Externalizing the Internality

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Abstract

We use a theoretical model and empirically-calibrated simulations of the automobile market to show how the traditional logic of Pigouvian taxation changes when consumers are inattentive to energy costs. Under inattention, there is a "Triple Dividend" from externality taxes: aside from reducing the provision of public bads and generating government revenue, they also reduce allocative inefficiencies caused by underinvestment in energy efficient capital stock. While Pigouvian taxes are clearly the preferred policy mechanism when externalities are the only market failure, inattention provides an "Internality Rationale" for alternative policies such as subsidies that reduce the relative price of energy efficient durable goods. However, heterogeneity in the way that consumers optimize or misoptimize means that non-discriminatory taxes and subsidies are blunt instruments for addressing misoptimization: any given policy is too strong for some consumers and too weak for others. We therefore discuss "Behavioral Targeting": the use of mechanisms such as tagging, screening, and nudges that preferentially affect misoptimizers. We also formally define a class of mechanisms called "Nudge-Inducing Policies," which are taxes specifically designed to encourage firms to use advertising, information provision, retail sales interactions, and other nudges to debias misoptimizing consumers.

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1   Introduction

A primary driver of the economic and policy interest in energy markets is concern about externalities from energy use, and in particular the carbon dioxide emissions from fossil fuel combustion. A second possible inefficiency is that consumers may be inattentive to energy costs when purchasing energy using durables such as automobiles and air conditioners (Hausman 1979). In the language of Hernstein, Loewenstein, Prelec, and Vaughan (1993), consumers may impose "internalities" on themselves by choosing goods that do not optimize their utility functions - in this case, goods that are unduly energy inefficient. Although the empirical evidence is still under debate, the idea that energy costs are not salient to consumers is consistent with findings that we are less elastic to sales taxes than to purchase prices (Chetty, Looney, and Kroft 2009) or that we are sometimes inattentive to "add-on costs" such as shipping and handling charges (Hossein and Morgan 2006).

This paper considers two types of public policies, energy taxes and product taxes, that can address inefficiencies from externalities and internalities. By "energy taxes," we refer to policies that directly affect energy prices, such as gasoline taxes, carbon taxes, or pollution cap-and-trade programs. By "product taxes," we refer to policies that affect the prices of energy using durables, such as "gas guzzler taxes" on low fuel economy automobiles and a large array of federal and state subsidies for home insulation, energy efficient appliances, and hybrid vehicles.

Since Pigou (1932), the conventional wisdom on energy taxes has been that they are the preferred, first best approach to addressing energy use externalities. Applied to carbon dioxide emissions, the Pigouvian logic is that energy taxes reduce current consumer welfare, this is offset by the fact that the reduction in climate change externalities produces a net increase in social welfare. Product taxes, on the other hand, are a second best approach: they do not impose the correct price on consumers' product utilization decisions, and they do not differentially affect the extensive margin choices of consumers who use a product more or less intensively. When energy use externalities are the only market failure, the evidence consistently shows that product taxes and related energy efficiency standards are extremely costly second best policies relative to the first best Pigouvian tax (Jacobsen 2010, Krupnick *et al.* 2010). The implication is that the political constraints against establishing a carbon tax or cap-and-trade program impose large costs in terms of economic efficiency.

Our paper begins by analyzing a stylized theoretical model where a competitive industry sells two durable goods, one higher cost but more energy efficient and one lower cost but energy inefficient, to a continuum of consumers with unit demand and a distribution of utilization needs. Using this model, we show that adding consumer inattention to energy costs reverses two fundamental elements of the above conventional wisdom on environmental taxes. First, we show that under inattention, a carbon tax not only reduces externalities but can actually increase consumer welfare. The intuitive reason is that inattention is a pre-existing distortion that reduces demand for energy efficient durable goods, and increasing energy taxes helps to correct this pre-existing distortion. Building on the canonical "Double Dividend" argument (Pearce 1991, Bovenberg and Goulder

1996), which is that Pigouvian taxes both reduce provision of public bads and generate revenue that can be used to reduce existing distortionary taxes, we call this effect the "Triple Dividend" of Pigouvian taxes.

The second fundamental reversal is that while inattention strengthens the case for energy taxes, it strengthens the case for product taxes even more. More specifically, we show that as inattention increases, correcting with an energy tax alone becomes less effective, because the larger tax required to correct larger extensive margin mistakes increasingly distorts intensive margin decisions. Meanwhile, the magnitude of the optimal product tax grows as consumers become more inattentive. As inattention grows and the optimal combination of energy and product taxes relies more heavily on the product tax, the welfare loss from having an energy tax constrained below marginal damages shrinks as a share of the total welfare gains from the optimal tax policy. The policy implication is that under inattention, constraints on the political feasibility of the Pigouvian tax do not impose such large costs in terms of economic efficiency, as it does not have its usual advantageous features relative to alternative policies. We call this the "Internality Rationale" for product taxes.

However, heterogeneity in the extent of consumers' inattention to energy costs substantially complicates the argument for product taxes and energy taxes. This sort of heterogeneity is probably quite realistic. For example, Allcott (2011b) shows that automobile owners have a wide dispersion in their understanding of energy costs and their beliefs about the potential savings from buying higher fuel economy vehicles. Furthermore, while 40 percent of Americans report that they "did not think about fuel costs at all" when buying their most recent vehicle (Allcott 2011a), others report explicitly calculating fuel costs, and one could also imagine that some consumers are overattentive.

Under heterogeneity, the first best no longer obtains under any combination of energy taxes and product taxes. Intuitively, this is because heterogeneous consumers on the margin between goods are making mistakes of different magnitudes, and taxes that affect all consumers equally are too strong for some consumers and too weak for others. We show that as the amount of heterogeneity increases, there is a growing remaining inefficiency between the welfare maximizing tax policy and the first best. This makes targeting very important, because the welfare effects of a policy trade off the gains from moving misoptimizing consumers toward their optima with the losses from distorting choices of consumers that were already optimizing.

To complement the theoretical analysis, we simulate a detailed model of automobile demand in the United States. The demand system is calibrated to match empirical data on the distribution and price elasticity of vehicle miles traveled, the market shares for a recent choice set of new vehicles, the average level of consumer inattention, and the survival probabilities of vehicles as they age. We estimate the magnitude of the Triple Dividend, showing that increasing the energy tax by the estimated climate change externality *increases* the present discounted value of consumer surplus by $5 per new vehicle buyer, or about $50 million per year.

We also simulate the Internality Rationale for product taxes. We estimate that the socially optimal product tax when the energy tax is politically constrained to zero generates more than twice

the social welfare gains of the socially optimal energy tax with the product tax constrained to zero. Furthermore, we show that this optimal product tax with a constrained energy tax generates more than 90 percent of the welfare gains of the unconstrained social welfare maximizing combination of energy and product taxes. Finally, the simulations illustrate the importance of heterogeneity in the internality: under what might be a conservative assumption about the variance of inattention, the social welfare maximizing pair of taxes leaves a remaining inefficiency of about 1/4 of the total potential welfare gains between the baseline and first best.

Heterogeneity in the internality motivates our final section. Ideally, the policymaker would utilize mechanisms that preferentially target inattentive consumers. We therefore present four general classes of policy mechanisms for "behavioral targeting," using examples from the context of energy efficiency. The first is "tagging," which analogous to the discussion of tax targeting in Akerlof (1978), is to limit program eligibility to classes of consumers who are observably more likely to be misoptimizing. The second mechanism is screening: designing programs that misoptimizing types are more likely to take up. Third, we discuss government-provided or government-mandated "nudges": aspects of a choice situation that affect misoptimizers more than rational consumers.

In practice, firms can use advertising and sales interactions to nudge consumers much more powerfully than the government, and many nudges are too nuanced to be verifiable. Motivated by this challenge, our fourth policy mechanism is what we call "Nudge-Inducing Policies": particular types of taxes, subsidies, or other mechanisms specifically structured to encourage firms to nudge. The intuition behind the Nudge-Inducing Policy is that firms "produce" internalities when they sell a consumer a product that does not maximize the consumer's experienced utility. While it may be very difficult to determine whether any specific consumer has misoptimized, correlates of internalities can often be found. For example, consumers that buy energy inefficient models and then use them heavily are more likely to have misoptimized than heavy users that buy energy efficient models. Taxing the firm on correlates of internality production - in this example, taxes on selling energy inefficient durable goods to consumers with high utilization - induces them to reduce that production by nudging misoptimizing consumers. We develop this idea in a formal model that builds on the behavioral competitive equilibrium notion in Koszegi and Heidhues (2009).

The Nudge-Inducing Policy is what motivates the title of our paper. A central message of traditional environmental policy is to "internalize the externality" through policies that insert the externality into firms' cost functions or consumers' utility functions. We point out that a potentially useful element of public policy when consumers misoptimize can be to "externalize the internality" through policies that insert consumers' internalities into firms' cost functions. While our examples center on energy efficiency, this broader insight can also apply to other domains: while economists have traditionally considered how policies affect demand directly, as well as indirectly through firms' pricing, entry, and exit decisions, we might also be interested in how policies affect firms incentives to influence demand through nudges.

The paper proceeds as follows. In Section 2, we provide more background on energy policies,

inattention to energy costs, and other related literature. Section 3 presents our theoretical model and formal results on optimal tax policy and heterogeneity. Section 4 details the vehicle market simulation model and its results. Section 5 gives details of the four behavioral targeting mechanisms. Section 6 concludes.

2   Background

2.1   Inattention to Energy Costs

Hausman (1979) estimated the discount rate implicit in consumers' tradeoffs between purchase prices and future energy costs for a cross section of air conditioners with different energy efficiency ratings. In Hausman's preferred specifications, these "implicit discount rates" were 15 to 25 percent, which was above most individuals' cost of capital and well above any reasonable social discount rate. There is a large literature that builds on Hausman's seminal paper and claims that there is an "Energy Efficiency Gap": a wedge between the potentially profitable level of investment in energy efficient capital stock and the level that is actually observed. Concrete examples of such investments in energy efficiency include choosing hybrid instead of standard vehicles, compact fluorescent lightbulbs instead of incandescents, or energy efficient models of air conditioners, washing machines, water heaters, and other appliances. An additional type of investment is weatherization, where homeowners install improved insulation and seal windows and doors in order to keep indoor temperatures comfortable with reduced use of heaters or air conditioners.

Although the magnitude of the Energy Efficiency Gap is quite difficult to convincingly document (Allcott and Greenstone 2011), there are several types of market failures that could generate socially-inefficient levels of investment in energy efficient capital stock. First, current homeowners and landlords have a disincentive to invest in energy efficiency because future buyers and renters may not be able to perfectly observe these investments, meaning that the investments would not be fully capitalized into resale prices or rents (Davis 2009, Gillingham, Harding, and Rapson 2010). Second, due to credit market inefficiencies, consumers or firms might not have access to credit at the social cost of capital. Third, consumers may have imperfect information about the relative energy efficiency of different energy-using durables in their choice sets, or they may be unaware of possible energy efficiency investments.

The present paper does not model these market failures or consider their policy implications. We focus specifically on a fourth potential source of inefficiency: that consumers may misoptimize in ways that on average cause underinvestment in energy efficient durable goods. Specifically, we model consumers that are *inattentive* to energy costs: they do not fully value the energy cost differences across models, because these future energy costs are not salient at the time of purchase. The inattentive consumers in our model will be mathematically similar to "myopic" consumers in Gabaix and Laibson (2006). Such consumers do not think about "add-on costs" when they

purchase a good or service, and instead focus on the purchase price. Furthermore, these consumers do not rationally acquire information about add-on costs or rationally infer their magnitude.

There is empirical evidence from multiple domains that consumers are inattentive to ancillary product costs. Consumers on eBay, for example, are less elastic to shipping and handling charges than to the listed purchase price (Hossain and Morgan 2006). Mutual fund investors appear to be less attentive to ongoing management fees than to upfront payments (Barber, Odean, and Zheng 2005). Chetty, Looney, and Kroft (2009) show that shoppers are less elastic to sales taxes than to prices. Allcott and Wozny (2011), Busse, Knittel, and Zettelmeyer (2011), and Sallee, West, and Fan (2011) test whether changes in relative vehicle prices fully reflect changes in the relative present discounted values of gasoline costs induced by changes in retail gasoline price expectations. If vehicle prices do not fully adjust, a leading explanation would be that consumers are inattentive to gasoline costs when they buy vehicles. These analyses have not completed peer review, and their empirical results are not yet in agreement.

2.2   Energy Tax and Subsidy Policies

There are a wide array of state and federal policies that encourage energy efficiency. Our analysis focuses specifically on what we call "product taxes": subsidies or taxes that reduce the relative prices of energy efficient capital stock. Such policies include tax credits of up to $3400 for hybrid vehicles, which were available for the bulk of the last decade, as well as the "gas guzzler tax," an excise tax ranging from $1000 to $7700 on the sale of low fuel economy passenger cars. Another example is the Weatherization Assistance Program, which heavily subsidizes weatherization for about 100,000 low-income homeowners each year. Furthermore, in many states, electricity taxes fund subsidies or rebates for weatherization and energy efficient appliances; these "Demand-Side Management programs" cost about $3.6 billion per year (U.S. EIA 2010).

Our model also captures the effects of Corporate Average Fuel Economy standard. This policy requires that the fleets of new cars and trucks sold by each auto manufacturer have a minimum average fuel economy rating. The CAFE standard is comparable to a product tax in that it adds a relative shadow cost to the sale of energy inefficient vehicles, inducing automakers to increase their relative prices. The standard was substantially strengthened as part of the 2007 Energy Independence and Security Act: by 2020, each manufacturer's new cars and trucks must average 35 miles per gallon, up from approximately 23 miles per gallon in 2008.

In models that do not include inattention, energy efficiency subsidies tend to be relatively inefficient substitutes for the Pigouvian tax. Corporate Average Fuel Economy (CAFE) standards are the setting where this argument has been most carefully made: under the assumption that consumers optimize and uninternalized externalities from carbon dioxide emissions are the only market failure, Jacobsen (2010a, table 8) estimates that an increase in the CAFE standard reduces carbon dioxide emissions at a welfare cost of $222 per metric ton. This compares very poorly the paper's estimate of $92 per metric ton for a comparable increase in the gasoline tax.

Similarly, Krupnick *et al.* (2010) compare the cap-and-trade provisions of the proposed Waxman-Markey climate change legislation to the legislation's energy efficiency provisions, which include standards for buildings, lighting, and appliances. The cap-and-trade, or an equivalent carbon tax, abates carbon at a welfare cost of $12 per ton. If consumers do not misoptimize and there are no other investment inefficiencies, the energy efficiency standards are extraordinarily costly, at $60 per ton.

2.3   Related Literature

While we provide a particular formalization, some others have argued that inattention to energy costs can help to justify policies that subsidize or mandate the sale of energy using durables. The argument dates at least to an informal conclusion in Hausman's seminal (1979) paper: "This finding of a high individual discount rate does not surprise most economists. At least since Pigou, many economists have commented on a "defective telescopic faculty." A simple fact emerges that in making decisions which involve discounting over time, individuals behave in a manner which implies a much higher discount rate than can be explained in terms of the opportunity cost of funds available in credit markets. Since this individual discount rate substantially exceeds the social discount rate used in benefit-cost calculations, the divergence might be narrowed by policies which lead to purchases of more energy-efficient equipment."

Others have informally echoed Hausman's argument, including Parry, Harrington, and Walls (2007) and Neubauer, deLaski, DiMascio, and Nadel (2009).[1] Indeed, paternalism is an important part of the U.S. government's official cost-benefit analysis of CAFE standards.[2] Allcott and Wozny (2011), Fischer, Harrington, and Parry (2007), Heutel (2011), Krupnick *et al.* (2010), and Parry, Evans, and Oates (2010) also present theoretical or analytical models of the extent to which misoptimization by consumers of energy-using durables justifies energy efficiency standards and subsidies. Some, but not all, of these analyses find that energy efficiency standards and subsidies can improve welfare if consumers are sufficiently inattentive.

These arguments all special cases of what Allcott and Greenstone (2011) call the "win-win

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[1] In a discussion of CAFE standards in the Journal of Economic Literature, Parry, Harrington, and Walls (2007) write, "Higher fuel economy standards significantly increase efficiency only if carbon and oil dependence externalities greatly exceed the mainstream estimates . . . or if consumers perceive only about a third of the actual fuel economy benefits." In advocating for appliance efficiency standards, Neubauer, deLaski, DiMascio, and Nadel (2009, page 63) argue that "When purchases are made, often the buyer is in a rush (e.g., a broken-down furnace or refrigerator must be replaced quickly). In such "panic purchase" situations, efficiency performance gets little attention."

[2] In its Regulatory Impact Analysis of the recent tightening of the standards (2010, page 2), the National Highway Traffic Safety Administration (NHTSA) writes, "Although the economy-wide or "social" benefits from requiring higher fuel economy represent an important share of the total economic benefits from raising CAFE standards, NHTSA estimates that benefits *to vehicle buyers themselves* [original emphasis] will significantly exceed the costs of complying with the stricter fuel economy standards this rule establishes . . . However, this raises the question of why current purchasing patterns do not result in higher average fuel economy, and why stricter fuel efficiency standards should be necessary to achieve that goal. To address this issue, the analysis examines possible explanations for this apparent paradox, including discrepancies between the consumers' perceptions of the value of fuel savings and those calculated by the agency . . . "

argument" for energy efficiency. This argument is that energy efficiency policies reduce allocative inefficiencies both from uninternalized energy use externalities and from inefficiently low levels of investment in energy efficient durables caused by consumer inattention to energy costs or other market failures. Our analyses of the "Triple Dividend" from energy taxes and the "Internality Rationale" for product taxes are formalizations of this discussion.

Our analysis of paternalistic taxation relates to O'Donoghue and Rabin's (2006) theoretical and simulation analysis of sin taxes. The authors model a world with both rational consumers and hyperbolic discounters who make consumption decisions over a sin good with present benefits and future costs. Elements of our model and the policy implications are qualitatively similar, but there are two fundamental differences. First, the underlying economics of energy demand are different than for sin goods: energy consumers make choices both on the intensive and extensive margins, and there are separate policy instruments - energy taxes and product taxes - that act directly on each margin. This leads us to analyze a two-dimensional policy space and to derive formal results about when one kind of policy lever is more affective than another. Second, we focus on the fact that heterogeneity implies an important role for policies that preferentially target misoptimizing consumers, and we discuss potential forms that these policies might take. Fundamentally, this argument highlights the behavioral equivalent of tax targeting in other areas of public finance, such as Akerlof (1978), and echoes Bernheim and Rangel's (2005) argument that sin taxes do not improve welfare if misoptimizing consumers are inelastic to the tax.

3 Optimal Taxation of Energy-Using Durables

3.1 Setup

3.1.1 Consumer Utility

We model consumers who choose between an energy inefficient durable I, and an energy efficient durable E. Consumers have single unit demand, and the durables differ in their energy efficiency. A durable $i \in \{I, E\}$ consumes e_i units of energy per unit of utilization m, with $e_I > e_E$.

Consumers are differentiated by a parameter θ, which corresponds to how much a consumer will utilize his durable. In particular, we assume that each consumer chooses a utilization level $m > \theta$, from which he derives utility $u(m - \theta)$. To ensure the existence of an interior optimum, we assume $u' > 0$, $u'' < 0$, $\lim_{x \to 0} u'(x) = -\infty$ and $\lim_{x \to 0} u'(x) = 0$. We also assume that $|xu''(x)/u'(x)| > 1$ to ensure that the price elasticity of energy use is less than 1 for each consumer and that consumers use less energy when they purchase the more energy efficient durable. The parameter θ is distributed according to some atomless distribution F with positive support on the positive reals.

For simplicity, we assume that the two durable goods differ only in energy efficiency and not in how they directly impact a consumer's utility. We also assume that there is no outside option.

We abstract away from the outside option for two reasons. First, because we remain agnostic about how exactly consumer inattentiveness to differences in energy costs impacts their choice of an outside option. Second, because excluding an outside option also allows us to interpret our model as a model of consumer choice of efficiency enhancements such as weatherization. Indeed, I can be viewed as the status quo of all consumers who have not weatherized their homes, whereas E is the improved efficiency of consumers who have weatherized their homes.

Whatever consumers don't spend on purchasing the durable and subsequent energy use, they spend on the numeraire good. So if p_g is the cost of energy, p_j is the price of durable j, T is a transfer from the government and Y is the budget constraint, then a consumer derives utility

$$\{Y + T - p_j - gme_j\} + u(m - \theta) \tag{1}$$

from purchasing durable j and choosing m units of utilization. Notice that the term in brackets is consumption of the numeraire good: the amount of money from income Y and transfers T that the consumer has left over after purchasing the durable good and paying for energy. Each consumer's budget constraint is large enough so that the optimal choice m^* is an interior solution.

3.1.2 Consumer Choice

We assume that while a consumer's utility is determined by θ alone, consumer choice may also be driven by a "mis-optimization" or attention parameter γ.

It is helpful to define the function v as follows:

$$v(\theta, e, p_g) \equiv \max_m \{u(m - \theta) - p_g me\}.$$

Then a fully optimizing consumer chooses durable E if and only if

$$v(\theta, e_E, p_g) - v(\theta, e_I, p_g) > p_E - p_I.$$

Think of $v(\theta, e_E, p_g) - v(\theta, e_I, p_g)$ as the gross relative utility gain from more energy efficiency, and $p_E - p_I$ as the price of more energy efficiency. Mis-optimizing consumers, on the other hand, are not fully attentive to how differences in energy efficiency will impact their future utility, and choose E if and only if

$$\gamma[v(\theta, e_E, p_g) - v(\theta, e_I, p_g)] > p_E - p_I \tag{2}$$

for some $\gamma \in (0, 1)$.

We will use the following additional notation throughout the paper: p will refer to the price vector (p_I, p_E, p_g) and $\xi(\theta, \gamma, p)$ will denote the consumer's choice of durable I or E (at prices p).

3.1.3 The Government

Products $j \in \{E, I\}$ are produced in a competitive economy at a constant marginal cost c_j, with $c_I < c_E$. Similarly, energy is produced in a competitive market at constant marginal cost g. We let τ_E and τ_g denote the respective taxes/subsidies on product E and energy that are set by the government.[3] Prices are then given by $p_I = c_I$, $p_E = c_E + \tau_E$, $p_g = c_g + \tau_g$. We will use τ to refer to the tax policy vector (τ_E, τ_g), and use $T(\tau)$ to refer to the tax revenue from that policy. Note that consumers get $T(\tau)$ as a lump-sum transfer.

The government keeps a balanced budget and can use lump-sum taxes. This means that taxing/subsidizing durables purchases or energy use has no distortionary effects on other dimensions of consumption—that is, we abstract to a simplified scenario in which the cost of public funds is 1.

Finally, the government also cares about the damage caused by energy use. In particular, let ϕ denote the marginal damage per unit of energy used. Let $Q_g(p)$ be the amount of energy used at prices p.

For a consumer of type (θ, γ), define

$$V(j, \theta, \gamma) \equiv v(\theta, e_j, p_g) - p_j$$

to be the utility from purchasing durable j. Notice that for $\gamma < 1$, consumers misoptimize and thus they don't necessarily choose j to maximize $V(j, \theta, \gamma)$. Let H denote the joint distribution of (θ, γ); the government then wishes to set τ so as to maximize consumer utility net of the damage caused by energy use:

$$W(\tau) \equiv \int [V(\xi(\theta, \gamma, p), \theta, \gamma) + Y_\theta + T(\tau)]dH - \phi Q_g(p).$$

We will all W the *social welfare* and call $W^{SB} \equiv \max_\tau W(\tau)$ the *second best*. We will use W^{FB} to refer to the *first best*—the maximum social welfare that is obtainable under any possible combination of choices of durables and utilizations by consumers.[4]

At times we will be interested in a slightly different objective function that doesn't consider the marginal damage and focuses solely on consumer utility. We use W_0 to denote this objective function and define it exactly the same way as W except without the final term $\phi Q(p)$. We will refer to W_0 as *consumer welfare*. Unless otherwise noted, however, we focus our analysis on the social welfare W.

Figure 1 illustrates the setup of equilibrium in the durable goods market. The two goods are supplied perfectly elastically, and the incremental price of good E is the horizontal black line. The first best demand curve, if consumers all have $\gamma = 1$, is the solid blue line through points c and a. The shape of the demand curve is determined by the distribution of gross relative utility gain from

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[3]We do not lose any generality by not considering taxes/subsidies on product I. In our model, taxes τ_I' and τ_E' on products I and E, respectively, are choice and welfare equivalent to taxes $\tau_I = 0$, $\tau_E = \tau_E' - \tau_I'$.

[4]To be more precise, set $w(\theta) \equiv \max_{m, i \in \{I, E\}} \{u(m - \theta) - (c_g + \phi)m - c_i\}$. Then $W^{FB} = \int w(\theta)dF$.

good E, $v(\theta, e_E, p_g) - v(\theta, e_I, p_g)$, which itself is determined by the distribution of utilization needs θ. The first best equilibrium is at point a, with quantity demanded q^*. For the marginal consumer at that point, the gross relative gain just equals the incremental price.

However, consumers that are inattentive undervalue the gross relative utility gain $v(\theta, e_E, p_g) - v(\theta, e_I, p_g)$ by factor $\gamma < 1$, and their demand curve for good E shifts downward proportionally. The equilibrium under inattention is at point b, and the consumer welfare loss from inattention is the triangle abc.

3.2   The Triple Dividend

To keep our results simple and sharp, we work with a simple distribution of attention in which a fraction α of consumers have attention parameter $\gamma_L \in (0, 1]$ and a fraction $(1-\alpha)$ of consumers have attention parameter $\gamma_H \in [\gamma_L, 1]$. The distribution of attention is independent of the distribution of θ.

A canonical result is that in the case with only perfectly optimizing consumers and no other market failures other than energy use externalities, the Pigouvian energy tax at the level of marginal damages achieves the first best. We note this as Claim 1:

Claim 1 *Suppose that consumers optimize perfectly ($\gamma_L = \gamma_H = 1$). Then the first best is uniquely achieved with $\tau_g^* = \phi$ and $\tau_E^* = 0$.*

Analogously, if the government is maximizing *consumer welfare* W_0, then the optimal tax policy is $\tau_g^* = 0$, $\tau_E^* = 0$. This means that while the Pigouvian tax $\tau_g^* = \phi$ increases social welfare, it reduces consumer welfare.

When there are some inattentive consumers, however, additional intervention is optimal. When at least some consumers underconsume E, it is optimal to encourage more purchase of E with either a subsidy or a higher energy tax.

Proposition 1 *Suppose that $\gamma_L < 1$. Then $-\frac{\partial}{\partial \tau_E} W > 0$ and $\frac{\partial}{\partial \tau_g} W > 0$ at $(\tau_E, \tau_g) = (0, \phi)$. If (τ_E^*, τ_g^*) is an optimal tax policy, then either $\tau_E^* < 0$ or $\tau_g^* > \phi$.*

It should be emphasized that this proposition holds even if $\gamma_H = 1$. That is, even if some consumers choose optimally, then additional intervention is still beneficial, even at the cost of making these consumers' choices less efficient. The reason is that if a consumer with attention γ_H is indifferent between E and I at the policy $(\tau_E, \tau_g) = (0, \phi)$, then the social benefit of giving E to this consumer equals the social benefit of giving I to this consumer. Thus the efficiency loss from changing the choices of optimizing consumers who are close to indifferent between E and I is first-order zero. On the other hand, the gain to encouraging more consumers with $\gamma_L < 1$ to purchase E is first-order positive. This intuition was first emphasized by O'Donoghue and Rabin (2006) in their analysis of optimal sin taxes.

A clear corollary to Proposition 1 is that even if the government ignores externalities and focuses solely on consumer welfare W_0, subsidies or energy taxes are optimal.

Corollary 1 *Suppose that $\gamma_L < 1$. Then $-\frac{\partial}{\partial \tau_E} W_0 > 0$ and $\frac{\partial}{\partial \tau_g} W_0 > 0$ at $(\tau_E, \tau_g) = (0, 0)$. If (τ_E^*, τ_g^*) maximizes consumer welfare, then either $\tau_E^* < 0$ or $\tau_g^* > 0$.*

This corollary begins to illustrate how inattention reverses the result that energy taxes reduce consumer welfare. Inattention is a pre-existing distortion that reduces demand for the energy efficient good E below consumers' private optima. A positive energy tax induces some consumers that had misoptimized by choosing good I to instead choose good E, increasing consumer welfare. With a nod to the traditional Double Dividend result introduced earlier, we call this the "Triple Dividend" of Pigouvian taxes. The following proposition and corollary complete this result.

First, notice that if the government chooses not to subsidize the more energy efficient durable, then the socially optimal energy tax is above the marginal damage:

Proposition 2 *Suppose that government chooses to set $\tau_E = 0$. Then the optimal energy tax is $\tau_g^{**} > \phi$.*

Now, by setting $\phi = 0$, we get the corollary that a positive energy tax improves consumer welfare without any reference to externalities. That is, a positive energy tax is justified even when the government maximizes W_0, the objective function that assigns zero weight to the externalities caused by energy use.

Corollary 2 *If the government maximizes W_0 then the energy tax that maximizes consumer welfare is $\tau_g^{**} > 0$.*

Figure 2 illustrates how an energy tax increases consumer welfare. The setup is the same as in figure 1. For simplicity, imagine that all consumers have homogeneous $\gamma < 1$ such that the dashed red line is the market demand curve and q_L is the quantity demanded of E. An energy tax rotates up the demand curve, shifting the equilibrium to point d. The set of consumers between q_L and q_L' now purchase good E, as they do in the first best, and consumer welfare is higher. Although consumers also pay more in taxes, this money is recycled to them through transfer T. The energy tax that maximizes consumer welfare trades off these gains from improved product allocation with the allocative losses from reduced utilization due to higher energy prices.

3.3 The Internality Rationale for Product Taxes

Claim 1 above reminds us not just that the energy tax obtains the first best, but that the socially optimal product tax is zero when externalities are the only market failure. In this model, correcting externalities with a product tax can improve the allocation of E and I, but it does not generate

the first best utilization. The reason is that the energy price is still below social cost, so consumers buy more energy efficient goods but then use them too much.

When consumers are inattentive, however, product taxes become a necessary tool in optimal tax policy. Our results in this section analyze this claim, and provide conditions under which more inattention implies that product taxes become more important. By "important," we mean that the socially-optimal product tax grows larger in magnitude and that the welfare gains from the product tax also grow relatively larger.

Before proceeding, we emphasize that the simple intuition that more inattention calls for more intervention is not necessarily correct. Consider, for example, the effect of varying γ_L while γ_H is fixed at $\gamma_H = 1$. For intermediate values of γ_L, the optimal intervention might be quite sizable. However, as γ_L gets close to zero so that the less attentive consumers are nearly insensitive to the advantages of purchasing E, any taxes that fall short of making $p_I \approx p_E$ will have very little effect on the less attentive consumers. To make this effect very clear, consider the limit case $\gamma_L = 0$, so that unless $p_I = p_E$, consumers will not purchase E. Thus any intervention that impacts the choices of the γ_L consumers forces all consumers with $\gamma_H = 1$ to purchase E. So if there are enough consumers with $\gamma_H = 1$, then no intervention may be optimal at all.

However, we show that holding heterogeneity constant, more inattention does imply a higher subsidy. In particular, we show that if α and the ratio γ_H/γ_L are held constant, then a lower level of attention implies more subsidy.

More formally, let G (G') denote the distribution in which a fraction α of consumers have attention weight γ_H (γ_H') and a fraction $1 - \alpha$ have attention weight γ_L (γ_L'). Suppose that attention heterogeneity, and thus the second best welfare, is the same for these two distributions of attention: $\gamma_H/\gamma_L = \gamma_H'/\gamma_L'$. Assume, also, that $\gamma_L' < \gamma_L$. Then we have:

Proposition 3 *Suppose that* (τ_E^*, τ_g^*) *is an optimal tax policy under* G, *and suppose that* $\tau_E^{**} < \tau_E^*$ *satisfies* $c_E - c_I + \tau_E^{**} = \frac{\gamma_L'}{\gamma_L}(c_E - c_I + \tau_E^*)$. *Then* (τ_E^{**}, τ_g^*) *is an optimal tax policy under* G'.

Notice that Proposition 3 shows that as consumers become less and less attentive, the subsidy τ_E becomes more and more important relative to the energy tax τ_g in the second best tax policy. Our next proposition complements this result. Proposition 4 shows that the social welfare that can be achieved by the energy tax alone is decreasing in the inattentiveness of the consumers. Define W_{energy}^{TB} to be the third-best level of social welfare that can be achieved by the energy tax alone when the subsidy is fixed at $\tau_E = 0$.

Proposition 4 W_{energy}^{TB} *is smaller under* G' *than under* G *and* $W^{SB} - W_{energy}^{TB}$ *is larger under* G' *than under* G.

Finally, we reexamine the traditional result that political economy constraints that prevent the use of an energy tax create a large inefficiency because the subsidy is a poor substitute. We show that the less attentive the consumers, the larger the portion of the total inefficiency that can be fixed

by the subsidy alone. In particular, define $W^{TB}_{subsidy}$ to be the third-best level of social welfare that can be achieved by the subsidy alone when the energy tax is fixed at $\tau_g = 0$. Let W^{BL} be the *baseline* level of social welfare when $\tau_E = \tau_g = 0$. Now notice that $\Delta^{SB} \equiv (W^{SB} - W^{BL})/(W^{FB} - W^{BL})$ is the fraction by which the total inefficiency is reduced by the optimal combination of subsidy and energy tax. Similarly, $\Delta^{TB}_{subsidy} \equiv (W^{TB}_{subsidy} - W^{BL})/(W^{FB} - W^{BL})$ is the fraction by which the total inefficiency is reduced by the optimal subsidy when the energy tax is fixed at $\tau_g = 0$. The next proposition shows that $W^{TB}_{subsidy}$ is the same under G and G', and that the difference between Δ^{SB} and $\Delta^{TB}_{subsidy}$ decreases as consumers become less and less attentive. That is, the fraction of the total inefficiency that is reduced by using the energy tax in addition to the subsidy decreases as consumers become less attentive.

Proposition 5 $W^{TB}_{subsidy}$ *is the same under G and G' and $\Delta^{SB} - \Delta^{TB}_{subsidy}$ is smaller under G' than under G.*

3.4 The Welfare Effects of Heterogeneity

We now examine how well the government can do with optimal tax policy in the presence of inattention. That is, how much closer to the first best can a judicious use of taxes and subsidies bring us?

Proposition 6 states that when consumers are homogeneous in their inattention ($\gamma_H = \gamma_L$), a proper choice of subsidy recovers the first best.

Proposition 6 *Suppose that $\gamma_L = \gamma_H \equiv \gamma < 1$. Then the first best is uniquely achieved with $\tau^*_g = \phi$ and $\tau^*_E < 0$. Moreover, the size of the optimal subsidy, $|\tau^*_E|$, is strictly decreasing in γ.*

The basic intuition for the previous proposition can be illustrated by returning to Figure 1. Here again, the line connecting points c and a would be the demand curve if $\gamma = 1$, and the dashed line through point b is the true demand curve for a population of consumers who all have $\gamma_L = \gamma_H = \gamma < 1$. At $\tau_g = \phi$, consumers will choose in a socially efficient way on the intensive margin. However, when $\tau_E = 0$, consumers will underpurchase E relative to the social optimum: the equilibrium quantity will be $q_L < q^*$. A subsidy that reduces the relative price of E to the point where the equilibrium quantity demanded is q^* achieves the first best.

When consumers are heterogeneous in their degree of attention ($\gamma_L \neq \gamma_H$), the first best is no longer possible. Figure 3 illustrates this point. Imagine that the solid blue line is the demand curve for a perfectly attentive subset of consumers with $\gamma = \gamma_H = 1$, and the dashed red line is the demand curve for the subset of inattentive consumers with $\gamma = \gamma_L < 1$. The first best quantity demanded of the energy efficient good is q_H. A subsidy that brings the relative price of E to the dotted horizontal line will improve allocations for inattentive consumers, increasing quantity demanded from q_L to q'_L. However, the subsidy also distorts the decisions of the perfectly attentive

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types, increasing quantity demanded from q_H to q'_H. The simple logic is that a homogeneous subsidy cannot correct misoptimization by heterogeneous types. The subsidy level drawn in Figure 3 is too large for some consumers and not strong enough for others.

Notice that whether or not the first best can be achieved does not depend on how inattentive the agents are, but rather on whether or not they are homogeneous in their inattention. We will now show that the gap between the first best and the second best is increasing in the heterogeneity of attention.

We take two approaches to thinking about heterogeneity. First, we ask what happens as we increase or decrease the fraction of less attentive agents in the population. As would be suggested by proposition 6, when $\alpha \approx 0$ or $\alpha \approx 1$, so that the agents are concentrated around one particular level of attention, the second best should be very close to the first best. As we move α further away from 1 or from 0, however, the gap between the first and second best increases. This is part 1 of Proposition 7.

Second, we ask what happens when we broaden the support of the distribution of attention. It turns out that what determines the second best is not the absolute difference $\gamma_H - \gamma_L$ between the highest and smallest levels of attention, but rather the ratio γ_H/γ_L. For example, if $\gamma_L = 0.8$ and $\gamma_H = 0.9$, so that $\gamma_H - \gamma_L = 0.1$ and $\gamma_H/\gamma_L = 1.125$, then the second best may be quite close to the first best. On the other hand, if $\gamma_L = 0.2$ and $\gamma_H = 0.1$, so that $\gamma_H/\gamma_L = 2$, the second best is now much further from the first best, even though we still have $\gamma_H - \gamma_L = 0.1$. Intuitively, this is because the relation between the marginal attentive consumer and the marginal inattentive consumer is determined by γ_H/γ_L. For example, if the marginal attentive consumer assigns twice as much weight to energy costs than the marginal inattentive consumer, then his energy cost savings from purchasing E will be approximately 50% of the energy cost savings of the marginal inattentive consumer. The welfare result then stems from the fact that the allocation is less socially efficient the bigger the difference between the marginal consumers from the different attention groups.

Proposition 7 *Let W^{FB} denote the first best welfare and let W^{SB} be the maximum achievable welfare using taxes τ_E and τ_g. Then*

1. *Holding γ_L and γ_H constant, there is $\alpha^\dagger \in (0,1)$ such that $W^{FB} - W^{SB}$ is increasing in α when $\alpha > \alpha^\dagger$ but decreasing in α when $\alpha < \alpha^\dagger$.*

2. *Holding α constant, $W^{FB} - W^{SB}$ is continuous and strictly increasing in γ_H/γ_L.*

Propositions 7 illustrates one of our main points about heterogeneity and the efficacy of taxes: as consumers become more and more heterogeneous in their levels of attention, tax policy becomes more and more of a blunt instrument. Intuitively, this is because as the distance between different consumers' levels of attention grows, any "compromise" tax policy becomes further from each type's own optimal level.

Heterogeneity also implies that the *targeting* of a policy is important. This is true not just for tax policies, but also information disclosure or any other mechanism in general. To see this

mathematically, consider some policy instrument, denoted n. Denote by $D_L(n)$ and $D_H(n)$ the demand curves of the two attention types as a function of n. The social benefit of a marginal increase in the strength of the policy is

$$\alpha D'_L(n)b_L + (1-\alpha)D'_H(n)b_H \tag{3}$$

where b_L and b_H are the marginal social benefits corresponding to the marginal consumer of type L or H purchasing E. As illustrated by Figure 3, $b_L > b_H$: the marginal low attention type is making a larger mistake by failing to purchase E than the marginal high attention type, and the social welfare gains from moving the marginal low-attention type to the energy efficient good are larger. At some levels of a policy, b_H will be negative while b_L is positive: moving the marginal high-attention type to the efficient good will reduce welfare, while moving the marginal low-attention type will still increase welfare. The implication is that other things equal, a marginal increase in a policy n produces larger social welfare gains when D'_L is large relative to D'_H, i.e. to the extent that the inattentive types are more elastic to the policy. In Section 5, we look for policies that are "well-targeted" in this sense.

4   Simulating Optimal Energy Taxes

In this section, we complement the generalized theoretical analysis with a richly detailed simulation of consumer demand for automobiles. We use the simulation model to analyze the effects of energy taxes and product taxes to correct for both externalities and internalities.

4.1   Setup

While our model of automobile demand is detailed, our model of the supply side is quite stylized. We assume a perfectly competitive market, meaning that prices equal marginal costs, and a fixed choice set, meaning that we abstract away from technological change. While markups and investments could in principle respond differently to different tax policies, they are less central to our theoretical arguments about taxation and demand, and endogenous changes to product offerings are particularly difficult to model credibly.

We use the set of new cars and trucks of model year 2007 as our choice set.[5] Models are defined at the level of a manufacturer's model name, and each model has the sales-weighted average price

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[5] We define the choice set to be all "substitutable" gasoline-fueled light duty vehicles with EPA fuel economy ratings. This includes cars, pickups, SUVs, minivans, and other light trucks, but not motorcycles, cutaway motor homes, limousines, chassis cab and tilt cab pickups, hearses, and cargo, passenger, and camper vans. We also exclude the following ultra-luxury and ultra-high performance exotic vehicles: the Acura NSX, Audi R8 and TT, Chrysler Prowler and TC, Cadilliac Allante and XLR Roadster, Chevrolet Corvette, Dodge Viper and Stealth, Ford GT, Plymouth Prowler, and all vehicles made by Alfa Romeo, Bentley, Ferrari, Jaguar, Lamborghini, Maserati, Maybach, Porsche, Rolls-Royce, and TVR.

and energy consumption across its submodels. There are a total of 292 models in the choice set. Table 1 presents an overview of the choice set and simulation assumptions.

Vehicle prices p_j are from the JD Power and Associates "Power Information Network," a network of more than 9,500 dealers which collects detailed data on about one third of U.S. retail auto transactions. Each model's price is the mean of the final transaction price across all sales, including any cash rebate that the customer received from the manufacturer or dealer. If the buyer traded in a used vehicle, the price is further adjusted for the difference between the negotiated trade-in price and the trade-in vehicle's actual resale value. Market shares are from the National Vehicle Population Profile, a comprehensive national database of vehicle registrations obtained from R.L. Polk. Energy intensity e_j is the inverse of the U.S. Environmental Protection Agency's miles per gallon (MPG) in-use fuel economy ratings.

As in the theoretical model, we simulate both a energy tax and a product tax, the revenues from which are redistributed through the lump sum transfer T. Given that the simulations involve many models with many different energy intensities, however, the product tax now takes the form of a sales tax that scales linearly in each model's energy intensity, increasing total upfront cost by amount $\tau_p e_j$. In this context, of course, the "energy tax" can also be thought of as a gasoline tax. We assume that the value of uninternalized externalities ϕ from gasoline use is \$0.18 per gallon. This reflects a marginal damage from carbon dioxide emissions of \$21 per metric ton, as estimated by the U.S. Government Interagency Working Group on Social Cost of Carbon (2010). We use a gasoline price p_g of \$3 per gallon.

As in the theoretical analysis, we model that there is no substitution between the new vehicle market and an outside option: every consumer observed to buy a new vehicle will also buy a new vehicle in the counterfactuals, and every consumer that did not buy a new vehicle will not. This assumption is conceptually useful in this specific analysis. The reason is that each year's new vehicles subsequently become used vehicles, and thus the effects of a policy on new vehicle markets gradually affect the entire vehicle stock. We therefore can interpret welfare results as "long-run" results per year that the tax policy is in place. This also means that the "product tax" on low fuel economy vehicles can equally be interpreted as a subsidy for high-MPG vehicles or as a revenue-neutral "feebate" that combines a fee on low-MPG vehicles with a rebate for high-MPG vehicles..

We model consumers with the same utility functions as above, with three changes that add richness to the model. First, we add heterogeneous preferences for different models. These preferences enter through a model-level mean utility shifter ψ_j and a consumer-by-model unobserved utility shock ϵ_{ij}. Using the Berry, Levinsohn, and Pakes (1995) contraction mapping, the mean utility shifters ψ_j are calibrated such that predicted and observed market shares are equal. In reality, consumers' idiosyncratic preferences are correlated within different vehicle classes: some consumers have large families and prefer minivans, while rural consumers often prefer pickup trucks, and others are in the market only for sedans. To capture this, we assume that the utility shocks ϵ_{ij} have a

distribution that gives nested logit substitution patterns, where the nests are nine vehicle classes: pickups, sport utility vehicles, minivans, vans, two-seaters, and five classes of cars based on interior volume.

The second change to utility is that we add a term η which scales consumers' relative preferences for the numeraire good. The parameter η is calibrated such that the mean own price elasticity of demand across the available models is 5. This value was chosen to be consistent with the mean own price elasticity estimated by Berry, Levinsohn, and Pakes (1995, Table V) in their study of the automobile market.

Third, to solve for a specific lifetime vehicle-miles traveled (VMT) m_{ij}^* for consumer i in vehicle j, we impose a Constant Relative Risk Aversion functional form on $m - \theta$:

$$u(m_{ij} - \theta_i) = \frac{A}{1-r} \left(m_{ij} - \theta_i\right)^{1-r} \tag{4}$$

In this equation, A is a scaling factor, and r is related to the price elasticity of demand.[6] We jointly calibrate these parameters to reflect actual U.S. VMT demand. Specifically, we set r such that the price elasticity of demand at the mean VMT is 0.15, which is in the range of recent empirical estimates by Hughes, Knittel, and Sperling (2007), Small and Van Dender (2007), and Gillingham (2010).[7] We set A such that $\overline{\theta} = \frac{\overline{m}}{2}$, which ensures that elasticity does not vary too much over the support of θ. We assume a uniform distribution of θ_i, with support ranging from zero to twice the mean.

The mean θ is calibrated such that the mean simulated VMT matches national average lifetime VMT for vehicles observed in the 2001 National Household Travel Survey (NHTS), the most recent national survey with available odometer readings. As part of the survey, odometers for about 25,000 vehicles were recorded twice, with several months between the readings, and these data were used to estimate annualized VMT. We project measured VMT onto a set of vehicle age dummies, giving a set of estimated age-specific VMTs, denoted $\widehat{m}_a^*$: for example, average annual VMTs decline from 14,500 when new to 9600 at age 12 and 4300 at age 25. The estimated U.S. average potential lifetime VMT m^* is the sum of these estimated coefficients over an assumed 25 year maximum lifetime, $\sum\limits_{a=1}^{25} \widehat{m}_a^*$.

Of course, not every vehicle will survive to age 25, and future years must be discounted to

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[6]Specifically, if $\eta > 0$ is the absolute value of elasticity of demand for VMT with respect to p_g, r is:

$$r = \frac{1}{\eta} \frac{m_{ij}^* - \theta_i}{m_{ij}^*}$$

The choice of m_{ij} that maximizes utility in Equation (6) is:

$$m_{ij}^* = \theta_i + \left(\frac{\eta p_g e_j}{A}\right)^{-1/r}$$

[7]Hughes, Knittel, and Sperling (2007) find that between 2001 and 2006, this elasticity was between -0.034 and -0.077. Small and Van Dender (2007) estimate that between 1997 and 2001, this elasticity was -0.022. Using data from California between 2001 and 2008, Gillingham (2010) estimates a short-run elasticity of -0.15 to -0.2.

the present. The fourth addition to utility is a realistic calibration of discount rates and vehicle survival probabilities. We use a six percent discount rate, which reflects the average discount rate for vehicle buyers calculated by Allcott and Wozny (2011). To estimate survival probabilities, we use our national data on new and used vehicle registrations from 1999 to 2008 and project model-level year-on-year survival probabilities onto age dummies. These results are used to construct cumulative survival probabilities, denoted ϕ_a: for example, a new vehicle has a 60 percent chance of surviving to age 12 and a ten percent chance of surviving to age 25. The discount rate and survival probabilities are used estimate a multiplier Λ that translates the potential undiscounted lifetime values of gasoline costs and $u(m - \theta)$ to expected discounted values. Denoting the annual discount factor by δ, the multiplier is:

$$\Lambda = \frac{\sum_{a=1}^{25} \delta^a m_a^* \phi_a}{\sum_{a=1}^{25} m_a^*} \approx 0.436 \tag{5}$$

After these modifications, we now have a modification of the utility in (1). The utility that consumer i experiences from purchasing product j, choosing utilization m_{ij}^*, and receiving a transfer T is:

$$\eta \left\{ Y_i + T - p_j - \Lambda p_g m_{ij}^* e_j \right\} + \Lambda u(m_{ij}^*) + \psi_j + \epsilon_{ij} \tag{6}$$

Notice that the term in brackets is consumption of the numeraire good: the amount of money from income y_i and transfers T that the consumer has left over after purchasing the durable good and paying for gasoline. The three terms on the right represent the utility that the consumer derives from owning and using the vehicle.

For the simulations, we use a triangular distribution of γ, with mean of 0.75, which approximates the homogeneous γ estimated by Allcott and Wozny (2011) for U.S. auto consumers. There are no empirical estimates of the distribution of γ; we assume that the support of this distribution is $[0.5, 1]$. As in Section 3, consumers with $\gamma_i \neq 1$ do not necessarily choose the vehicle that maximizes indirect utility. Instead, they choose vehicle j over vehicle k if and only if:

$$\gamma_i \left[u(m_{ij}^*) - u(m_{ik}^*) \right] + \left[(\psi_j + \epsilon_{ij}) - (\psi_k + \epsilon_{ik}) \right] > \eta \left[(p_j - p_k) + \gamma_i \Lambda p_g \left(m_{ij}^* e_j - m_{ik}^* e_k \right) \right] \tag{7}$$

As in the theoretical model, we will be interested in policies that maximize either social welfare $W(\tau)$ or consumer welfare $W_0(\tau)$. We follow the Allcott and Wozny (2011) approach to calculating consumer surplus in discrete choice models when consumers misoptimize. In brief, this approach exploits the fact that experienced utility can written as the difference between a decision utility function, which represents a function that the consumer acts as if he is optimizing, and the internal-

ity, which captures the magnitude by which the consumer misoptimizes. Decision consumer surplus is the integral over consumers of decision utility, which can be calculated using the nested logit version of standard discrete choice consumer surplus formulas originally due to Small and Rosen (1981). The total internality is simply the sum over consumers of the internality. The change in experienced consumer surplus, which is our true measure of how a policy affects consumer welfare, is the change in decision consumer surplus minus the change in the total internality.

4.2   Simulation Results

Table 2 presents simulation results. Column 1 is the initial base equilibrium. The average new vehicle sold in 2007 has harmonic mean fuel economy 19.9 MPG, costs $15,446 in present discounted dollars to fuel over its lifetime, and emits a total of 67.3 metric tons of CO2. Column 2 is the first best. This could be obtained under $\tau_e = \phi$ in combination with individual-specific product taxes with magnitudes that depend on each consumer's γ and θ, calibrated to exactly offset the consumer's mistake. Compared to the baseline, experienced consumer welfare is higher by $34 per new vehicle buyer, discounted over the life of the vehicle. The present discounted value of marginal damages decreases by about $25 per consumer, meaning that total social welfare W is $58 higher.

As Allcott and Wozny (2011) point out, under plausible assumptions about the average population inattention, misoptimization causes much larger welfare losses than the uninternalized damages from carbon emissions. Some evidence of this can be seen in Column 2 by comparing the increase in consumer welfare between the baseline and first best, which is $58, to the reduction in externality damages, which is $25. Intuitively, this is because uninternalized carbon externalities are assumed to be $0.18 cents per gallon, or about six percent of gasoline costs, while the average inattention is assumed to be $\overline{\gamma} = 0.75$, which leaves 25 percent of gasoline costs uninternalized into product choices. Both sources of inefficiency act on the extensive margin the same way, by inducing consumers to buy vehicles that have lower fuel economy than in the social optimum, but under these parameter assumptions, misoptimization generates larger allocative distortions and therefore much larger welfare losses.

In presenting simulation results, we first discuss the optimal "second best" tax policy, by which we mean the combination of energy and product taxes that maximizes social welfare. We then present the magnitude of the Triple Dividend, the Internality Rationale for product taxes, and the welfare implications of increasing heterogeneity in the internality.

4.2.1   Second Best Tax Policy Combination

Column 3 of Table 2 presents the second best combination of energy and product taxes. The optimal level of this sales tax is $81,599 per gallon per mile energy intensity rating. A 20 MPG vehicle, such as a Subaru Outback Wagon, uses 0.05 gallons per mile, while a 25 MPG vehicle, such

as a Toyota Corolla, uses 0.04. This second-best τ_p thus implies a relative price increase of \$816 for the 20 MPG model.

Notice that the optimal gas tax is \$0.19, which is just above the level of marginal damages. To understand why this is the case, it is useful to contrast with the results from Proposition 6. In a setup with only one consumer type on the margin and homogeneous $\gamma < 1$, the first best can be obtained by setting a gas tax equal to marginal damages and a product tax that moves the correct consumer to the margin. However, as we introduce idiosyncratic utility shocks ϵ_{ij}, this generates variation in the θ types of consumers on the margin. Because the magnitude of the internality tends to be larger for consumers that drive more, it is optimal to impose larger relative vehicle price changes on these high-utilization consumers. The energy tax does this, while the product tax does not, so the second best optimal energy tax may be above marginal damages. As we will discuss momentarily, however, depending on the distribution of γ, the second best optimal energy tax could also be negative.

The policy maker may wish to restrict attention to policies where $\tau_g = \phi$. This could be because the distribution of γ is unknown, and this distribution has important implications for the magnitude and even the sign of the second best optimal energy tax. This could also be because pricing gasoline differently than social cost could distort other markets that are not subject to the same inefficiencies. Column 4 shows the effects of setting a product tax to maximize social welfare conditional on $\tau_g = \phi$. The social welfare gains are \$49 per consumer, which up to rounding error is identical to the gains from the second best combination of taxes.

From a practical perspective, the similarity of these two numbers is extremely important. The reason is that the socially optimal second best combination of taxes depends on the distribution of γ, which is difficult to know. However, it is almost as good to institute a "heuristic policy" of setting a Pigouvian energy tax at the level of marginal damages and setting the product tax to maximize social welfare given an assumed distribution of inattention. As we showed in Proposition 6, this heuristic policy achieves the first best when γ is homogeneous. Even in alternative simulation runs with very wide assumed distributions of γ, the heuristic policy never does worse than achieving 98 percent of the welfare gains from the socially optimal second best combination of energy and product taxes.

These corrective taxes help consumers in different ways. Figure 4 shows the average effects of the optimal second best combination of taxes as a function of the level of inattention γ. The Tax Recycling and Tax Payment lines, which average \$5000 and -\$5000 per consumer, respectively, are omitted to reduce the scale of the graph. All γ types benefit equally from tax revenue recycling and from reduced externalities. However, consumers with high γ buy lower-MPG vehicles and thus buy less fuel and pay substantially less in taxes.

The solid black line shows the "allocative" gains from the taxes. By "allocative" gains, we mean the gains in experienced consumer surplus W_0 net of tax payments and redistribution from tax recycling T. In essence, this is the net private gain to consumers from changes in vehicle

choices induced by the tax. The customers with lower values of γ experience greater improvement in allocations. However, for consumers that are more attentive, the corrective taxes worsen their choices: they are now buying vehicles that are more energy efficient than their private optima. We return to this issue later when we discuss heterogeneity: the second best tax combination is too strong for some types and too weak for other types, and the larger the variance of γ, the worse that a non-discriminatory tax policy does relative to the first best.

The triple blue line shows the net social welfare gain, including the externality reduction, by γ type. The integral of the area between the net social welfare gain and externality reduction lines, weighted by the density of γ types, is the total gain in consumer welfare; as reported in Column 3 of Table 2, this is $26 per consumer. For low-γ consumers, the allocative gains are balanced by higher tax payments, while for high-γ consumers, the allocative losses are balanced by lower tax payments. As a result, the net gains from the tax policy are fairly evenly distributed across the distribution of γ. The average consumer of each γ type experiences a welfare gain.

However, while Figure 3 presents the average welfare gains for the set of consumers within each γ type, this still averages over significant heterogeneity within γ. Aside from variability in γ, consumers also have idiosyncratic preferences ϵ_{ij} for individual vehicles and tastes θ_i for utilization. Consumers with large θ will pay large energy taxes and may experience net welfare losses. Consumers whose taste shocks ϵ_{ij} imply that they prefer low-MPG vehicles will pay large product taxes and may similarly be worse off. In the terminology of O'Donoghue and Rabin (2006), the tax policy generates a "quasi-Pareto improvement": although it does not generate a pure Pareto improvement across all consumers, it does increase welfare for the average consumer of each γ type.

This result is analogous to O'Donoghue and Rabin's (2006) finding that sin taxes with lump sum redistribution can generate quasi-Pareto improvements. The mechanism is the same: the consumers that make the largest mistakes pay the most in taxes, but they also benefit the most from improved choices. Consumers that did not misoptimize lose because the tax distorts their choices, but they pay less in taxes and benefit from redistributed tax revenues paid largely by the inattentive types.

4.2.2 The Triple Dividend

Aside from calibrating the second best tax combination, the simulations can also be used to measure the magnitude of the Triple Dividend: the potential *increase* in consumer welfare from energy taxes. This issue is important because energy taxes have proven politically intractable because of concerns that they will reduce consumer welfare. Consider now energy taxes in isolation, with zero product taxes. In Column 5, we set the energy tax equal to the marginal damage, which generates a gas tax of $0.18 per gallon. Consumer welfare increases by a present discounted value of $5 per new vehicle buyer. The Pigouvian energy tax set at the level of marginal damages reduces carbon dioxide emissions by 0.8 metric tons per consumer while increasing consumer welfare by $6.70 per metric ton abated. Column 6 presents the "third best energy tax," by which we mean the energy tax that

maximizes social welfare when the energy tax is constrained to zero. This is $0.39 per gallon - well above the level of marginal damages.

Figure 5 presents the gains in social welfare and consumer welfare at different levels of the energy tax, when the product tax is set to zero. The consumer welfare maximizing energy tax is $0.19, which is naturally below the level that maximizes social welfare. Any energy tax below about $0.40 per gallon, however, actually increases consumer welfare through the improvements in allocative efficiency generated by correcting the mistakes of inattentive consumers.

4.2.3   The Internality Rationale for Product Taxes

We now calibrate what we have labeled the "Internality Rationale" for product taxes, which is that inattention makes the product tax increasingly important relative to the energy tax. Consider first the "third best product tax," by which we mean the product tax τ_p that maximizes social welfare when the energy tax τ_e is constrained to zero. Column 7 of Table 2 shows that the third best level of τ_p is $94,069 per gallon per mile energy intensity rating. Using the example pair of vehicles from above, the third best social welfare maximizing τ_p imposes a sales tax that is about $941 larger for the 20 MPG Subaru Outback compared to the $25 MPG Toyota Corolla. The third best social welfare maximizing product tax increases consumer welfare by a PDV of $30 per new vehicle buyer, reducing carbon emissions at a *negative* private cost of $27.10 per ton.

In the traditional model without misoptimization, we have noted that the product tax is an inefficient substitute for the energy tax as a policy to address externalities. In that model, there are two primary reasons why the product tax performs more poorly than the energy tax. First, the product tax affects equally the vehicle choices of all consumers regardless of their utilization demand θ, whereas in the first best, it is more important to affect the vehicle choices of high-utilization consumers. Second, the product tax does not generate the optimal utilization decision.

However, adding inattention to the model changes the social planner's perspective on product taxes vs. energy taxes. Consider a situation where political constraints force a choice between the third best product tax and the third best energy tax. Columns 6 and 7 of Table 2 show that while the social welfare gain from the third best energy tax was $21 per consumer, the social welfare gain from the third best product tax is $45 per consumer, or about twice as large. Another way to see this is to compare policies that are equivalent in terms of carbon abatement. Column 8 presents the effects of a product tax set to abate the same amount of carbon as in Column 5, where the energy tax is set at the level of marginal damages. The changes to consumer welfare are much larger: $30 per consumer, compared to $5 in Column 5. The product tax abates carbon dioxide emissions at a consumer welfare gain of $40.40 per ton, compared to $6.70 per ton for the energy tax.

If the energy tax is politically constrained but the product tax or subsidy is not, the relevant welfare comparison is between the third best product tax and the second best tax combination. Comparing the social welfare gains in Column 3 to Column 7, we see that the product tax attains a remarkable 91 percent of the welfare gains as the second best. In contrast, Columns 3 and

8 show that the third best energy tax attains only 42 percent of the second best welfare gains. These results are the empirical calibration of the Internality Rationale for product taxes: under inattention, product taxes are more effective than energy taxes at improving welfare, and political constraints on raising energy taxes are relatively unimportant.

As we showed in Propositions 4 and 5, as the internality becomes more severe, the product tax becomes more important from a welfare perspective. Figure 6 graphs the welfare gains from different tax policies under increasing inattention. The four lines represent gains relative to a baseline of zero taxes from the first best discriminatory tax policy, the second best tax combination, the third best gas tax, and the third best energy tax. As we move from right to left on the graph, the mean of the triangular distribution has been decreased from one to one half, with the support widening from zero to one, generating more inattention in the population.

At the far right, when the distribution limits to a point mass of perfectly optimizing consumers with $\gamma = 1$, the first best, second best, and third best energy tax all increase social welfare by $5 per consumer, while the third best product tax performs more poorly, increasing social welfare by $1 per consumer. At the far left of the graph, where consumers are modeled with a triangular distribution of γ with mean of 0.5 and support on $[0, 1]$, the product tax performs almost as well as the second best tax combination. At this distribution of γ, there is still slippage between the second best and the first best due to heterogeneity in γ, but much more slippage from using only the energy tax in isolation. The graph further underscores how inattention reverses the tradition result on the relative appeal of energy taxes compared to product taxes.

In Proposition 3, we showed that as consumers become more inattentive, the product tax also becomes more important in the sense that the second best optimal level is larger. Figure 7 illustrates this, increasing inattention from right to left in the same way as in Figure 6. As the mean level of inattention decreases from 1 to 0.5, the optimal product tax increases from zero to approximately $170,000 per GPM. Using our example vehicles from above, this latter level of τ_{gpm} increases the relative price of the 20 MPG Subaru Outback relative to the 25 MPG Toyota Corolla by $1700.

An interesting feature of Figure 6 is how the optimal second best energy tax takes an inverted U shape. At the far right, when all consumers have $\gamma = 1$, the optimal energy tax is $\tau_g = \phi$, or $0.18. As γ decreases to a moderate level, say the 0.75 assumed in the simulations in Table 2, the optimal second best energy tax is slightly above the level of marginal damages. As we discussed earlier, this is because the energy tax is relatively effective at targeting high-θ consumers. However, when we add increasing numbers of consumers that are inattentive to gasoline costs and gas taxes, the energy tax does not affect their product choices. As we approach the far left of the graph, the optimal tax combination involves a smaller energy tax and increasing reliance on the product tax.

Depending on other parameter assumptions, as we further increase the concentration of low-γ consumers, the second best optimal tax combination may actually involve an energy *subsidy* in combination with a large product tax. This result is generated by differential targeting of the taxes: the large product tax is used to reduce the distortions of low-γ consumers who are inattentive to

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the gasoline price, while the gasoline subsidy is used to correct the distortions that the product tax causes for high-γ consumers who are attentive to the gasoline price. Because our empirical calibrations imply that the internality is so important from a welfare perspective relative to the externality and that utilization is fairly inelastic, it is of less consequence that the energy subsidy distorts consumers' intensive margin decisions.

These results give a clear set of comparative statics that inform how hard a policy maker should push for a Pigouvian tax on carbon in a world where such a tax is politically difficult to implement. As the magnitude of average consumer inattention shrinks, the externality grows, or the price elasticity of utilization demand increases, it becomes increasingly important to have an energy tax at the level of marginal damages. As the distribution of the bias shifts such that there are more consumers with especially low γ, however, the product tax becomes an increasingly important element of optimal tax policy. As inattention increases, a politically constrained energy tax generates both a smaller share of the total inefficiency and a smaller absolute welfare loss, because the gas tax does not affect the decisions of people that are inattentive to gas costs.

4.2.4 The Welfare Effects of Heterogeneity

As we showed in Proposition 6, if all consumers make mistakes of the same magnitude, the first best obtains under an appropriate combination of energy taxes and product taxes that are uniform across consumers. As in Proposition 7, however, as the variability of the internality increases, the distance between the first best and the second best increases. This variability in the internality for each vehicle's marginal consumers comes from the product of two factors, the attention weight γ and the utilization $m^*(\theta_i)$. Figure 8 plots the welfare gains relative to baseline for the first best and for the second best tax combination. As we hold the mode of the triangular distribution of γ constant at 0.75 but increase the distribution's halfwidth, the distance between the first best and second best widens: tax policy performs worse and worse relative to what is possible.

These results imply that even a policymaker with perfect information who constructs the second best tax policy leaves significant uncaptured potential welfare gains for especially inattentive consumers while reducing welfare for consumers whose decisions were already close to optimal. Ideally, the policymaker would have available other instruments that preferentially target inattentive consumers and can be used without perfect information about which consumers are making different types of mistakes.

5 Targeting Inattentive Consumers

In this section, we discuss four approaches to "behavioral targeting." The goal is to understand policy designs that preferentially improve inattentive consumers' decisions while imposing less distortion on the choices of rational types. We present four general concepts: tagging, screening,

nudges, and nudge-inducing policies. For each concept, we discuss examples related to energy efficiency policy.

5.1 Tagging

In the context of Akerlof (1978), "tagging" is to restrict eligibility for welfare programs to households whose observable characteristics suggest greater need. In the behavioral context, tagging is to explicitly limit a policy to apply only consumers that are more likely to be misoptimizing.

Definition 1 *Behavioral Tagging: Restricting a policy to affect only individuals with observable characteristics correlated with misoptimization.*

The effectiveness of tagging depends on the correlation of the internality with the characteristics used to tag. At the individual level, the internality is difficult to measure, because unobserved preferences can rationalize any number of choices. In the specific context of energy policy, however, there are several observables which, across a population of consumers, are plausibly correlated with inattention to energy costs. For example, homeowners that have previously participated in other energy efficiency programs are more likely to be attentive to energy costs. Homeowners with relatively high energy use are more likely to be inattentive.

As we discussed in Section 2, there may be other inefficiencies that reduce demand for energy efficient durable goods, including credit constraints and agency problems between landlords and tenants. One could similarly imagine targeting consumers subject to these other market failures, for example by limiting eligibility to low-income households, which are more likely to be subject to credit constraints, or to landlords and tenants.

5.2 Screening

A second approach to behavioral targeting is to use screening devices. Traditionally, a screening device is a contract or policy that induces agents to sort themselves by type. Behavioral screening is to structure policies such that they are more appealing to consumers that misoptimize.

Definition 2 *Behavioral Screening: Offering a program that misoptimizing consumers are more likely to adopt.*

Consumers that are inattentive to energy costs are less likely to have made energy efficiency investments and will therefore have high energy use conditional on observables. Therefore, one way to implement behavioral screening in the context of energy efficiency is to offer larger subsidies to consumers with larger energy use.

There already exist some policies that serve as behavioral screens, although these policies have typically been justified for other reasons. For example, some energy efficiency programs subsidize

the cost of weatherization investments equally for all households, while others make the household's subsidy a function of estimated energy savings. The latter structure provides additional encouragement for high-θ households to weatherize, and these high-θ households who have not weatherized are more likely to inattentive than low-θ households that have not weatherized. The traditional motivation for this design is that high-θ households impose higher externalities, and thus a larger subsidy for these households more closely approximates the Pigouvian tax. Inattention provides additional justification, as high-θ households who have not weatherized are more likely to have larger internalities.

5.3 Nudges

The third targeting mechanism is for the government to provide "nudges" or mandate that firms provide them. Essentially by definition, a nudge is well-targeted.

Definition 3 ***Nudges****: Factors that preferentially improve the choices of misoptimizing consumers without affecting the behavior of rational consumers.*

This is intended to closely paraphrase Thaler and Sunstein (2008, page 8), who define a nudge as "any factor that significantly alters the behavior of Humans, even though it would be ignored by Econs." Put differently (page 6), a nudge is "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives."

One tangible example of a nudge is the attention-drawing element of information provision. The traditional model of information disclosure is that it improves choices of consumers that optimize but were imperfectly informed. However, information provision can also draw attention to product attributes that were not previously salient to consumers.

There are a number of examples of salient energy cost information disclosure. The US government mandates that retailers display yellow energy cost information tags on new appliances and requires auto manufacturers to post fuel economy labels on new vehicles delivered to dealerships. The federal Department of Energy also provides information and promotes energy efficiency through its Energy Star marketing campaign. Furthermore, many electric and natural gas utilities provide energy use information and energy conservation tips to residential consumers (Allcott 2011c). Of course, it is important to consider empirical data on whether these campaigns are in practice more or less effective with consumers who are inattentive to or previously unaware of energy efficiency, and the benefits of nudges should of course be weighed against the costs of providing them.

"On-bill financing" programs are a second example of a nudge related to energy efficiency. Through these programs, the utility pays part of the upfront cost of a home energy efficiency investment and amortizes that cost over several years on the homeowner's energy bills. In other words, this is a loan from the utility that the customer repays with his energy bill. Traditionally, a

primary rationale for these programs has been that they alleviate credit constraints, as the utility can access credit at lower interest rates than individual homeowners. However, an additional useful feature of on-bill financing is that it puts upfront investment costs and future energy costs into the same payment stream, eliminating the possibility that the consumer could attend differently to the two types of costs.

To model this in a very simple way, suppose that when some portion ρ of the price of E is eligible to be financed on energy bills, consumers also weight ρ by γ. That is, equation (2) is now modified so that a consumer purchases E if and only if

$$\gamma[v(\theta, e_E, p_g) - v(\theta, e_I, p_g)] > (p_E - \rho) - p_I + \gamma\rho. \tag{8}$$

Then if $\rho = p_E - p_I$, so that consumers can delay the extra up-front cost they would incur by purchasing E, consumers will choose E if and only if

$$\gamma[v(\theta, e_E, p_g) - v(\theta, e_I, p_g)] > \gamma(p_E - p_I)$$

or, equivalently, if and only if

$$v(\theta, e_E, p_g) - v(\theta, e_I, p_g)] > p_E - p_I. \tag{9}$$

Equation (9) is exactly the choice of a perfectly optimizing consumer. Therefore, setting taxes $(\tau_E, \tau_g) = (0, \phi)$ and financing portion $\rho = p_E - p_I$ on energy bills causes consumers to make the privately optimal choice. Importantly, equation (9) holds for all consumers regardless of γ, so the on-bill financing program is perfectly targeted: it generates the first best.

The opposite of on-bill financing, loading energy costs into the upfront price of the product, has similar benefits. For example, auto dealerships could sell gas cards in the amount of the car's estimated gasoline usage, and the price of the card would be included in the purchase price. In this way, energy costs would mechanically receive the same attention weight as upfront costs. We do not model this formally, but the results would be analogous to those for the on-bill financing program.

5.4   Externalizing the Internality

Firms often have much more powerful capacity to inform or nudge consumers than the government does. For example, firms can run advertising campaigns that either emphasize or de-emphasize energy efficiency. They can make information disclosure confusing or useless instead of salient, for example by including relevant energy cost information amidst fine print or hiding energy cost information tags inside appliances on the retail floor. Firms can also direct their retail sales staff either to make extra effort to inform consumers about the energy costs of different models, or to

instead focus on other attributes.[8] In practice, these kinds of nudges are often too nuanced to be verifiable, which makes them difficult to mandate.

Instead of mandating firms to nudge, however, the government can institute Nudge-Inducing Policies.

Definition 4 *Nudge-Inducing Policy: A tax, subsidy, or other policy instrument that inserts a correlate of the internality into firms' profit functions.*

The basic logic behind these policies is to tax sellers for socially inefficient choices made by their consumers. If firms can nudge consumers at sufficiently low cost, their optimal response is to do so. Nudging reduces the extent of consumers' inefficient choices, thereby reducing the firm's tax burden.

Our example of a Nudge-Inducing Policy is motivated by the theoretical model in Section 3. In this model, there is one utilization type θ^{**} that is on the margin between the two goods in the first best. Let m_I^{**} be the utilization choice of this consumer if he were to choose I. Then any consumer who chooses the energy inefficient model and utilizes more than m_I^{**} has misoptimized. An "ex-post utilization tax" imposed on the firm for each of its consumers that has misoptimized in this way will encourage the firm to nudge consumers in an effort to reduce sales of the inefficient model to high utilization consumers.

One advantage of this type of policy is that the government only needs to evaluate *ex-post* whether the sellers' transactions were socially efficient or not. For example, rather than having to predict which consumers will likely have high utilizations and thus benefit from E, the government need only observe those consumers' ex-post choices of utilization. A second advantage of such policies is that they do not create perverse incentives for consumers. For example, directly subsidizing E for high-utilization consumers may create distortionary incentives for consumers to either misrepresent their type or may cause consumers to increase their utilization choice beyond the socially efficient level.

To formally model the market, suppose that the market matches each consumer of type $i = (\theta, \gamma)$ to a transaction $\mathcal{C}_i = (j_i, p_i, n_i)$ that specifies a product $j \in \{I, E\}$, a corresponding price p for that product, and an informational nudge $n \in \{0, 1\}$ that represents the soft information describing the terms of transaction such as an advertising tactic. When $n = 1$, the salesman "nudges" the consumer and explains the impacts of differing energy efficiencies instead of just focusing on other features of the durable. A nudged consumer then fully appreciates differences in energy efficiency. When $n = 0$, the consumer continues to be inattentive to differences in energy efficiency. For simplicity, we take both $n = 1$ and $n = 0$ to be costless.

Although throughout all previous analysis all that mattered is that consumers underweighed the difference in utilities that results from different energy efficiencies, for the types of policies we

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[8]We thank Rich Sweeney for some investigative research at auto dealerships and appliance retailers that brought these examples to our attention.

consider here it will be necessary to define how much utility a consumer thinks he will derive from each of the durables. For simplicity, we assume that consumer correctly evaluate the utility from purchasing E, but overestimate the utility from purchasing I because they neglect to think about the disadvantages of owning a less energy efficient durable.[9] That is

$$
\begin{aligned}
\widetilde{V}(i, E, p_E) &= v(\theta, e_E, p_g) - p_E \\
\widetilde{V}(i, I, p_I) &= v(\theta, e_I, p_g) - p_E + (1 - \gamma)[v(\theta, e_E, p_g) - v(\theta, e_I, p_g)]
\end{aligned}
$$

Then as before, we have that $\widetilde{V}(i, E, p_E) - \widetilde{V}(i, I, p_I) = \gamma[v(\theta, e_E, p_g) - v(\theta, e_I, p_g)] - (p_E - p_I)$, so that the consumer underreacts to the utility difference that comes from differing energy efficiencies. As before, we define the actual experienced utility as $V(i, j, p_j) = v(\theta, e_j, p_g) - p_j$.

Then building on Koszegi and Heidhues (2009) we define a competitive equilibrium as a set of transactions $\{\mathcal{C}_i\}$ such that for all i and i':

1. **Consumer "optimization"** $V(i, j_i, p_i) \geq V(i, j_{i'}, p_{i'})$ if $n_i = 1$ and $\widetilde{V}(i, j_i, p_i) \geq \widetilde{V}(i, j_{i'}, p_{i'})$ if $n = 0$

2. **Competitive market** Each transaction earns the seller zero profits

3. **No profitable deviation** There is no other $\mathcal{C}'_i = (j'_i, p'_i, n'_i)$ that earns positive profits and such that $V(i, j'_i, p'_i) > V(i, j_{i'}, p_{i'})$ if $n'_i = 1$ and $\widetilde{V}(i, j'_i, p'_i) > \widetilde{V}(i, j_{i'}, p_{i'})$ if $n'_i = 0$.

The first condition states that consumers maximize their decision utility, given the nudge provided by the seller. If the consumer transacts with a seller who doesn't explain the importance of fuel economy ($n = 0$) then the consumer shouldn't prefer any other transaction $\mathcal{C}_{i'}$ offered by the seller when the ranking is done according to decision utility $\widetilde{V}$. If the seller explains the importance of fuel economy to the consumer ($n = 1$), then the consumer should be much happier to purchase the more energy efficient durable from the seller. In that case, the consumer should not prefer any other possible transaction $\mathcal{C}_{i'}$ when the ranking is done according to the actual utility V. The second condition simply requires that the economy is competitive. The third condition requires that if $\mathcal{C}_i$ is the contract offered to a type i, then it shouldn't be possible for a seller to offer type i some other contract that *appears* better to type i and that generates a positive profit for the seller. For example, the market cannot offer only I in equilibrium since there are some consumers who would prefer to pay at least $c_E - c_I + \epsilon$ more for E than for I; thus some seller could obtain positive profits by offering E at price $P_E = c_E + \epsilon$ to those consumers (when $\tau_E = 0$, without loss of generality). The condition also rules out the situation in which all sellers try hard to convince all of potential consumers that their less efficient cars I have terrible fuel economy—a profitable

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[9]In a sense, this is without loss of generality. If consumers thought of E as better than it is, but still underestimated its value relative to I, then it would still be necessary to reduce consumers' overevaluation of I (though not completely). On the other hand, the market we describe would not allow underestimation of E because it tries to make all its products maximally attractive.

deviation would be for some seller to advertise *his* line of the less energy efficient cars in a much more positive way (say by drawing attention to the nice features of this line of cars), and thus charge higher prices.

Our first point, which follows directly from our definition of equilibrium, is that under the tax policies we have considered so far—subsidies τ_E and energy taxes τ_g—the market will set $n = 0$ for all consumers so as to make the products look maximally attractive.

Proposition 8 *Under taxes (τ_E, τ_g), the market prices for the durables will be $p_I = c_I$, $p_E = c_E + \tau_E$ for all transactions, firms will set $n = 0$ for all consumers, and a consumer will end up with E if and only if $\widetilde{V}(i, E, p_E) - \tilde{V}(i, I, p_I) > 0$.*

Our second point is that taxes that closer align market incentives with social welfare can induce the market to match consumers to products in a more efficient way. Consider, for example, an ex-post utilization tax that charges firms for selling I to users with a high utilization need who would be better off purchasing E. In particular, let m_I^{**} be the utilization of a type θ for whom $[v(\theta, e_E, c_g + \phi) - v(\theta, e_I, p_g + \phi)] - (p_E - p_I) = 0$. Then consider a simple ex-post utilization tax under which a firm must pay $\tau_{ex} > 0$ for each consumer with utilization $m^*(\theta, e_I, \phi) > m_I^{**}$ who purchases product I.

Proposition 9 *Set $\tau_g = \phi$ and $\tau_E = 0$. For a high enough τ_{ex}, the market will nudge all consumers with $\widetilde{V}(i, E, p_E) - \widetilde{V}(i, I, p_I) < 0$ and $V(i, E, p_E) - V(i, I, p_I) > 0$. Thus each consumer will purchase E if and only if $[v(\theta, e_E, c_g + \phi) - v(\theta, e_I, c_g + \phi)] - (c_E - c_I) > 0$ and the first best will obtain.*

In reality, consumers are often differentiated not just by θ and γ, but also by heterogeneity in tastes for product attributes other than energy efficiency. As a result, there is no one utilization level above which it is necessarily optimal for consumers to own an energy efficient good. This issue becomes obvious with a concrete example: automobile consumers have heterogeneous preferences for size and power, so an individual who buys an SUV and drives a lot may or may not have misoptimized. Given this consideration, a more general version of the ex-post tax would be to simply tax the firm for the energy used by its products. By taxing the firm more heavily for selling low fuel economy vehicles to high VMT drivers, this form of tax induces the firm to nudge high-VMT drivers to buy high fuel economy cars.

Market power that allows firms to charge mark-ups will also interact with the firms' nudging strategies. If firms can charge a higher mark-up on one product rather than another, then they will have more incentive to nudge consumers toward the product with the higher mark-up. However, a policy such as the one in Proposition 9 would still work. As long as the ex-post utilization tax penalizes firms enough for selling I to consumers who should be purchasing E, firms will try to steer consumers away from I.

Most generally, the idea of Proposition 9 is a tax that correlates with the level of the "internality" that a seller indirectly imposes on its consumers by providing them with a suboptimal transaction.

In practice, such taxes may be constructed by using consumer characteristics other than just their utilization level.

6   Conclusion

Since Pigou (1932), the idea of "internalizing the externality," or taxation at the level of marginal damage, has been a foundational principle of public economics. In this paper, we re-evaluate the Pigouvian logic for energy taxes in a world where consumers are inattentive to energy costs when they buy energy-using durables. Inattention reverses two fundamental economic results, generating a Triple Dividend from energy taxes and an Internality Rationale for product taxes. However, heterogeneity across consumers in the magnitudes of their internalities generates a wedge between the first best and the second best outcome that can be achieved through uniform tax policies. This motivates our discussion of behavioral targeting mechanisms, including tagging, screening, and nudges.

One of the important takeaways is that policy makers should carefully consider the targeting of energy efficiency policies, and in particular the incentives that these policies give to firms to target consumers subject to market failures. Product taxes affect relative prices for all consumers, changing decisions for consumers who *think* that they should be close to the margin. Under heterogeneous internalities, these marginal consumers are not necessarily the ones that would experience the greatest welfare gains from more energy efficient goods. However, in many cases firms have a capacity to advertise, inform, and otherwise nudge individual consumers towards their privately-optimal allocations. In these situations, policy makers should consider instruments that encourage firms to allocate products to consumers that would benefit the most. In other words, policy makers should consider "externalizing the internality."

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Tables

Table 1: Simulation Overview

	Mean	SD	Min	Max
Choice Set				
Number of Models	292			
Price p_j ($)	36,615	25,086	12,038	174,541
Gallons per Mile e_j	0.054	0.011	0.022	0.084
2007 Sales Quantity	47,891	75,155	93	627,809
Consumers				
Nested Logit Substitution Parameter σ	0.6			
Annual Discount Rate	6%			
Lifetime Multiplier Λ	0.436			
VMT Elasticity	0.15			
Lifetime Potential VMT m^*	237,220	72,870	108,400	382,840
γ	0.75	0.10	0.50	1.0
Energy				
Gasoline Price p_g ($ per gallon)	3			
Marginal Damage ϕ ($ per gallon)	0.18			

Notes: All dollars are real 2005 dollars.

Table 2: Simulation Results

Setup	1	2	3	4	5	6	7	8
Case	Base	FB	SB	Heur		TBE	TBP	Equal CO2
Policy Space			τ_g, τ_p	τ_g	$\tau_g = \phi$	τ_g	τ_p	τ_p
Parameters								
Average γ	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Halfwidth of $f(\gamma)$	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
VMT Elasticity	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Policies								
τ_g (\$/gallon)		0.18	0.19	0.18	0.18	0.39		
τ_E (\$/GPM)			81,599	82,185			94,069	63,247
Results								
Average MPG	19.9	20.3	20.3	20.3	19.9	20.0	20.3	20.1
Average Lifetime VMT	237,520	236,170	236,060	236,170	235,540	233,410	238,250	238,000
Average Gas Cost PDV	15,446	15,938	16,001	15,962	16,194	17,054	15,194	15,277
Average CO2 Tons	67.3	65.5	65.6	65.6	66.5	65.7	66.2	66.5
Welfare								
Energy Tax Redistribution		902	949	904	917	1,961	0	0
Product Tax Redistribution		4,869	4,028	4,057	0	0	4,644	3,142
ΔConsumer Welfare		34	26	26	5	0	30	30
ΔDamages		-25	-24	-23	-10	-21	-15	-10
ΔSocial Welfare		58	49	49	15	21	45	40
CW Cost per Ton CO2		-19.0	-14.9	-15.4	-6.7	0.2	-27.1	-40.4

Notes: All dollars are real 2005 dollars. Welfare figures are dollars per new vehicle buyer, discounted at 6 percent annually. In the "Case" row, "Base" refers to the baseline equilibrium with zero taxes, "FB" to the first best, "SB" to the second best, "Heur" to the "Heuristic second best," "TBE" to the third best energy tax, "TBP" to the third best product tax, and "Equal CO2" to the product tax that gives the same CO2 abatement as the energy tax set at marginal damages.

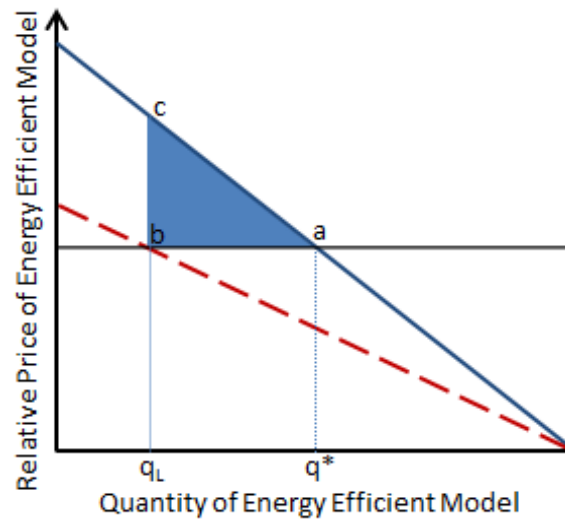# Figures

Figure 1: Baseline Equilibrium

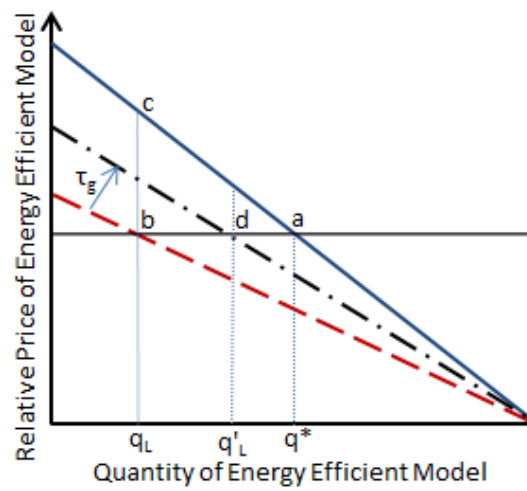## Figure 2: Equilibrium with Energy Tax

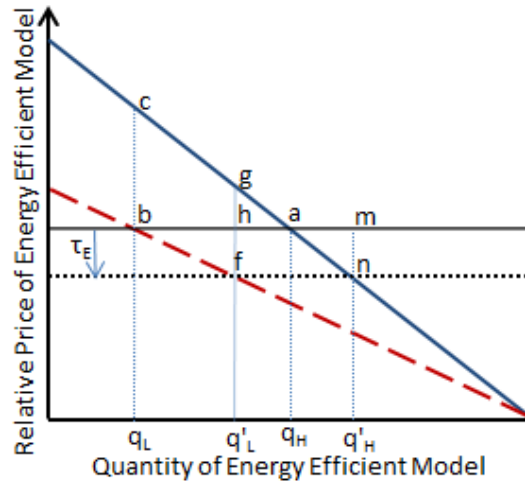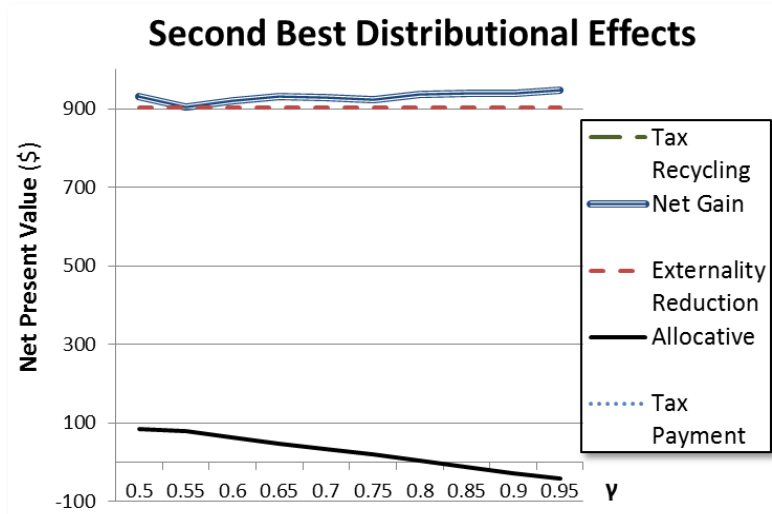**Figure 3: Equilibrium with Product Tax**

Figure 4: Distributional Effects

Note: The Tax Recycling and Tax Payment lines, which average $5000 and -$5000 per consumer, respectively, are omitted to reduce the scale of the graph.
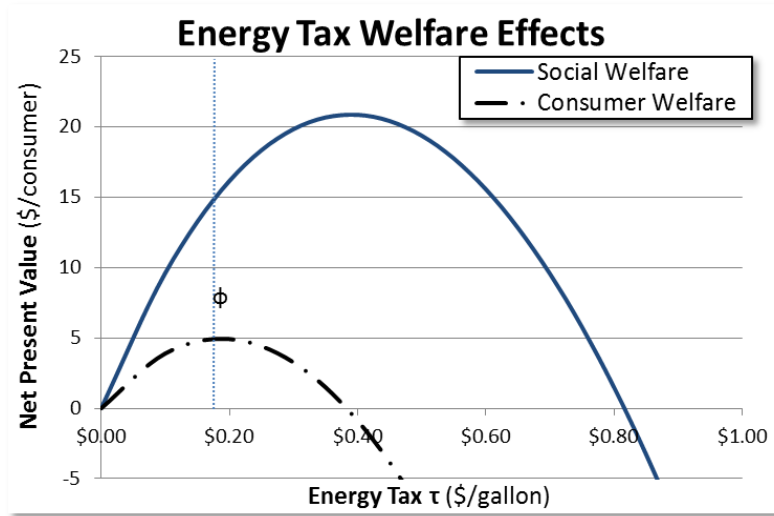
Figure 5: The Triple Dividend
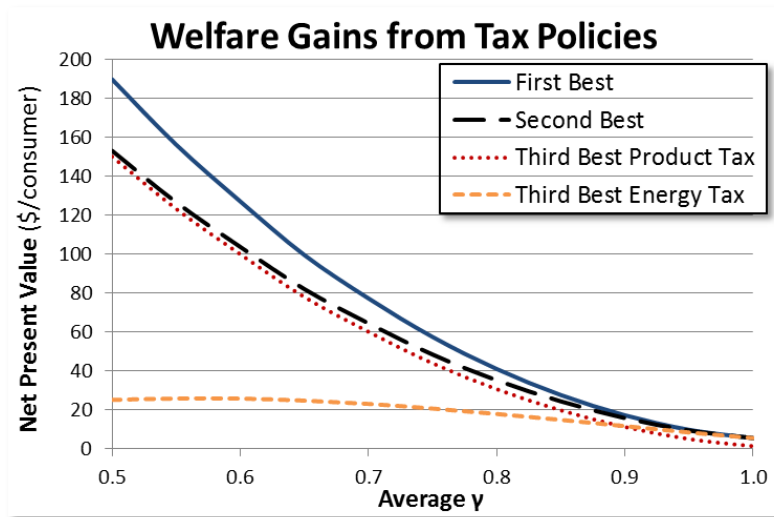

Figure 6: The Internality Rationale for Product Taxes

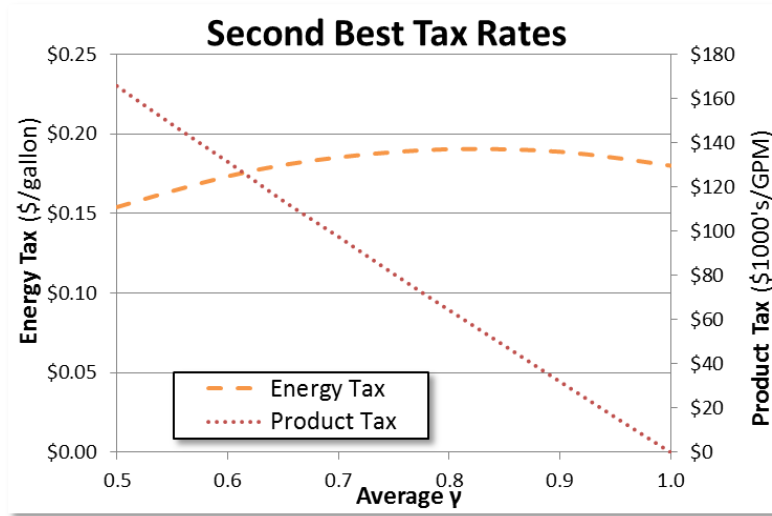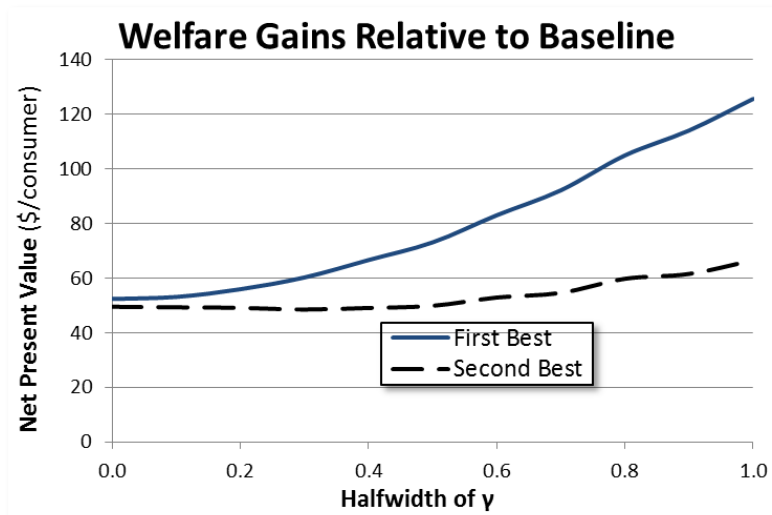**Figure 7: Second Best Tax Rates**

Figure 8: Implications of Heterogeneity

7 Appendix: Proofs

Preliminaries

We begin with a series of core results that will be used throughout subsequent proofs.

Lemma 1 *Set* $m^*(\theta, e, p_g) \equiv argmax\{u(m-\theta) - p_g me\}$. *Then* $\frac{\partial}{\partial \theta} m^*(\theta, e, p_g) = 1$.

Proof. Follows from differentiation of the first order condition for m^* and basic algebra. ∎

Lemma 2 $em^*(\theta, g, e)$ *is increasing in* e

Proof. We have

$$\frac{\partial}{\partial e} em^*(\theta, g, e) = m^*(\theta, g, e) + e\frac{\partial}{\partial e} m^*(\theta, g, e). \tag{10}$$

Differentiating the first order condition $v'(m^* - \theta) - ge = 0$ with respect to e yields $v''(m^* - \theta)\frac{\partial m^*}{\partial e} = g$.
Thus

$$\frac{\partial}{\partial e} em^* = m^* - \frac{eg}{v''(m^* - \theta)} = m^* - \frac{v'(m^* - \theta)}{v''(m^* - \theta)}.$$

But $m - \theta > \frac{v'(m-\theta)}{v''(m-\theta)}$ by assumption, and thus the expression (10) is positive. ∎

Lemma 3 $v(\theta, e_E, p_g) - v(\theta, e_I, p_g)$ *is increasing in* θ *and* p_g.

Proof. From the envelope theorem and lemma 1, we have that

$$\frac{\partial}{\partial \theta} v(\theta, e, p_g) = -p_g e.$$

Thus

$$\frac{\partial}{\partial \theta}[v(\theta, e_E, p_g) - v(\theta, e_I, p_g)] = p_g(e_I - e_E) > 0. \tag{11}$$

We also have

$$\frac{\partial}{\partial p_g} v(\theta, e, p_g) = -m^* e$$

and thus

$$\frac{\partial}{\partial p_g}[v(\theta, e_E, p_g) - v(\theta, e_I, p_g)] = m^*(\theta, e_I, p_g)e_I - m^*(\theta, e_E, p_g)e_E \tag{12}$$

∎

The next lemma is the key to many of the results in the paper, as it characterizes the marginal consumer between E and I as a function of the various policies and attention. To begin, define the perceived benefit to purchasing E over I for consumers with attention weight γ to be

$$B(\theta, k, p_g, \Delta p) \equiv \gamma p_g[e_I m^*(\theta, e_I, p_g) - e_E m^*(\theta, e_E, p_g)] + \gamma[u(m^*(\theta, e_E, p_g) - \theta) - u(m^*(\theta, e_I, p_g) - \theta)] - \Delta p$$

where $\Delta p = p_E - p_I$ is the difference in prices. Notice that by Lemma 1, however, $u(m^*(\theta, e_E, p_g) - \theta) - u(m^*(\theta, e_I, p_g) - \theta)$ is constant over all θ, and thus we can rewrite as a function $\Delta u(e_E, e_I, p_g) \equiv u(m^*(\theta, e_E, p_g) - \theta) - u(m^*(\theta, e_I, p_g) - \theta)$. Define also $\theta^\dagger$ to satisfy $B(\theta^\dagger, k, p_g, \Delta p) = 0$. Then we have:

Lemma 4 *1.* $\frac{\partial}{\partial k} \theta^\dagger = -\frac{\Delta p}{\gamma p_g(e_I - e_E)} < 0$

2. $\frac{\partial}{\partial \Delta p} \theta^\dagger = \frac{1}{\gamma(p_g(e_I - e_E))} > 0$

3. $\frac{\partial}{\partial p_g} \theta^\dagger = -\frac{\Delta p - \Delta u(e_E, e_I, p_g)}{\gamma(p_g(e_I - e_E))} < 0$

Proof. First, note that $\frac{\partial}{\partial \theta} B = p_g(e_I - e_E)$, as shown in equation (11).

To prove 1, notice that $\frac{\partial}{\partial k} B = v(\theta, e_E, p_g) - v(\theta, e_I, p_g)$, and since $v(\theta^\dagger, e_E, p_g) - v(\theta^\dagger, e_I, p_g) = \Delta p / \gamma$ by definition, differentiating $B(\theta_L^\dagger, k, p_g, \Delta p) = 0$ with respect to k thus yields

$$\frac{\partial}{\partial k} \theta^\dagger = -\frac{\frac{\partial}{\partial k} B}{\frac{\partial}{\partial \theta}} = -\frac{\Delta p}{\gamma p_g(e_I - e_E)}.$$

Part 2 is proven likewise. Note that $\frac{\partial}{\partial \Delta p} B = -1$, and then differentiate $B(\theta_L^\dagger, k, p_g, \Delta p) = 0$ with respect to Δp.

Part 3 is proven similarly, noting $\Delta p - \Delta u(e_E, e_I, p_g) = m^*(\theta, e_I, p_g)e_I - m^*(\theta, e_E, p_g)e_E > 0$ by Lemma 2. ∎

Lemma 5 *The function $M(\theta, e, p_g) \equiv v(\theta, e, p_g) + (p_g - c_g - \phi)em^*(\theta, e, p_g)$ is strictly concave and differentiable in p_g and attains its maximum at $p_g = c_g + \phi$.*

Proof. Since

$$\frac{\partial}{\partial p_g} v(\theta, e, p_g) = m^* e$$

some algebra shows that

$$\frac{\partial}{\partial p_g} M(\theta, e, p_g) = (p_g - c_g - \phi)e \frac{\partial}{\partial p_g} m^*(\theta, e, p_g).$$

Since

$$\frac{\partial}{\partial p_g} m^*(\theta, e, p_g) < 0$$

we know that $\frac{\partial}{\partial p_g} M(\theta, e, p_g)$ is positive for $p_g < c_g + \phi$ and negative for $p_g > c_g + \phi$. ∎

Lemma 6 *$M(\theta, e_E, p_g) - M(\theta, e_I, p_g)$ is increasing in θ.*

Proof. Differentiating the quantity with respect to θ and using Lemma 1 and equation (11) yields

$$\frac{\partial}{\partial \theta} [M(\theta, e_E, p_g) - M(\theta, e_I, p_g)] = (c_g + \phi)(e_I p_g - e_E p_g) > 0.$$

∎

Proofs of claims and propositions in paper

Proof of Claim 1. Obviously the proposed policy achieves the first best.

We now check that no other policy achieves the first best. First, notice that by Lemma 5, $\tau_g = \phi$ in any policy that achieves the first best; otherwise the intensive margin choice will be inefficient. Now with τ_g fixed at ϕ, notice that $\tau_E \neq 0$ creates an inefficiency in the extensive margin choice of durables. ∎

Proof of Proposition 1. Begin by calculating $\frac{\partial}{\partial \tau_E} W$. If $\theta_L^\dagger$ and $\theta_H^\dagger$ correspond to the utilization needs of the marginal agents for the two attention types then, setting $\Delta c \equiv c_E - c_I$, we have

$$\frac{\partial}{\partial \tau_E} W = [M(\theta_L^\dagger, e_E, p_g) - M(\theta_L^\dagger, e_I, p_g) - \Delta c] \frac{\partial \theta_L^\dagger}{\partial \tau_E} f(\theta_L^\dagger) + [M(\theta_H^\dagger, e_E, p_g) - M(\theta_H^\dagger, e_I, p_g)] \frac{\partial \theta_H^\dagger}{\partial \tau_E} f(\theta_H^\dagger). \quad (13)$$

where f is the probability density function of F. Let θ^* be the type such that in the first best allocation, any type with $\theta > \theta^*$ must purchase E and any type with $\theta < \theta^*$ must purchase I. Now when $\tau_g = \phi$, $M(\theta, e, p_g) = v(\theta, e, p_g)$. Moreover, if $\theta_L^\dagger > \theta^*$ then since $v(\theta^*, e_E, p_g) - v(\theta^*, e_I, p_g) - (c_E - c_I) = 0$ by definition, Lemma 3 implies that $v(\theta_L^\dagger, e_E, p_g) - v(\theta_L^\dagger, e_I, p_g) - (c_E - c_I) > 0$. A similar calculation shows that $v(\theta_H^\dagger, e_E, p_g) - v(\theta_H^\dagger, e_I, p_g) - (c_E - c_I) \geq 0$ if $\theta_H^\dagger \geq \theta^*$. Combining this with Lemma 4 then implies that $\frac{\partial}{\partial \tau_E} W < 0$ whenever $\tau_E \geq 0$ and $\tau_g = \phi$.

Next, calculate $\frac{\partial}{\partial \tau_g} W$:

$$
\begin{aligned}
\frac{\partial W}{\partial \tau_g} &= [M(\theta_L^\dagger, e_E, p_g) - M(\theta_L^\dagger, e_I, p_g) - \Delta c]\frac{\partial \theta_L^\dagger}{\partial \tau_g} f(\theta_L^\dagger) + \left[\int_{\theta \leq \theta_L^\dagger} \frac{\partial}{\partial p_g} M(\theta, e_I, p_g) dF(\theta) + \int_{\theta \geq \theta_L^\dagger} \frac{\partial}{\partial p_g} M(\theta, e_E, p_g) dF(\theta)\right] \\
&+ [M(\theta_H^\dagger, e_E, p_g) - M(\theta_H^\dagger, e_I, p_g) - \Delta c]\frac{\partial \theta_H^\dagger}{\partial \tau_g} f(\theta_H^\dagger) + \left[\int_{\theta \leq \theta_H^\dagger} \frac{\partial}{\partial p_g} M(\theta, e_I, p_g) dF(\theta) + \int_{\theta \geq \theta_H^\dagger} \frac{\partial}{\partial p_g} M(\theta, e_E, p_g) dF(\theta)\right]
\end{aligned}
$$

The first and second lines of the previous equation correspond to the impact on agents with attentions γ_L and γ_H, respectively. The first bracketed term in each line corresponds to the extensive margin effect, and the second bracketed term in each line corresponds to the intensive margin effect.

By Lemma 5, the intensive margin effect is zero when $\tau_g = \phi$. An argument identical to the one for changing τ_E shows that the extensive margin effect of raising τ_g is non-negative for each attention type, and positive for γ_L consumers. Thus $\frac{\partial}{\partial \tau_g} W > 0$ at $(\tau_E, \tau_g) = (0, \phi)$.

Last, we show that $\tau_E \geq 0$ and $\tau_g \leq \phi$ can not constitute an optimal tax policy. First, we have already established that if $\tau_g = \phi$ then $\tau_E \geq 0$ is suboptimal. Second, suppose that $\tau_g < \phi$ and $\tau_E \geq 0$. Consider a consumer with utilization need θ. If this consumer sees a benefit of B to purchasing E, then the social benefit of this consumer purchasing E is at least

$$
B + \tau_E + (\tau_g - \phi)[e_E m^*(\theta, e_E, p_g) - e_I m^*(\theta, e_I, p_g) > B.
$$

The inequality follows from the assumption that $\tau_g < \phi$ and because $e_E m^*(\theta, e_E, p_g) < e_I m^*(\theta, e_I, p_g)$ by Lemma 2. Thus under the proposed tax policy, it is socially optimal for any consumer who is indifferent between E and I to purchase E. By Lemma 4 the marginal impact of decreasing τ_E is thus positive. ∎

Proof of Proposition 2. Proposition 1 establishes that $\tau_g = \phi$ can't be optimal. We now show that $\tau_g < \phi$ can't be optimal. Suppose, for the sake of contradiction, that it is. By Lemma 5, the intensive margin effect of increasing τ_g is then positive. An argument that is identical to the one in the proof of Proposition 1 establishes that the extensive margin effect of increasing τ_g is also positive. Thus $\tau_g < \phi$ can't be optimal. ∎

Proof of Proposition 3. As will be shown in Proposition 7, W^{SB} is the same under G and G'. Thus it only needs to be shown that if W^{SB} is achieved under the policy $\tau^* = (\tau_E^*, \tau_g^*)$ when the distribution is G, then W^{SB} is achieved by $\tau^{**} = (\tau_E^{**}, \tau_g^*)$ when the distribution is G'. To do this, just check that if $\theta_L^\dagger$ and $\theta_H^\dagger$ are the utilization needs of the marginal γ_L and γ_H consumers under τ^* and G, then $\theta_L^\dagger$ and $\theta_H^\dagger$ will also be the utilization needs of the marginal γ_L and γ_H consumers under τ^{**}. Checking this fact is boring algebra that we omit. ∎

Proof of Proposition 4. Let G be a distribution of attention with weights γ_H and γ_L, and let $G(k)$ be a "scaled down" version of G with weights $k\gamma_H$ and $k\gamma_L$. Let $W_{energy}^{TB}(k)$ be the third-best welfare corresponding to $G(k)$. We will show that $W_{energy}^{TB}(k)$ is decreasing in k. This will complete teh proof as Proposition 7 shows that W^{SB} is constant in k.

For the rest of the proof, it helps to keep track of the equations determining the utilization needs $\theta_L^\dagger$ and

$\theta_H^\dagger$ of the marginal γ_L and γ_H agents:

$$\gamma_L[e_I m^*(\theta_L^\dagger, e_I, p_g) - e_E m^*(\theta_L^\dagger, e_E, p_g)] + \gamma_L[u(m^*(\theta_L^\dagger, e_E, p_g) - \theta) - u(m^*(\theta_L^\dagger, e_I, p_g) - \theta)] = c_E - c_I$$
$$\gamma_H[e_I m^*(\theta_H^\dagger, e_I, p_g) - e_E m^*(\theta_H^\dagger, e_E, p_g)] + \gamma_H[u(m^*(\theta_H^\dagger, e_E, p_g) - \theta) - u(m^*(\theta_H^\dagger, e_I, p_g) - \theta)] = c_E - c_I$$

Lemma 4 shows that

$$\frac{\frac{\partial}{\partial k}\theta_L^\dagger}{\frac{\partial}{\partial k}\theta_H^\dagger} = -\frac{\gamma_H}{\gamma_L}.$$

Likewise, Lemma 4 shows that

$$\frac{\frac{\partial}{\partial p_g}\theta_L^\dagger}{\frac{\partial}{\partial p_g}\theta_H^\dagger} = -\frac{c_E - c_I - \gamma_L \Delta u(e_E, e_I, p_g)}{c_E - c_I - \gamma_H \Delta u(e_E, e_I, p_g)}.$$

Now since $u'(m^*(\theta^\dagger, e, p_g) - \theta^\dagger) = pe$, we know that the slope between $u(m^*(\theta^\dagger, e_E, p_g) - \theta^\dagger)$ and $u(m^*(\theta_L^\dagger, e_E, p_g) - \theta^\dagger)$ is never greater than pe_I, and thus that

$$\Delta u(e_E, e_I, p_g) < e_I(m^*(\theta^\dagger, e_E, p_g) - m^*(\theta^\dagger, e_I, p_g)) < e_E m^*(\theta^\dagger, e_E, p_g) - e_I m^*(\theta^\dagger, e_I, p_g).$$

Thus $\Delta u(e_E, e_I, p_g) < (c_E - c_I)/2$. Moreover, because $\frac{c_E - c_I - \gamma_L \Delta u(e_E, e_I, p_g)}{c_E - c_I - \gamma_H \Delta u(e_E, e_I, p_g)}$ is increasing in Δu, this quantity is maximized at $\Delta u = (c_E - c_I)/2$ and thus

$$\frac{c_E - c_I - \gamma_L \Delta u}{c_E - c_I - \gamma_H \Delta u} < \frac{2 - \gamma_L}{2 - \gamma_H}$$

Because the function $x(2 - x)$ is increasing on $[0, 1]$, we also have that $\gamma_L(2 - \gamma_L) < \gamma_H(2 - \gamma_H)$ and so

$$\frac{2 - \gamma_L}{2 - \gamma_H} < \frac{\gamma_H}{\gamma_L}.$$

This means that increasing k by a small amount has a larger relative effect on the γ_L agents than does increasing the energy tax by a small amount.

Now the optimal energy tax satisfies $\tau_E^* > \phi$ by Proposition 2. As in the proof of Proposition 1, we decompose the effects of increasing τ_E into the extensive margin effect and the intensive margin effect. By Lemma 5, the intensive margin effect is negative, and thus the assumption that τ_E is set optimally implies that the extensive margin effect is positive. It is also easy to verify that the energy tax must be set such that the γ_L agents are still underpurchasing E (relative to the social optimum) while the γ_H agents are overpurchasing E. Thus increasing k by a small amount has a net positive effect on social welfare because it has a positive extensive margin effect and a zero intensive margin effect. ∎

Proof of Proposition 5. Analogously to the proof of Proposition 7 (part 2), we can show that if γ_H/γ_L is held constant then W^{TB} does not change as the distribution of attention changes. On the other hand, W^{BL} clearly decreases as consumers become more biased. So $(W^{SB} - W^{TB})/(W^{FB} - W^{BL})$ decreases. ∎

Proof of Proposition 6. Let θ^* be the type such that in the first best allocation, any type with $\theta > \theta^*$ must purchase E and any type with $\theta < \theta^*$ must purchase I.

For this type, the *perceived* gain from purchasing E is

$$\gamma[v(\theta^*, e_I, p_g) - v(\theta^*, e_E, p_g)] - (p_E - p_I).$$

Thus this type will be indifferent between E and I when $\tau_g = \phi$ if and only if

$$\tau_E = (1 - \gamma)[v(\theta^*, e_I, p_g) - v(\theta^*, e_E, p_g)].$$

By Lemma 3, a consumer will purchase E if and only if $\theta > \theta^*$, and thus the consumer choice will be first best at this policy. An argument analogous to the proof of Claim 1 shows that no other policy achieves the first best. ∎

Proof of Proposition 7, part 1. Let $W_L(\tau)$ and $W_H(\tau)$ correspond to the social welfare of each attention group γ_L and γ_H, so that $W(\tau) = \alpha W_L(\tau) + (1 - \alpha)W_H(\tau)$. Now keep γ_L and γ_H constant, and let A be the set of α such that there is an optimal tax policy τ^* under which $W_L(\tau^*) > W_H(\tau^*)$. Set $\alpha^\dagger = \sup A$. First, we claim that W^{SB} is decreasing in α for $\alpha < \alpha^\dagger$. This follows simply because $\alpha W_L + (1 - \alpha)W_H$ is decreasing in α when $W_L > W_H$, and thus if $\alpha_1 < \alpha_2 < \alpha^\dagger$, then any second best welfare level achievable under α_2 is also achievable under α_1. Analogous logic shows that W^{SB} is increasing in α when $\alpha > \alpha^\dagger$. ∎

Proof of Proposition 7, part 2. Set $r = \gamma_H/\gamma_L$ and assume that $k > 1$. Let $\theta_L^\dagger(r)$ and $\theta_H^\dagger(r)$ be the utilization needs corresponding to the γ_L and γ_H consumers that are on the margin when a second best tax policy $\tau^* = (\tau_E^*, \tau_g^*)$ is implemented. Now consider a different distribution of attention G' in which $\gamma_H'/\gamma_L' = r' < r$, and consider a tax policy (τ_E^{**}, τ_g^*) such that the utilization need of the γ_H consumer who is indifferent between E and I under this policy is still $\theta_H^\dagger(r)$. We will be done if we can just show that under τ^{**} and attention H', the utilization need $\theta_L^\dagger(\tau_E^{**})$ of the marginal γ_L consumer is lower than $\theta_L^\dagger(r)$. To see why this is enough to complete the proof, let θ^{**} be the utilization type such that if the energy tax is set at $\tau_g = \tau_g^*$, then it is socially optimal for any type $\theta < \theta^{**}$ to purchase I and socially optimal for any type $\theta > \theta^{**}$ to purchase E. Such threshold type θ^{**} exists by Lemma 6. But standard envelope theorem arguments imply that τ_E^* is such that $\theta_H^\dagger(r) < \theta^{**} < \theta_L^\dagger(k)$. Thus if $\theta_L^\dagger(\tau^{**}) > \theta^{**}$ we are done, since that implies that under τ^{**} and distribution G', the choices of the more attentive consumers are the same, while the choices of the less attentive consumers are more efficient.

On the other hand, if $\theta_L^\dagger(\tau^{**}) < \theta^{**}$ then we can increase τ_E^{**} to a level τ_E^{***} such that the utilization demand of of the marginal γ_L consumer equals θ^{**} while the utilization demand of the marginal γ_H consumer is now higher than $\theta_H^\dagger(k)$. Then choices of the less and more attentive consumers are again more efficient under G' and the adjusted tax policy.

To finish, some algebra shows that if $\theta_L^\dagger$ and $\theta_H^\dagger$ are the marginal utilization needs under some tax policy, then

$$v(\theta_L^\dagger, e_E, p_g) - v(\theta_L^\dagger, e_I, p_g) = \frac{\gamma_H}{\gamma_L}(v(\theta_H^\dagger, e_E, p_g) - v(\theta_H^\dagger, e_I, p_g)).$$

Thus by Lemma 3, if $\theta_H^\dagger$ is held constant while γ_H/γ_L decreases, $\theta_L^\dagger$ will decrease. ∎

Proof of Proposition 8. Obvious from definitions. ∎

Proof of Proposition 9. The proposed equilibrium clearly satisfies conditions 1 and 2. We now check that the proposed equilibrium satisfies condition 3, and that no other equilibrium satisfies condition 3.

Set $\tau_g = \phi$ and $\tau_E = 0$. As usual, let θ^* be such that it is efficient for a consumer to purchase E if and

only if $\theta \geq \theta^*$. Set $\underline{\tau}_{ex} \equiv (1 - \gamma_L)[v(\theta^*, e_E, c_g + \phi) - v(\theta^*, e_I, c_g + \phi)]$. Choose $\tau_{ex} > \underline{\tau}_{ex}$. Then by Lemma 3,

$$\widetilde{V}(i, I, p_I) - \tau_{ex} - c_I < V(i, E, p_E) - c_E \tag{14}$$

for all consumers.

Now suppose, for the sake of contradiction, that the market sold I to consumers with $\theta > \theta^*$. Then by the zero profit condition, the market price would be $P_I = c_I + \tau_{ex}$ to these consumers. However, equation (14) implies that consumers would not purchase I at this price. Thus there can not be equilibria other than the one we propose.

To verify that our proposed equilibrium is indeed an equilibrium, notice that the only deviation that could potentially be profitable to a seller is to try to sell I to consumers with $\theta > \theta^*$. However, the most that consumers would be willing to pay for I, even if the seller sets $n = 0$, is $\widetilde{V}(i, I, p_I) - (V(i, E, p_E) - c_E) < \tau_{ex} + c_I$. Thus a seller can not profitably sell I to these consumers. ∎