Health Care Management Science 5, 113–120, 2002

The Use of Simulation Models for the Surveillance, Justification and Understanding of Tobacco Control Policies

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Received January 2001; Revised June 2001

Abstract. Debates over national tobacco legislation and the use of state settlement funds demonstrate a need for information on the effects of tobacco control policies. Computer simulation models that are based on empirical evidence and that account for the variety of influences on tobacco use can be useful tools for informing policy makers. They can identify the effects of different policies, convey the importance of policy approaches to tobacco control, and help policy planners and researchers to better understand policies. This paper examines the role of simulation models in public policy, and discusses several recent models and limitations of those models.

1. Introduction

Public concern about smoking levels in the United States has stimulated consideration of a number of public policies [33,34]. Many of the recent strategies have focused on youth, such as increased retail compliance with minimum purchase age laws, school-based education programs, and restrictions on advertising and promotions [14]. Other public policies, such as tax increases and clean air laws, affect all age groups, but their effects may vary by age, gender and racial/ethnic group [6]. Further, different cohorts of smokers have different smoking rates [4], which in turn influence the effect of policies.

The ultimate goal of tobacco policies from a public health perspective is to reduce the health-related harms associated with smoking. While some of these harms are relatively immediate, such as increases in low birth weight babies or injuries from smoking-related fires, most measurable health effects are delayed until later years. For example, most individuals who begin smoking at age 18 experience higher death rates relative to non-smokers when they are 40 years and older. In general, the health-related pay-offs from anti-smoking public policies are largely experienced in the future and will depend on the age of smokers affected by the policies.

The complexity of the problem of smoking along with the number of interacting factors and potential prevention strategies leave policy makers with difficult choices. Science-based tools for evaluating the potential effects of policy alternatives may facilitate the process. One such tool is computer simulation.

Simulation models are useful in predicting and describing complex social phenomena. They are particularly helpful in understanding policies directed at tobacco use because effects of the policies unfold over time and depend on the cohort, age, and other socio-demographic characteristics of smokers. Simulation models of tobacco control policy employ mathematical formulas that describe the relationships between tobacco policy or treatment availability, tobacco-related behaviors and mortality. The formulas are generally based on a synthesis of the best available published research findings and survey and other data. Where insufficient information is available, reasonable estimates and some knowledge of the structure of effects may be developed from other areas, such as research on the impacts of alcohol and illicit drug control policies or more generally from the disciplines of economics, psychology, and sociology.

In recent years, a variety of efforts to model the impact of tobacco control policies on youth and adult smoking prevalence, smoking-related morbidity and mortality, the economic costs of tobacco use, tobacco tax revenues, and other issues have been undertaken. Predictions from these simulation models have been used, for example, in debates over proposals for national tobacco legislation and the feasibility of

Healthy People 2010 goals [26], and the use of funds resulting from the master settlement agreement between tobacco companies [2] and the states. Well-developed models of this type are needed to inform the debate over appropriate and effective tobacco control measures and their likely impact on tobacco use, its consequences, and related outcomes. They may also be useful in helping state and local planners implement effective policies.

This paper first discusses the use of simulation models to help in the surveillance and development of tobacco control policy. We then describe three different models that have been independently developed: the "SimSmoke" model [17,22] funded by the Center for Substance Abuse and Prevention (CSAP) and the Robert Wood Johnson Foundation Foundation's Substance Abuse Policy Research Program, the Smoking Control Dynamic Model funded by GlaxoSmithKline Beecham Consumer Healthcare, and the System Dynamic Model funded by the Robert Wood Johnson Foundation's Substance Abuse Policy Research Program [25,26]. Limitations of the models are then discussed.

2. The uses of simulation models

Simulation models can be useful tools in informing policy makers who are trying to develop an appropriate mix of policies to reduce tobacco use and its consequences, and, more generally, in helping to understand the effects of tobacco policies. They can serve to predict future tobacco use and the effect of policies on that use, justify the implementation of particular policies, and help to better understand the impact of these policies.

Simulation models generally start with a *status-quo* scenario, which projects smoking rates and health outcomes from some date forward in the absence of any specific policy addressing tobacco use. This type of information enables policy makers to understand and plan for likely future trends. Status quo scenarios generally reflect current policies, which is generally the base most relevant to policy makers. The models predict the effect of new policies on current levels and trends in smoking rates. The level of socio-demographic detail may vary from model to model, but, at a minimum, variation in smoking levels across different age cohorts is needed.

Simulation models can allow policy makers to conduct experiments to determine the effects of well-defined programs and/or policies on smoking rates and specific tobacco-related problems in their communities before the actual expenditure of funds. Policies may be considered individually and then compared. For example, policy makers can use models as a tool to estimate the long-term impact of a tax increase on smoking rates or deaths, and to compare these effects to those of youth access policies. The effects of policies may be gauged in terms of the level and timing of their effect on smoking-related harms as well on smoking rates.

Different policies may be also considered together or implemented in some sequence. The effect of newly implemented policies in a state or community is likely to depend on the policies already in effect, as well as on the intensity of their implementation and enforcement, and on policies being considered. For example, mass media-related policies may be more effective if they are accompanied by attempts to pass clean air laws or raise taxes.

The effects of policies on different socio-demographic groups may also be considered. Many policies are likely to affect those of different ages, genders, racial/ethnic groups, or income/ education levels in different ways. Consequently, knowledge of the effects of policies on these different groups will be helpful in targeting policies to particular populations where the need is greatest, and in coordinating the effects of different policies. For example, treatment-oriented policies aimed at adult smokers may be an important adjunct to youth-oriented policies, not only because they affect a different population but also because adults serve as a role model for youth and as a potential source of cigarettes.

The results of simulation models may be used to justify specific tobacco policies or tobacco policies in general. The effect of one tobacco control policy may be considered relative to another policy in order to determine which is more effective. Alternatively, tobacco control policies may be compared to other public health policies, such as treatment for alcohol abuse. The effects of other policies may be considered in the model or may be derived from other models or literature. In comparing different policies, cost-effectiveness analyses are often useful. When combined with information on the costs of the policies, their effect may be gauged relative to the expenditure of scarce resources. The choice between tobacco policies may also be justified.

Part of justifying tobacco control policies is a "heuristic" role of explaining the effects of policies to those less familiar with the public health literature. Simulation models demonstrate what is known from the scientific literature concerning the relative effectiveness of various policy approaches on the prevention of smoking and its consequences. They provide a useful method for helping to understand the basic effects of policies.

Besides being used as a teaching device, simulation models may help to provide guidance on research needs in the field of public health and help define priorities and new directions for this research. In developing equations in simulation models, decisions must be made to explain how policies affect smoking outcomes. Policies may be transmitted through the population in various ways. They may affect the physical or financial availability of tobacco products, norms regarding use, or the ability to get successful treatment. They may affect initiation, quit or relapse rates, may have effects of different magnitude and duration, and may affect different socio-demographic groups in different ways. Policies may have interactive effects. In other words, simulation models force the developers to think in a system wide fashion that provides a basis for a more complete understanding of the policies. In developing the linkages, the limitations of our knowledge on the effects of different policies are also made more explicit.

In addition to examining how policies affect the population, simulation models may be used to examine the form that policies may take. For example, youth access policies generally involve some combination of compliance checks, penalties on those who violate the law, and attempts to educate and mobilize the community. The model may consider how different uses of these components may affect outcomes of the policy. Thereby, models can help policy makers to more effectively implement policy. In addition, simulation models may provide a structure for those studying public health to better understand and explore the effects of a policy.

3. Three simulation models

Three simulation models are discussed. The construction, data, purposes, outcomes, and some of the findings from these models are summarized in table 1.

3.1. SimSmoke

SimSmoke is currently being developed with funding from the Substance Abuse and Mental Health Administration's Center for Substance Abuse Prevention and the Robert Wood Johnson Foundation. It has been developed as a national model for the United States, but can be adapted to state level analysis. The model was originally intended to be used primarily for prediction purposes, but has also proven to be a heuristic device for better understanding the effects of tobacco control policies.

Programming is in Visual C++. The interface provides the user with the capabilities to examine smoking rates and smoking-attributable deaths of the total population and by demographic group. The model subdivides the population by age, gender and five racial/ethnic groups [17,22]. Each of these demographic groups is further divided into never smokers, current smokers, and former smokers (which is further subdivided by years since cessation).

A discrete time first order Markov process is employed to simulate future population growth and smoking rates. The population model incorporates separate equations for births, through female fertility, and deaths. Individuals are classified as never smokers from birth until they initiate smoking or die. Since initiation generally occurs before age 25 [33], initiation in the model occurs until age 25. Cessation and relapse are tracked after age 24, when permanent health effects for ex-smokers are more likely. Relapse takes place after the first year by category of ex-smoker (1–2, 3–5, 6–10, 11–15 and >15 years since quitting).

The source of data on smoking prevalence, initiation and quit rates is the 1992/3 Tobacco Supplement of the Census Population Survey [3] for those age 15 and above, and the 1993 Teenage Attitudes and Practices Survey [28] for those below age 15. Relapse rates are based on COMMIT data [7] and other studies [12,24,35]. Population and fertility data are from the 1993 Census of Population and mortality rates are from the 1993 Multiple Cause-of-Death File [1]. Deaths are distinguished by demographic and smoking groups based on the Cancer Prevention Study II [32]. They are predicted using standard attribution measures, based on prevalence rates

Table 1
Characteristics of tobacco control policy simulation models.

Model	SimSmoke	Smoking Control Dynamic Model	System Dynamic Model
Purpose	Prediction and policy analysis	Explanatory	Prediction and policy analysis
Structure	Discrete time dynamic model	Continuous time dynamic	Discrete time dynamic model
Detail	High	High	Medium
Parameters	External	External	External and internally estimated
Demographic groups	Age, gender, and racial/ethnic group	None (though gender could be activated)	Age
Data sources	Primarily the Census of Population Survey Tobacco Use Supplement [3] and National Health Interview Survey [28]	Primarily the National Health Interview Survey [27]	National Health Interview Survey [5]
Outcomes	Smoking prevalence and smoking attributable deaths	Annual quit attempts, distribution of assisted and unassisted quitting, successful quitters and total smokers	Smoking prevalence
Policies considered	Taxes, clean air laws, media campaigns, cessation treatment and youth access enforcement	Level of availability and access to nicotine replacement therapy, including retail setting and advertising/marketing	None
Key findings	Policies have substantial impact on smoking rates and deaths, effects of policies depend on how implemented	Reducing barriers to access to pharmacotherapies increases their utilization	Smoking rates will fall over time, but will not fall to reach target rates in Healthy 2010

and the risks of smokers and ex-smokers relative to non-smokers [8,31].

Smoking rates and deaths are projected over a 40-year time frame [17,22]. For the years 1993 through 2000, the effects of public policies are incorporated as described below. The smoking rate begins at 19.2% of the total population (all ages including youth) in 1994 and falls to 18.5% by 2000. Under the status quo scenario (with policies at their 2000 level), smoking rates are predicted to gradually fall to 15.4% by the year 2040. Nationwide, SimSmoke estimates deaths attributable to smoking were about 400,000 in 2000. The number of deaths per year is predicted to increase to 507,000 in 2030 and then decrease to 468,000 in 2040.

SimSmoke models the effects of five types of tobacco control policies: taxes, clean indoor air laws, strategies to reduce youth access to cigarettes, strategies to promote cessation treatments, and mass media policies. Each of the policy modules relies on information from the literature as well as on "reasonable estimates" where information is not available. A panel of experts in tobacco policy research (Lois Biener, Frank Chaloupka, Michael Cummings, Joseph DiFranza, William Evans, Matthew Farrelly, Jean Forster, and others) played a particularly important role in the development of the policy modules. In addition, sensitivity tests were conducted to assure that values of each policy variable for the allowable ranges yielded reasonable values, and benchmarking tests were conducted to determine if the results were consistent with those in the literature and with the opinions of an expert panel.

The tax module assumes that cigarette prices increase by the amount of the tax. When a tax is permanently increased, smoking prevalence is reduced over a three-year period, and initiation and quit rates are permanently changed through elasticity parameters, which imply constant proportional effects. While the module was able to use fairly reliable estimates from the literature on the relationship of price to smoking prevalence, "reasonable estimates" of the effect on initiation and cessation had to be developed. The module shows the importance of increasing taxes over time to keep up with inflation (i.e., indexation). The module shows fairly substantial and immediate effects of tax policies on smoking rates in all age groups, particularly youth and young adults and quite substantial savings in lives within a relatively short period of time [16].

The clean indoor air module examines the effect of four types of laws (work site, restaurant, school and other public places), and the role of enforcement and media publicity [21]. The module predicts about an 11% reduction in smoking rates as a result of all policies implemented with strong enforcement and media publicity, with the effects on death rates relatively immediate. Work site laws have the biggest effect, comprising almost 70% of the effect, with restaurant laws comprising about 15% of the effect.

While there are many studies of youth access policies, the literature provides limited guidance on their effects [18,23]. The youth access module attempts to go beyond the literature to consider the components of a successful strategy and the role of non-retail sources of cigarettes (which are an important alternative source of cigarettes for youth). The module considers bans on self-service and vending machines, compliance checks, penalties, and merchant awareness/community mobilization. The model takes into account the interactive effects between the policy components and diminishing returns to each of them. A well-designed policy requires that each of the components be at a sufficient level, but that additional use of a component beyond some level yields little additional impact. The youth access module also shows how, as retail sales to youth are reduced, youth switch to non-retail sources such as theft, older peers and parents. This substitution limits the effect of youth access policies to a maximum estimated 25% reduction in youth smoking prevalence, with the effects on smoking-related deaths largely delayed 40 years into the future [18,23].

The cessation policy module considers the effects of public policies that involve payment for tobacco treatments [15]. The module is based on a decision theoretic model of the decision to quit and the choice of treatments (over-the-counter or prescription pharmaceutical therapy, behavioral therapy, or combinations of these therapies). Policies may apply to limited sets of treatments, and may affect the decision to quit or the chosen method(s) of treatment. The model allows for substitution among treatment alternatives and diminishing effectiveness as smokers are induced by policies to quit. Policies with the broadest coverage and supplemented with physician reinforcement lead to as much as a 50% increase in quit rates [15]. Because of the limited evidence on the effects of cessation policies, estimates are viewed as tentative, but the module illustrates the different ways in which cessation treatment policies can be implemented and their effects.

The mass media module distinguishes policies directed at all smokers from those targeting youth, and considers the effects of scale and duration. Since the literature provides limited information on these effects, use is made of the product advertising literature [20]. Mass media expenditures have to be implemented at a high enough level to reach smokers a sufficient number of times, but show diminishing returns after some point. Mass media policy effects peak at a 7% reduction in smoking rates over the entire population. Youth-oriented campaigns peak at 6.5% reduction in youth prevalence, implying much smaller effects on the prevalence of all age smokers [19]. The module also shows how the effect of media policies is enhanced by other public policies that lead to publicity.

3.2. Smoking Control Dynamic Model

In early 1998, Paul Heugh, European Smoking Control Project Director for SmithKline Beecham (the predecessor to GlaxoSmithKline), suggested the need for a Dynamic Model for Smoking Control. They hired HVR Consulting Services, Ltd. as model consultants (led by Rod Brown as principal designer of the model) and Pinney Associates as the smoking science consultants (John Pinney, Saul Shiffman, Jack Henningfield, Karl Fagerström, and Joe Gitchell). They also involved an external review panel (Frank Chaloupka, David Levy, Kenneth Warner, David Mendez, John Tauras, and others). The software engine used by the model is PowerSim Constructor version 2.5.

Tobacco control policy was recognized as a complex phenomenon with multiple interrelated dynamics. There was a need for a powerful heuristic tool to enable managers within the firm to quickly appreciate the complexity of smoking control, particularly the process of smoking cessation. Building a simulation model was also recognized as an opportunity to encourage dialogue outside the company with policy makers and experts on the importance of treatment as part of tobacco control programs.

The model focuses on the decision to quit. While the model is intended to help predict quitting behavior and the demand for Nicotine Replacement Therapy (NRT) in particular, it also has an important heuristic role in helping marketing managers to understand the decision to quit and the factors affecting those decisions. It considers the intermediate steps largely for that purpose. A primary goal is to build understanding of the factors that influence the market for treatment. To a much lesser extent, and solely to provide for more realistic estimates over time, the model includes estimates of smoking initiation.

The intermediate steps in the decision to quit are the based on the "stages of change" literature [29]. First, smokers contemplate quitting. They may then become ready for quitting. Among those who decide to quit, they then flow into assisted or unassisted quitting methods (the default is that first-time quitters select unassisted or "cold turkey" quitting). They may succeed in the short run (0–10 weeks) or the longer run (10+ weeks). Hazard curves then determine relapse rates (with varying risks for unassisted and assisted quitting methods), with inputs provided by the Normative Aging Study [11] and the AHCPR Guidelines [10]. Relapsed smokers then begin the cycle of quitting again. Those who maintain cessation are considered sustained quitters, while those who relapse return to the pool of smokers. Individuals are not tracked separately, since there is no capacity to track cumulative quit attempts. The model does not distinguish among smokers according to their number of previous quit attempts, with the exception of the differentiating the first quit attempt from all subsequent attempts.

The model explicitly considers factors that affect each of the quit decisions and outcomes. Factors that may lead to contemplating a decision to quit are, for example, social pressure to quit or a change in cigarette price. Factors that may lead to a decision to quit are health advertising, NRT product advertising, or a new NRT product launch. Factors affecting the use of NRT are NRT product advertising, new product launch, word of mouth, the effect of the Committed Quitters Program (the behavioral support program using tailored messages available with GlaxoSmithKline smoking control products) on positive experience, visibility and availability (allowing for three "classes" of availability: prescription-only, nonprescription in pharmacy only, and nonprescription in general sales), and the price of NRT relative to cigarette prices.

The model was first built using data from the United States, though the current version uses population data from the United Kingdom, including birth, emigration, and death rates. Total population data were derived from Census data, and the National Health Interview Surveys [27] were the primary sources for smoking prevalence, initiation and quitting behavior. These data were obtained by gender and age. Pharmacotherapy use for quitting relied on data reported in an analysis of the increase in medication use following the prescription-to-nonprescription switch of nicotine gum and patch [30]. Socio-demographic distinctions are not made in the model except by gender, although there are provisions for differing levels of smoking. This limitation of the model is due to the lack of sufficient data on the response to all of the factors influencing the decision to quit and the method used by different socio-demographic groups.

The model employs a "streamlined" interface. The user is able to change input variables on a host of "flow rates" and starting proportions, that influence, for example, the average amount of time between quit attempts or the number of retail outlets where NRT is available. The best data from the United States were estimates of annual quit attempts and the proportion of quit attempts using assistance. Intermediate variables (e.g., rates of flow through various states of readiness to quit) are calibrated to match the known data, which leaves their precision open to question.

From the beginning of its development, the builders of the model faced the trade-off of creating a model of greater complexity that captures more of the details associated with smoking and quitting behavior versus making the model simpler and easier to use for predictive purposes. The developers often found that there was insufficient data to "calibrate" all variables. In particular, reliable longitudinal data on smokers was found to be lacking. They found that they had to assume many "rates of flow" because attempts to measure these factors at the necessary level of detail would in and of itself influence behavior. The model was found to be an important resource for examining unknown elements of cessation behavior.

3.3. System Dynamic Model

The System Dynamic Model [17] predicts smoking prevalence over time by keeping track of the inflow of new smokers as well as the outflow caused by death or smoking cessation. The model employs age-specific death rates as well as age-cohort specific initiation and quitting rates. Birth cohort sizes are supplied exogenously to the model. The model does not consider the effect of migration on future population size and smoking prevalence, because the immigration pool is small compared to the domestic population.

Death rates are differentiated by year, age and smoking status. Current smokers in any given year are estimated as the number of current smokers in the previous year who survived to the current year and did not quit smoking. Smoking prevalence at age 18, supplied exogenously to the model for each cohort under study, is used to calculate the size of each year's cohort of new adult smokers. Smoking prevalence for any age group in a specific year is computed by taking the ratio of current smokers to the total number of people within the group that year.

The model assumes that there is no smoking initiation after age 18, when prevalence attains its peak value for the cohort. After age 18, smoking cessation drives the dynamics of the model. This is consistent with data that shows that by the 1980s almost all regular smoking began before the age of 20 years, and by 1991, the mean age of becoming a daily smoker was 17.7 years [13,33,34].

The National Health Interview Survey (NHIS) is the principal source of information on the health of the civilian noninstitutionalized population. The annual survey consists of a basic set of questions on health, socioeconomic and demographic items. To determine the prevalence of smoking among adults, the NHIS collects self-reported smoking information on cigarette smoking from adults, defined as individuals 18 years of age and older.

Quit rates were estimated within the model using historical adult smoking prevalence data from the Centers for Disease Control and Prevention [5], which were estimated from the NHIS. Specifically, the model used smoking prevalence for the age-groups 18–24, 25–44, 45–64, and 65 and over, and for the years 1970, 1974, 1978–1980, 1983, 1985, 1987, 1988, 1990–1993.

Quit rates were estimated by feeding the response of the dynamic model and the observed data into a minimization routine that controlled the changes in parameter values while minimizing the sum of squared differences between observed and calculated prevalence data [25]. Quit rates were estimated for two different time periods: 1970–1980 and 1981–1993, and three age groups: 18–30, 31–50, and older than 50. The parameter estimates indicated that the background quit rate rose sharply with age and has increased from the seventies to the eighties, consistent with prior studies [5,9,13]. Coefficients for the rates corresponding to the two older age groups are statistically significant in the post-1980 time period. For the period 1970–1980, only the coefficient for the older age group was statistically significant. Estimates of the quit rate may have been confounded by initiation rates particularly in the earlier time period. This confounding may downwardly bias the estimates and partially account for the lack of significance in some of the coefficients. The model produced a good fit for the data with an overall corrected R^2 of 0.98.

The model has been used to examine smoking prevalence over the next three decades, given contemporary smoking patterns. Observed smoking prevalence data in the nineties suggest that adult prevalence has stalled, raising the fear that it will not continue its historic 30-year decline [13]. Analyses with the System Dynamic Model suggest otherwise [17]. If age-specific quit rates remain stable at the levels exhibited during the eighties and tobacco control policies do not change, overall prevalence is likely to continue falling during the remainder of this decade and through the next. In fact, the model predicts that overall prevalence will continue to fall even if the initiation rate rises to 35%, a level not reached since 1975. Under current initiation rates, the decrease in quit rates necessary to maintain current smoking prevalence is extremely unlikely.

While smoking rates are expected to fall, the model has shown that the Healthy People 2010 goal of achieving an adult smoking prevalence of 13% by the year 2010 is implausible under realistic assumptions about expected changes in initiation and quit rates [25]. Thereby, the model has helped to demonstrate how data driven methods can be used in setting attainable goals.

The System Dynamic Model provides likely scenarios for adult smoking prevalence in the United States in the absence of any additional smoking control policies. This model can be modified to recognize the effect of smoking interventions on smoking related mortality. Similar to the SimSmoke Model described above, the model can be modified to incorporate the effect of smoking control policies on prevalence and smoking related mortality. This effect can be recognized by modeling explicitly the impact of smoking policies, individually or in combination, on the smoking initiation and quit rates. Specific values for the effects of policies on smoking rates can be obtained from the literature. In cases where the literature is controversial or nonexistent, sensitivity analysis can be used to determine a range of likely values for these effects.

The System Dynamic Model is also suitable for target analysis; a desired output range can be specified and the model will run backward to find the inputs that produce the desired output. This analysis is useful in the evaluation of proposed policies for which effectiveness on smoking initiation and cessation is unknown. Specifying as targets the benefits derived from benchmark policies, the model can be used to recognize how effective (in terms of modifying smoking initiation and/or quit rates) the evaluated policy will need to be in order to perform as well as the benchmark.

3.4. Limitations of the models and areas for future model development

Simulation models have proven valuable in justifying tobacco control policies. The SimSmoke and System Dynamic Models have been used in predicting future smoking rates. As a way of summarizing evidence of past studies they provide a useful way to present the effect of public policies on health-related outcomes, as seen in SimSmoke. In modeling public policies and their effects, they may help policy planners to understand the role of different policies and how policies can be more effectively implemented. The SimSmoke and Smoking Control Dynamic Model have proven useful in that regard.

The value of these models in predicting future events has not yet been well tested. Two recent trends will need to be explained by the simulation models. First is the sharp increase in youth smoking initiation in the early to mid-1990s at a time when many states were implementing tobacco control policies. The fall in prices and increase in tobacco-related advertising and promotion during this time may be partial determinants of this trend. A second important recent trend is the reduction in quit rates observed in the mid-nineties. While the nature of this trend is not yet clear, it comes at a time when new treatments have come into the market and when access to these treatments has expanded. Some of the reduction may be due to a temporary rise in NRT use in the early nineties with the introduction of the nicotine patch, but further exploration is warranted. As more is known about these trends, they will need to be incorporated into the models. At the same time, simulation models can help us to better understand the underlying causes for these trends.

The simulation models are limited by the quality of data to track smoking rates over time. While good measures of smoking prevalence are available, better measures of initiation, cessation and relapse are needed. The more commonly used measures of initiation, such as youth cigarette use in the last 30 days, are likely to be of limited use in predicting long-term trends, because many young smokers do not go on to become regular adult smokers. Measures of cessation generally focus on quit attempts, but to predict the long-term effects of policies, better measures of long-term quit success and relapse are needed. The long-term impact of cessation treatment use on these rates was identified as a particular gap in the data. To better understand quit rates, the role of quantity of cigarettes smoked per smoker will need to be better understood.

Better information is also needed on the effects of public policies on initiation and quitting behavior. Most previous studies examine the relationship between the existence of policies and either smoking consumption (total cigarettes smoked) or smoking prevalence [6]. The specific effects on quantity smoked per continuing smoker, cessation (and its duration) and initiation need to be distinguished. It will also be important to determine how these effects vary with the level or intensity of policies, and how these effects may vary over time as the smoking prevalence and average quantity smoked by those who continue to smoke declines.

States that have been relatively successful in reducing smoking have implemented a combination of policies [34]. The interactive effects of different public policies on smokers generally and on smokers of different age, gender and racial/ethnic groups require close attention. In addition, it will be important to consider whether efforts to reduce smoking will continue to be as successful over time. Some policies may affect particular smokers, but leave behind a group of smokers who are less sensitive to changes in norms, availability and other factors affected by public policy.

Finally, it will also be important to better link smoking outcomes with health outcomes. Most models rely on the Cancer Prevention Study II study for deaths of smokers relative to non-smokers and former smokers. As such, they are subject to the limitations inherent in that study [32]. As smoking practices and other health-related behaviors change, it will be important to update the simulation models to reflect these changes. In particular, public policies may affect particular types of smokers that in turn influence the nature of health effects. For many purposes, simulation models may need to go beyond considering the effects of policies on death rates to consider the effects on morbidity, including asthma, childhood sickness and pregnancy-related problems.

Acknowledgements

This paper arose out of a meeting in February, 2000 of tobacco policy simulators. The meeting was supported by GlaxoSmithKline Consumer Healthcare and the Substance Abuse Policy Research Program of the Robert Wood Johnson Foundation. Mendez's and Warner's work on this paper, and on their model described in the paper, has been supported by a grant from the Substance Abuse Policy Research Program of the Robert Wood Johnson Foundation.

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