' measures

I include only studies that examine initiation or onset. That is, I only include studies that examine the transition between never smoking and smoking. I exclude any of the following: participation, consumption, cessation, substitution, escalation or persistence.

Search methods for identification of studies

I searched the computerised bibliographic database MEDLINE via PubMed and EconLit. Unpublished literature was also searched via Google and Google Scholar. Four specialty journals were hand-searched (*Health Economics*, *Journal of Health Economics*, *Nicotine & Tobacco Research* and *Tobacco Control*) and the references from recent reviews were examined.[1–8] Searches were last conducted on 21 February 2012. The following search strategy was employed:

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MEDLINE: (price*[Title/Abstract] OR 'Taxes'[MeSH] OR tax* [Title/Abstract]) AND (smok*[Title/Abstract] OR tobacco* [Title/Abstract] OR 'Tobacco'[MeSH] OR 'Smoking'[MeSH]); EconLit: (TI(tobacco* or smok* or cigar*) or AB(tobacco* or smok* or cigar*)) and (TI(tax* or price*) or AB(tax* or price*)).

Review methods

The review process had four stages:

1. Studies identified in the electronic and hand-search were pre-screened for relevance.
2. Relevant studies were assessed for inclusion.
3. Data were extracted using a standardised form.
4. The extracted data were analysed and synthesised in user-friendly tables.

RESULTS

The search of electronic bibliographic databases yielded 2732 potential articles (MEDLINE: 1998; EconLit: 734), 336 of which (MEDLINE: 166; EconLit: 248) were selected for further investigation. A further 12 studies were identified via Google and Google Scholar. No additional studies were identified through hand-searches. The review of abstracts (and, when necessary, full articles) yielded a total of 27 studies,[10 14–40] a substantially larger number than reviewed in any other single study or review. Nearly all studies, however, were conducted using data from the USA and to a lesser extent data from other high-income Organisation for Economic Co-operation and Development countries (Australia, Canada, France, Great Britain, Ireland, Spain and Sweden). Only one study[27] used data from a low-income country (until the late 2000s, Vietnam was categorised as a low-income economy by the World Bank. It is now categorized as a lower-middle-income economy).

Tables 1–3 present a synthesised overview of each study included in this review. Studies are presented in chronological order, based on year of publication. The following study characteristics are presented: (1) authors, year of publication, country, journal; (2) methods (statistical analyses, number of time periods modelled); (3) data (type, population, source, sample size); (4) a description of the price/tax measure and, where applicable, how the price/tax measure was adjusted for inflation; (5) covariates; (6) testing for mis-specification; (7) sensitivity analyses; (8) results and (9) whether the sources of support were clearly acknowledged. It is important to note that the descriptions provided represent the reviewer's interpretation and are not necessarily the interpretations provided by the authors. I return to this point later. The appendix presents a glossary of technical terms to facilitate the technical discussion in the following sections.

On the whole, most studies have important limitations, some serious enough that considerable caution is needed when interpreting results. The limitations can be categorised into two broad groups: data and measurement issues; and methodological issues.

Data and measurement issues

Measures of price and of smoking onset can suffer from a variety of measurement issues. Both are examined in turn. First, Tauras *et al*[18] pointed out that when one uses retrospective data, the current location may not match the location at the time of decision. Studies that use a price indicator measured at subnational level (eg, state or province) and that experience high levels of within-country migration or that use long time series will be disproportionally affected. Second, Forster and Jones[16] pointed out that their results may be sensitive to their choice of deflators. This issue is likely to be more relevant to studies that use prices measured at province or state level. Such studies, however, typically use national price indices to deflate province-level and state-level prices. One exception is Zhang *et al*,[31] who used consumer price index all-items measured at province level.[i] Sensitivity analyses using alternative measures of inflation appear to be warranted. Third, prices collected at different points in time may not be comparable. For example, Laxminarayan and Deolalikar[27] used cigarette price data for 1992/1993 and 1997/1998 that are not comparable, as they are for different brands that are not in the same price category. Fourth, when one uses longitudinal data, current prices may not match those at the time of decision. With one exception,[24] the longitudinal data used have not been collected on an annual basis. Hence most authors resolve to regress smoking onset that occurred over a 2-year period on contemporaneous prices.[ii]

Taurus and Chaloupka[41] stressed that recall bias—imperfect recall by respondents—when using retrospective data can introduce substantial measurement errors. This is especially problematic when respondents are asked to recall the exact year or age at which they initiated smoking when such events occurred decades earlier. How smoking onset is defined varies widely across studies. Little distinction is made between experimentation, occasional smoking, current smoking or daily smoking. Emery *et al*[42] argue that previous studies have not had adequate measures of smoking experience to examine whether prices may affect teens' smoking decisions. Here again, sensitivity analysis seems particularly warranted. Tauras *et al*[18] and Cawley *et al*[24] present results for such sensitivity analysis. Models with alternative measures of smoking onset are compared and their findings suggest large differences in effect sizes.

The limited number of covariates that are exogenously determined before or when individuals initiated smoking, particularly when using retrospective data, is an additional concern. For example, several studies include individuals' highest educational attainment, an indicator that is generally not exogenously determined before or when individuals initiate smoking.

Methodological issues

As first highlighted by Forster and Jones,[16] there is a general failure to apply diagnostic tests to assess the fit of the empirical models of smoking onset. Similarly, the choice of estimators and distributional assumptions are seldom discussed. For example, standard duration models (continuous and discrete) rest on the assumption that each individual will eventually fail (ie, die or, in this case, start smoking). Such an assumption is reasonable when mortality is the outcome under study but can be problematic when smoking onset is the outcome being modeled, as a large proportion of the population never starts smoking. López Nicolás,[21] and Kidd and Hopkins[26] compared split population models (ie, models that treat the probability of eventual smoking onset as an additional parameter to estimate) and non-split models and found vastly different effects. Similarly, how

[i] DeCicca *et al*[19] argued that state-specific cost of living indices in the United States are unreliable.

[ii] A revealing example is DeCicca *et al*,[37] who regressed smoking initiation that occurred at any time between 1992 and 2000 on cigarette tax rates in 2000.

Table 1 Characteristics of included studies: methods and data

Study	Country	Journal	Methods	Data
Douglas, Hariharan (1994)[10]	United States	*Journal of Health Economics*	Split population duration models (probability of ever starting: probit; duration: log-logistic) Number of time period modelled: 26	Type: retrospective (1954-1979) Population: representative sample (sample excludes individuals who were > 15 in 1954) Source: National Health Interview Survey (1978 and 1979) Sample size: 10,219
Douglas (1998)[14]	United States	*Economic Inquiry*	Split population duration models (probability of ever starting: ordered probit; duration: log-logistic) Number of time period modelled: 34	Type: retrospective (1954-1987) Population: representative sample (sample excludes individuals over 12 in 1954 and individuals who were <25 at time of interview) Source: National Health Interview Survey: Cancer Risk Factor Supplement (1987) Sample size: 8745
DeCicca, Kenkel, Mathios (2000)[15]	United States	*Journal of Risk and Uncertainty*	Discrete-time hazard models: same as DeCicca, Kenkel, Mathios (2002)	Same as DeCicca, Kenkel, Mathios (2002)
Forster, Jones (2001; 2003)[16 23]	Britain	*Journal of the Royal Statistical Society*	Split population duration models (probability of ever starting: probit; duration: log-logistic). Men and women samples estimated separately. Number of time period modelled: 64	Type: retrospective (1920-1984) Population: representative sample Source: British Health and Lifestyle Survey (1984) Sample size: 5098 (men 3737; women 4861)
Hammar, Martinsson (2001)[17]	Sweden	*Working paper*	Log-logistic and gamma duration models on subsamples of smokers Number of time period modelled: 56	Type: retrospective (1945-2000) Population: Smokers (sample restricted to individuals who were older than 9 and younger than 25 when they started and who were born between 1935 and 1965) Source: Survey conducted in the counties of Norrbotten and Västerbotten in the northern part of Sweden (2000) Sample size: 385
Tauras, O'Malley, Johnston (2001)[18]	United States	*NBER working paper*	Discrete-time hazard models (model: probit; duration: not reported) Number of time period modelled: 3 and 4	Type: longitudinal Population: Eighth and ten graders in 1991, 1992 and 1993 with follow-up surveys at two-year intervals Source: Monitoring the Future (1991-1999) Sample size: 8447 (sample size person/years = 15,548)
DeCicca, Kenkel, Mathios (2002)[19]	United States	*Journal of Political Economy*	Discrete-time hazard models (model: probit; duration: unclear, likely non parametric) Number of time period modelled: 3 (1988, 1990, 1992)	Type: longitudinal Population: Eighth graders in 1988 Source: National Education Longitudinal Study (1988, 1990, 1992) Sample size: person/years = 32,392
			Ordered probit Number of time period modelled: 1 (1988-1992)	Sample size: 12,485 (onset between 8th and 10th grade) and 12,262 (onset between 8th and 12th grade) Time: 1
			Ordered probit Number of time period modelled: 1 (1988-1992)	Sample size: 12,089 (13,989 when imputing missing values) Time: 1
			Probit Number of time period modelled: 1 (1988-1992)	Sample size: 12,089 (13,989 when imputing missing values) Time: 1
Glied (2002)[20]	United States	*Journal of Health Economics*	Probit Number of time period modelled: 1 (see description of dependent variables)	Type: longitudinal Population: youth aged 14-23 in 1979 Source: National Longitudinal Survey of Youth (1979, 1984, 1992, 1994) Sample size: 2822 in 1984; 2301 in 1992; 2295 in 1994
López Nicolás (2002)[21]	Spain	*Health Economics*	Split population duration models (probability of ever starting: probit; duration: log-logistic) Number of time period modelled: 34	Type: retrospective (1957-1990) Population: representative sample (sample restricted to individuals born after 1957) Source: Spanish National Health Survey (1993, 1995, 1997) Sample size: 14,005 (men 7092; women 6913)

Continued

Table 1 Continued

Study	Country	Journal	Methods	Data
Cawley, Markowitz, Tauras (2004)[24]	United States	*Journal of Health Economics*	Discrete-time hazard models (model: probit; duration: not reported) Models separately estimated for males and females Number of time period modelled: 3 (1997-2000)	Type: longitudinal Population: 12-16 years old in 1996 Source: National Longitudinal Survey of Youth 1997 cohort (1998, 1999, 2000) Sample size: 6255 males and 6027 females
Grignon, Pierrard (2004)[25]	France	*Journal d'Économie Médicale [in French]*	Split population duration models (probability of ever starting: not reported; duration: log-logistic) Number of time period modelled: 48	Type: retrospective (1953-2000) Population: representative sample (sample restricted to individuals aged 20-47 in 2000) Source: Enquête Santé et Protection Sociale (2000) Sample size: 9997
Kidd, Hopkins (2004)[26]	Australia	*Economic Record*	Split population duration models (probability of ever starting: probit; duration: log-logistic) Number of time period modelled: 38	Type: retrospective (1963-1990) Population: representative sample (sample restricted to individuals aged 27-37 in 1990) Source: National Health Interview Survey: Australian Health Survey (1990) Sample size: 9402 (men 4619; women 4783)
Laxminarayan, Deolalikar (2004)[27]	Vietnam	*Health Economics*	Multinomial logit Number of time period modelled: 1 (1992/93-1997/98)	Type: longitudinal Population: Source: Vietnam Living Standard Survey (1992/93, 1997/98) Sample size: 1578
Arzhenovsky (2006)[28]	Russia	*Quantile Journal [in Russian]*	Cox proportional hazards models Number of time period modelled: unclear	Type: panel 1994-2001 (1994-1996, 1998, 2000-2001) Population: representative sample (sample restricted to individuals aged 14-65) Source: Russia Longitudinal Monitoring Survey (1994, 1995, 1996, 1998, 2000 and 2001) Sample size: 4798 (men 1129; women 3669)
Cawley, Markowitz, Tauras (2006)[29]	United States	*Eastern Economic Journal*	Linear probability; IV (instrument: mother's weight). Models separately estimated for males and females Number of time period modelled: 7 (1979, 1988, 1990, 1992, 1994, 1996, 1998, 2000)	Type: longitudinal Population: children born to women aged 14-21 in 1979 Source: Children of the National Longitudinal Survey of Youth, 1979 cohort (1988, 1990, 1992, 1994, 1996, 1998, 2000) Sample size: 3755 females; 4700 males
Kim, Clark (2006)[30]	United States	*J Epidemiol Community Health*	Logit Number of time period modelled: 1 (1994/95-2001/02)	Type: longitudinal Population: representative sample of adolescents, grades 7-10 Source: Add Health, wave 1 (1994/95) and wave 3 (2001/02) (sample restricted to women younger than 18 at wave 1) Sample size: 2697
Zhang, Cohen, Ferrence, Rehm (2006)[31]	Canada	*American Journal of Preventive Medicine*	Logit Number of time period modelled: 1 (1994/95-1996/97)	Type: longitudinal Population: young adults aged 20-24 who did not smoke at baseline Source: National Population Health Survey (1994/95, 1996/97) Sample size: 636
Coppejans, Gilleskie, Sieg, Strumpf (2007)[32]	United States	*Review of Economics and Statistics*	Cox proportional hazards models Number of time period modelled: unclear	Type: longitudinal Population: Eighth graders in 1988 Source: National Education Longitudinal Study (1988, 1990, 1992) Sample size: person/years = 11,146
Grignon (2007)[33]	France	*Working paper*	Split population duration models (probability of ever starting: logit; duration: log-logistic) Number of time period modelled: not reported	Type: retrospective (years not reported) Population: unclear Source: Enquête Santé et Protection Sociale (2004) Sample size: not reported
Madden (2007)[22]	Ireland	*Applied Economics*	Split population duration models (probability of ever starting: probit; duration: log-logistic) Number of time period modelled: 39	Type: retrospective (1960-1998) Population: women aged 10-48 in 1998 Source: Saffron Survey (1998) Sample size: 703 women (sample size person/years = 11,733)

Continued

Table 1 Continued

Study	Country	Journal	Methods	Data
DeCicca, Kenkel, Mathios, Shin, Lim (2008)[34]	United States	*Health Economics*	Discrete-time hazard models (model: not reported; duration: not reported) Number of time period modelled: 4 (1988, 1990, 1992, 2000)	Type: longitudinal Population: Eighth graders in 1988 Source: National Education Longitudinal Study (1988, 1990, 1992, 2000) Sample size: person/years = 37,937
DeCicca, Kenkel, and Mathios (2008)[37]	United States	*Journal of Health Economics*	Probit Number of time period modelled:1 (1992-2000)	Type: longitudinal Population: Eighth graders in 1988 Source: National Education Longitudinal Study (1992, 2000) Sample size: 8759 Time: 1
Malhotra, Boudarbat (2009)[36]	Canada	*International Journal of Economic Perspectives*	Split population duration models (probability of ever starting: probit; duration: log-logistic) Number of time period modelled: 54	Type: retrospective (1949-2002) Population: representative sample of population aged 15 + Source: Canadian Tobacco Use Monitoring Survey (2002) Sample size: 22,396
Kenkel, Lillard, Liu (2009)[35]	China	*Health Economics*	Discrete-time hazard models (model: LPM; duration: not reported) Number of time period modelled: 49	Type: retrospective (1952-2000) Population: non-representative sample from nine provinces -Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong (sample restricted to men aged 21-60 in 2000 and person-year observations corresponding to ages <= 30) Source: China Health and Nutrition Survey (2000) Sample size: person/years = 169,386
Liu (2010)[38]	United States	*Applied Economics*	Probit; Probit-IV (instrument: state-level cigarette taxes). Number of time period modelled: 1 (started to smoke in last 12 months)	Type: retrospective Population: representative sample of population aged 15 + Source: The Tobacco Use Supplement to the Current Population Survey (TUS-CPS) (1992, 1993, 1995, 1996, 1998, 1999, 2001, 2002, 2003) Sample size: total sample size = 895,668; sample size for initiation specifications not reported
Étilé, Jones (2010)[40]	France	*Working paper*	Discrete-time hazard models (model: LPM (OLS, IV); duration: linear cohort trend, linear time trend, age dummies) Number of time period modelled: not reported	Type: retrospective Population: representative sample of population aged 15+ (EPCV), representative sample of population (ES) -sample exclude individuals who were still studying or were under 24 years-old or were 60+ years-old Source: Enque?te Permanente sur les Conditions de Vie des Me?nages (EPCV) (2001); Enque?te Sante? (ES) (1992, 2003) Sample size: not reported
Nonnemaker, Farelly (2011)[39]	United States	*Journal of Health Economics*	Discrete-time hazard models (model: logit; duration: not reported) Number of time period modelled: not reported	Type: retrospective and longitudinal Population: 12-16 years old in 1996 Source: National Longitudinal Survey of Youth 1997 cohort (1998-2006) Sample size: not reported

IV, Instrumental Variable; LPM, Linear Probability Model.

Table 2 Characteristics of included studies: dependent variables; price/tax measure and covariates

Study	Country	Dependent variable	Price/tax variable	Covariates
Douglas, Hariharan (1994)[10]	United States	Onset: Not reported Smoker: Not reported Time origin: Birth	Prices: state-level average cigarette prices (price when 18 years old and change in ln of price between 15-18 years old) Deflator: CPI all-items	Price; household income; education; 1964 Surgeon General's report; age, age squared; sex; marital status; ethnicity.
Douglas (1998)[14]	United States	Onset: reported age of "starting smoking regularly" Smoker: not defined Time origin: 11 years old	Prices: state-level average cigarette prices (average price when 15-19 years old included in probit model; past, current and future prices included in duration model) Deflator: CPI all-items	Probit: price; household income; education; age, age squared; sex; marital status; ethnicity. Duration: price; education; 1964 surgeon's general report; broadcast ban; index of state regulations; sex; marital status; ethnicity.
DeCicca, Kenkel, Mathios (2000)[15]	United States	Same as DeCicca, Kenkel, Mathios (2002)	Prices: average cigarette price per package of 20 cigarettes weighted by market share, exclusive of generic brands, inclusive of taxes (measured in November of the survey year with adjustments for timing of survey). Prices are calculated at state-level. Deflator: CPI all-items	Same as DeCicca, Kenkel, Mathios (2002)
Forster, Jones (2001; 2003)[16 23]	Britain	Onset: How old were you when you started to smoke cigarettes? Smoker: Smoked at least one cigarette per day for a minimum of 6 months Time origin: Birth (and 4 years old)	Taxes: total receipts from tobacco duty as a share of the total sales volume Deflator: All-item price index	Probit: social class; education; parental smoking; ethnicity; Duration: price; social class; education; parental smoking; ethnicity; time trend (quartic polynomial)
Hammar, Martinsson (2001)[17]	Sweden	Onset: How old were you when you started to smoke every day? Smoker: smoked every day Time origin: 9 years old	Prices: average cigarette prices Deflator: CPI all-items	Price; social class; parental smoking; tobacco control policy indicators; sex; time trend (trend, trend^2, trend^3)
Tauras, O'Malley, Johnston (2001)[18]	United States	Onset: starting to smoke in period t, given individual did not smoke in period t-1 Smoker: 1. Consumed any cigarettes in past 30 days; 2. Consumed at least 5 cigarettes in past 30 days; 3. Consumed at least 10 cigarettes in past 30 days. Only individuals who have never smoked are allowed to enter the risk pool.	Prices: weighted average of the first six months using average cigarette price (Tobacco Institute). Prices calculated at state-level. Deflator: CPI all-items at national level.	Price; seven youth access law policy indicators (at state-level); sex; age; race; living arrangement; parental education; mother's work status; religious participation; marital status; number of children; hours worked; education; income; number of observations per individual in the full sample; year; region.
DeCicca, Kenkel, Mathios (2002)[19]	United States	Onset: starting to smoke in period t, given individual did not smoke in period t-1 Smoker: How many cigarettes do you currently smoke in a day? 0, 1–5, 6–10, 11–40, and 40 or more. In 1990 and 1992 <1 cigarette a day was a possible response. This category was combined with the 1–5 category. Smoker defined as >=1 cigarette per day.	Taxes: state excise taxes Deflator: CPI all-items	Tax; sex; ethnicity; dropout; test score; region; suburb; rural; religion; age; family income; mother's education; father's education; mother's occupation; father's occupation; family size; number of siblings; family composition; indices of restrictions on public smoking and youth smoking; index of smokers' right laws; state FE
		Onset: starting to smoke between 8th and 10th grade; and 8th and 12th grade Smoker: as above	Taxes: state excise taxes (contemporaneous) Deflator: n/a	As above
		Onset: starting to smoke between 8th and 12th grade Smoker: as above	Taxes: state excise taxes (change from 1988 to 1992; levels in 1988) Deflator: n/a	As above
		Onset: starting to smoke between 8th and 12th grade Smoker: >10 cigarette per day. Users of 1-10 cigarettes a day are treated as smokers	As above	As above
Glied (2002)[20]	United States	Onset: model 1. Did not smoke by age 16 but were smoking in 1984; model 2. Did not smoke in 1984 (aged 27-35) but were smoking in 1992; model 3. Did not smoke in 1984 (aged 29-37) but were smoking in 1994. Smoker: Smoked at least 1 cigarette per day in last 30 days (1984 survey); Smoked at least 100 cigarettes in lifetime and now smoke 1 or more cigarettes per day (1992 and 1994 surveys)	Taxes: state excise taxes at age 14 Deflator: not reported	Tax; race, sex, age, marital status in year of interview, grade of school completed by year of interview, AFQT score, and whether respondent lived in an SMSA in year of interview.

Continued

Table 2 Continued

Study	Country	Dependent variable	Price/tax variable	Covariates
López Nicolás (2002)[21]	Spain	Onset: What age were you when you started smoking? Smoker: not defined Time origin: Birth	Prices: average price of black cigarettes and blond cigarettes and weighted average black/blond Deflator: CPI all-items	Probit: education; age (born pre-1967; 1967-1976; 1977+) Duration: price; education; advertising ban; time trends
Cawley, Markowitz, Tauras (2004)[24]	United States	Onset: starting to smoke in period t, given that the youth had not smoked in period t-1 Smoker: 1. transition from non-smoker to smoking any positive quantity of cigarettes; 2. transition from non-smoker to a frequent smoker, as measured by having smoked at least 15 days of the past 30 days. Light smokers (those smoking <15 days but more than 0) treated as missing.	Prices: weighted average of a pack of 20 cigarettes based on the prices of single packs, cartons, and vending machine sales where the weights are the national proportions of each type of sale. Prices are calculated at state-level and are inclusive of state level sales taxes. Deflator: not reported	Price; BMI (>85th percentile); attempted to lose weight; self-perceived under/over weight; tobacco state regulations (clean indoor air index, purchase/use/possession index; producing states); age; race; sex; education level; marital status; youth income; household size; family structure; religion; work status; depressed; obese mother; behavior problems.
Grignon, Pierrard (2004)[25]	France	Onset: For how many years have you been a smoker? For how many years had you smoked; For how many years did you quit; Smoker: not reported Time origin: birth	Prices: index of cigarette prices (price when 15 years old and price when 18 years old) Deflator: CPI all-items	Price; current income; education; sex; nationality;
Kidd, Hopkins (2004)[26]	Australia	Onset: age commenced regular smoking Smoker: one or more cigarettes per day on average Time origin: 10 years old	Prices: index of tobacco and cigarettes, by capital city (8 cities) Deflator:	Probit: education; Australian born; sex. Duration: price; education; Australian born; sex; time trend (quartic polynomial)
Laxminarayan, Deolalikar (2004)[27]	Vietnam	Onset: Individuals reporting being non-smokers in 1993: 1. Remain non-smoker; 2. Initiate cigarette smoking; 3. Initiate water pipe smoking. Smoker: not defined	Price: cigarette and waterpipe prices at commune-level. Deflator: not reported	Price: cigarette and waterpipe tobacco; in levels (1993) and changes between 1993 and 1998); total household expenditures (in levels (1993) and changes between 1993 and 1998); age, age squared; education.
Arzhenovsky (2006)[28]	Russia	Onset: When did you start smoking? How old were you then? Do you smoke now [unclear which question was used] Smoker: not defined Time origin: not reported	Prices: Self-reported, at the household-level (estimated from expenditures and quantity smoked; calculated for 'cheap' and 'expensive' brands at PSU -level); City-based prices of locally manufactured pack (Goskomstat) Deflator: CPI all-items, region-based	Price; sex; marital status; urban/rural; household size; self-reported health status; age; survey dummies;
Cawley, Markowitz, Tauras (2006)[29]	United States	Onset: starting to smoke in period t, given individual did not smoke in period t-1 Smoker: whether respondent has ever smoked a cigarette	Prices: average cigarette price (Tobacco Institute). Prices calculated at state-level. Deflator: CPI all-items at national level.	Price; regulation indices (youth use; smoke-free air; youth access); obesity indicators (BMI; weight; underweight, risk of overweight, overweight) ln of family income; grade, percentile score on PIAT reading test; year; mother's highest grade completed; mother's age; race/ethnicity; age; enrolled in school; mother's characteristics (married with her spouse present; employed; has smoked 100 cigarettes in lifetime; currently smokes)
Kim, Clark (2006)[30]	United States	Onset: respondents who reported smoking at wave 3 who were never smokers at wave 1 Smoker: smoked at least an entire cigarette at least once but not every day in the past 30 days Never smoker: never puffed a cigarette	Prices: State tax 1995 in $ Deflator: n/a	Tax; ethnicity; age; family income; parent's education; parent structure; family bonding; ease of cigarette availability at home; peer smoking; school smoking rates; state level tobacco control policies.
Zhang, Cohen, Ferrence, Rehm (2006)[31]	Canada	Onset: starting to smoke in period t, given individual did not smoke in period t-1 Smoker: daily or occasional (definition not provided)	Prices: quarterly cigarette prices at time *t* minus prices at time *t-1* in 26 major cities. Individuals not living in cities for which price data are available are assigned province average. Deflator: CPI all-items at province level	Price; age; sex; education; income; marital status; tobacco control indicators (smoke-free bylaws for restaurants, bylaw enforcement, bylaw signage, and tobacco control expenditures); province FE
Coppejans, Gilleskie, Sieg, Strumpf (2007)[32]	United States	Onset: starting to smoke in period t, given individual did not smoke in period t-1 Smoker: How many cigarettes do you currently smoke in a day? 0, 1–5, 6–10, 11–40, and 40 or more. In 1990 and 1992 <1 cigarette a day was a possible response. Smoker defined as >0 cigarette per day. Time origin: not reported	Prices: Metropolitan areas monthly price indices for tobacco and smoking products collected by the Bureau of Labor Statistics. Deflator: not reported	Price; price volatility; sex; race; age; standardized test scores; religion; dropout indicator; sibling dropout indicator; family composition; family SES; parent's education; income; employment status; guardian's age; school characteristics.

Continued

Table 2 Continued

Study	Country	Dependent variable	Price/tax variable	Covariates
Grignon (2007)[33]	France	Onset: For how many years have you been a smoker; for how many years were you a smoker; which year did you quit Smoker: not defined Time origin: Birth	Prices: index of tobacco prices Deflator: CPI all-items	Price; sex; education; SES
Madden (2007)[22]	Ireland	Onset: Current smokers: for approximately how many years have you smoked; Ex-smokers: for approximately how many years have you smoked, and what year did you stop Smoker: Not defined Time origin: 10 years old	Taxes: total tax component of retail price. Deflator: personal consumption deflator	Probit: education; cohort; health knowledge; married Duration: tax, education; cohort; health knowledge; time trend (third-order polynomial)
DeCicca, Kenkel, Mathios, Shin, Lim (2008)[34]	United States	Onset: starting to smoke in period t, given that the youth had not smoked regularly in period t-1 (smoked regularly not defined) Smoker: not reported	Prices: average cigarette price per package of 20 cigarettes weighted by market share, exclusive of generic brands, inclusive of taxes (measured in November of the survey year). Prices are calculated at state-level. Deflator: CPI all-items	Price; state FE; other covariates not reported
DeCicca, Kenkel, Mathios (2008)[37]	United States	Onset: starting to smoke between 1992 and 2000, given individual did not smoke in 1992 Smoker: How many cigarettes do you currently smoke in a day? 0, <1, 1–5, 6–10, 11–40, and 40 or more. Smoker: >1 cigarette per day (<1 included in non-smokers)	Taxes: state excise taxes in 2000 Deflator: n/a	Tax; sex; ethnicity; age; test score; region.
Malhotra, Boudarbat (2009)[36]	Canada	Onset: At what age did you smoke your first cigarette? Smoker: current smoker: currently smokes cigarettes daily or occasionally; former smoker: has smoked at least 100 cigarettes in his life, but currently does not smoke. Time origin: birth	Prices: index of cigarette prices (price when 15 years old) Deflator: CPI all-items	Probit/duration: price; age; marital status; household size; Census Metropolitan Area; speaks other than French/English at home; province FE
Kenkel, Lillard, Liu (2009)[35]	China	Onset: Not reported Smoker: Not reported Time origin: Birth	Prices: average retail price of cigarettes from 1952 to 1992 and a tobacco price index for 1993–2003. Deflator: Not reported	Price; education; age; wealth; occupation; urban-rural status, household size, province FE, time trend
Liu (2010)[38]	United States	Onset: Started to smoke in last 12 months based on current smoking status and question: Around this time 12 months ago, were you smoking cigarettes every day, some days or not at all? Smoker: Do you now smoke cigarettes every day, some days or not at all?	Prices: state-level average cigarette prices Deflator: Urban CPI all-items	Price; household income; household size; age; age squared; sex; race/ethnicity; education; marital status; survey month indicators; year FE; anti-smoking sentiment index; state FE
Étilé, Jones (2010)[40]	France	Onset: How old were you when you started to smoke daily; for how many years have you smoked; how long ago did you quit (in months or years); for how many years have you smoked? Smoker: smokes or used to smoke at least one cigarette a day Time origin: 10 years old	Prices: index of tobacco prices Deflator: not reported	Price; education, household income, region, urban/rural, membership of upper social class, loi Veil
Nonnemaker, Farelly (2011)[39]	United States	Onset: If smoker in 1997: how old were you when you smoked your first cigarette. If never smoker in 1997: starting to smoke in period t, given that the youth had not smoked in period t-1. Respondents with missing responses (n = 819), were assumed to have initiated at the midpoint of the period of missing data if the respondent entered the period of missing data as never smoking but reported smoking in the first period after the missing data. Smoker: not reported	Prices: state-level average cigarette prices Taxes: state-level cigarette taxes (including federal, state, and New York city and Cook County, Illinois local taxes) Deflator: not reported	Price or tax; age; state-level smoking prevalence in 1997; household size; parents' education in 1997; living with both biological parents in 1997; Master Settlement Agreement; perceived smoking prevalence in 1997; region FE.

BMI, body mass index; CPI, consumer price index; FE, fixed effects; n/a, not applicable; SES, socioeconomic status.

Table 3 Characteristics of included studies: testing for misspecification, sensitivity analyses, results, and acknowledgement of sources of support

Study	Country	Testing for misspecification	Sensitivity analyses	Results	Sources of support clearly acknowledged
Douglas, Hariharan (1994)[10]	United States	Graphical assessments (predicted hazard function vs. nonparametric hazard functions).	Split-population duration models (probability of ever starting: probit; duration: lognormal); Log-logistic duration models.	Small effect sizes and not statistically significant.	No
Douglas (1998)[14]	United States	None reported.	Reports results with and without index of state regulations.	Small effect sizes and not statistically significant. When past prices are excluded, future prices are found to have a statistically significant effect (results not reported).	No
DeCicca, Kenkel, Mathios (2000)[15]	United States	None reported.	Models with/without state FE are compared; results are presented for the white, Hispanic and african-american sub-samples, but not for the full sample.	Prices not statistically significant for white and african-american samples but significant for Hispanic sub-sample.	Yes
Forster, Jones (2001; 2003)[16 23]	Britain	Graphical assessments (predicted survivor functions vs. KM survivor functions; Cox-Snell residuals); comparison of predicted proportions of starters vs. actual proportion of starters; LR tests to discriminate between pooled and sex-specific models.	Log-logistic duration models on subsamples of smokers.	Small effect sizes and not statistically significant.	No
Hammar, Martinsson (2001)[17]	Sweden	Ramsey's regression error specification test (RESET); AIC to discriminate between six specifications (lognormal, loglogistic, generalized gamma with and without heterogeneity).	Reports results for lognormal duration models with/without indicators of tobacco con policies and with/without price change last year and price chance next year.	Large wrongly signed effect sizes and not statistically significant.	Yes
Tauras, O'Malley, Johnston (2001)[18]	United States	None reported.	Ten models with and without state fixed effects with different covariates are estimated. Models in which clustering is based on zip codes are also estimated (results not reported).	Large effect sizes and statistically significant. Results robust to alternative specifications.	Yes
DeCicca, Kenkel, Mathios (2002)[19]	United States	None reported.	Models with/without state FE and with/without interactions between tax and survey year are compared; models with prices instead of taxes are examined but results not reported.	Taxes statistically significant without FE but not statistically significant with FE.	Yes
		None reported.	Models with prices instead of taxes are examined (results not reported).	Onset between 8th and 10th grade: Large effect sizes and statistically significant; Onset between 8th and 12h grade: Large effect sizes and not statistically significant.	
		None reported.	Models with and without mean imputation are examined; Models with prices instead of taxes are examined (results not reported).	Large effect sizes and not statistically significant.	
		None reported.	Models with and without mean imputation are examined; Models with prices instead of taxes are examined (results not reported).	Small, wrongly signed effect sizes and not statistically significant.	
Glied (2002)[20]	United States	None reported.	Report results of specifications that include current taxes and two lags of current taxes. Models estimated on sub-samples of respondents: 1. whose family income in 1979 was below the sample median; 2. by sex.	Model 1: Large effect sizes and statistically significant. Model 2, 3: large positive effect sizes but not statistically significant.	No
López Nicolás (2002)[21]	Spain	Graphical assessments (predicted survivor functions vs. KM survivor functions; Cox-Snell residuals); LR tests to discriminate between pooled and sex-specific models.	Non-split log-logistic duration models.	Statistically significant but small effect size for both men and women.	Yes
Cawley, Markowitz, Tauras (2004)[24]	United States	None reported.	Models with alternative measures of onset are compared.	Large and statistically significant effect size for males only. Results robust to alternative specifications.	Yes
Grignon, Pierrard (2004)[25]	France	LR tests to discriminate between log-logistic and Weibull distribution.	None reported.	Price when 15 not statistically significant; Price when 18 statistically significant.	No

Continued

Table 3 Continued

Study	Country	Testing for misspecification	Sensitivity analyses	Results	Sources of support clearly acknowledged
Kidd, Hopkins (2004)[26]	Australia	Graphical assessments (predicted survivor functions vs. KM survivor functions); LR tests to discriminate between split and non-split models and between pooled and sex-specific models.	Models are re-estimated using alternative age groups and alternative dataset; Log-logistic duration models on subsamples of smokers.	Large effect size for both men and women (elasticity = 0.162 and 0.122) and statistically significant. Results not robust to alternative specifications.	Yes
Laxminarayan, Deolalikar (2004)[27]	Vietnam	None reported.	None reported.	Changes in the price of cigarettes (but not waterpipe tobacco) are significantly and negatively associated with smoking onset.	No
Arzhenovsky (2006)[28]	Russia	Graphical assessments (Cox-Snell residuals); comparison of predicted proportions of starters vs. actual proportion of starters; Schoenfeld residuals tests;	Models are re-estimated using alternative age groups and alternative price measure.	Price of 'cheap' brands: Statistically significant effect. Price of 'expensive' brands: Statistically significant effect (wrongly signed).	Yes
Cawley, Markowitz, Tauras (2006)[29]	United States	None reported.	Models estimated using: 1. three separate indicators of obesity; 2. probit instead of linear probability; 3. IV in which the weight of a sibling is used as the instrument; 4. IV in which the in which the endogenous variable is an indicator for whether the respondent was clinically underweight (instead of overweight).	Large and statistically significant effect size for males only. Results robust to alternative specifications.	Yes
Kim and Clark (2006)[30]	United States	None reported.	Results presented for low, middle, and high SES.	Fairly large effect sizes for low and high SES but not statistically significant.	Yes
Zhang, Cohen, Ferrence, Rehm (2006)[31]	Canada	None reported.	Models estimated on sub-samples of respondents with primary policy data, of respondents not living within 40 km of border to province with lower prices (<$5 per carton), and of respondents who remained in same province.	Large effect sizes and statistically significant.	Yes
Coppejans, Gilleskie, Sieg, Strumpf (2007)[32]	United States	None reported.	Models are re-estimated using alternative measures of price volatility.	Price levels and price volatility statistically significantly associated with the hazard of starting.	Yes
Grignon (2007)[33]	France	None reported.	Models are re-estimated with correction for recall errors (heaped values) using dummy variables; Models separately estimated for individuals who report different time preference.	Large effect size and statistically significant.	No
Madden (2007)[22]	Ireland	Graphical assessments (Cox-Snell residuals).	Models are re-estimated using alternative specifications: 1. split-population loglogistic-probit models with interaction between tax and education; 2. Non-split loglogistic duration models (with and without frailty).	Small effect sizes and not statistically significant. Limited evidence that education modifies the effect of taxes on smoking onset.	No
DeCicca, Kenkel, Mathios, Shin, Lim (2008)[34]	United States	None reported.	Models with and without state FE are compared.	Prices statistically significant without FE but not statistically significant with FE	No
DeCicca, Kenkel, Mathios (2008)[37]	United States	None reported.	Models estimated on sub-samples of individuals who lived in the same state in 1992 and 2000 (stayers), of individuals who lived in different states 1992 and 2000 (movers).	Large effect size and statistically significant. When movers are excluded, effect size is large and statistically significant.	No
Malhotra, Boudarbat (2009)[36]	Canada	Graphical assessments (predicted hazard function vs. nonparametric hazard functions).	None reported.	Price when 15 statistically significantly associated with participation but not duration.	No
Kenkel, Lillard, Liu (2009)[35]	China	None reported.	Models estimated using alternative time trends (results not reported).	Small effect sizes and not statistically significant. Results sensitive to alternative specifications.	Yes

Continued

Table 3 Continued

Study	Country	Testing for misspecification	Sensitivity analyses	Results	Sources of support clearly acknowledged
Liu (2010)[38]	United States	None reported.	Models estimated using alternative specifications: by age (15-24; 25-44) for baseline; state FE; antismoking sentiment index.	Age 15-24: large effect sizes; only statistically significant in baseline specification. Age 25-44: not statistically significant; small effect size or wrongly signed.	No
Étilé, Jones (2010)[40]	France	Two specification tests to assess the robustness of the IV procedure.	Several alternative models estimated.	Large and statistically significant effect size for women only. Results robust to alternative specifications.	Yes
Nonnemaker, Farelly (2011)[39]	United States	None reported.	Alternative models estimated with additional covariates: time variant measure of state-level prevalence; antismoking sentiment index; state FE; state-level.	Taxes: statistical significance and effect sizes vary across specifications; effect sizes largest for black youth Prices: generally statistically significant and moderately large; effect sizes generally largest for black youth.	Yes

AIC, Akaike information criterion; FE, fixed effects; IV, instrumental variables; KM, Kaplan–Meier; LR, likelihood ratio; SES, socioeconomic status.

the issue of duration is incorporated into discrete time model is seldom discussed. This can be important, as ignoring time dependency in the baseline hazard produces a model that is more or less equivalent to an exponential model (ie, the hazard probability is flat with respect to time).[43] Another example is the failure to examine the parallel regression assumption that is implicit in ordinal regression models. The parallel regression assumption requires that the separate equations for each category differ only in their intercepts (ie, the slopes are assumed to be the same when going from each category to the next).[44]

Tauras *et al*[18] and Cawley *et al*[24] submitted that there is not enough variation in cigarette prices within the USA to employ fixed effects (FE). Including FE disallows any of the average unit-to-unit variations in regressors from being used to estimate the parameters of the model. In the USA's case, it amounts to examining only if intra-state changes in smoking onset are associated with intra-state changes in prices. In addition, variables that change slowly will tend to have relatively large SEs. Using ordinary least squares, Cawley *et al*[24] regressed cigarette prices on state and time FE, and found a coefficient of determination of 0.99. This can be of consequence. For example, the main result of DeCicca *et al*[19] (that taxes are not associated with smoking onset) is dependent on the inclusion of state FE.

Forster and Jones[16 23] estimated pooled models and models split by gender, and discriminated between them by using likelihood ratio tests. Their results suggested that models should be analysed separately for men and women. Of interest are the results of Kidd and Hopkins,[26] and Cawley *et al*.[24] Both found that the effects of prices on smoking onset are substantially different across genders. Several studies included price as time-invariant covariates when using duration models. For example, Douglas and Hariharan[10] included measures of prices when the respondents were 18 years old and the change in price between the ages of 15 and 18 years, Grignon and Pierrard[25] included prices when the respondents were 14 and 18 years old, Malhotra and Boudarbat[36] included prices when the respondents were 15 years old, and Glied[20] explored the effect of taxes when the respondents were 14 years old on 'late' initiation (defined as initiation that occurred after the age of 16 years). Treating price as a time-variant variable is conceptually more intuitive, as the decision whether or not to start smoking is an ongoing decision, made on the basis of current information.[14] Several studies[10 24 28 32 39] that use duration analysis techniques include a measure of age as an explanatory variable in the duration component of the model. This can be problematic, as age is, by construction, related to age of initiation.[iii]

Additional limitations include possible correlations between taxes and tobacco control measures or antismoking sentiment[iv] and, for studies that use longitudinal data, the minimal number of panels available.

Synthesis of results

Despite the relatively large number of studies identified, the considerable heterogeneity in their methodological approaches

[iii]Co-linearity between age and elapsed time at risk (ie, duration) makes it difficult to identify their separate effects.

[iv]DeCicca *et al*[19] argued that if taxes are correlated with tobacco control measures such as advertising bans and smoke-free policies, or antismoking sentiment, estimates of the price or tax responsiveness will be inaccurate. This issue is mostly relevant to studies conducted in federated states such as the USA, Canada and India, where taxes and tobacco control measures may differ substantially across states or provinces.

and the limitations described above greatly limit the ability to make conclusive statements about the impact of tobacco prices on smoking onset. Additionally, several studies use the same data, so the number of independent estimates is substantially smaller than the number of studies. If one considers studies that use a split population duration approach with retrospective data and treat price as a time-variant[v] covariate, the evidence is fairly limited. Douglas and Hariharan[10] (using data from the USA, 1954–1987), Forster and Jones[16 23] (using data from Great Britain, 1920–1984) and Madden[22] (using data from a survey of Irish women, 1960–1998) found small effect sizes that were not statistically significant; López Nicolás[21] (using Spanish data, 1957–1990), and Kidd and Hopkins[26] (using data from Australia, 1963–1990) found statistically significant but relatively small effect sizes: a 10% increase in prices would delay starting by about 1–1.5 months. Grignon,[33] using retrospective data from France, found statistically significant and moderately large effect sizes: a 10% increase in prices would delay starting by about 3–6 months, depending on the specifications.[vi]

Studies that use a binary approach (eg, probit, logit or linear probability models) provide mixed evidence. DeCicca *et al*,[19 37] using longitudinal data from the USA, found large and statistically significant effect sizes for some specifications; for other specifications, small and not statistically significant effect sizes were found. Zhang *et al*,[31] using longitudinal Canadian data, found large and statistically significant effect sizes (the elasticity of initiation with respect to cigarette prices was −3.36), while Cawley *et al*,[29] using USA longitudinal data, found large and statistically significant effect sizes, but for boys only (the elasticity of initiation with respect to cigarette prices was −1.2). Liu,[38] using retrospective data from nine large repeated-cross-sectional surveys conducted between 1992 and 2003 in the USA, found large and statistically significant effect sizes for some specifications, and small, wrongly signed and not statistically significant effect sizes for other specifications.

As mentioned earlier, only one study used data from a low-income country. Laxminarayan and Deolalikar,[27] using longitudinal data from Vietnam, examined the association between the odds of initiating cigarette smoking and waterpipe tobacco smoking between 1992/1993 and 1997/1998 and changes in the prices of the two tobacco products. They found that changes in the price of cigarettes are significantly and negatively associated with the decision to initiate cigarette smoking (the elasticity of cigarette smoking initiation with respect to cigarette prices was −1.18). With respect to the impact of waterpipe tobacco prices on waterpipe smoking initiation, they found large effect sizes (the elasticity of waterpipe smoking initiation with respect to waterpipe tobacco prices was −1.56) that were, however, not statistically significant. An important limitation of Laxminarayan and Deolalikar's study is that the cigarette price data for 1992/1993 and 1997/1998 are not comparable, as they are for different brands that are not in the same price category. Additionally, waterpipe tobacco prices were not measured in 1997/1998 and had to be imputed.

Studies that use discrete time hazard models generally provide evidence that prices have a statistically significant impact on smoking onset. These findings, however, should be interpreted with caution, as only one study[40] discusses how duration is incorporated. As stressed earlier, ignoring time dependency in the baseline hazard produces a model that is more or less equivalent to an exponential model.[43] Moreover, all studies assume that each individual will eventually fail (ie, start smoking). DeCicca *et al*,[19 34] using longitudinal data from the USA (1988, 1990, 1992, 2000), found, on the whole, large and statistically significant effect sizes for some specifications and small and not statistically significant effect sizes for other specifications. More specifically, DeCicca *et al*[15] found ethnicity differences: they found that prices have a statistically significant impact on smoking onset for Hispanic people but not for those of white and African-American ethnicity. Tauras *et al*,[18] using longitudinal data from the USA (1991–1999),[vii] found statistically significant and large effect sizes that were robust to alternative specifications. Cawley *et al*,[24] using longitudinal data from the USA (1997–2000), found statistically significant and large effect sizes that were robust to alternative specifications, but for men and boys only. Kim and Clark,[30] using longitudinal data from the USA (1994/1995 and 2001/2002), found some fairly large effect sizes for some specifications that were, however, not statistically significant. Etilé and Jones,[40] using retrospective data from France, found large and statistically significant effect size for women only. Kenkel *et al*,[35] using retrospective data from China, found small effect sizes that were not statistically significant. These results, however, were sensitive to alternative specifications. Nonnemaker and Farrelly,[39] using retrospective and longitudinal data from the USA, found that taxes and prices were generally statistically significant and had a moderately large impact, with effect sizes being largest for African-American youth.

Lastly, studies that use more traditional duration models generally provide evidence that prices have a statistically significant impact on smoking onset. Coppejans *et al*,[32] using longitudinal USA data (1988, 1990 and 1992) and Cox proportional hazards models, found that cigarette price levels and price volatility were statistically significantly associated with the hazard of starting smoking. Hammar and Martinsson,[17] using Swedish retrospective data (1945–2000) and log-logistic and gamma duration models on a subsample of smokers, found large but wrongly signed effect sizes that were not statistically significant. Arzhenovsky,[28] using longitudinal data from Russia and Cox proportional hazards models, found that the price of 'cheap' brands, but not the price of 'expensive' brands, was statistically significantly associated with the hazard of starting smoking.

A number of studies that did not meet the inclusion criteria merit discussion. Hamilton *et al*[46] assessed the effect of the tobacco tax cuts made in 1994 on the smoking habits of Canadians by comparing short-term trends between provinces where taxes were cut and provinces where taxes were not cut. Hamilton *et al* observed that the rates of starting cigarette smoking were higher in the provinces where taxes had been cut than in those where taxes had not been cut. Auld,[47] using cross-sectional and retrospective data from a Canadian youth survey conducted in 1994 and endogenously switching binary response regressions, examined the impact of cigarette prices on 'early

[v]A number of studies used a split population duration approach with retrospective data but included a time invariant measure of price. These studies are described in all three tables.

[vi]Grignon's working paper[33] was subsequently published in the *Journal of Socio-Economics*.[44] The price elasticity of smoking onset estimates, however, do not appear in the journal version. Hence the findings discussed refer to Grignon's working paper.

[vii]Eight and 10 graders in 1991, 1992 and 1993 with follow-up surveys at 2-year intervals until 1999.

initiation' (if a respondent had smoked at least one whole cigarette for 7 consecutive days and was 14 years old or younger when he/she first began to do so) and 'late initiation' (if a respondent aged 15–19 years (in 1994) reported having smoked on at least 21 days in the last month). Auld found that prices had a statistically significant impact on early initiation but no impact on late initiation. Farrelly *et al*[48] evaluated the effectiveness of the National Truth Campaign, a prominent USA national youth smoking prevention campaign. Using a longitudinal survey of adolescents aged 12–17 years who were interviewed annually from 1997 to 2004 and a discrete time hazard model, Farrelly *et al* examined whether variable levels of exposure to antismoking messages over time and across 210 media markets affected smoking initiation. The authors included a time-varying measure of price at state level in their model but did not report its impact. Sen and Wirjanto,[49] using a small subsample from a longitudinal survey conducted in South-Western Ontario, Canada, in the early 1990s, found that changes in taxes had fairly large impacts on the initiation and persistence of youth smoking. This study was excluded because it is not possible to disentangle the impact of tax changes on initiation and persistence. Finally, a number of studies examined the impact of price on smoking transitions, uptake or escalation and generally concluded that prices can prevent transitions to higher thresholds of smoking uptake.[42 50–53]

DISCUSSION

The review points to a number of lessons. First, the extent of the evidence base has been and still is unappreciated (eg, Cawley *et al*[29] and Sen and Wirjanto[49]). Second, the distinction between smoking initiation/onset (ie, the transition from never smoking to smoking) and smoking participation or smoking uptake is sometimes blurry. Studies that do not examine smoking onset are, at times, cited as evidence that prices have a significant impact on smoking onset (eg, Zhang *et al*[31] and Rice *et al*[7]). Third, the interpretation of a study's results may differ between the authors' own interpretations and the interpretations of the reader (as they may differ between readers). For example, on the one hand, one reader might find that the body of work of DeCicca *et al*[15 19 34 37] provides evidence that prices do not affect smoking onset. On the other hand, if one dismisses the FE specifications, the same body of work can provide evidence that prices do, in fact, impact smoking onset. The interpretation of effect sizes can be even cloudier. A particular concern is the frequent comparison of the elasticities obtained from duration models that are often not comparable across studies, as different 'time origins' are used. For example, Forster and Jones,[16] and López Nicolás[21] assumed that individuals are first exposed to the risk of starting at the age of 0 years; Etilé and Jones,[40] Kidd and Hopkins,[26] and Madden[22] at the age of 10 years; and Douglas[14] at the age of 11 years.

Based on the current review, the evidence is not sufficient to conclude that prices (or taxes) affect smoking onset. It is important to note that this review does not conclude that there is evidence of no effect. Rather, this review concludes that the evidence is too limited to make any conclusive statements about the impact of tobacco prices or taxes on smoking onset. Similarly, this review does not challenge the overwhelming evidence that prices and taxes reduce overall tobacco use and, more specifically, tobacco use among youth.

The conclusion of the current review is at odds with the conclusions of previous reviews. Rice *et al*[7] concluded that '[o]verall, the evidence suggests that price is effective in deterring young people from starting to smoke'. (p. viii). The very low number of studies included in the Rice *et al* review probably explains the conflicting conclusions.[viii] Chaloupka *et al*,[54] writing on behalf of the International Agency for Research on Cancer (IARC) *Handbook Volume 14* Working Group, concluded that there is sufficient[ix] evidence to conclude that '[i]ncreases in tobacco excise taxes that increase prices reduce the initiation and uptake of tobacco use among young people, with a greater impact on the transition to regular use'. Explaining the conflicting conclusions of this review and that of IARC is more arduous. This review's emphasis on methodological approaches and the differing search strategies and inclusion criteria (the IARC study evaluated 17 studies, including two[49 55] which are excluded from this review) may, at least partially, explain the conflicting conclusions. IARC's approach, which emphasises the role of expert opinion, may also explain the conflicting conclusions. Research has highlighted the limitations of expert opinion. For example, there is evidence that experts tend to use non-systematic methods when they review research.[56]

This review has several limitations. First, although the search strategy was systematic, the review process was not. Screening for relevance, assessment for inclusion, data extraction and interpretation were conducted by a single reviewer. It is better methodology that at least two independent reviewers conduct such tasks.[12 13] Second, a priori methods of assessment were not used because of the lack of quality assessment tools and the heterogeneity in the methods utilised.[12 13] Readers are urged to refer to original studies and not to rely uncritically on the descriptive information of the individual studies provided in this review. Third, a number of the studies reviewed failed to provide important methodological information, which rendered quality assessment difficult. As discussed earlier, most studies that used discrete time hazard models failed to discuss how the issue of duration was incorporated into their models. One study even failed to report how discrete time hazard models were estimated (eg, probit, logit, complementary log-log, etc).[34]

This review highlights a number of data and methodological limitations in existing studies that examined the impact of prices or taxes on smoking onset, and concludes that limitations are pervasive and serious enough that considerable caution is needed when interpreting results. Consequently, future research of higher methodological quality is warranted. The dearth of studies conducted using data from low-income and middle-income countries is an additional concern. The generalisability of studies conducted in high-income economies to low-income and middle-income settings, notably to countries with dramatically different patterns of tobacco use and tobacco control environments, is fairly limited. The contributions of additional studies that use similar USA data and similarly weak methodologies pale in comparison to the potential of methodologically rigorous studies conducted in low-income and middle-income settings.

[viii]Only seven studies are included in the Rice *et al* review,[7] including one study that does not examine smoking onset.

[ix]IARC evaluates the strength of the evidence using four categories: inadequate/no evidence, limited evidence, strong evidence and sufficient evidence. 'Sufficient evidence: an association has been observed between the intervention under consideration and a given effect in studies in which chance, bias and confounding can be ruled out with reasonable confidence. The association is highly likely to be causal'.[54]

What this paper adds

- Existing reviews clearly demonstrate that increasing the prices of tobacco products reduces smoking prevalence and cigarette consumption.
- Only a small number of studies included in existing reviews have examined smoking onset (the transition between never smoking and smoking); moreover, existing reviews provide limited quality assessment of the data and methods used.
- This review identifies a substantially larger number of studies than those reviewed in any other single study or review, assesses their data and methods and, on the whole, finds that the evidence is not sufficient to conclude that prices (or taxes) affect smoking onset.

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REFERENCES

1 Cameron S. Estimation of the demand for cigarettes: a review of the literature. *Econ Issues* 1998;3:351–72.
2 Chaloupka FJ, Hu T-W, Warner KE, *et al*. The taxation of tobacco products. In: Jha P, Chaloupka FJ.eds. *Tobacco control policies in developing countries*. New York: Oxford University Press, 2000:237–72.
3 Chaloupka FJ, Warner KE. The economics of smoking. In: Culyer AJ, Newhouse JP. eds. *Handbook of health economics*. Amsterdam: Elsevier Science, North-Holland, 2000:1539–627.
4 Gallet CA, List JA. Cigarette demand: a meta-analysis of elasticities. *Health Econ* 2003;12:821–35.
5 Guindon GE, Perucic A-M, Boisclair D. *Higher tobacco prices and Taxes in South-East Asia: an effective tool to reduce tobacco use, save lives and increase government revenue*. HNP Discussion Paper. Economics of Tobacco Control Paper No. 11. Washington: The World Bank, 2003.
6 Laporte A. Price responsiveness of demand for cigarettes: does rationality matter? *Subst Use Misuse* 2006;41:511–31.
7 Rice N, Godfrey C, Slack R, *et al*. *A systematic review of the effects of price on the smoking behaviour of young people*. York: Public Health Research Consortium, 2010.
8 International Agency for Research on Cancer. *IARC handbooks of cancer prevention: tobacco control. Volume 14. Effectiveness of price and tax policies for control of tobacco*. Lyon: International Agency for Research on Cancer, 2011.
9 Hatsukami DK, Stead LF, Gupta PC. Tobacco addiction. *Lancet* 2008;371:2027–38.
10 Douglas S, Hariharan G. The hazard of starting smoking: estimates from a split population duration model. *J Health Econ* 1994;13:213–30.
11 Beaglehole R, Yach D. Globalisation and the prevention and control of non-communicable disease: the neglected chronic diseases of adults. *Lancet* 2003;362:903–8.
12 Shea BJ, Bouter LM, Peterson J, *et al*. External validation of a measurement tool to assess systematic reviews (AMSTAR). *PLoS One* 2007;2:e1350.
13 Shea BJ, Grimshaw JM, Wells GA, *et al*. Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. *BMC Med Res Methodol* 2007;7:10 http://www.biomedcentral.com/1471-2288/7/10 (accessed 3 Dec 2012)..
14 Douglas S. The duration of the smoking habit. *Econ Inq* 1998;36:49–64.
15 DeCicca P, Kenkel D, Mathios A. Racial difference in the determinants of smoking onset. *J Risk Uncertainty* 2000;21:311–40.
16 Forster M, Jones AM. The role of tobacco taxes in starting and quitting smoking: duration analysis of British data. *J R Statist Soc A* 2001;164:517–47.
17 Hammar H, Martinsson P. *The effect of cigarette prices and antismoking policies on the age of smoking initiation*. Working papers in Economics no 62. Göteborg: Department of Economics, Göteborg University, 2001.
18 Tauras JA, O'Malley PM, Johnston LD. *Effects of price and access laws on teenage smoking initiation: a national longitudinal analysis*. Cambridge, MA: National Bureau of Economic Research, NBER Working paper no. 8331, 2001.
19 DeCicca P, Kenkel D, Mathios A. Putting out the fires: will higher taxes reduce the onset of youth smoking? *J Polit Econ* 2002;110:144–69.
20 Glied S. Youth tobacco control: reconciling theory and empirical evidence. *J Health Econ* 2002;21:117–35.
21 López Nicolás Á. How important are tobacco prices in the propensity to start and quit smoking? An analysis of smoking histories from the Spanish National Health Survey. *Health Econ* 2002;11:521–35.
22 Madden D. Tobacco taxes and starting and quitting smoking: does the effect differ by education? *Appl Econ* 2007;39:613–27.
23 Forster M, Jones AM. Corrigendum: the role of tobacco taxes in starting and quitting smoking: duration analysis of British data. *J R Statist Soc A* 2003;166:441–42.
24 Cawley J, Markowitz S, Tauras JA. Lighting up and slimming down: the effects of body weight and cigarette prices on adolescent smoking initiation. *J Health Econ* 2004;23:293–311.
25 Grignon M, Pierrard B. [The impact of price on young people's smoking behavior]. *Journal d'Économie Médicale* 2004;22:119–30. French.
26 Kidd MP, Hopkins S. The hazards of starting and quitting smoking: some Australian evidence. *Econ Record* 2004;80:177–92.
27 Laxminarayan R, Deolalikar A. Tobacco initiation, cessation, and change: evidence from Vietnam. *Health Econ* 2004;13:1191–201.
28 Arzhenovskiy S. [Socioeconomic determinants of smoking in Russia]. *Quantile* 2006;1:81–100. Russian
29 Cawley J, Markowitz S, Tauras JA. Obesity, cigarette prices, youth access laws, and adolescent smoking initiation. *East Econ J* 2006;32:149–70.
30 Kim H, Clark PI. Cigarette smoking transition in females of low socioeconomic status: impact of state, school, and individual factors. *J Epidemiol Community Health* 2006;60(Suppl 2):13–19.
31 Zhang B, Cohen J, Ferrence R, *et al*. . The impact of tobacco tax cuts on smoking initiation among Canadian young adults. *Am J Prev Med* 2006;30:474–9.
32 Coppejans M, Gilleskie D, Sieg H, *et al*. Consumer demand under price uncertainty: empirical evidence from the market for cigarettes. *Rev Econ Stat* 2007;89:510–21.
33 Grignon M. *Using cigarette taxes when smokers are heterogeneous: evidence on hyperbolic preferences, endogenous preferences, smoking, and price elasticity of smoking in France*. Centre for Health Economics and Policy Analysis working paper series 07–10. Hamilton: CHEPA, McMaster University, 2007.
34 DeCicca P, Kenkel D, Mathios A, *et al*. Youth smoking, cigarette prices, and anti-smoking sentiment. *Health Econ* 2008;17:733–49.
35 Kenkel D, Lillard DR, Liu F. An analysis of life-course smoking behavior in China. *Health Econ* 2009;18(Suppl 2):S147–56.
36 Malhotra N, Boudarbat B. The hazard of starting the smoking habit among the Canadian population. *Int J Econ Perspect* 2009;3:93–106.
37 DeCicca P, Kenkel D, Mathios A. Cigarette taxes and the transition from youth to adult smoking: smoking initiation, cessation, and participation. *J Health Econ* 2008;27:904–17.
38 Liu F. Cutting through the smoke: separating the effect of price on smoking initiation, relapse and cessation. *Appl Econ* 2010;42:2921–39.
39 Nonnemaker JM, Farrelly MC. Smoking initiation among youth: the role of cigarette excise taxes and prices by race/ethnicity and gender. *J Health Econ* 2011;30:560–7.
40 Etilé F, Jones AM. *Schooling and smoking among the baby boomers and evaluation of the impact of educational expansion in France*. Health, Economics and Data Group working paper 10/02. York: Health, Econometrics and Data Group, Department of Economics, University of York, 2010.
41 Tauras JA, Chaloupka FJ. *Determinants of smoking cessation: an analysis of young adult men and women*. NBER working paper no. 7262. Cambridge: National Bureau of Economic Research, 1999.
42 Emery S, White MM, Pierce JP. Does cigarette price influence adolescent experimentation? *J Health Econ* 2001;20:261–70.
43 Box-Steffensmeier JM, Jones BS. *Event history modeling: a guide for social scientists*. Cambridge: Cambridge University Press, 2004.
44 Long JS. *Regression models for categorical and limited dependent variables*. Thousand Oaks; London: Sage, 1997.
45 Grignon M. An empirical investigation of heterogeneity in time preferences and smoking behaviors. *J Socio-Economics* 2009;38:739–51.
46 Hamilton VH, Levinton C, St-Pierre Y, *et al*. The effect of tobacco tax cuts on cigarette smoking in Canada. *CMAJ* 1997;156:187–91.
47 Auld MC. Causal effect of early initiation on adolescent smoking patterns. *Can J Econ/Revue Canadienne d'Economique* 2005;38:709–34.
48 Farrelly MC, Nonnemaker J, Davis KC, *et al*. The influence of the national truth campaign on smoking initiation. *Am J Prev Med* 2009;36:379–84.

49 Sen A, Wirjanto T. Estimating the impacts of cigarette taxes on youth smoking participation, initiation, and persistence: empirical evidence from Canada. *Health Econ* 2010;19:1264–80.
50 Liang L, Chaloupka FJ. Differential effects of cigarette price on youth smoking intensity. *Nicotine Tob Res* 2002;4:109–14.
51 Ross H, Chaloupka FJ, Wakefield M. Youth smoking uptake progress: price and public policy effects. *East Econ J* 2006;32:355–67.
52 Slater SJ, Chaloupka FJ, Wakefield M, *et al*. The impact of retail cigarette marketing practices on youth smoking uptake. *Arch Pediatr Adolesc Med* 2007;161:440–5.
53 Tauras JA. Can public policy deter smoking escalation among young adults? *J Policy Anal Manage* 2005;24:771–84.
54 Chaloupka FJ, Straif K, Leon ME. Effectiveness of tax and price policies in tobacco control. *Tob Control* 2011;20:235–38.
55 Peretti-Watel P. Pricing policy and some other predictors of smoking behaviours: an analysis of French retrospective data. *Int J Drug Policy* 2005;16:19–26.
56 Oxman AD, Lavis JN, Fretheim A. Use of evidence in WHO recommendations. *Lancet* 2007;369:1883–9.
57 Kennedy P. *A guide to econometrics*. 5th edn. Cambridge: MIT Press, 2003
58 Allison PD. Discrete-time methods for the analysis of event histories. *Sociological Methodol* 1982;13:61–98.
59 Singer JD, Willett JB. It's about time: using discrete-time survival analysis to study duration and the timing of events. *J Educ Stat* 1993;18:155–95.
60 Schmidt P, Witte AD. Predicting criminal recidivism using 'split population' survival time models. *J Econometrics* 1989;40:141–59.
61 Cox DR. Regression models and life-tables. *J Royal Stat Soc Series B (Methodological)* 1972;34:187–220.
62 Jones AM. Health econometrics. In: Culyer AJ, Newhouse JP.eds. *Handbook of health economics*. Amsterdam: Elsevier Science, North-Holland, 2000:265–344.
63 Jones AM. *Applied econometrics for health economists: a practical guide*. 2nd edn. Oxford: Radcliffe, 2007.
64 Jenkins SP. Easy estimation methods for discrete-time duration models. *Oxf Bull Econ Stat* 1995;57:129–38.
65 Zorn CJW. Modeling duration dependence. *Political Anal* 2000;8:367–80.
66 Beck N, Katz JN, Tucker R. Taking time seriously: time-series–cross-section analysis with a binary dependent variable. *Am J Political Sci* 1998;42:1260–88.
67 Hurley JE. *Health economics*. 1st edn. Toronto: McGraw-Hill Ryerson, 2010.
68 Gelman A. Analysis of variance—why it is more important than ever. *Ann Stat* 2005;33:1–31.
69 Beck N, Katz JN. Throwing out the baby with the bath water: a comment on Green, Kim, and Yoon. *Int Organ* 2001;55:487–95.
70 Grotpeter JK. Respondent recall. In: Menard SW.ed. *Handbook of longitudinal research: design, measurement, and analysis*. 1st edn. Burlington, MA: Elsevier, 2008:109–21.
71 Eurostat. Eurostat's concepts and definitions database. Secondary Eurostat's concepts and definitions database 2012. http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL_GLOSSARY&StrNom=CODED2&StrLanguageCode=EN (accessed 26 Oct 2012).

APPENDIX
GLOSSARY OF TECHNICAL TERMS

Duration analysis: analysis in which the dependent variable measures the duration of time that units spend in a state before experiencing some event.[43] Duration analysis is also known as survival analysis, event history analysis, failure-time analysis and reliability analysis.[43 57]

Continuous-time duration analysis: duration analysis in which time is measured as a continuous variable (ie, it can take on any non-negative value)[58]; the exact time of duration is known or assumed to be known.[57 59]

Discrete time duration analysis: duration analysis in which time is not measured as a continuous variable; rather, time is divided into discrete units.[58 59]

Split population duration model: duration model in which the probability of eventual failure is less than one (ie, the duration model does not assume that all units will eventually fail); also known as a split population survival time model, mixture model or cure model.[16 60]

Cox proportional hazard model: duration model in which the baseline hazard is left unspecified, treated as an unknown function of time; the most commonly used duration model.[61–63] The *baseline hazard function,* which depends on time (but not on covariates), summarises the pattern of duration dependence, assumed to be common to all units.[64]

Duration (or time) dependency: the extent to which the conditional hazards of the events of interest rise or fall over time.[65] The *hazard rate* is, roughly, an indication of how likely failure is to occur at any given time, provided the unit has survived until that time.[66]

Duration independence: a hazard rate that is time invariant (ie, the risk of failure does not depend on how long a unit has survived).[66]

Duration dependence: a hazard rate that is time variant (ie, the risk of failure varies with time).[66]

Elasticity: a measure of the responsiveness of one variable to a change in the value of another variable. Specifically, the ratio of the percentage change in the former to the percentage change in the latter.[67]

Price elasticity (of demand): a measure of the responsiveness of the demand for a good or service to a change in its price.[67]

Fixed effects (FE): generally refers to effects (or coefficients) that are constant if they are identical for all groups in a population.[68] Including FE disallows any of the average unit-to-unit variations in the regressors from being used to estimate the parameters of the model.[57 69] See Gelman (2005) for a discussion of various definitions of fixed effects.[68]

Multinomial regression model: regression model in which the dependent variable measures a nominal outcome (ie, an unranked categorical outcome).[44]

Ordinal regression model: regression model in which the dependent variable measures an ordinal outcome (ie, a rank-ordered categorical outcome). Ordered logit and ordered probit models are the most commonly used models for ordinal outcomes in health and social sciences.[44]

Parallel regression assumption (proportional odds assumption for the ordinal logit model): an assumption implicit in ordinal regression models which requires that the separate equations for each category differ only in their intercepts (ie, the slopes are assumed to be the same when going from one category to the next).[44]

Retrospective data: longitudinal data obtained using retrospective recall methods (ie, reporting events that happened in the past).[70]

Heaping: when respondents cannot recall a specific value and provide a 'prototypical' response near the actual value, resulting in the over-representation of certain values.[70]

Longitudinal data: data in which the same units are observed over multiple time periods. For example, data pertaining to individual-level changes over time, observed periodically over a certain duration.[71]

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