DOES A MEAT TAX TRUMP GREEN LABEL EDUCATION EFFECTS

by

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ABSTRACT

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External cost from meat consumption raises an issue of possible government mechanisms toward mitigation. Economic theory provides a framework for determining the optimal set of mechanisms considering the associated benefits and costs. Such a theoretical development rests on the responsiveness of consumers to alternative mechanisms. Considering two mechanisms, a Pigouvian tax and green-label education, yields tandem theoretical optimal government mechanisms. Populating this theoretical model with empirically derived elasticities and other parameters provides an application. Results indicate education alone will likely not yield a high social-optimal level of mitigation. Instead, a Pigouvian tax will be required to move consumption toward a socially desired state.

CHAPTER 1. INTRODUCTION

1.1 Importance in the World Today

An expanding global middle class with changing dietary patterns toward meat consumption creates major health and environmental challenges. It has driven up global meat consumption more than 500% from 1992 to 2016, with projections of continued growth (FAIRR 2017; Vranken et al. 2014). The agricultural sector is responsible for 25% to 30% global anthropogenic greenhouse gas (GHG) emissions with livestock the major sector's contributor at 8% to 18% (Heller and Keoleian 2015; FAIRR 2017; O'Mara 2011; Wirsenius et al. 2011). Despite this impact, the agricultural sector and livestock in particular has generally witnessed limited GHG government-policy mechanisms.

Complementing livestock impacts on GHG, the popular press is concerned with the impact of meat consumption on global-health epidemics including obesity, cancer, and antibiotic resistance (Giubilini et al. 2017; Hamblin 2017). In addition, evidence connects meat consumption with higher risks of type 2 diabetes, threats to global food security and water availability, and soil degradation and deforestation (FAIRR 2017). Animal rights advocates are also concerned with animal husbandry leading to possible mistreatment (PETA 2018).

Confronting the health and environmental external costs of meat consumption is the status symbol of meat eating (Rowland 2017), so it may not be easy to change consumer preferences toward lowering meat consumption. Nordgren (2012a) suggests voluntary changes in lifestyle toward reduced meat consumption may not be sufficient. Instead, he suggests it may require some coercive measures including a Pigouvian meat tax.

Research is lacking in the investigation of measures based on a theoretical economic foundation. Such a foundation provides a framework for determining consumer and livestock sectors' response to government mechanisms designed for internalizing meat-consumption external costs. The unique contribution is to provide such a foundation with the associated hypothesis: education is a weak mechanism for yielding a high social-optimal level of mitigation. Instead, a Pigouvian tax as a strong mechanism is required to move consumption toward the socially desired state. Optimal government mechanisms for addressing the external costs of meat consumption require consideration of the benefits and costs of such mechanisms. Results reveal consumer response to government mechanisms designed to mitigate external costs are the foundation for any optimal set of mechanisms. Initial empirical estimates of the optimal beef tax in conjunction with programs for changing consumer preferences reveal their relative impacts on beef consumption and reducing external costs. Populating a theoretical optimal-mechanism model supports the hypothesis by revealing the dominance of a Pigouvian tax over an educational program.

Springmann et al. (2016) states the adoption of diets meeting Healthy Global Dietary guidelines would have annual environmental benefits of $234 billion, with a range of $89 to $729 billion. Green-consumption taxes on meat can align diets with lower relative animal-sourced foods. Limited if any literature exists addressing the magnitude of any kind of meat tax. One exception is Springmann et al. (2018), where they measure the optimal red meat and processed meat tax across 149 regions when considering health impacts. As addressed by Heffernan (2017), there is a question if consumers can wean themselves from current levels of meat consumption. The issue of the optimal level of government mechanisms (meat tax and education) is unresolved.

Considering an optimal meat tax, as addressed by Bénabou and Tirole (2006) providing a government mechanism (a meat tax) for consumers taking a certain action (reduce meat consumption) can have perverse effects. The classic example is paying for blood donations could actually reduce supply (Titmuss 1970), with a recent application to solar photovoltaic technologies by Liu (2018). Consumer prosocial behavior is the intrinsic motivation to take actions, which are in society's best interest. Consistent with motivational-crowding theory (Frey and Jegen 2001), an external meat tax can result in a loss (crowding out or rebound effect) of intrinsic motivation. Consumers' reputation for being prosocial may not be as strong with a meat tax.

1.2 Meat Tax vs Green-Meat Label

The taxation approach for curbing GHG emission and health effects are a blunt instrument, which may be less effective than methods taking a deeper look at consumer choice and then developing a targeted approach (Briggs et al. 2016). One option could be climate labelling (Tidåker and Richert 2018) or building a case for government policy (Wellesley and Froggatt 2015). This would involve developing evidence, which resonates with policymakers. Initiate a national debate on meat consumption to heighten public awareness and pursue comprehensive approaches toward shifting diets. Modify consumer preferences toward being prosocial on meat consumption. Laestadius et al. (2013) argue for continued public education campaigns with clear messaging.

Labeling is a program designed to alter consumer's behavior (Magat and Viscusi 1992). Extending climate labeling of meat products to consider all the external cost of meat consumption yields a label termed green-meat label. For theoretical analysis, the green-meat label could serve as a surrogate for all government mechanisms designed to modify consumer preferences toward prosocial meat consumption and individual improved health and nutrition.

As addressed by Golan et al. (2001), government-mandated labeling may be a useful mechanism for modifying consumer preferences. Specifically, the Family Smoking Prevention and Tobacco Control Act passed in 2009 mandates labeling of cigarette packages, which aims to increase consumer education and decrease cigarette consumption (FDA 2011). However, Golan et al. (2001) discuss that designing government mechanisms is complex and a nontrivial task, which requires determining the benefits to society and costs of government-market intervention.

There are alternatives to a Pigouvian tax and labelling. Economic theory identifies a number of government mechanisms, which may be preferred to internalizing external costs. For instance, bans, quotas, production regulations, and/or standards. These are supply-side mechanisms, which do not directly influence consumer preferences. They only limit the availability of commodities. Interest instead is on government mechanisms such as labelling, which may directly influence consumer preferences. Revell (2015) emphasizes the importance is considering the market effects of changes in meat consumption habits (demand oriented policies).

1.3 Technology

In terms of the supply-side, sustainable technologies are under development, which may require providing information on the technologies, possibly through labelling, for consumers to change their preferences (Heffernan 2017). Hyland et al. (2017) reviews complexities regarding sustainability of meat consumption and provide some strategies for mitigating the external costs. They indicate sustainable diets are possible without elimination of meat in consumer diets. On-farm sustainability offers promise with a balance between supply and demand approaches toward mitigation.

Bonny et al. (2015) argue the livestock sector cannot respond to demand increases by allocating increasing resources toward production. The sector will have to find solutions regarding animal welfare, health, and sustainability then facing competition from emerging non-traditional meat and protein products. The livestock sector can internalize external costs by adopting agro-ecological concepts and biotechnologies for sustainable production systems (Bonny et al. 2015). Herrero et al. (2016) estimate an annual reduction in GHG emissions from livestock of approximately 2.4 billion tons through use of technology and management. This represents 50% of the mitigation potential from agriculture, forestry, and the land-use sector. Achieving this reduction is dependent on improved feeding practices including better pastures and new feeds, manure-handling methods, and genetics and animal management. A 30% reduction in GHG is possible if producers adopted least-emission intensive practices (FAO 2014). Government mechanisms curbing meat consumption may reduce such adoption and curb research and development on mitigating the external costs (Briggs et al. 2015; Von Massow and Cranfield 2018). Reduced revenue from government mechanisms may decrease the incentive to fund research and development.

1.4 Artificial and Replacement Meat

Research and development is currently progressing in the realm of artificial meat. The future of artificial meat, designed to meet the issues facing the conventional meat industry, is uncertain. As addressed by Bonny et al. (2015), currently these artificial meats have no real capacity to compete with conventional meat production. In the future, technology may result in competitively priced artificial meat without the external costs. In contrast, meat replacement manufactured from plant proteins and mycoproteins are gaining in market share.

1.5 Meat Tax

Without government mechanisms, Nordgren (2012b) argues livestock-sector technological solutions will probably not be sufficient. High monitoring costs and comparatively low technical potential for emission reductions in the livestock sector, leaves the option of reduced meat production and consumption (Wirsenius et al. 2011). This suggests government mechanisms such as meat taxes and green labelling are required.

Not addressed in the literature is the enforcement of any such meat tax. In contrast to cigarettes, alcohol, and gasoline, meat is relatively easy to produce. Any high tax could spawn a black market for meat sales. Demand for legal meat sales will be highly elastic with black-market sales as a substitute. This could result in high enforcement costs reducing any net revenue generated.

Limited research has addressed the allocation of net revenue collected from a meat tax. The revenue could fund technology and development including alternatives to antibiotics in animal husbandry (Giubilini et al. 2017). Such returns to the livestock sector would mitigate possible reduction in research and development from a meat tax. An alternative is returning revenue by lowering consumer taxes. This could be in the form of reduced payroll taxes and/or Medicare and Medicaid expenditures. Lowering these costs would help address the income regressive nature of a meat tax (Allais et al. 2010; Briggs et al. 2016; Säll 2018). Results by Vranken et al. (2014) indicate evidence for an inverted U-shaped relationship between meat consumption and income. At a certain level of income, average meat consumption will stagnate or even decline.

1.6 Denmark's Meat Tax

As the first country to do so, Denmark introduced a tax on saturated fat in 2011 and subsequently repealed it in 2012. Vallgårda et al. (2015) present arguments and themes involved in the debates surrounding its introduction and repeal. Opposition to the tax stated it harmed the economy with no positive influence on health. Research indicates the tax was effective in changing consumer behavior with a reduction in saturated fat consumption (Jensen et al. 2015).

CHAPTER 2. THEORETICAL MODEL

Incorporating previous literature outlining the impact of government mechanisms on meat consumption and the associated external costs into a theoretical lattice will provide an understanding of how to design an effective and efficient program.

The theory employed for determining the optimal tax/subsidy for vehicle fuel (Parry and Small 2005; Vedenov and Wetzstein 2008; Wu 2012), photovoltaic solar panel (Liu et al. 2018), and food waste (Katare et al. 2017) is modified for developing the theoretical optimal meat tax and green-label education. As a basis for this theoretical foundation, consider consumer determinants for meat purchases along with social costs not considered by consumers. Let τ denote a per-unit tax on meat, M, and L represent a per-unit government mechanism of educating consumers on the external costs of meat consumption with green-label education as an icon for this mechanism.

Considering prosocial behavior, let θ represent this social benefit, where a per-unit meat tax, τ, will reduce the benefit, $\partial\theta/\partial\tau < 0$ with $\partial^2\theta /\partial\tau^2 > 0$. Reducing meat consumption provides a consumer a positive reputation or mystique of being prosocial, $\partial\theta/\partial M < 0$ with $\partial^2\theta /\partial M^2 > 0$. A meat tax may reduce any prosocial benefits with consumers' reduced meat consumption not necessarily for reputation but for the higher cost of meat. With the tax internalizing the external costs, some consumers may consider the tax replaces prosocial choice. This external meat tax can result in a loss (crowding out or rebound effect) of intrinsic motivation. In contrast, funding a green-label education per-unit of consumer meat consumption, L, can support the positive reputation, so $\partial\theta/\partial L > 0$ with $\partial^2\theta /\partial L^2 < 0$. Expenditures on green labeling internalize the external costs without any rebound effect.

2.1 Consumer Decision Model

In the development of the theory of consumer meat consumption, consider the principles of consumer theory. The main objective is to provide an outline of consumer meat consumption in a universal setting for all types of meats. With this treatment as a foundation, the goal is to provide an empirical investigation in modeling a consumer's beef-consumption response to government mechanisms. Such treatment will direct the development of theoretically sound elasticity estimates and their application to beef consumption policy. This will provide the first theoretical development of the welfare policies focused on mediating consumers' meat consumption and society's social meat-consumption costs.

Assume a consumer receives satisfaction from meat consumption, M, and meat replacement, S. Then represent a utility function as

$$u[M, S, \theta(\tau, L)], \qquad (1)$$

where all the determinants positively influence a quasiconcave utility function. Associated with this utility function are external costs, D, which the consumer does not consider. These costs are composed of any social costs associated with GHG emissions, health effects, natural resource degradation, and animal husbandry. Specifically,

$$D = D(M, S, TR), \partial D/\partial M > 0,$$

with $\partial^2 D/\partial M^2 > 0$, $\partial D/\partial S > 0$ with $\partial^2 D/\partial S^2 > 0$, and $\partial D/\partial TR < 0$ with $\partial^2 D/\partial TR^2 > 0$,

where $TR = (p - \tau)M$ denotes total revenue with p representing a constant price per-unit of meat. Assuming elastic demand, with an increase in the meat tax or green-label education, revenue for the meat industry declines and possibly associated with less funding for research and development of green (sustainable) meat. Meat replacement also contributes to the external costs, D, through the nonmarket costs associated with nonmeat agricultural production.

Consider a meat tax as an augmented price on the private meat commodity. In contrast, the green-label education is a public good, which the government incurs a production cost. Consumers consume the green label through the effect it has on both their private meat consumption and their prosocial behavior, θ. Government meat-tax revenue minus the cost for administration and enforcement of the tax plus the cost of promoting green labeling is

$$G = (\tau - \omega)M - LM,\ \partial G/\partial\tau = M + (\tau - \omega - L)\frac{\partial M}{\partial \tau},\ \partial G/\partial L = (\tau - \omega)\frac{\partial M}{\partial L} - M - L\frac{\partial M}{\partial L},$$

where ω denotes the per-unit cost of tax administration and enforcement.

A consumer in its choice of meat, M, and its replacement, S, does not consider the external cost, D, and government net revenue, G, and then maximizes (1) subject to the following budget constraint

$$(p + \tau)M + S = I + \propto G,$$

where I denotes consumer income allocated to protein purchases and the price of meat replacement, S, is a numeraire. Augmenting income, I, is a share of the net revenue from the tax, $0 \geq \propto \leq 1$, rebated to the consumer. This would partially mitigate the regressive nature of a meat tax. The indirect utility function is then

$$V(\tau, L, p, I) = \max u[M, S, \theta(\tau, M, L)] + \lambda[I + \propto G - (p + \tau)M - S] - \delta(D) + \rho[(1 - \propto)G], \tag{2}$$

where δ, $\delta' > 0$, is quasiconcave, representing the disutility from external costs and ρ, $\rho' > 0$, is quasiconcave denoting the utility from net government revenue not rebated to the consumer. Embedded in ρ is the equity issue of a regressive meat tax. The greater concern for this equity issue, the higher effort/expense on education. Consumers ignore the effects of external costs, the last two terms in (2). The F.O.C.s are then

$$u_M - \lambda(p+\tau) = 0,$$

$$u_S - \lambda = 0,$$

$$I + \propto G - (p+\tau)M - S = 0,$$

where the subscripts represent partial derivatives.

2.2 Welfare Model

The welfare effect of an incremental change in a meat tax and green-label education may be determined by totally differentiating (2). Note that in contrast to the F.O.C.s for (2), there is now internalization of consumer's external costs into the calculus. With the aid of the envelope theorem

$$\frac{dV}{d\tau} = -\lambda M + \lambda \propto \left[M + (\tau - \omega - L)\frac{\partial M}{\partial \tau}\right] + u_\theta \frac{\partial \theta}{\partial \tau}$$
$$-\delta' \left[\frac{\partial D}{\partial M}\frac{\partial M}{\partial \tau} + \frac{\partial D}{\partial S}\frac{\partial S}{\partial \tau} + \frac{\partial D}{\partial TR}\left(-M + (p-\tau)\frac{\partial M}{\partial \tau}\right)\right] + \rho'(1-\propto)\left[M + (\tau - \omega - L)\frac{\partial M}{\partial \tau}\right]. \quad \text{(3a)}$$

$$\frac{dV}{dL} = \lambda \propto \left[(\tau - \omega - L)\frac{\partial M}{\partial L} - M\right] + u_\theta \frac{\partial \theta}{\partial L}$$
$$-\delta' \left[\frac{\partial D}{\partial M}\frac{\partial M}{\partial L} + \frac{\partial D}{\partial S}\frac{\partial S}{\partial L} + \frac{\partial D}{\partial TR}\left((p-\tau)\frac{\partial M}{\partial L}\right)\right] + \rho'(1-\propto)\left[(\tau - \omega - L)\frac{\partial M}{\partial L} - M\right].$$

(3b)

Defining the marginal external costs of meat and meat replacement consumption as $MEC_M = \frac{\delta'}{\lambda}\frac{\partial D}{\partial M} > 0$ and $MEC_S = \frac{\delta'}{\lambda}\frac{\partial D}{\partial S} > 0$, respectively, the marginal external benefits as $MEB = -\frac{\delta'}{\lambda}\frac{\partial D}{\partial TR} > 0$, and dividing (3) by λ results in the marginal monetary welfare effect of a meat tax and green-label education

$$\frac{1}{\lambda}\frac{dV}{d\tau} = -M + \propto \left[(\tau - \omega - L)\frac{\partial M}{\partial \tau} + M\right] + \frac{u_\theta}{\lambda}\frac{\partial \theta}{\partial \tau}$$

$$-\left[MEC_M \frac{\partial M}{\partial \tau} + MEC_S \frac{\partial S}{\partial \tau} - MEB\left(-M + (p-\tau)\frac{\partial M}{\partial \tau}\right)\right]$$

$$+\frac{\rho'}{\lambda}(1-\propto)\left[M + (\tau - \omega - L)\frac{\partial M}{\partial \tau}\right].$$

(4a)

$$\frac{1}{\lambda}\frac{dV}{dL} = \propto \left[(\tau - \omega - L)\frac{\partial M}{\partial L} - M\right] + \frac{u_\theta}{\lambda}\frac{\partial \theta}{\partial L}$$

$$-\left[MEC_M \frac{\partial M}{\partial L} + MEC_S \frac{\partial S}{\partial L} - MEB(p-\tau)\frac{\partial M}{\partial L}\right]$$

$$+\frac{\rho'}{\lambda}(1-\propto)\left[(\tau - \omega - L)\frac{\partial M}{\partial L} - M\right].$$

(4b)

From (4) it is possible to derive the optimal meat tax and green-label education.

Theorem 1. Optimal Meat tax and Green-Label Education

$$\tau^* = \frac{\frac{u_\theta}{\lambda}\frac{\theta}{M}\epsilon_{\theta,\tau} + \left[-\left(\propto + \frac{\rho'}{\lambda}(1-\propto)\right)(\omega+L) - MEC_M + pMEB\right]\epsilon_{M,\tau} - \frac{S}{M}MEC_S\epsilon_{S,\tau}}{1-\left(1+\epsilon_{M,\tau}\right)\left(\propto + \frac{\rho'}{\lambda}(1-\propto) - MEB\right)}$$

(5a)

$$L^* = \frac{\frac{u_\theta}{\lambda}\frac{\theta}{M}\epsilon_{\theta,L} + \left[\left(\propto + \frac{\rho'}{\lambda}(1-\propto)\right)(\tau-\omega) - MEC_M + (p-\tau)MEB\right]\epsilon_{M,L} - \frac{S}{M}MEC_S\epsilon_{S,L}}{\left[\propto + \frac{\rho'}{\lambda}(1-\propto)\right]\left(1+\epsilon_{M,L}\right)}$$

(5b)

Proof:

Setting the first-order condition (4a) to zero and multiplying by τ/M yields

$$-\tau + \propto \left[(\tau - \omega - L)\epsilon_{M,\tau} + \tau\right] + \frac{u_\theta}{\lambda}\frac{\theta}{M}\epsilon_{\theta,\tau} - MEC_M\epsilon_{M,\tau} - \frac{S}{M}MEC_S\epsilon_{S,\tau}$$

$$+MEB\left(-\tau + (p-\tau)\epsilon_{M,\tau}\right) + \frac{\rho'}{\lambda}(1-\propto)\left[\tau + (\tau - \omega - L)\epsilon_{M,\tau}\right] = 0.$$

Solving for τ yields the optimal meat tax (5a).

Setting first-order condition (4b) to zero and multiplying by L/M yields

$$\propto \left[(\tau - \omega - L)\epsilon_{M,L} - L\right] + \frac{u_\theta}{\lambda}\frac{\theta}{M}\epsilon_{\theta,L} - MEC\epsilon_{M,L} - \frac{S}{M}MEC_S\epsilon_{S,L}$$

$$+MEB(p-\tau)\epsilon_{M,L} + \frac{\rho'}{\lambda}(1-\propto)\left[(\tau-\omega-L)\epsilon_{M,L} - L\right] = 0.$$

Solving for L yields the optimal green-label education per-unit of meat consumed (5b).

□

Table 1 summaries the underlying determinants of (5), assuming $-(MEC_M - pMEB)\epsilon_{M,\tau} > \frac{S}{M}MEC_S\epsilon_{S,\tau}$ and $-[MEC_M - (p-\tau)MEB]\epsilon_{M,L} > \frac{S}{M}MEC_S\epsilon_{S,L}$. The meat tax and green-label education reduce the external meat costs more than the increase in external meat-replacement costs. As listed in Table 1, the optimal government mechanisms are the sum of prosocial behavior, marginal external costs and benefits, tax rebate, and government administration/education costs and revenue.

Theorem 1 yields the follow propositions.

Proposition 1: Pigouvian Tax and Green-Label Education

If there is no prosocial behavior, no administration and education cost, no technology effect on reducing external cost, and all government revenue is rebated to consumers, then

$\tau^* = MEC_M + \frac{S}{M}MEC_S\frac{\epsilon_{S,\tau}}{\epsilon_{M,\tau}}$, Pigouvian tax,

(6a)

$L^* = \frac{\tau\epsilon_{M,L} - MEC_M\epsilon_{M,L} - \frac{S}{M}MEC_S\epsilon_{S,L}}{(1+\epsilon_{M,L})}$, Pigouvian green-label education.

(6b)

The Pigouvian tax and green-label education are set equal to the influence they have on reducing the marginal external costs of meat consumption, which is mitigated by the additional external costs of meat-replacement consumption. Note that $\epsilon_{M,\tau}, \epsilon_{M,L} < 0$, and $\epsilon_{S,\tau}, \epsilon_{S,L} > 0$. The $\frac{S}{M}$ ratio converts the effect of the government mechanisms on meat replacement to a per-unit of meat consumption. Similarly, in (6a), the elasticity ratio, $\frac{\epsilon_{S,\tau}}{\epsilon_{M,\tau}}$, converts the response of meat in terms of its replacement. The first term on the right-hand-side of (6b), measures the lost revenue from green-label education reducing meat consumption.

The denominator in (6b) is the elasticity of total green-label education, $\epsilon_{E,L} = 1 + \epsilon_{M,L} > 0$, where $E = LM$. This assumes an inelastic response of meat consumption to green-label education. An increase in green-label education will increase total expenditures. The denominator then converts the expenditures into a per-unit increment.

Corollary 1: Given Proposition 1:

- **a.** The higher the marginal external meat costs; the larger the optimal meat tax and green-label education.
- **b.** Any increase in the external cost of meat replacement, dampens the effectiveness of the meat tax and green-label education.
- **c.** The more responsive meat replacement is to government mechanisms, the lower will be the tax and green-label education.
- **d.** The more responsive meat is to its own tax and education, the higher will be the optimal tax and green-label education, respectively.

Corollary 1a is the classical Pigouvian solution with Corollary 1b creating a wedge between an optimal mechanism and the associated externality. For an optimal meat tax, this results in $\tau^* < MEC_M$. The more responsive meat replacement is to the government mechanisms the wedge increases, Corollary 1c, which lowers the optimal government mechanisms. Corollary 1d implies the optimal objective is to concentrate on the government mechanism that provides the larger impact on reducing the external costs. The proof of Corollary 1d for the optimal green-label education relies on Corollary 1b result of $\tau^* < MEC_M$.

Corollary 2: Given Proposition 1, if $\epsilon_{S,\tau} = \epsilon_{S,L}$ and $\epsilon_{M,\tau} = \epsilon_{M,L}$, then $\tau^* > L^*$.

Proof:

Taking the ratio of (6) reveals the corollary

$$\frac{\tau^*}{L^*} \propto \frac{MEC_M + \frac{S}{M} MEC_S \frac{\epsilon_{S,\tau}}{\epsilon_{M,\tau}}}{MEC_M + \frac{S}{M} MEC_S \frac{\epsilon_{S,L}}{\epsilon_{M,L}} - \tau} > 0.$$

□

Given Corollary 2, both government mechanisms exert the same effects on MEC_M and MEC_S, but green-label education is reducing the tax-revenue rebate. Corollary 2 is analogous to the classic tax versus subsidy issue. Assuming both provide the same internalization effect, taxing with a rebate is generally preferable to a subsidy in modifying consumers' decisions (Ballard and Medema 1993).

For further investigating (5), first consider the denominator in (5a). Consistent with the profit-maximizing meat sector only operating in the elastic response region, $(1 + \epsilon_{M,\tau}) < 0$.

Proposition 2: Meat Industry Paradox

An increase in *MEB* will decrease τ^* and L^*.

If the marginal benefits from increased meat sector revenue results in a very strong reduction in external costs, then the optimal meat tax and green-label education would be very low and theoretically could be nonpositive. This corresponds to a meat subsidy instead of a tax and the government promoting meat consumption instead green-label substitutes, which leads to the paradox. The idea is as consumer demand for green-meat increases, the market will respond with meat producers, through technology advancement, satisfying this demand. No requirement exists for government mechanisms to internalize the external costs. This assumes consumers possess full information on the external costs and are willing-to-pay for internalization.

Proof of Proposition 2 follows directly by taking the derivative of (5) with respect to MEB.

Proposition 3: Tax Rebate

Government rebate of a meat tax will lower the optimal green-label education, L^*, if consumer utility is greater than government benefits from a meat tax. Specifically

$$\frac{\partial L^*}{\partial \propto} < 0, \text{ if } \; 1 - \frac{\rho'}{\lambda} > 0.$$

Proof of Proposition 3 follows directly by taking the derivative of (5b) with respect to $\propto$.

This proof relies of the assumption a consumer rebate, $\propto$, enhances welfare

$$\frac{\partial\left(\propto + \frac{\rho'}{\lambda}(1-\propto)\right)}{\partial \propto} = 1 - \frac{\rho'}{\lambda} > 0.$$

If the regressive nature of a meat tax is correct, then a redistribution of tax revenue in the form of a rebate is a possible mechanism toward mitigation. This suggests the marginal monetary benefits of government is relatively low, which results in $1 - \frac{\rho'}{\lambda} > 0$. It assumes enhancing welfare is greater by augmenting consumer income, a tax rebate, than by increasing government expenditures on green-label education. This leads directly to the proof of Proposition 3 and retaining an elastic response of meat to its tax. The effect of a change in the rebate on the optimal tax is indeterminate.

Proposition 4: Prosocial Behavior

An increase in prosocial behavior will lower the optimal meat tax and raise the green-label education.

This is by design, so interest is in the magnitude of the behavior and its effect on the optimal government mechanisms. The idea is the existence of a possible motivational-crowding effect associated with a tax and in contrast motivational enhancement with green-label education. There is slippage with a tax where a proportion of the tax is replacing any prosocial effects. In the extreme, the meat tax would crowd out all the prosocial behavior and green-label education would enhance social behavior. In the other extreme, if there is no response of behavior to the tax, then there is no motivational crowding. The smaller a consumer's prosocial behavior to meat consumption, $\frac{\theta}{M}$, the less effective is the elasticity of prosocial behavior to the tax and label. Even a relatively large response of prosocial behavior to a tax or label, a "meat-lover" with low prosocial interest will result in little motivational crowding and social enhancement. This is reinforced if the marginal monetary utility of prosocial utility, $\frac{u_\theta}{\lambda}$, is low.

The second terms in the numerators of (5) comprise the administration and enforcement cost. Any increase costs, ω, requires a higher optimal meat tax and green-label education. In contrast, any increase in the price of meat, p, will reduce the optimal government mechanisms.

As noted by Parry and Small (2005), the optimal government mechanisms are only second-best, given (5) depends on parameters at the social optimum and any observed values apply to the non-optimal equilibrium. It is assumed the elasticities and other parameters are constant and observed data directly populate (5).

CHAPTER 3. EMPIRICAL APPLICATION FOR BEEF IN THE UNITED STATES

3.1 Benchmark Values

Table 2 lists the parameter benchmark values and ranges for populating the optimal government mechanisms (5). These values reflect just one possible scenario for beef, developed in the appendix, and provide only a template for numerically applying the theory. Policymakers can substitute their own estimates and then derive their optimal government mechanisms. The numerical analysis does yield an indication on the influence and magnitude various parameters have on the optimal mechanisms.

Applying the benchmark parameter values from Table 2 directly to (5) and solving yields an estimated optimal beef tax, $\tau^* = \$3.43$, 68.6%, and green-label education $L^* = 0.027$, 0.54% (Table 3). Similarly, Proposition 1 yields $\tau^* = \$3.47$, 69.4%, and green-label education $L^* = 0.005$, 0.10%. For internalizing the external costs of beef consumption, a relatively large percentage of the beef price is required in the form of a Pigouvian tax relative to education. For these elasticities and other parameter values, a beef tax is relatively more effective than green-label education in internalizing external costs. In this case, green-label education is a weak mechanism for such internalization. Dissecting the components of the optimal government mechanisms reveals the underlying reasons for this result. The responsiveness of beef and its replacement to the tax, $(\epsilon_{M,\tau}, \epsilon_{S,\tau})$, influence all the components comprising the optimal tax. Similarly, the green-label educational influence on beef and its replacement affect the components associated with optimal label. The limited or zero response of beef to education yields the relatively low Pigouvian green-label education. In contrast, the relative effectiveness of a Pigouvian tax at reducing beef yields a relatively higher optimal tax.

These results are consistent with the tax/education effectiveness of other commodities associated with relatively high external costs. Evidence indicates health-warning labeling on cigarette packages have limited or no effect on the prevalence of smoking (Krugmann et al. 1999; CDC 1992). Some research has even indicated cigarette-warning labels were associated with increases in smoking prevalence (Robinson and Killen 1997). An explanation for this general ineffectiveness of labeling is consumers ignoring or not reading the labels (Magat and Viscusi 1992). Possibly, psychologically, consumers have cognitive dissonance when confronted with information, such as meat green labeling or eco-labeling, which contradicts their beliefs and attitudes. They then resolve this mental discomfort by discounting the information. Such discounting reduces the effectiveness of education (Beretti et al. 2009). In a dynamic setting, this suggests consumers may have a slow speed of adjustment when faced with new information. Green-label education may then be a long-run mechanism for altering consumer preferences.

In contrast, Pigouvian taxes are effective in reducing smoking and nicotine use (Sung et al. 1994; Keeler et al. 1993). Specifically, Keeler et al. (1993) estimated the price elasticity of demand for cigarettes in the short run within the range of -0.3 to -0.5. Becker et al. (1994) indicate a long-run response to smoking addiction will be twice that of the short-run effects.

Table 3 reveals government benefits and costs as the main drivers of the optimal mechanisms. In terms of the tax, removing the government benefits increases the optimal tax to \$5.92, 118%. As indicted in the denominator of (5b), as government cost of education approaches zero, the optimal level of education approaches infinity, which may then internalize all the external costs. From Proposition 3, government rebates of a meat tax in the form of enhancing consumer income will result in a lower optimal green-label education, L^*, and also in this case a lower optimal tax, τ^*. However, such rebates have a minor impact on the optimal mechanisms. Removing the rebate, $\propto = 0$, only reduces the optimal tax and green-label education by \$0.04 and \$0.004, respectively. This is the result of social return to investment being close to one, 1.05.

Associated with the optimal tax, the other main driver of the optimal is the marginal monetary external cost of beef, $-MEC_M \epsilon_{M,\tau}$. Prosocial behavior, marginal monetary external cost of meat replacement, and marginal monetary benefit only slightly mitigate these external costs. In particular, prosocial behavior's relativity small impact indicates limited crowding out effects.

In contrast, prosocial behavior in conjunction with the marginal monetary external cost of beef, support an educational effort with its costs mitigating the effort. However, the government cost of education is the major driver, which lowers optimal green-label education. Marginal monetary external cost of beef replacement, marginal monetary benefit, and administration/education play minor roles in determining an optimal green-label education.

3.2 Sensitivity Analysis

The wide range of parameter values in Table 2 suggests the benchmark optimal government mechanisms in Table 3 are associated with rather large variances. For investigating the sensitivity of the optimal government mechanism to ranges of the parameter values, we consider both individual parameter variation and Monte Carlo analysis.

As addressed in the appendix, Lawing et al. (2019) represents the first attempt at measuring the educational response, so subsequent research may reveal more elastic responses. Considering this possibility, Figure 1 illustrates the sensitivity of optimal green-label education to changes in beef and its replacement response to education. As the elasticity of beef to green-label education approaches unity, the optimal educational expenditure approaches infinity. For justifying a relatively high government expenditure on green-label education, this responsiveness would have to be markedly more elastic than estimates from Lawing et al. (2019). A damped response would occur if there were a corresponding more elastic response of beef substitutes to green-label education.

From (5), the optimal mechanisms are linear in their corresponding responsiveness of prosocial behavior to government mechanisms. The elasticity of the optimal tax to the responsiveness of prosocial behavior to the tax is highly inelastic, $\epsilon_{\tau^*,\varepsilon_{\theta,\tau}} = -0.013$. At least for the parameters listed in Table 2, there appears to be limited motivational crowding. Similarly, $\epsilon_{L^*,\varepsilon_{\theta,L}} = 0.039$, also yields limited prosocial enhancement.

For further sensitively analysis, consider a Monte Carlo simulation generating 10,000 random draws of the parameters, employing a uniform probability distribution over the parameter ranges listed in Table 2. Figure 2 illustrates the CDFs for the optimal government mechanisms. Relative to the optimal green-label education, the optimal-tax CDF varies over a wide range. The optimal green-label education is concentrated at a very low level of expenditures per pound of beef. This yields a median optimal green-label education of 0.02 compared to the optimal tax median of 3.43. For justifying a higher level of educational expenditures, the associated elasticities and parameters must be beyond the ranges listed in Table 2.

3.3 Implications

Society's possible interest in internalizing the negative external costs of meat consumption warrants consideration of a meat tax associated with green-label education. Such government mechanisms should consider their effect on prosocial behavior, external costs of meat replacement, benefits of research on reducing meat external costs, and administration/education costs. Economics provide a logical mechanism for categorizing the benefit and costs of such government mechanisms, which can yield an optimal set of mechanisms. The underlying drivers in determining the optimums rest on consumer response to the mechanisms. Economists have investigated the response of meat consumption to price (tax) with little associated effort on meat replacement. In contrast, meat consumption response to some form of education, green-label, generally does not exist. In support, of populating the developed theoretical model, Lawing et al. (2019) provide an initial attempt at measuring responsiveness to education. Their results indicate at best limited consumer meat consumption responsiveness to green-label education. This precipitated education being a weak mechanism for addressing the external cost of meat consumption, which supports the underlying hypothesis of a Pigouvian tax necessity. Education may be a long-run mechanism associated with consumers having a slow speed of adjustment. Future efforts will hopefully follow, yielding a definitive conclusion on the possible role of education. Current results indicate education alone will not yield a high socially desired effect of addressing meat consumption externalities. Society probably requires a strong mechanism (Pigouvian tax) to shift consumers' meat consumption toward a social optimal.

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APPENDIX

In 2018, the USDA, Economic Research Service reported per-capita consumption was 84, 67, 107, and 18 pounds of beef, pork, chicken, and other meats (predominantly turkey), respectively (Jones et al. 2018). For populating the model, consider per-capita beef consumption, *M*, as 84 lbs. The U.S. Dry Bean Council estimates the average 2018 per-capita bean consumption is approximately seven pounds (U.S. Dry Bean Council 2019). For an application, consider beans and non-beef meats as beef replacements. Beef replacement, *S*, is then the sum of annual pork, chicken, beans, and other meat consumption. The price per pound of beef ranges from \$4.07 to \$7.58 for ground beef and beefsteaks (U.S. Bureau of Labor Statistics 2018). We consider the average price of \$5.00 as the benchmark for *p*.

Diederich and Goeschl (2011) estimated \$8.76 per metric ton as consumers' willingness-to-pay for CO_2 abatement. Beef production generates 6.350 to 14.515 kilograms of CO_2 per pound of beef (Fankhauser 1994). This results in a prosocial behavior, $\frac{u_\theta}{\lambda}\frac{\theta}{M}$, range of \$0.055 to \$0.126 per pound of beef. Assuming the possibility of zero prosocial behavior, the benchmark is set at \$0.055 with a range of \$0.00 to \$0.126.

For administration and enforcement costs, a proxy considers the government costs for a sugar sweetened beverage tax for beef tax implementation and regulation, ω. The Seattle Community Advisory Board estimates the cost for their sugar sweetened beverage tax implementation is \$0.28 per-capita (Advisory Board 2017), while Long et al. (2015) determine a cost of \$0.155 per-capita. The administrative cost of implementing a tax on beef purchase in the city if Seattle amounts to about \$0.0033 per pound. On a per-pound of beef, the Seattle cost is \$0.0033. The annual expenditure for marijuana control is estimated to be \$13.7 billion (Miron 2010), which on a per-capita of beef consumption represents approximately \$0.50 per lb. Considering this cost an upper bound, as the regulation also has to control a well-established and widespread black market. For the application, consider a benchmark of \$0.0033 with an upper bound of \$0.50 per pound and a lower bound of \$0.00.

As a measurement of the social return on tax dollars, ρ'/λ, consider community returns to school and road-construction investments. Estimated school returns are as high as \$3.00 to \$1.00 with road-construction returns at \$1.05 per investment dollar (Martinez et al. 2013; Shirley and Winston 2004). Assuming returns of \$3.00 to education is not representative of all government programs, consider a benchmark of \$1.05 with a range of \$0.00 to \$3.00. Associated with this social return is the consumer tax-revenue rebate, $\propto$, which spans a range of 0 to 1, with 0.5 as the benchmark.

Marginal external cost of beef production, MEC_M, relies on upper and lower bound estimates for social cost of CO_2, health costs, animal cruelty, and natural resource degradation (De Vries and De Boer 2010; Peters et al. 2010; Simon 2013; Springmann et al. 2018). De Vries and De Boer (2010) estimate that one kilogram of beef production yields 14 to 32 kilograms of CO_2 equivalent GHGs. Converting kilograms to pounds and employing \$25.30 per metric ton of carbon as emission cost, one pound of beef production leads to \$0.16 to \$0.37 external costs with \$0.37 as the benchmark (Fankhauser, 1994). Simon (2013) estimates a much higher cost of \$3.35, which serves as the upper limit.

Springmann et al. (2018) estimate a high-income regions' health cost of beef at \$2.07 lb. They included disease states of coronary heart disease, stroke, and colorectal cancer. For low-income regions, this cost is \$0.04. When considering the disease associated with total cancer and cardiovascular disease, the costs could double. This yields a range of \$4.14 and \$0.04 with \$2.07 as the benchmark.

Simon (2013) estimates animal cruelty, based on an auction to end cruel farming practices, at \$1.90, assumed to be on the upper limit with a benchmark of \$0.85 and lower range of \$0.00.

Considering water use as the natural-resource external cost of beef production, Peters et al. (2010) estimate the water removed from beef production relative to its absence to be 0.010 to 0.315 thousand gallons per pound. At a price of water of \$1.50 per thousand gallons, this yields a range of \$0.016 to \$0.472 with a midpoint range of \$0.24 as the benchmark (Walton 2018).

The marginal external cost of beef replacement, MEC_S, is a composite value built by summing the proportion of each substitute multiplied by its minimum and maximum kilogram of CO_2 per pound of output (Jones et al. 2018; U.S. Dry Bean Council 2019). The value for CO_2 produced from bean production employs estimates from Williams et al. (2006) with a benchmark of 10% for beef production damage. These minimum and maximum values yield the range of \$0.04 to \$0.09 for MEC_S with \$0.065 as the benchmark midpoint. In terms of health cost estimates for beef substitutes, it is assumed they range from a low of zero to half that for beef, \$1.04, with a midpoint of \$0.52. It is further assumed there are no associated animal crudity and resource degradation for beef replacement.

In sum, considering the social cost of CO_2, health costs, animal cruelty, natural resource degradation, the benchmark MEC_M and MEC_S are \$3.53 and \$0.117, respectively with corresponding ranges of \$0.22 to \$9.86 and \$0.04 to \$1.13.

Marginal external benefits, *MEB*, depend on the assumption of how much of the beef tax is passed onto beef consumers. Schneider and McCarl (2005) estimate that most of an energy tax on U.S. agriculture shifts to consumers. This would result in a lower bound of $MEB = 0$. For an upper bound, assume no tax shift, so $MEB = \frac{MEC_S}{P}$. This yields *MEB* = *\$0.013*. For a benchmark, set *MEB* at the midpoint, \$0.006.

According to Frey and Torgle (2007), when taxes increased from 40% to 65%, the instances of tax evasion rose from 25% to 32%. These yield a benchmark percent change of prosocial behavior benefit given the implementation of a tax on beef, $\epsilon_{\theta\tau}$= −0.45 with a range of −0.9 to 0.00, assuming the benchmark value is doubled. The high range of zero comes from the result that prosocial crowding-out effect does not impact males, and gender components will heavily influence the elasticity of a tax on prosocial behavior (Frey and Torgle 2007).

Assume the responsiveness of prosocial behavior to green-label education, $\epsilon_{\theta L}$, is the antithesis of $\epsilon_{\theta\tau}$. This assumes green-label education is a subsidy with the direct opposite response of a tax.

In determining the own tax responsiveness of beef, $\epsilon_{M\tau}$, Lusk and Tonsor (2016) estimate the own price elasticity of ground beef in a range of −1.96 to −1.67. The mean of −1.82 serves as the benchmark. The change in beef replacement consumption from a beef tax is a composite elasticity. The estimate weights elasticities of each replacement by its proportion and then sums (Lusk and Tonsor 2016). The benchmark value is the maxmin value for these cross-price elasticities, 0.391, with a range set at the lowest minimum, 0.285, and highest maximum, 0.459.

Theory associated with Proposition 1 indicates the beef response to green-label educations is inelastic, but does not reveal its magnitude. Supporting research, directly designed to provide this magnitude, resulted in $\epsilon_{M,L} = -0.08$ and $\epsilon_{S,L} = 0.00$ (Lawing et al. 2019). We conducted a Becker-DeGroot-Marschak auction eliciting the willingness to pay a premium for a green-labeled sustainably produced beef and beef substitutes. Each of the 269 participants submitted the premium they were willing-to-pay for the green-labeled sustainably produced beef or its replacement over the $5.00 basic price of the conventional beef product. The treatment participants received information on the external costs associated with beef production and consumption. The difference in the elasticities between the control and treatment participants yields the magnitude of consumer responsiveness to green label education for beef and its replacement. The benchmark values obtained from our auction data are $\epsilon_{M,L} = -0.08$ and $\epsilon_{S,L} = 0.00$ with a one standard deviation for the upper ranges.

Table 1. Effects of Underlying Determinants on the Optimal Meat Tax and Green-Label Education

Description	Optimal			
	Meat Tax, τ^*		Green-Label Education, L^*	
	Term	Sign	Term	Sign
Prosocial Behavior	$\frac{u_\theta}{\lambda}\frac{\theta}{M}\epsilon_{\theta,\tau}$	$-$	$\frac{u_\theta}{\lambda}\frac{\theta}{M}\epsilon_{\theta,L}$	$+$
Marginal monetary external costs				
Meat	$-MEC_M\epsilon_{M,\tau}$	$+$	$-MEC_M\epsilon_{M,L}$	$+$
Meat Replacement	$-\frac{S}{M}MEC_S\epsilon_{S,\tau}$	$-$	$-\frac{S}{M}MEC_S\epsilon_{S,L}$	$-$
Marginal monetary benefits				
Quantity effect	$pMEB\epsilon_{M,\tau}$	$-$	$(p-\tau)MEB)\epsilon_{M,L}$	$-$
Tax effect	$(1+\epsilon_{M,\tau})MEB$	$-$	-	
Marginal tax rebate plus government benefits				
Administration/ education	$-\left(\propto+\frac{\rho'}{\lambda}(1-\propto)\right)(\omega+L)\epsilon_{M,\tau}$	$+$	$-\left(\propto+\frac{\rho'}{\lambda}(1-\propto)\right)\omega\epsilon_{M,L}$	$+$
Revenue	$-(1+\epsilon_{M,\tau})\left(\propto+\frac{\rho'}{\lambda}(1-\propto)\right)$	$+$	$\left(\propto+\frac{\rho'}{\lambda}(1-\propto)\right)\tau\epsilon_{M,L}$	$-$
			$\left[\propto+\frac{\rho'}{\lambda}(1-\propto)\right](1+\epsilon_{M,L})$	$+$

Table 2. Beef Parameter Values

Description	Parameter	Value: Benchmark	Value: Range
Beef consumption (lbs. per capita.)	M	84	
Beef Replacement (lbs. per capita.)	S	199	
Price of beef ($/lb.)	p	5.00	4.07 to 7.58
Prosocial behavior ($/lb.)	$\frac{u_\theta}{\lambda}\frac{\theta}{M}$	0.055	0.00 to 0.126
Administration and tax enforcement costs ($/lb.)	ω	0.0033	0.00 to 0.50
Social return to investment ($/lb.)	ρ'/	1.05	0.00 to 3.00
Tax rebate to the consumer (%)	α	0.5	0 to 1
Marginal external cost of beef ($/lb.)	MEC_M	3.53	0.22 to 9.86
Marginal external cost of beef replacement ($/lb.)	MEC_S	0.117	0.04 to 1.13
Marginal economic benefit of beef production ($/lb.)	MEB	0.006	0.00 to 0.013
Responsiveness of prosocial behavior to a beef tax	$\epsilon_{\theta\tau}$	−0.45	−0.9 to 0
Responsiveness of prosocial behavior to green-label education	$\epsilon_{\theta L}$	0.45	0 to 0.9
Responsiveness of beef to own tax	$\epsilon_{M\tau}$	−1.82	−1.96 to −1.67
Responsiveness of a beef replacement to a cross beef tax	$\epsilon_{S\tau}$	0.391	0.285 to 0.459
Responsiveness of beef to green-label education	ϵ_{ML}	−0.08	−0.15 to 0.00
Responsiveness of beef replacement to green-label education	ϵ_{SL}	0.00	0.00 to 0.07

Table 3. Benchmark Calculations of the Optimal Beef Tax and Green-Label Education

Description	Optimal			
	Beef Tax, τ^*		Green-Label Education, L^*	
	Term	Value	Term	Value
Prosocial Behavior	$\frac{u_\theta}{\lambda}\frac{\theta}{M}\epsilon_{\theta,\tau}$	-0.025	$\frac{u_\theta}{\lambda}\frac{\theta}{M}\epsilon_{\theta,L}$	0.025
Marginal monetary external costs				
Beef	$-MEC_M\epsilon_{M,\tau}$	6.42	$-MEC_M\epsilon_{M,L}$	0.028
Beef Replacement	$-\frac{S}{M}MEC_S\epsilon_{S,\tau}$	-0.108	$-\frac{S}{M}MEC_S\epsilon_{S,L}$	0.00
Marginal monetary benefits				
Quantity effect	$pMEB\epsilon_{M,\tau}$	-0.055	$(p-\tau)MEB\epsilon_{M,L}$	-0.0008
Tax effect	$(1+\epsilon_{M,\tau})MEB$	-0.005	-	
Marginal tax rebate plus government benefits				
Administration/ education	$-\left(\propto+\frac{\rho'}{\lambda}(1-\propto)\right)(\omega+L)\epsilon_{M,\tau}$	0.057	$-\left(\propto+\frac{\rho'}{\lambda}(1-\propto)\right)\omega\epsilon_{M,L}$	0.0003
Revenue	$-(1+\epsilon_{M,\tau})\left(\propto+\frac{\rho'}{\lambda}(1-\propto)\right)$	0.841	$\left(\propto+\frac{\rho'}{\lambda}(1-\propto)\right)\tau\epsilon_{M,L}$	-0.281
			$\left[\propto+\frac{\rho'}{\lambda}(1-\propto)\right](1+\epsilon_{M,L})$	0.943
Optimal government mechanism	τ^*	\$3.43	L^*	\$0.027
Percentage of beef price, \$5.00		68.6%		0.54%

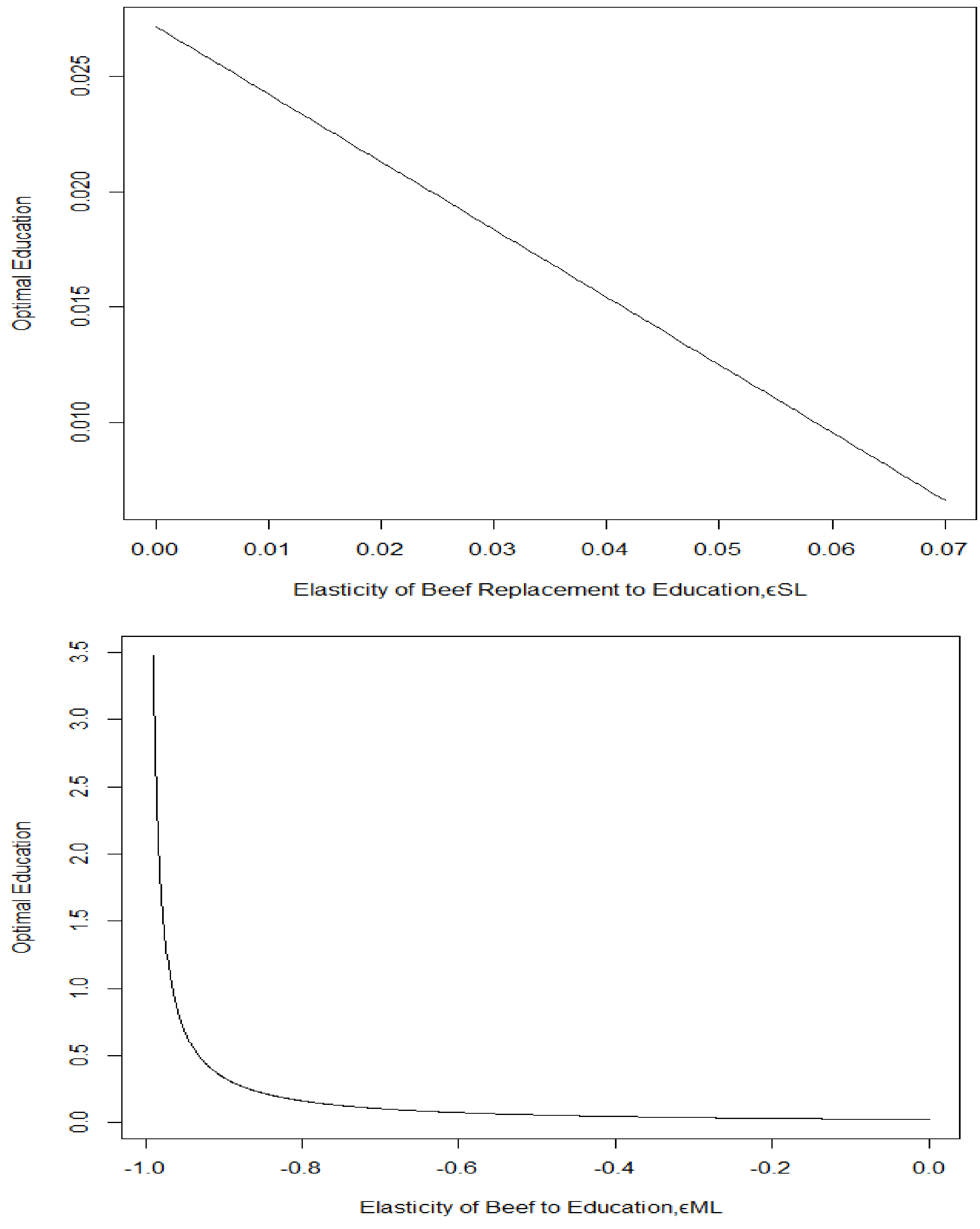

Figure 1. Sensitivity of optimal green-label education, L^*, to variation in the response of beef and its replacement to green-label education

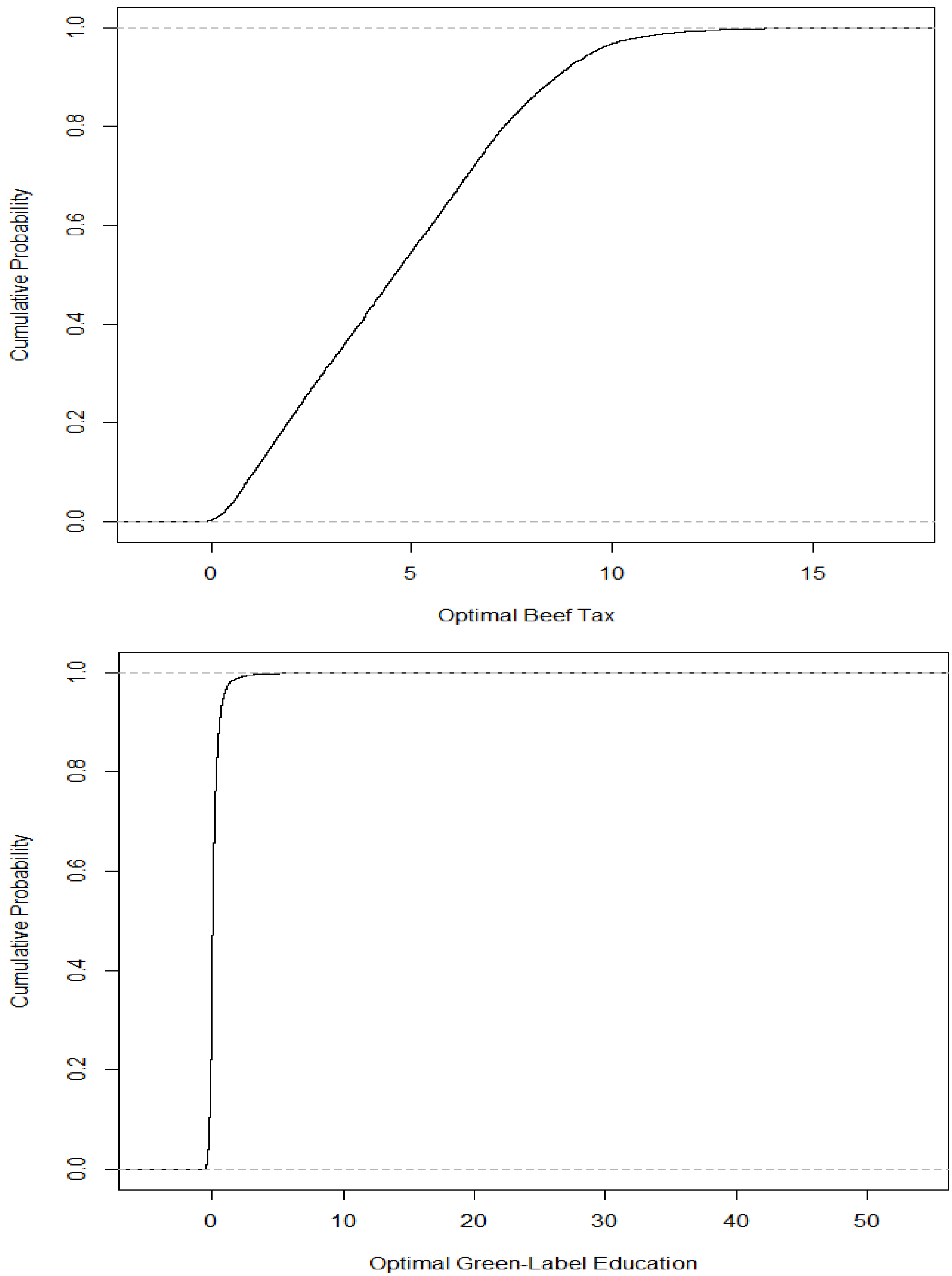

Figure 2. Optimal Government Mechanisms' Distribution