NBER WORKING PAPER SERIES

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Working Paper 22471
http://www.nber.org/papers/w22471

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2016

We thank Abigail Friedman and Don Kenkel for helpful comments. We gratefully acknowledge funding for this project from NIH grant number 5R03CA182990 and, for Levy, from NIA grant number K01AG034232. The funders played no role in the study design, analysis, writing, or the decision to submit the article for publication The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 22471
July 2016
JEL No. D61,I12,I18

ABSTRACT

Recent tobacco regulations proposed by the Food and Drug Administration have raised a thorny question: how should the cost-benefit analysis accompanying such policies value foregone consumer surplus associated with regulation-induced reductions in smoking? In a model with rational and fully informed consumers, this question is straightforward. There is disagreement, however, about whether consumers are rational and fully informed, and the literature offers little practical guidance about what approach the FDA should use if they are not. In this paper, we outline the history of the FDA's recent attempts to regulate cigarettes and other tobacco products and how they have valued foregone consumer surplus in cost-benefit analyses. We discuss the evidence on whether consumers are fully informed about the risks of smoking and whether their choices are rational, reviewing the competing arguments made by different authors about these questions. We describe the appropriate approach to welfare analysis under different assumptions about consumer information and rationality. Based on our reading of the theoretical and empirical literatures, we advocate using a behavioral public finance framework borrowed from the literature on environmental regulation. This approach applies standard tools of welfare analysis while allowing consumer behavior to deviate from rationality and full information without requiring specific assumptions about the reason for the deviation. The use of this approach would substantially reduce the confusion currently surrounding welfare analysis of tobacco regulation.

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I. Introduction

In 2009, the Family Smoking Prevention and Tobacco Control Act gave the Food and Drug Administration (FDA) statutory authority to regulate cigarettes, opening a new front in the war on tobacco. A central provision of this law required graphic warning labels on cigarette packages, and the FDA proposed regulations to implement this requirement in 2010. Not surprisingly, tobacco companies pushed back, mounting a legal challenge that has prevented the implementation of the graphic warning labels. More recently, the FDA has proposed extending its regulatory authority to new tobacco products such as e-cigarettes. These actions are controversial and raise fundamental questions about the appropriate role of regulation in a competitive economy.

A critical piece of the debate around the FDA's actions concerns the economic case for regulation. Executive Order 12866, signed in 1993, requires an economic impact analysis documenting benefits and costs for any regulation that is "economically significant," a category that includes but is not limited to regulations with an annual effect on the economy of $100 million or more. The main benefits of regulations that reduce smoking are straightforward: improved health for smokers and also for non-smokers who are less likely to be exposed to secondhand smoke. But a question that arises immediately is how much of the benefit to smokers is offset by their lost enjoyment — that is, foregone consumer surplus — associated with less smoking.

There are strikingly different views on the correct size of this offset. At one end of the spectrum are those who argue that there should be no offset at all. Economists Frank J. Chaloupka, Jonathan Gruber, and Kenneth E. Warner have stated unequivocally "that the 'lost pleasure' from tobacco use…should not be included as a cost in FDA economic impact analyses

of tobacco regulations" (Chaloupka et al. 2015). They are joined in this view by groups such as the American Heart Association and the American Lung Association. One commentator derided FDA as a "toothless tiger" and speculated that the economic analysis accompanying the graphic warning label rule suggested "regulatory capture" of the agency by the tobacco industry (Malone 2015). At the other end of the spectrum are those who have argued, for various reasons, that the loss of consumer surplus may be so large as to offset nearly *all* of the regulation-induced health gains for smokers. This latter group includes government economists Elizabeth Ashley, Clark Nardinelli, and Rosemarie Lavaty (Ashley et al. 2015) and economic experts hired by the tobacco industry (comment submitted by Robert S. Maness on behalf of R.J. Reynolds Tobacco Company, Lorillard Tobacco Company, and Commonwealth Brands, Inc., Docket No. FDA-2010-N-0568, downloaded from regulations.gov on 3/19/2012).

What explains the divergence between these two views — particularly between economists on both sides of the debate? And, as a practical matter, how should the FDA account for foregone consumer surplus in its regulatory impact analyses? Correctly accounting for lost consumer surplus depends on critical assumptions about, among other things, whether or not consumers are fully informed about the health risks of smoking and whether consumer smoking behavior is rational in the sense of reflecting stable preferences that fully take into account the current and expected future consequences of current choices (note that rationality does not imply perfect foresight). The peer-reviewed literature in economics has offered the FDA little guidance on this subject. The goal of this paper is to address these questions to help inform economic impact estimates associated with future tobacco regulations.

This paper makes five main contributions to this contentious and important literature.

First, we emphasize that the correct approach to evaluating the economic impact of regulation is to calculate changes in the welfare of a rational and fully informed consumer, rather than first calculating the value of health gains and then offsetting them by some amount. Second, we briefly review the economics literature on whether consumers are fully informed and rational in their decisions about tobacco consumption, because these are critical assumptions to inform the welfare analysis. Third, we adopt the behavioral public finance framework of Allcott and Sunstein (2015) for welfare calculations. This framework is already used in other areas, most notably environmental economics; it has the advantage of explicitly allowing quasi-rational behavior or imperfect information and focusing on the net welfare effects of government interventions rather than trying to estimate the gross health gains and corresponding offsets. Fourth, we consider how the welfare analysis changes under the assumption that demand exhibits constant elasticity of substitution, rather than the typical assumption of linear demand. This shows the sensitivity of the results to one of the main arbitrary assumptions. Finally, we motivate all our research in the context of the ongoing regulatory debate.

The paper proceeds as follows. We begin by outlining the economic arguments underpinning the regulatory impact analyses accompanying recent tobacco-related FDA regulations and the counterarguments offered by those who have commented publicly. Next, we summarize the key differences that drive these arguments: specifically, differences in underlying assumptions about consumer information, rationality, and the correct framework for welfare analysis. We present a simple theoretical framework for welfare analysis, borrowed from environmental economics, which is flexible enough to allow different assumptions about information and rationality. Using this framework, we present graphical examples of welfare analysis of regulatory interventions, varying assumptions about information and rationality while

maintaining the assumption of linear demand. We then discuss the implications of relaxing the assumption of linear demand. We conclude by offering implications for regulatory impact analysis, as well as a discussion of topics for future research.

II. A brief history of the FDA's treatment of foregone consumer surplus in economic impact analyses related to recent tobacco regulation

In 1995, the FDA proposed regulations to restrict access to cigarettes by minors. The accompanying regulatory impact analysis acknowledged the difficulty of calculating an offset for foregone consumer surplus, but stated that no offset was required only because minors, rather than adults, were the target of the restrictions: "FDA's proposed rule imposes no access restrictions on adults, who would be free to consume tobacco products if they so desired. Thus, FDA has not included any value for lost consumer surplus in its estimate of societal costs" (Regulations Restricting the Sale and Distribution of Cigarettes and Smokeless Tobacco Products to Protect Children and Adolescents," 60 FR 155 (11 August 1995), pp. 41314 – 41375). The Supreme Court would ultimately strike down this attempt to regulate on the grounds that the FDA lacked the statutory authority to regulate cigarettes (Croley 2008). But the notion that the enjoyment consumers who are minors derive from smoking can be ignored for purposes of a cost-benefit analysis foreshadows a theme of the current debate.

Following the Supreme Court's rejection of the FDA's attempt to regulate, anti-smoking policy developed over the subsequent decade not through regulation, but through the courts, resulting in the "Master Settlement" between the tobacco industry and state attorneys general. One consequence of the fact that this process unfolded in the courts was that there was no regulatory impact analysis by FDA. An academic cost-benefit analysis notes the critical

importance of valuing lost consumer surplus, which they refer to as "foregone pleasure," but remains agnostic about how this should be done (Cutler et al. 2002).

In November 2010, the FDA issued proposed regulations requiring graphic warning labels on cigarette packages as required by the Family Smoking Prevention and Tobacco Control Act of 2009. The accompanying regulatory impact analysis acknowledged the need to take foregone consumer surplus into account: "This range [of monetized gross health benefits to smokers] tends to overstate the net benefits of reduced smoking because it does not account for lost consumer surplus associated with the activity of smoking. Cutler…suggests that lost consumer surplus might equal around fifty percent of the dollar value of life-year gains, which necessitates dividing the estimated gross benefits in half." (The FDA analysis, like ours, considers the magnitude of lost consumer surplus relative to health gains to smokers, without considering health gains to non-smokers. Effects for non-smokers are important for evaluating the overall impact of the regulation but not for the narrower question of how to evaluate its impact *on smokers*, which is our focus.) In other words, the FDA proposed that the offset for lost enjoyment should be one half. They invited comment on this approach to calculating the offset, which they referred to as the "Cutler adjustment factor." ("Required Warnings for Cigarette Packages and Advertisements," Fed. Reg. Vol. 75 No. 218, 69524-69565.)

The resulting comments showed that anti-smoking groups and the tobacco industry could agree on one thing; namely, their dislike of the FDA's approach to determining the offset. A coalition of anti-smoking groups including the American Heart Association, the American Lung Association, and the American Academy of Pediatrics derided the very idea of an offset as "wholly improper and inappropriate" and complained that "no citation whatsoever is provided" to support this method (comment submitted in response to Docket No. FDA-2010-N-0568,

downloaded from regulations.gov on 10/19/2012). An economic expert hired by the tobacco industry characterized the method as "arbitrary and without any empirical support" (comment submitted by Robert S. Maness, Docket No. FDA-2010-N-0568, downloaded from regulations.gov on 3/19/2012).

Several economists offered comments on the proposed rule as well. Frank Chaloupka commented that the offset should not exceed 10% of gross internal health benefits, without providing justification for that specific threshold (comment submitted by Frank Chaloupka in response to Docket No. FDA-2010-N-0568, downloaded from regulations.gov on May 12, 2015). In contrast, W. Kip Viscusi argued that there is ample evidence that consumers are fully aware of smoking's health risks and may even overestimate them (comment submitted by W. Kip Viscusi on behalf of R.J. Reynolds Tobacco Company, Lorillard Tobacco Company, and Commonwealth Brands, Inc. in response to Docket No. FDA-2010-N-0568, downloaded from regulations.gov on March 19, 2012). Viscusi stated in his comment that he was compensated by tobacco companies for providing this comment, although none of his research, which is published in well-regarded, peer-reviewed journals, has been "funded or otherwise supported by the tobacco industry" (p. 1 of Viscusi comment).

In response to these comments and others, the FDA offered an expanded analysis in the impact study accompanying the final version of the rule in June 2011 ("Required Warnings for Cigarette Packages and Advertisements," 76 FR 120 (22 June 2011), pp. 36628 – 36777). In particular, they did two things: first, they developed more theory to support the idea of an offset. They discussed at length the possibility that the decision to smoke may reflect some non-rationality, citing (among others) Gruber and Koszegi (2001), Bernheim and Rangel (2004), and Gul and Pesendorfer (2007). Following this literature, they imposed a range of different

assumptions about the fraction of lost consumer surplus that should be counted as a cost and used to offset the health gains to smokers. The estimates of lost enjoyment in the regulatory impact analysis that accompanied the final version of the rule ranged from 10 percent to 93 percent; in other words, the FDA analysis suggested that somewhere between almost none and almost all of the health benefits to smokers from reduced smoking are offset by lost enjoyment. Second, they proposed a completely different method of estimating the regulation's net health benefit (that is, the health benefit minus the lost enjoyment) for smokers. This method posits that the net benefit can be inferred directly from smokers' willingness to pay for smoking cessation programs, obviating the need to make an explicit assumption about the gross health benefit and the offsetting loss of consumer surplus. This method results in much lower net benefits associated with the regulation — so low, in fact, that they are exceeded by FDA's upper-range estimate of the costs of the regulation. Thus, getting the method for valuing lost consumer surplus right is not simply an academic question; it may actually determine whether or not the regulation is admissible from a cost-benefit perspective.

Almost immediately after the Final Rule was issued, a coalition of tobacco companies sued the FDA, arguing both that the labels violated their constitutional right to free speech and that the FDA's regulatory impact analysis had overstated benefits and understated costs associated with the regulation. In November 2011, before the regulation was to have taken effect, a US District Court issued an injunction preventing its implementation. In August 2012, the courts ruled in favor of the tobacco companies, effectively barring the FDA from requiring graphic warning labels (R.J. Reynolds Tobacco Co., et al., v. Food & Drug Administration, et al., 696 F.3d 1205 (D.C. Cir. 2012)). The rationale for the court's ruling was that the FDA had failed to show that the graphic warning labels would reduce smoking; absent any reductions in

smoking, the policy would have no gross health benefits. Because the rule failed to meet even that threshold, the court did not address the issue of how net health benefits should be calculated. As a result, the critical questions of whether people are already well informed, whether they are rational, and how regulatory impact analysis should reflect these considerations do not arise in the court's ruling. The government's request for a rehearing was denied, and the FDA did not seek further review of the ruling.[1] Graphic warning labels therefore remain in limbo — required by legislation, but ruled unconstitutional by the courts — for reasons that are not directly related to the controversy over foregone consumer surplus.

A more recent rule issued by the FDA in April 25, 2014 proposes deeming tobacco products such as cigars and e-cigarettes subject to FDA regulation. Although the regulatory impact analysis accompanying this proposed rule avoids even using the term "consumer surplus" (referring instead to "full welfare gains"), the approach is conceptually similar to the regulatory impact analysis accompanying the final rule for the graphic warning labels, with foregone consumer surplus offsetting 67 to 84 percent of the value of smokers' private health gains. The regulatory impact analysis accompanying the final version of this rule, released in May 2016, backed away from this estimate. Instead, the May 2016 analysis took a "breakeven" approach that did not quantify the rule's benefits but instead calculated how large the benefits of the rule would have to be to justify the costs (which are quantified), effectively sidestepping the question of how large the consumer surplus offset should be.[2]

In response to these FDA rules, some have argued that the FDA should abandon altogether its attempt to value foregone consumer surplus associated with reductions in smoking.

[1] Source: http://www.fda.gov/tobaccoproducts/labeling/labeling/cigarettewarninglabels/default.htm, downloaded 2/3/2015.

[2] The May 2016 FDA analysis includes a careful, thorough discussion of the many complexities associated with this question and notes that it is the subject of ongoing research.

In particular, Chaloupka and colleagues (2015) published a commentary arguing that this approach is inappropriate because smoking behavior is irrational, an assertion they support with two observations: first, most smokers began smoking while they were youths, and second, most smokers regret having started smoking. Others, however, would argue that these observations do not present insurmountable obstacles to applying the tools of cost-benefit analysis, suitably modified to incorporate some deviations from standard assumptions (Weimer et al. 2009; Jin et al. 2015; Cutler et al. 2015).

III. Why is there such disagreement? Enumerating the key assumptions on which there is a lack of consensus and proposing a model that can encompass them all

This academic debate reflects fundamental underlying disagreement about how to evaluate the welfare consequences of regulations that reduce smoking. Specifically, there is a lack of consensus about three key questions. First, under the assumption that consumers are fully informed and rational, what is the appropriate framework for welfare analysis of government regulations that yield both health gains and also potentially large losses in consumer surplus? Second, are consumers fully informed and rational? Third, what is the appropriate framework for welfare analysis if consumers are *not* fully informed and rational? In this section, we discuss each of these questions.

A. If consumers are fully informed and rational, how should we evaluate the welfare consequences of regulation?

This question might seem almost rhetorical; after all, welfare analysis when consumers are fully informed and rational is a staple of intermediate microeconomics at the undergraduate

level. The textbook answer would be that in this simple case, welfare analysis should be based on consumer surplus: how does consumer surplus change when regulation causes a change in the equilibrium level of consumption? This approach is noteworthy for what it does *not* do; in particular, the standard welfare analysis does not begin by calculating the health gains and then estimate an offset for lost enjoyment. On the contrary, calculating health gains is redundant, because consumer surplus already reflects the consumer's valuation of any health gains resulting from the change in demand. This illustrates an extremely important principle which holds even when consumers are not fully informed and rational: there is no good reason why the welfare analysis of regulations that reduce smoking should begin by calculating health benefits. (Note that as discussed above, we are considering only internal health benefits to the smoker herself; any externalities would need to be considered separately.)

Two other basic points are worth making about the welfare consequences of regulation when consumers are fully informed and rational. The first is that consumers cannot be made better off by an intervention (such as a tax) that reduces smoking, if their initial smoking decisions were truly the result of rational decision-making with full information. The second is that providing accurate information that was already publicly available should not change their behavior; by definition, if the provision of accurate information changes consumers' behavior, they must initially have been either uninformed or failing to use all information available to them. We return to these points in our subsequent discussion.

B. Are consumers fully informed and rational?

A large body of evidence suggests that consumers are aware of the health risks of smoking (for example, Viscusi 1990; Viscusi and Hakes 2008); indeed, some evidence suggests

that smokers actually *overestimate* some of the health risks of smoking (see Viscusi 2010 for a review). At the same time, they may underestimate the difficulty of quitting (Sloan, Smith, and Taylor, 2003). Note that being fully informed does not mean that there is no *uncertainty* about the negative health effects of smoking. Uncertainty about the nature and magnitude of the negative health effects of smoking seems pervasive, as medical research continues to uncover new links between smoking and negative health effects. For example, recent studies show elevated indicators of respiratory impairment in current former smokers even without evidence of clinical disease (Regan et al. 2016; Woodruff et al. 2016). In other words, the long-term negative health consequences smoking — even for those who have quit smoking — are even worse than anyone had thought. The key point, though, is that if no one was aware of this relationship (as might be inferred from the fact that these studies were published in high-impact medical journals) this indicates that there was *uncertainty*, rather than a lack of information on the part of smokers. While uncertainty complicates cost-benefit analysis, it does not by itself offer a rationale for regulation; in contrast, if consumers are not fully informed about the known risks of smoking, then informing them of these risks would improve their welfare. Therefore, our focus here is not on whether there is uncertainty, but on whether consumers are fully informed about known risks. Our reading of the evidence is that consumers are for the most part aware of the risks of smoking, even if as noted above they may underestimate the difficulty of quitting.

It is much harder to say whether consumers are rational in the sense of reflecting stable preferences that fully take into account the available information on current and expected future consequences of current choices; "[a]ddictions would seem to be the antithesis of rational behavior" (Becker and Murphy, 1988). The theory of rational addiction developed by Becker and Murphy (1988), building on prior work by Stigler and Becker (1977) and by Iannaccone (1986),

is the starting point for how economists analyze consumption of addictive goods using rational models.

While a full review of the rational addiction model is beyond the scope of this paper, a few points are important both for our discussion of welfare analysis and as an introduction to later research that extends the basic rational addiction model. As the name suggests, the rational addiction model starts with the assumption that consumers are rational utility-maximizers who take into account the future consequences of their current choices. The model does not necessarily assume that consumers are fully informed, although their consumption of addictive substances is not driven by a lack of information. The key feature of rational addiction is adjacent complementarity between consumption in different periods. Adjacent complementarity implies that smoking now will increase the pleasure of future smoking. As a result, consumption in the current period increases consumption in future periods. Therefore, the decision to smoke is different each period because the stock of past smoking gradually changes, making it a dynamic model. The full price of consumption of an addictive good includes its discounted future effect on utility, including changes in income and health. The rational addiction model allows discount rates to differ across individuals; indeed, consumers with high discount rates are more likely to consume addictive goods because they place less weight on future adverse effects.

The rational addiction model dispels the notion that smoking (or consumption of other addictive goods) is *ipso facto* evidence of irrationality. Indeed, the rational addiction model can explain observed behaviors that might appear to be less than rational, including binges, increased use during stressful times, higher use by people with higher discount rates, and quitting cold turkey instead of gradually. But the original rational addiction model is subject to a number of criticisms, which have led to further research in this area. Criticisms of the rational addiction

model include the assumption of perfect foresight, the assumption of time consistency, and the lack of any role for regret (Song, Brown, and Glantz 2014). Perfect foresight is a convenient modeling tool but is hardly realistic. Many smokers express regret at having ever started, but the classic rational addiction model has no role for regret.

Orphanides and Zervos (1995) propose a model that maintains the central assumption of rationality but relaxes the assumption of perfect foresight, which also creates a role for the experience of regret. Instead of perfect foresight, Orphanides and Zervos allow for uncertainty in whether a person is likely to become addicted. The uncertainty arises because people have different tolerances, meaning some people become addicted more easily than others, and consumers learn about their own specific addiction tendency through personal experience. The model assumes that people act rationally given their beliefs, which change over time with experience. In their model, a person who (mistakenly) believes that they are unlikely to become addicted may smoke so much that they become addicted before they realize their error. This leads some smokers to experience regret. The smokers most likely to experience regret are those whose initial beliefs differ strongly from their actual addiction tendency.

Suranovic, Goldfarb, and Leonard (1999) modify the rational addiction model in two important ways. First, they explicitly assume that quitting smoking is costly to the consumer, in utility terms. Second, and more relevant for our current discussion, they assume a simple form of "bounded rationality" in which, rather than optimizing over the lifespan, consumers optimize only their consumption in the current period. In this model, some smokers become trapped by past optimizing decisions into a situation where smoking is worse than non-smoking, except that to quit would incur such enormous costs that the smoker continues, regretfully.

More recent models, reflecting developments in the field of behavioral economics, relax the assumption of time consistency that characterized the original rational addiction model. Gruber and Koszegi (2001, 2004) modify the rational addiction model by assuming quasi-hyperbolic discounting, so all future utility is discounted by an additional factor (β) beyond the standard per-period discount rate (δ). Including β in the model (with $\beta<1$) means that future utility is discounted even more, so that future costs of smoking appear lower. The result is that time-inconsistent people smoke more in the current period, which, through adjacent complementarities, increases future smoking. A time-inconsistent person ($\beta<1$) will smoke more than a time-consistent person with the same discount rate (δ). Just as a time-inconsistent obese person may plan to start exercising tomorrow, a time-inconsistent smoker may plan to reduce smoking tomorrow. The fundamental problem with time inconsistency is that it creates tension between current and future selves, with smoking by the current self imposing an internality (i.e. a health cost) on the future self.

Bernheim and Rangel (2004) propose an alternate theory of the consumption of addictive goods, incorporating insights from psychology. They argue that the consumption of addictive goods is often a mistake triggered by environmental cues. In their model, a person makes choices in two modes. The "cold" mode is rational, but the "hot" mode is swayed by environmental cues and may lead to choices of addictive substances that are different from choices that would have been made in a "cold" mode.

Does the recent emphasis on quasi-rational models reflect a consensus that smoking behavior cannot be described by rational models? It does not. As noted by Gruber and Koszegi (2001, 2004), there is a lack of compelling evidence about whether smokers are time consistent or time inconsistent. Instead, there is much evidence on people's behavior in general being time

inconsistent, but little evidence on smokers specifically. Moreover, there is no empirical test that distinguishes clearly between rational and quasi-rational models of smoking behavior.

What *is* clear, however, is that the welfare implications of different anti-smoking policies depend heavily on whether smokers are rational or not. As noted above, when consumers are rational and fully informed, interventions such as taxes that reduce smoking unambiguously make consumers worse off. This is not the case in any of the non-rational models that we have discussed. For example, Suranovic et al. (1999) argue that government intervention (such as taxes) would help prevent consumers from falling into a smoking "trap." In the model of Bernheim and Rangel (2004), taxes may (under certain additional assumptions about the pattern of consumption) be welfare-enhancing. In the model of Gruber and Koszegi (2004), a time-inconsistent consumer would be made better off by a tax that would reduce smoking and, in effect, save her future self from her current self. While these arguments are all intuitively appealing, each arises from a specific model of non-rational behavior, and there is no consensus about how welfare analysis should proceed in the general case where consumers are not rational in some unspecified way. Ideally, methods of welfare analysis would apply regardless of the nature of the deviation from rationality, with rational behavior treated as a special case of a more general model. The model that we discuss below has this feature.

III.C. How should we evaluate welfare when consumers are not fully informed and rational?

We propose a framework for analyzing the welfare implications of government interventions under different assumptions about consumer information and choice that is borrowed from Allcott and Sunstein (2015), whose applications are largely drawn from environmental regulation. The literature on welfare analysis under inconsistent choice is much

better developed (albeit evolving rapidly) in the context of environmental policy than health policy, so we rely on references and terminology that are relatively novel to the debate over tobacco regulation. Nonetheless, we argue that the underlying issues are the same[3] and that there is a great deal to be learned from the debates occurring in that field.

Allcott and Sunstein (2015), summarizing earlier work in behavioral public finance by, among others, Chetty (2015), Mullanaithan, Schwartzstein, and Congdon (2012), and Allcott and Taubinsky (2015), present a simple model in which individuals make a discrete decision such as whether or not to quit smoking. They take this action when their *decision utility d* exceeds a critical value p. The decision utility d is equal to the *experienced utility v* minus a bias parameter b. That is, $d = v - b$. The bias parameter b could reflect any one of a number of different inconsistencies, such as present bias (which is particularly relevant for smoking), inattention, or imperfect information. If the bias parameter b is zero, then the model is simply the classic model of demand, which is considered unbiased. The source of the bias is not important, however, for welfare analysis, as long as the amount of bias accurately reflects consumer choice. (The source of the bias will matter, however, for thinking about which policies might actually change consumer behavior.)

There are three implications from this framework for the welfare analysis of interventions that reduce smoking. The first is that there is a difference between the unbiased demand curve and the observed, biased demand curve. In the context of smoking, we think of the bias parameter as shifting demand outwards; this could be due to incorrect information about the health risks of smoking, incorrect beliefs about the difficulty of quitting, or the difference in perspectives between current and future selves driven by internally inconsistent discount rates. (In a nutshell, biased consumers smoke more than unbiased ones, which could be because they

[3] Note the similarity between Figure 1 in Alcott and Sunstein (2015) and Figure 1 in Ashley et al. (2014).

do not know how bad it is for them, do not realize how hard it will be to quit down the road, or simply cannot control themselves.) In a graphical analysis, we will need to draw (at least) two different demand curves for the welfare analysis, one representing the choices of the unbiased consumer (where "unbiased" is equivalent to "fully informed and rational") and another reflecting her actual, "biased" choices.

The second implication is that welfare analysis should be carried out using the unbiased demand curve. Consider a bias arising from imperfect information and an intervention that provides the consumer with perfect information. Her initial choices are uninformed, and once the information is provided her demand changes to the informed quantity. The welfare implications of this shift should be evaluated from the perspective of the fully informed consumer. In the case of an informational intervention that leaves consumers imperfectly informed — for example, overestimating or underestimating the health risks of smoking — it may be necessary to keep track of more than two demand curves. Typically there is one demand curve for the uninformed person, one for the person after they see the information (when the person has more information than before, but may not be fully informed), and a third for a fully informed person (who may or may not be equivalent to the person who sees the information). Some version of this approach appears in many of the recent papers that analyze the welfare implications of tobacco regulation under the assumption that consumers are not fully informed and rational. For example, Cutler et al. (2015) evaluate the costs and benefits of different interventions for what they term Type II consumers (those with higher demand for cigarettes, which may be due to misinformation and/or limited rationality) using the demand curve estimated for Type I consumers (the rational, fully informed consumers). Gruber and Koszegi observe in both their papers that they "take the agent's long-run preferences as those relevant for social welfare maximization" (Gruber and

Koszegi, p. 1287, 2001; p. 1966, 2004), while Bernheim and Rangel (2004) treat "cold" preferences as a welfare standard. Thus, the idea of using the unbiased demand curve for welfare analysis already appears in the literature on tobacco regulation under several different names.

A third implication is that we can rely on consumer surplus calculated using the unbiased demand curve for welfare analysis, because the unbiased demand curve reflects the value that fully informed and rational consumers place on different aspects of well-being (e.g., their own health versus the enjoyment from smoking). In particular, it is not necessary to calculate the health gains of a particular policy and then calculate an offset for foregone enjoyment; it is sufficient simply to look at changes in consumer surplus. Jin and colleagues (2015) emphasize this point in their discussion. It is possible to calculate the health gains and, by comparing them to changes in consumer surplus, see how much of an offset is implied relative to the gross health gains. Below, we derive a general formula for the relationship between consumer surplus gains and health gains that reinforces the point that these approaches are mathematically interchangeable. It also demonstrates that the necessary offset, in an approach that begins with health gains, may be very small or very large depending on how far demand is from the optimal level. Moreover, the emphasis placed (albeit implicitly) on different outcomes is quite different if we begin by focusing on health gains and, as an afterthought, subtract off some loss of consumer well-being than if we posit at the outset that consumer surplus is the starting point for a discussion of a policy's welfare impact.

Having proposed this framework, we now use it to illustrate graphically the welfare implications of either taxes or information campaigns. Throughout, we identify both the change in net consumer welfare and the (internal) health gains associated with any reduction in smoking, so that the difference between these two quantities is clear.

IV. Welfare analysis of policies that discourage smoking: static model

We present a graphical analysis of the welfare implications of two different types of policies: taxes and an informational intervention. We assume that the demand curve is linear and that the supply curve is flat. We vary the size of the taxes and the effectiveness of the informational intervention, and we will illustrate the welfare implications of these policies under different assumptions about whether consumer demand is biased or not. We begin by assuming that consumer choices are unbiased, and then we relax that assumption to allow some bias.

As already noted, we ignore any externalities from smoking and focus only on how the government intervention affects the smoker. Although spillover effects of smoking through second-hand smoke are considerable and important, they are not part of this analysis. The FDA analysis already takes into account the effects of smoking (or cessation) on others; the only point of contention is how to count the foregone consumer surplus of the smoker. Moreover, there is no interaction between the externality of smoking on others and any lost consumer surplus. We also do not consider peer effects; for a discussion of this issue, which is conceptually similar to an externality, see Laux (2000). Our graphical analyses are restricted to a one-period model, which is unrealistic, but necessary for graphical presentation; the behavioral public finance framework itself is readily adaptable to a multi-period model.

We begin with the simplest case, in which consumers are unbiased and there is no government intervention (Figure 1). In this situation, consumption is Q_1: the intersection of D_u (the unbiased demand curve) and market price. There is no deadweight loss. Suppose that the government then imposes a per-unit tax. By definition, since consumer choices are unbiased, the imposition of a tax reduces consumer surplus; however, the tax also yields health gains. Let *s* be

the per-unit health loss to the smoker. Figures 2A and 2B depict the impact of the tax; they are identical except for the fact that Figure 2A highlights the health gains from this tax, relative to the no-tax equilibrium depicted in Figure 1, while Figure 2B highlights the change in consumer surplus. The health gains are the parallelogram *H* in Figure 2A, with area $s(Q_1 - Q_0)$, while the consumer surplus loss is triangle W_L in Figure 2B, with area $0.5t(Q_1 - Q_0)$. In the special case where the tax *t* is exactly equal to the health cost *s*, then the welfare loss W_L is exactly one-half the size of the health gain *H*. In this case, although the tax yields health gains, it has negative consequences for consumer welfare.

Next, we consider a slightly more complicated case in which consumer demand is biased by some factor *b* which shifts the demand curve outward. In this case, consumption is Q_0: the intersection of the biased demand curve D_b and the market price (Figure 3). The unbiased demand curve D_u lies below D_b and the unbiased level of consumption would be Q_1. In other words, biased consumers consume more cigarettes than they would if they were unbiased. Suppose that, as before, the government imposes a per-unit tax *t*; for purposes of illustration, suppose that the magnitude of *t* is such that it exactly offsets the bias *b* and moves consumption to Q_0. Figure 4A highlights the health gain from the tax, relative to the no-tax equilibrium in Figure 3, as the parallelogram *H*. Figure 4B indicates the welfare gain from the tax as the triangle W_G, which is one-half the size of the health gain *H*. In the special case where the tax *t* exactly offsets *b*, the welfare gain W_G is exactly one-half the size of the health gain *H*. In contrast to the example above in which consumer demand was not biased (Figures 1 and 2), the imposition of a tax in this case improves consumer welfare, although not by as much as the health gains would suggest.

A similar analysis holds if we consider informational interventions rather than taxes. One complication in this case is that in order for information to have any effect, the nature of the bias must be either a lack of information (which we consider implausible in the case of tobacco) or a deviation from rationality that is amenable to the provision of information. Taxes, in contrast, have the power to change behavior regardless of the reason for the bias, or indeed, the existence of a bias. But if we are willing to allow the possibility of bias that is amenable to the provision of information, Figure 5A and 5B depict the health and welfare gains, respectively, associated with an information campaign that is optimal in the sense that it exactly offsets *b* and moves consumer demand to the unbiased optimum Q_1; these gains are identical to those depicted in Figures 4A and 4B. Taxes are not identical to informational interventions; for one thing, they transfer resources from consumers to the government in the form of tax revenue. The point of Figures 5A and 5B, though, is that the relationship between health gains *H* and welfare gains *W* is the same for any intervention that yields a change in consumption, regardless of whether the intervention is a tax or an informational campaign.

The examples in Figures 4 and 5 focus on interventions that are optimal in the sense that they move consumption to the unbiased level. Similar analyses apply if the government imposes a tax that is either less than or greater than this optimal level, reducing consumption not quite as far as the unbiased level in the case of a too-small tax or below the unbiased level in the case of a too-big tax. Appendix 1 illustrates these scenarios graphically, both for taxes and for informational campaigns. More generally, we can derive expressions for the welfare gain and health gain as a function of the tax *t*. For a biased consumer whose demand curve D_b lies *b* units above the unbiased demand curve D_u, the deadweight loss associated with a tax *t* is

$$DWL(t) = 0.5m(b-t)^2, \quad (1)$$

where *m* is the absolute value of the inverse of the slope of the demand curve. At $t = 0$, the deadweight loss is $0.5mb^2$. As *t* increases from zero to b, deadweight loss declines; at $t = b$, there is no deadweight loss, because the tax exactly offsets the bias. As *t* increases beyond *b*, the deadweight loss increases. The *change* in deadweight loss associated with a tax *t* compared with no tax is given by

$$\frac{\Delta DWL(t)}{\Delta t}|_{t=0}^{t=t} = 0.5m(b-t)^2|_{t=0}^{t=t} = -0.5mt(2b-t). \quad (2)$$

The welfare gain associated with a tax t is simply the negative of the change in the deadweight loss, which is a quadratic function of the tax:

$$W(t) = 0.5mt(2b-t) = -0.5mt^2 + mtb. \quad (3)$$

In contrast, the health gains $H(t)$ associated with a tax are linear in the tax:

$$H(t) = mbt. \quad (4)$$

Both of these functions are illustrated in Figure 6: the health gains grow linearly with a tax, while the welfare gains first increase, then decrease, with the square of the tax. Using equations (3) and (4), we can easily see how the health gains compare to the welfare gains. Taking the ratio of welfare gains to health gains and simplifying yields the expression

$$\frac{W(t)}{H(t)} = 1 - \frac{t}{2b}. \quad (5)$$

In other words, at $t = 0$, the health gains are equal to the welfare gains; at $t = b$, welfare gains are exactly half of health gains; as *t* approaches $2b$, the welfare gains represent an infinitesimal fraction of the health gains. Any tax greater than *2b* yields welfare losses, not gains, relative to the no-intervention equilibrium. Formulating these relationships in terms of the "consumer surplus offset" simply requires subtracting equation (5) from the number 1:

$$Offset = 1 - \frac{W(t)}{H(t)} = (t/2b). \quad (6)$$

Thus, for extremely small taxes (close to zero) health gains closely approximate welfare gains for biased consumers, and the consumer surplus offset that is required for regulatory impact analysis is negligible. For taxes close to the optimal level ($t = b$), the health gains are twice the welfare gains, so the offset is 50 percent. As taxes increase beyond the optimal level, the offset increases linearly, until it is 100% at $t = 2b$. For a tax greater than *2b* the notion of an offset is no longer applicable because taxes in this range actually entail welfare losses, relative to the no-intervention equilibrium. This example underscores the important point that even in a simple case, the consumer surplus offset is not constant, but varies depending on the size of the intervention-induced consumption change. This relationship is illustrated in Figure 8.

There are two points worth emphasizing about this analysis. First, for a consumer who is unbiased, taxes of any size will create welfare loss. Second, for a consumer who is biased, taxes or other interventions to offset behavioral biases will increase consumer welfare, provided that

the intervention is not too big in the sense that is pushes demand below the unbiased optimum. Third, for a consumer who is biased, interventions that push demand below the unbiased optimum have an ambiguous effect on welfare, relative to the no-intervention state, depending on how far below the unbiased optimum the intervention reduces demand. There is a range in which interventions that are "too big" are preferable, in terms of consumer welfare, to the absence of intervention; but there comes a point at which no intervention would be preferable.

V. Extensions: Non-linear demand curves and multi-period models

The figures in section IV show linear demand curves. These curves are easy to draw, easy to shift, and easy to analyze. Actual demand curves, however, may not be linear. While the theoretical literature is partial to linear demand curves, the empirical literature is partial to constant elasticity curves, which are convex to the origin. We are not aware of empirical literature that conclusively resolves whether demand curves for smoking are linear or log linear, although as we show in this section such evidence would be important to know.

Non-linear demand curves are not merely of academic interest. The area under the demand curve is affected by the shape of the curve. If the shape of the demand curve is decidedly non-linear and convex, then any welfare loss would be lower. The consensus estimate for the price elasticity of overall demand is around −0.4, with a fairly narrow range of −0.3 to −0.5 (Chaloupka and Warner, 2000). If we take the estimate of −0.4, then the area under the constant elasticity curve compared to the area of the triangle assuming linear demand is about one-third lower for a change in demand of 50 percent (see Appendix 2 for proof). Therefore, estimates of the welfare effects that assume linear demand curves may overstate those effects by about one-third.

As already noted, our graphical analysis above is for a static model. In the real world, most smokers purchase cigarettes over many years, perhaps over their entire adult lifetime. Therefore, any welfare effects should be summed over a lifetime and discounted appropriately. This is straightforward when decisions in each period are independent of decisions in other periods and discounting is exponential. In this case, the only economic consideration is what discount rate to use; the range used in regulatory impact analyses is typically three to seven percent, as suggested in Circular A-4, a "best practices" guide published by the Office of Management and Budget in 2003 (available at https://www.whitehouse.gov/omb/circulars_a004_a-4/). While the choice of a discount rate can be critical for cost-benefit analysis — particularly for policies that have upfront costs and benefits in the future — this is not our focus here.

VI. Discussion

Our review of recent tobacco regulation and related published papers leads us to reject the notion that foregone consumer surplus should not be counted as a cost in regulatory impact analysis. In other words, we are unconvinced by Chaloupka et al. (2015) that foregone consumer surplus should be largely ignored and gross health benefits used instead as a measure of consumer welfare. Even if consumers are not rational, the correct response from an economic perspective is not to abandon welfare analysis in favor of policies that maximize health; rather, it should be to figure out how to perform welfare analysis when consumers are not rational. We propose that health economists should embrace the behavioral welfare economics framework developed for this purpose, developed primarily with reference to environmental economics.

We acknowledge, however, the practical difficulty of implementing this framework. In particular, the behavioral welfare economics approach requires knowing the shape of not only the biased market demand curve, but also the shape of the hypothetical unbiased demand curve. This is a tall order. Once again, we propose drawing on the literature in environmental economics and behavioral welfare economics for inspiration (Allcott and Sunstein 2015; Chetty 2015; Mullanaithan et al. 2012). Researchers in this literature have for some time focused on the empirical question of identifying the extent of bias in consumer choices. We conclude by mentioning four approaches used in this literature, to sketch a research agenda that might help fill this key gap in health economics. In some cases, as we note below, health economics research has already used these approaches without necessarily linking them to behavioral welfare economics.

One approach that would offer some insight into the extent of bias is measuring the effects of nudges, where nudges are interventions that remove bias. In the smoking context, for example, graphic warning labels ought to serve as a nudge, as discussed by Bernheim and Rangel (2004), who refer to such labels as "counter-cues." The effect of graphic warning labels on actual smoking behavior remains an active and controversial area of research (Huang et al. 2014; Irvine 2016).[4]

Another approach uses self-reported well-being as an outcome measure. Chetty (2012) points out that this is analogous to the use of contingent valuation methods for valuing externalities: both approaches rely on individuals' reported assessments of their well-being or valuation of goods rather than observed willingness-to-pay. An excellent example of this

[4] Note that the impact of the Canadian graphic warning labels is important not only for what it would tell us about the extent of bias, but because it helps inform whether the labels yield even gross (let alone net) health benefits. The 2012 US Circuit court decision rejecting the FDA's attempt to require labels cites the FDA's analysis of the impact of graphic warning labels in Canada on smoking.

approach in the smoking context is Gruber and Mullainathan (2001), who find that excise taxes on cigarettes raise the self-reported well-being of smokers, but not non-smokers, which is consistent with the idea that smokers' behavior reflects bias. Similar evidence for graphic warning labels — for example, using data on well-being from one of the many countries that have these labels — would provide evidence on the extent of bias that is amenable to this intervention[5].

Perhaps the most theoretically obvious, but hard-to-implement approach, is identifying some consumers who are unbiased (or settings in which consumers may be unbiased) and comparing their demand with that of biased consumers. This approach goes by different names. For example, Chetty (2015) describes it with the term "sufficient statistics," Mullainathan et al. (2012) employ the phrase "using knowledge of when choices better reflect true preferences," and Cutler et al. (2016) refer to this as the "rational benchmark;" but the idea is the same. The difficulty lies in identifying which consumers are biased. Several papers in the smoking literature have used some version of this approach, relying on either demographic characteristics (age and education) or indicators of the extent to which smokers are addicted as proxies for being rational/unbiased (Weimer et al. 2009, Jin et al. 2015; Cutler et al. 2015).

A final approach is structural modeling. In practice, this requires making assumptions about the nature of the bias — for example, assuming that it is driven by time inconsistency that can be captured in a parameter such as present bias — and then bounding the consequences of a hypothetical policy by varying the parameter assumptions. Gruber and Koszegi (2001) use this approach to determine a possible range of optimal cigarette taxes. An appealing feature of this approach, in terms of regulatory impact analysis, is that these analyses already routinely include

[5] But see also Adler (2016) for cautions against the use of subjective well-being as a substitute for data on objective well-being.

a range of estimates generated by different assumptions about parameters such as discount rates, so that this aspect of the structural modeling approach is already familiar.

None of these approaches are easy, and we do not claim to have solved the practical question of how the FDA should carry out regulatory impact analysis of anti-smoking policies. But we hope that we have at least offered a bridge to a larger literature in behavioral welfare economics that will ultimately yield a general solution to the question of how to do cost-benefit analysis when consumer choice may be biased. Within health economics, this problem arises for many applications in addition to anti-smoking regulations. The regulation of alcohol; menu labelling; regulation of opioids; and decisions about whether or not certain drugs can be sold over-the-counter all raise the same difficult questions about how to measure benefits when consumer choice may be biased by information problems, lack of self-control, or time inconsistency, to name just a few possible sources of bias in these applications. The benefits of a general solution to this question, even within health economics, go well beyond anti-smoking regulations.

REFERENCES

Adler, Matthew D. "Behavioral Economics, Happiness Surveys, and Public Policy." Journal of Benefit-Cost Analysis 7, no. 01 (2016): 196-219.

Allcott, H., S. Mullainathan, and D. Taubinsky. 2014. "Energy policy with externalities and internalities." *Journal of Public Economics* 112: 72-88.

Allcott, H., and C.R. Sunstein. 2015. "Regulating Internalities." *Journal of Policy Analysis and Management* 34 (3): 698-705.

Allcott, H., and D. Taubinsky. 2015. "Evaluating Behaviorally-Motivated Policy: Experimental Evidence from the Lightbulb Market." *American Economic Review* 105 (8): 2501-2538.

Ashley, E.M., C. Nardinelli, and R.A. Lavaty. 2015. "Estimating the Benefits of Public Health Policies that Reduce Harmful Consumption." *Health Economics* 24 (5): 617–624.

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

Bernheim, B.D., and A. Rangel. 2004. "Addiction and Cue-Triggered Decision Processes." *American Economic Review* 94 (5): 1558–1590.

Chaloupka, F.J., and K.E. Warner. 2000. "The Economics of Smoking." In Handbook of Health Economics, Volume IB, A.J. Culyer and J.P. Newhouse, eds, pp. 1539–1627. New York, NY: Elsevier Science B.V.

Chaloupka, F. J., J. Gruber, and K.E. Warner. 2015. "Accounting for `Lost Pleasure' in a Cost-Benefit Analysis of Government Regulation: The Case of the Food and Drug Administration's Proposed Cigarette Labeling Regulation." *Annals of Internal Medicine* 162 (1): 64-65.

Chetty, R. 2015. “Behavioral economics and public policy: A pragmatic perspective.” *National Bureau of Economic Research* working paper number 20928.

Croley, S.P., 2008. “Regulation and Public Interests: The Possibility of Good Regulatory Government.” Princeton University Press, Princeton NJ.

Croson, R., and N. Treich. 2014. “Behavioral Environmental Economics: Promises and Challenges.” *Environmental and Resource Economics* 58 (3): 335–351.

Cutler, D. M., J. Gruber, R.S. Hartman, M.B. Landrum, J.P. Newhouse, and M.B. Rosenthal. 2002. “The economic impacts of the tobacco settlement.” *Journal of Policy Analysis and Management* 21 (1): 1-19.

Cutler, David M., Amber Jessup, Donald Kenkel, and Martha A. Starr. 2015. “Valuing Regulations Affecting Addictive or Habitual Goods.” *Journal of Benefit-Cost Analysis* 6 (2): 247-280.

Cutler, David M., Amber I. Jessup, Donald S. Kenkel, and Martha A. Starr. "Economic approaches to estimating benefits of regulations affecting addictive goods." American journal of preventive medicine 50, no. 5 (2016): S20-S26.

DellaVigna, S., 2009. “Psychology and economics: Evidence from the field.” *Journal of Economic Literature* 47: 315–372.

Gruber, J., and B. Koszegi. 2001. “Is addiction `rational’? Theory and evidence.” *Quarterly Journal of Economics* 116 (4): 1261–1303.

Gruber, J., and B. Koszegi. 2004. “Tax incidence when individuals are time-inconsistent: the case of cigarette excise taxes.” *Journal of Public Economics* 88 (9–10): 1959–1987.

Gul, F., and W. Pesendorfer. 2007. “Harmful addiction.” *Review of Economic Studies* 74 (1): 147–172.

Huang, Jidong, Frank J. Chaloupka, and Geoffrey T. Fong. "Cigarette graphic warning labels and smoking prevalence in Canada: a critical examination and reformulation of the FDA regulatory impact analysis." Tobacco control 23, no. suppl 1 (2014): i7-i12.

Iannaccone, L.R., 1986. "Addiction and Satiation." *Economics Letters* 21 (1): 95–99.

Irvine, I. 2016. "Graphic Warning Labels on Cigarette Packaging in Canada: A Targeted Commentary on our Limited State of Knowledge." Working Paper, Department of Economics, Concordia University, Quebec, Canada.

Jin, Lawrence, Don Kenkel, Feng Liu, and Hua Wang. 2015. "Retrospective and Prospective Benefit-Cost Analyses of US Anti-Smoking Policies." *Journal of Benefit-Cost Analysis* 6 (1): 154-186.

Laux, F.L. 2000. "Addiction as a market failure: using rational addiction results to justify tobacco regulation." *Journal of Health Economics* 19 (4): 421–437.

Malone, R.E. 2015. "FDA's toothless tiger and its `lost pleasure' analysis." *Tobacco Control* 24 (2): 105–105.

Mullainathan, S., and J. Schwartzstein, W.J. Congdon. 2012. "A Reduced-form Approach to Behavioral Public Finance." *Annual Review of Economics* 4: 511–540.

Orphanides, A., and D. Zervos. 1995. "Rational addiction with learning and regret." *Journal of Political Economy* 103(4): 739–758.

Regan, Elizabeth A., David A. Lynch, Douglas Curran-Everett, Jeffrey L. Curtis, John HM Austin, Philippe A. Grenier, Hans-Ulrich Kauczor et al. "Clinical and radiologic disease in smokers with normal spirometry." JAMA internal medicine 175, no. 9 (2015): 1539-1549.

Robinson, L.A., and J.K. Hammitt. 2011. “Behavioral economics and the conduct of benefit-cost analysis: towards principles and standards.” *Journal of Benefit-Cost Analysis* 2 (2): 1–51.

Sloan, F.A., V.K. Smith, and D.H. Taylor Jr. 2003. The Smoking Puzzle. Harvard University Press: Cambridge, Massachusetts.

Song, A.V., P. Brown, and S.A. Glantz. 2014. “When health policy and empirical evidence collide: the case of cigarette package warning labels and economic consumer surplus.” *American Journal of Public Health* 104 (2): e42-e51.

Stigler, G.J., and G.S. Becker. 1977. “De Gustibus non est Disputandum.” *American Economic Review* 67 (2): 76–90.

Suranovic, S.M., R.S. Goldfarb, and T.C. Leonard. 1999. “An economic theory of cigarette addiction.” *Journal of Health Economics* 18 (1): 1–29.

Viscusi, W. Kip. 1990. “Do smokers underestimate risks?” *Journal of Political Economy* 98 (6): 1253-1269.

Viscusi, W. Kip. Smoke-filled rooms: a postmortem on the tobacco deal. University of Chicago Press, 2010.

Viscusi, W.K, and Jahn K. Hakes. 2008. “Risk beliefs and smoking behavior.” *Economic Inquiry* 46 (1): 45-59.

Weimer, D.L., A.R. Vining, R.K. Thomas. 2009. “Cost-benefit analysis involving addictive goods: Contingent valuation to estimate willingness-to-pay for smoking cessation.” *Health Economics* 18 (2): 181-202.

Woodruff, Prescott G., R. Graham Barr, Eugene Bleecker, Stephanie A. Christenson, David Couper, Jeffrey L. Curtis, Natalia A. Gouskova et al. "Clinical significance of symptoms

in smokers with preserved pulmonary function." New England Journal of Medicine 374, no. 19 (2016): 1811-1821.

Comment submitted in response to Docket No. FDA-2010-N-0568, downloaded from regulations.gov on 10/19/2012

Comment submitted by Robert S. Maness, Docket No. FDA-2010-N-0568, downloaded from regulations.gov on 3/19/2012

“Required Warnings for Cigarette Packages and Advertisements,” 76 FR 120 (22 June 2011), pp. 36628 – 36777

Regulations Restricting the Sale and Distribution of Cigarettes and Smokeless Tobacco Products to Protect Children and Adolescents,” 60 FR 155 (11 August 1995), pp. 41314 – 41375

Figure 1

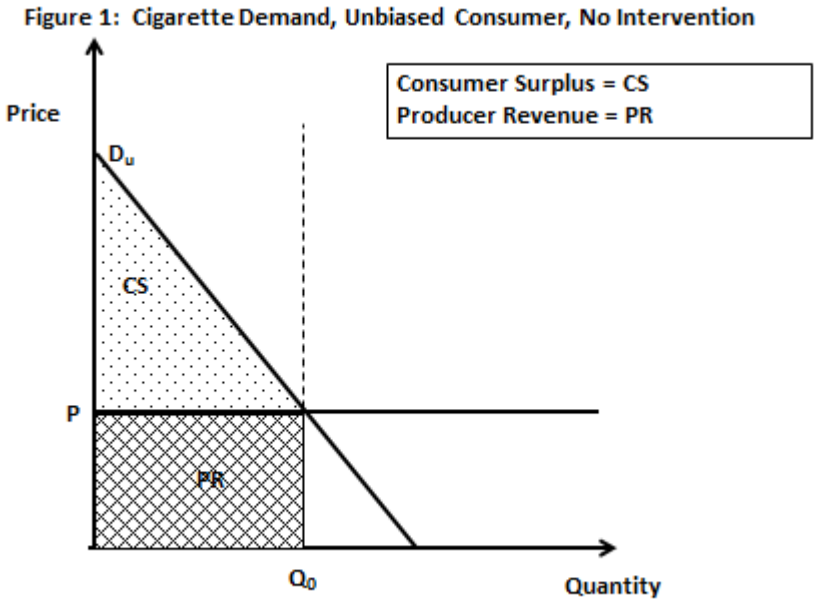


Figure 1: Cigarette Demand, Unbiased Consumer, No Intervention
Consumer Surplus = CS
Producer Revenue = PR
Price
D_u
CS
P
PR
Q_0
Quantity

Figure 2

Figure 2A: Cigarette Demand, Unbiased Consumer, Tax = health cost

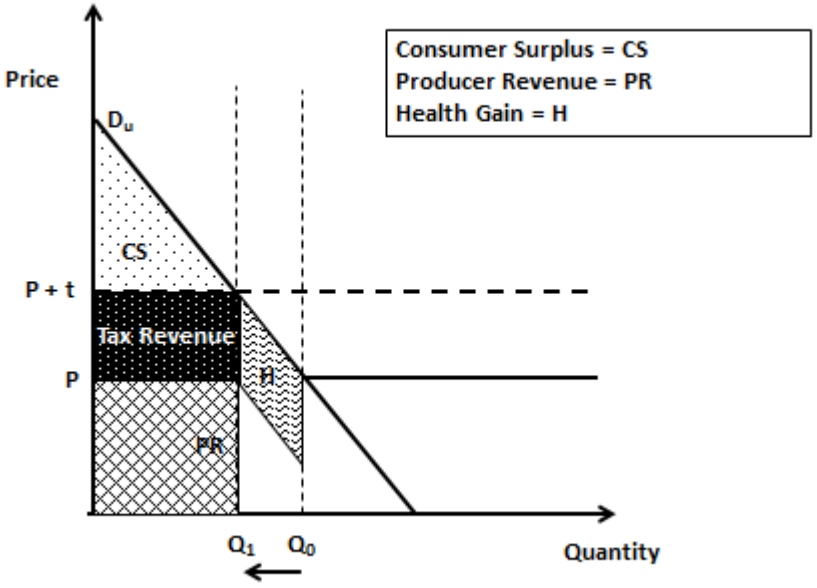


Figure 2B: Cigarette Demand, Unbiased Consumer, Tax = health cost

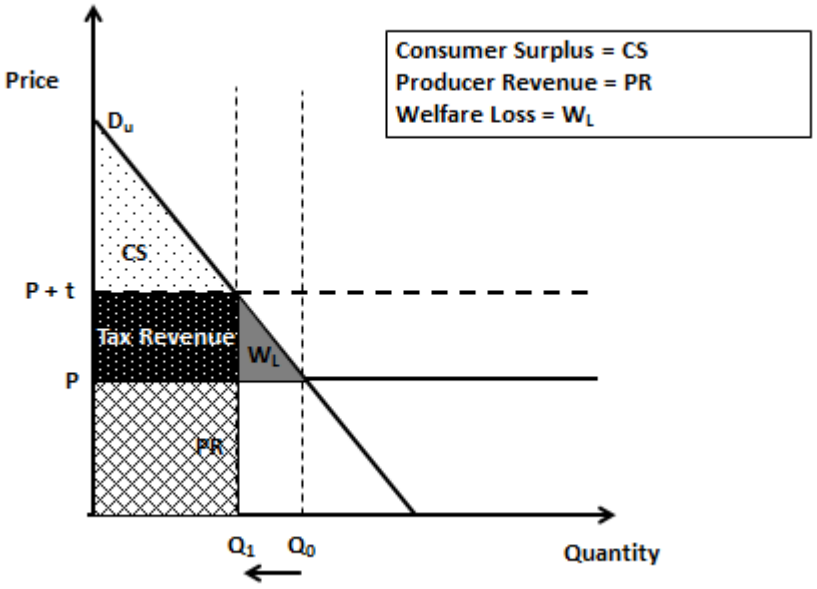


Figure 3

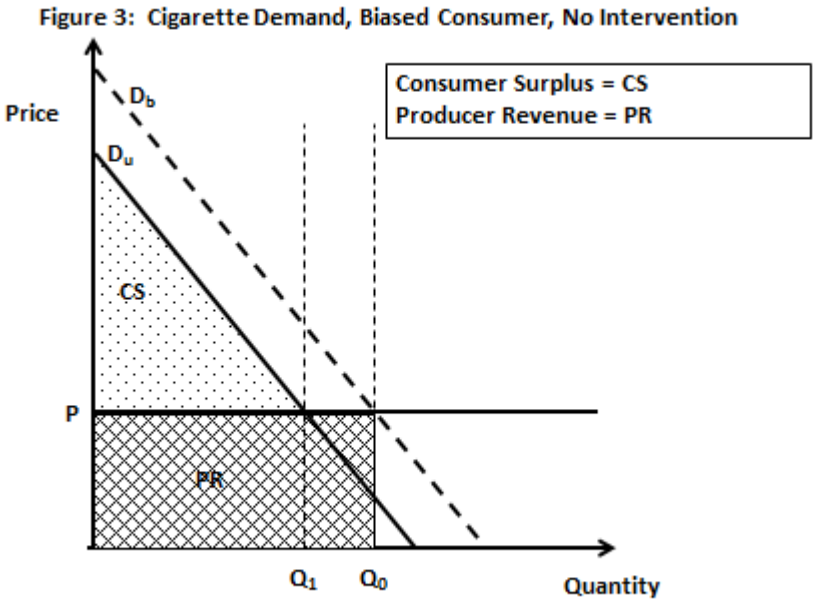


Figure 3: Cigarette Demand, Biased Consumer, No Intervention
Consumer Surplus = CS
Producer Revenue = PR
Price
D_b
D_u
CS
P
PR
Q_1
Q_0
Quantity

Figure 4

Figure 4A: Cigarette Demand, Biased Consumer, Optimal Tax

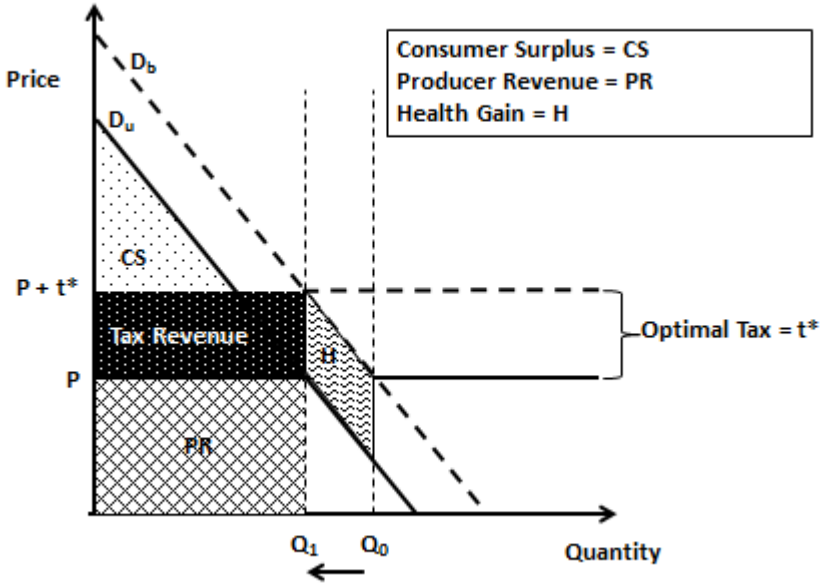


Figure 4B: Cigarette Demand, Biased Consumer, Optimal Tax

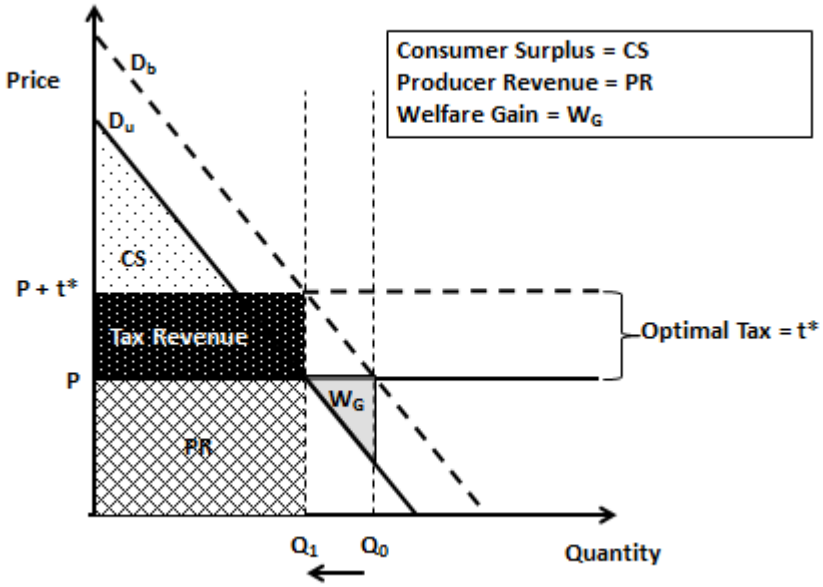


Figure 5

Figure 5A: Cigarette Demand, Biased Consumer, Optimal Info Campaign

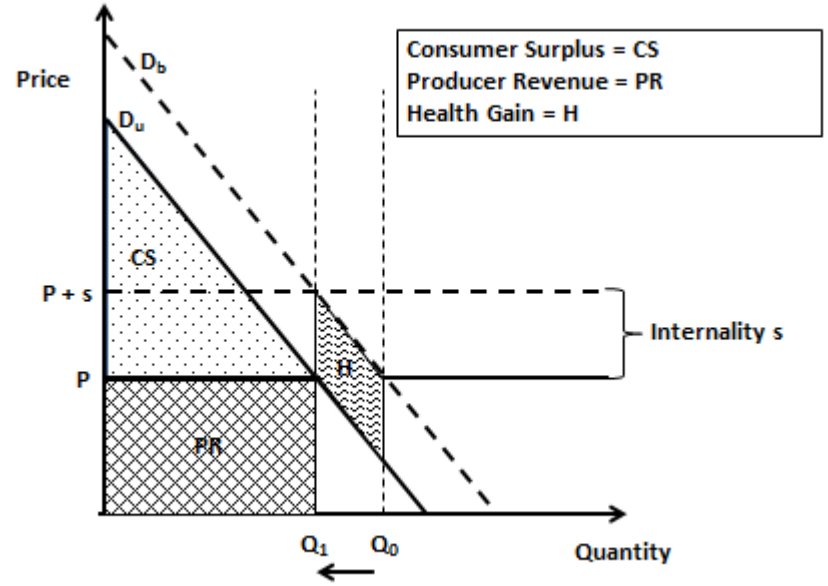


Figure 5B: Cigarette Demand, Biased Consumer, Optimal Info Campaign

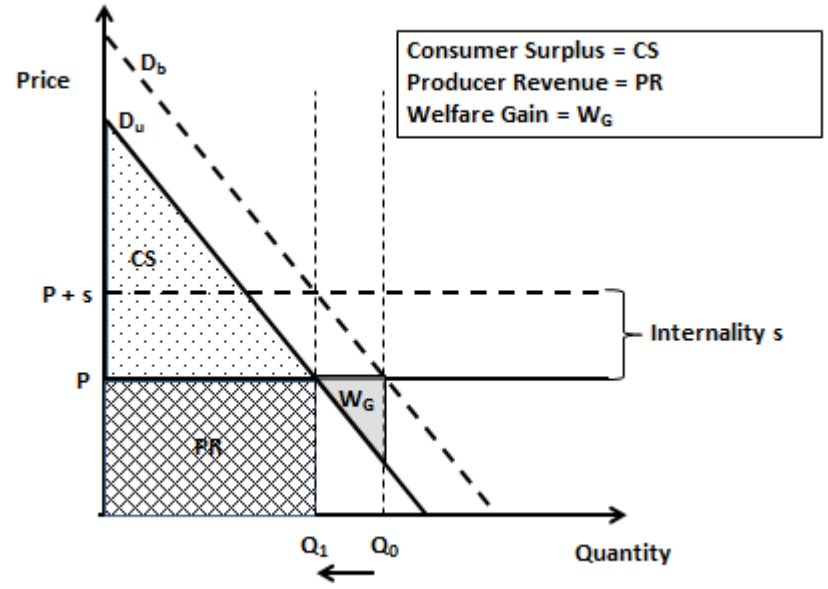


Figure 6

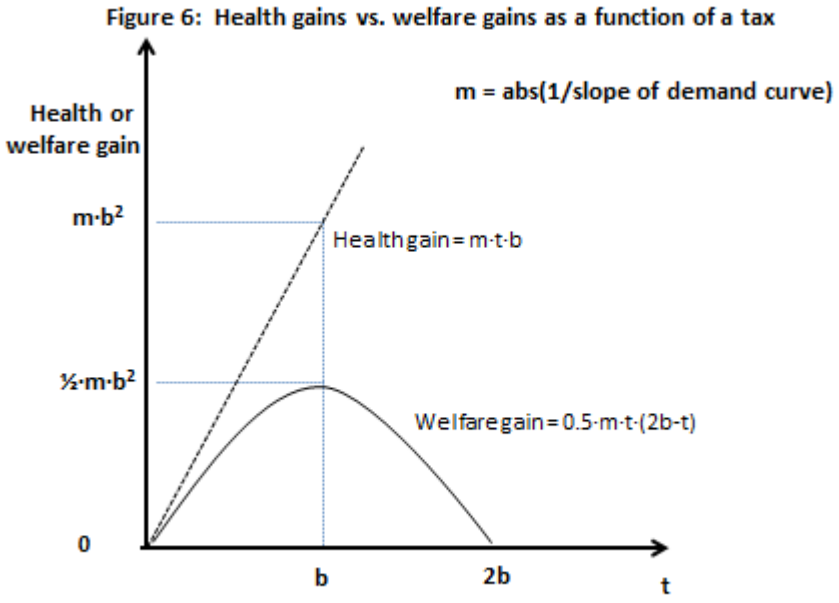


Figure 6: Health gains vs. welfare gains as a function of a tax
m = abs(1/slope of demand curve)
Health or welfare gain
m·b²
½·m·b²
0
Healthgain = m·t·b
Welfaregain = 0.5·m·t·(2b-t)
b
2b
t

Figure 7

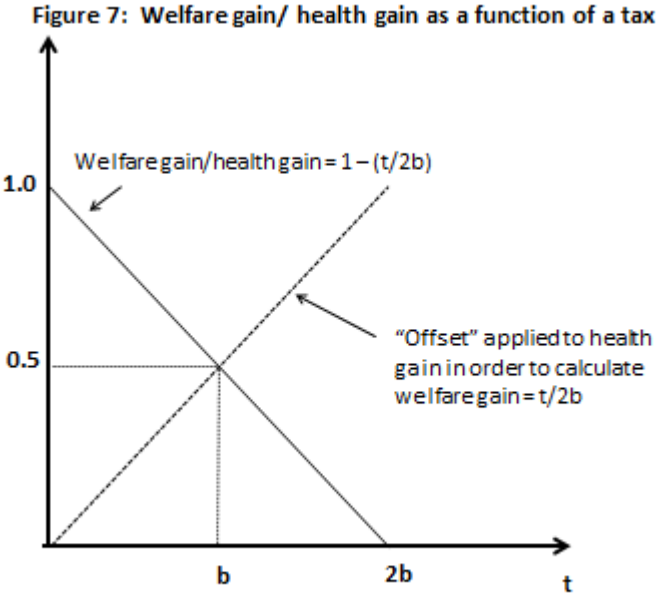


Figure 7: Welfare gain/ health gain as a function of a tax
Welfare gain/health gain = 1 – (t/2b)
1.0
0.5
"Offset" applied to health gain in order to calculate welfare gain = t/2b
b
2b
t

Appendix 1: Supplementary Figures Illustrating the Impact of Taxes or Informational Intervention when Consumers Are Biased

Figures 4 and 5 in the paper show the health gains and changes in consumer welfare in response to the imposition of an optimal tax (Figure 4) or an optimal informational intervention (Figure 5), relative to the no-intervention state shown in Figure 3, when consumer demand is biased upward and "optimal" is defined as a tax/informational intervention that shifts demand to the unbiased level. In this appendix, we show similar figures for taxes and informational interventions that are either smaller or larger than the optima level.

Appendix Figures 1A and 1B shows the health gains and welfare gains, respectively, associated with the imposition of a tax that is smaller than the optimal tax. Both the health and welfare gains are positive, compared to the no-intervention state shown in Figure 3 in the paper; but they are smaller than the corresponding health and welfare gains shown in Appendix Figures 4A and 4B. The important point, though, is that the welfare gain shown in Appendix Figure 1B is smaller than the health gain shown in Appendix Figure 1A; as the intervention increases from zero to its optimal level, the ratio of W to H declines from one to one-half (as illustrated in Figure 7 in the paper).

Appendix Figures 2A and 2B are exactly analogous to Appendix Figures 1A and 1B, except that they illustrate the impact of an informational intervention, rather than a tax, that is smaller than the optimal level in the sense that consumption is reduced, but not to the unbiased level.

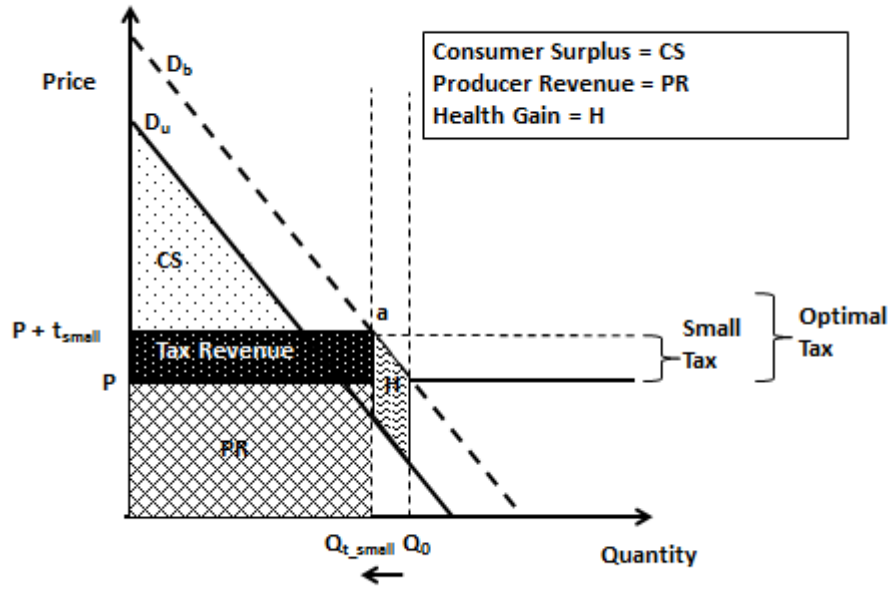
Next, we consider taxes that are larger than the optimal level. Appendix Figure 3A shows the health gains associated with a larger-than-optimal tax, which are even larger than the health gains associated with the optimal tax (depicted in Figure 4A in the paper). The welfare gain,

however, is another story. Appendix Figure 3B shows that the larger-than-optimal tax creates a welfare loss triangle in addition to the welfare gain triangle that was created by the optimal tax. The larger the tax, the larger the welfare loss triangle; ultimately, the welfare loss will be larger than the welfare gain, and the net effect of the tax on welfare will be negative. The health gains, in contrast, continue to increase linearly.

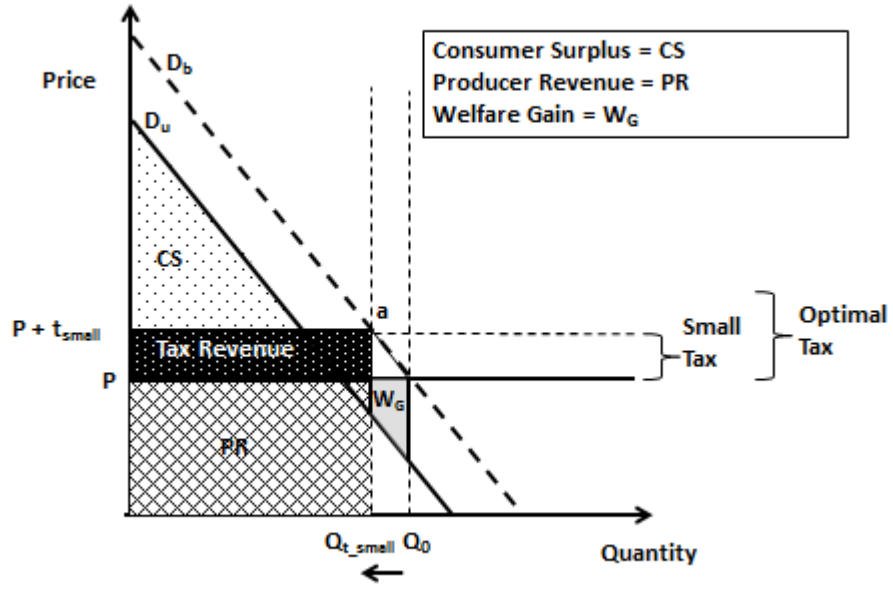
Finally, Appendix Figures 5A and 5B illustrate the impact of informational interventions that are larger than the optimal level, with results exactly analogous to those shown in Appendix Figures 4A and 4B.

Appendix Figure 1

Appendix Figure 1A: Cigarette Demand, Biased Consumer, Tax < Optimal Tax

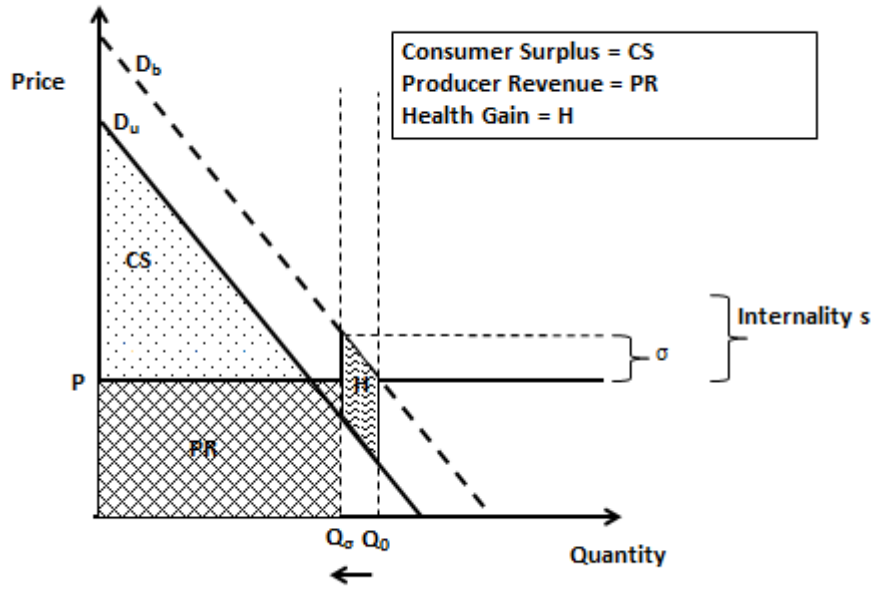


Appendix Figure 1B: Cigarette Demand, Biased Consumer, Tax < Optimal Tax

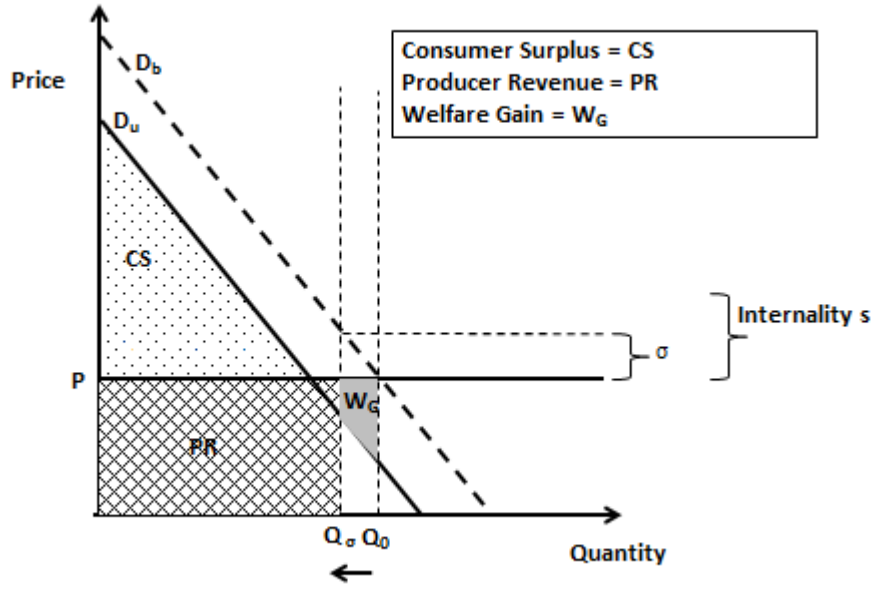


Appendix Figure 2

Appendix Figure 2A: Cigarette Demand, Biased Consumer, Smaller-than-Optimal Informational Intervention

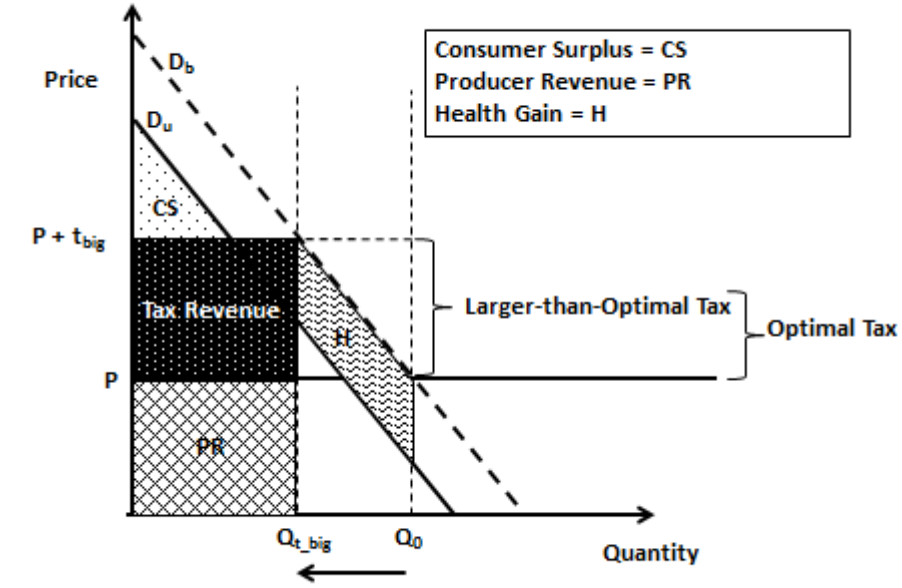


Appendix Figure 2B: Cigarette Demand, Biased Consumer, Smaller-than-Optimal Informational Intervention

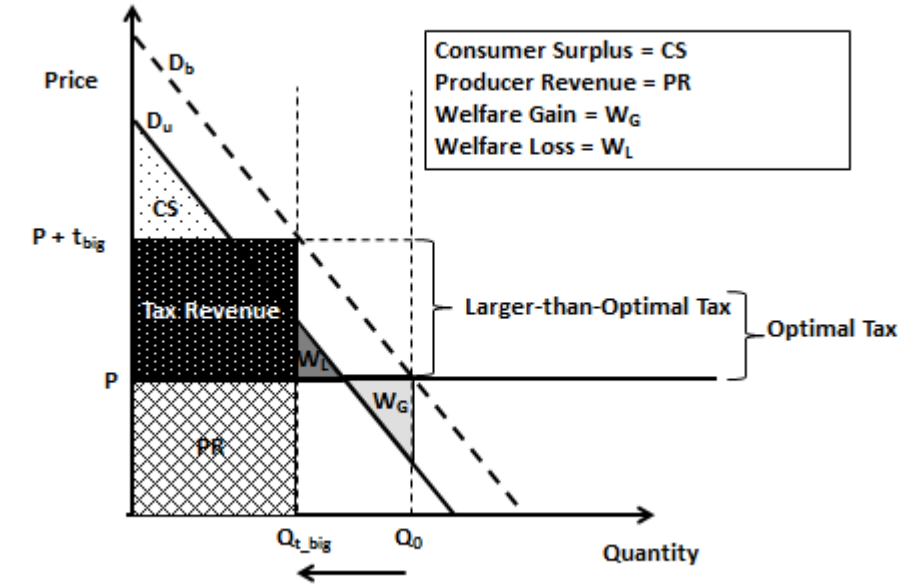


Appendix Figure 3

Appendix Figure 3A: Cigarette Demand, Biased Consumer, Tax > Optimal Tax

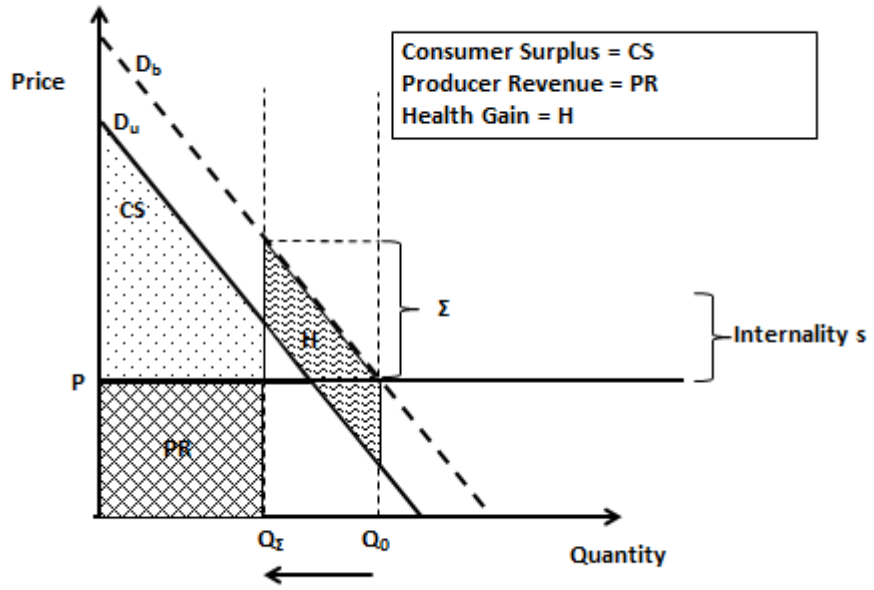


Appendix Figure 3B: Cigarette Demand, Biased Consumer, Tax > Optimal Tax

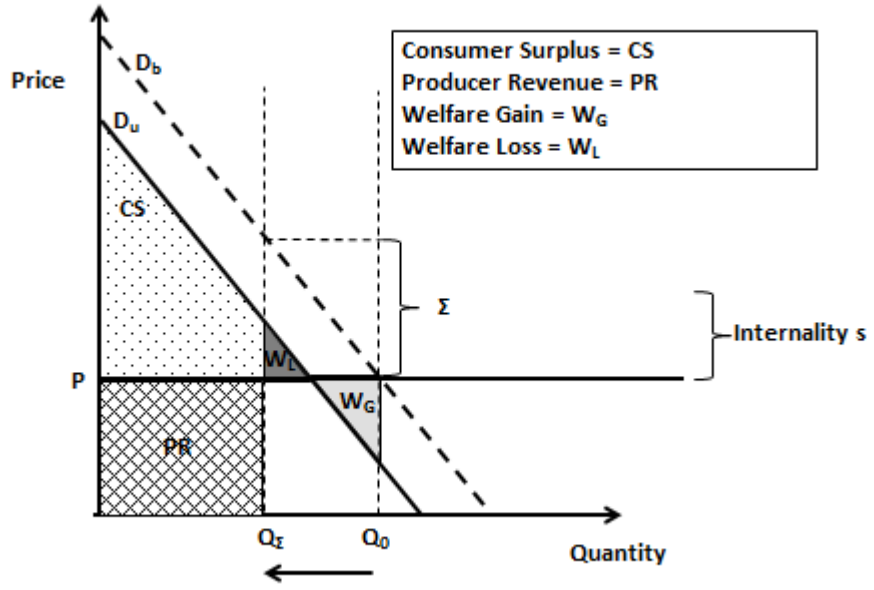


Appendix Figure 4

Appendix Figure 4A: Cigarette Demand, Biased Consumer, Larger-than-Optimal Informational Intervention



Appendix Figure 4B: Cigarette Demand, Biased Consumer, Larger-than-Optimal Informational Intervention



Appendix 2: Varying Assumptions about the Shape of the Demand Curve

The purpose of this section is to compare the welfare loss under two different assumptions about the shape of the demand curve, linear or constant elasticity. In the standard case of linear demand and flat supply curve, the welfare loss is a triangle. In the case of constant elasticity of demand, the demand curve is convex to the origin.

Let the demand curve have constant price elasticity, where the natural log of quantity *Q* is a linear function of the natural log of price *P*. The linear equation has constant *C* and elasticity *e*.

$$lnQ = C + elnP$$

Solving for *P*

$$lnP = \frac{1}{e}(lnQ - C)$$

$$P = \frac{exp\left(lnQ^{\frac{1}{e}}\right)}{exp\left(\frac{C}{e}\right)} = kQ^{\frac{1}{e}}$$

where $k = exp(-C/e)$.

Suppose that a tax lowers demand from $2q$ to q (as in Figure 2B). What will the welfare loss be? For the constant elasticity demand, the welfare loss is found by integrating the area between the demand and supply curves, from q to $2q$. Because the supply curve is flat, it equals the price at $P = k(2q)^{\frac{1}{e}}$.

$$ElasticityArea = \int_{q}^{2q} kQ^{\frac{1}{e}}dQ - q\,k(2q)^{\frac{1}{e}}$$

$$ElasticityArea = \frac{ke}{1+e}\left((2q)^{\frac{1+e}{e}} - (q)^{\frac{1+e}{e}}\right) - k2^{\frac{1}{e}}q^{\frac{1+e}{e}}$$

$$ElasticityArea = \left[\frac{e}{1+e}\left(2^{\frac{1+e}{e}} - 1\right) - 2^{\frac{1}{e}}\right] kq^{\frac{1+e}{e}}$$

For comparison to the linear demand case, we compute the area under the linear demand curve using the same two prices. The welfare loss with linear demand is one-half the change in quantity $(2q - q)$ times the change in price $P(q) - P(2q)$.

$$TriangleArea = 0.5q\left(kq^{\frac{1}{e}} - k(2q)^{\frac{1}{e}}\right)$$

$$TriangleArea = 0.5kq^{\frac{1+e}{e}}\left(1 - 2^{\frac{1}{e}}\right)$$

The ratio of the two areas is a constant.

$$\frac{ElasticityArea}{TriangleArea} = \frac{\left[\frac{e}{1+e}\left(2^{\frac{1+e}{e}} - 1\right) - 2^{\frac{1}{e}}\right] kq^{\frac{1+e}{e}}}{0.5kq^{\frac{1+e}{e}}\left(1 - 2^{\frac{1}{e}}\right)}$$

The constant *k* (containing *C*) and the quantity *q* fall out of the ratio.

$$\frac{ElasticityArea}{TriangleArea} = \frac{\left[\frac{e}{1+e}\left(2^{\frac{1+e}{e}} - 1\right) - 2^{\frac{1}{e}}\right]}{0.5\left(1 - 2^{\frac{1}{e}}\right)}$$

Appendix Table A-1 shows the value of this ratio for values of the elasticity between –0.9 and –0.1, where –0.4 is the consensus price elasticity from the smoking literature.

Appendix Table A-1: Ratio of Welfare Loss with Linear Demand and Constant Elasticity Demand

e	Ratio
–0.9	.760
–0.8	.745
–0.7	.726
–0.6	.701
–0.5	.667
–0.4	**.618**
–0.3	.542
–0.2	.419
–0.1	.220