A Model to Compare Market Intervention vs. Information to Address Climate Change Using Substitute Goods

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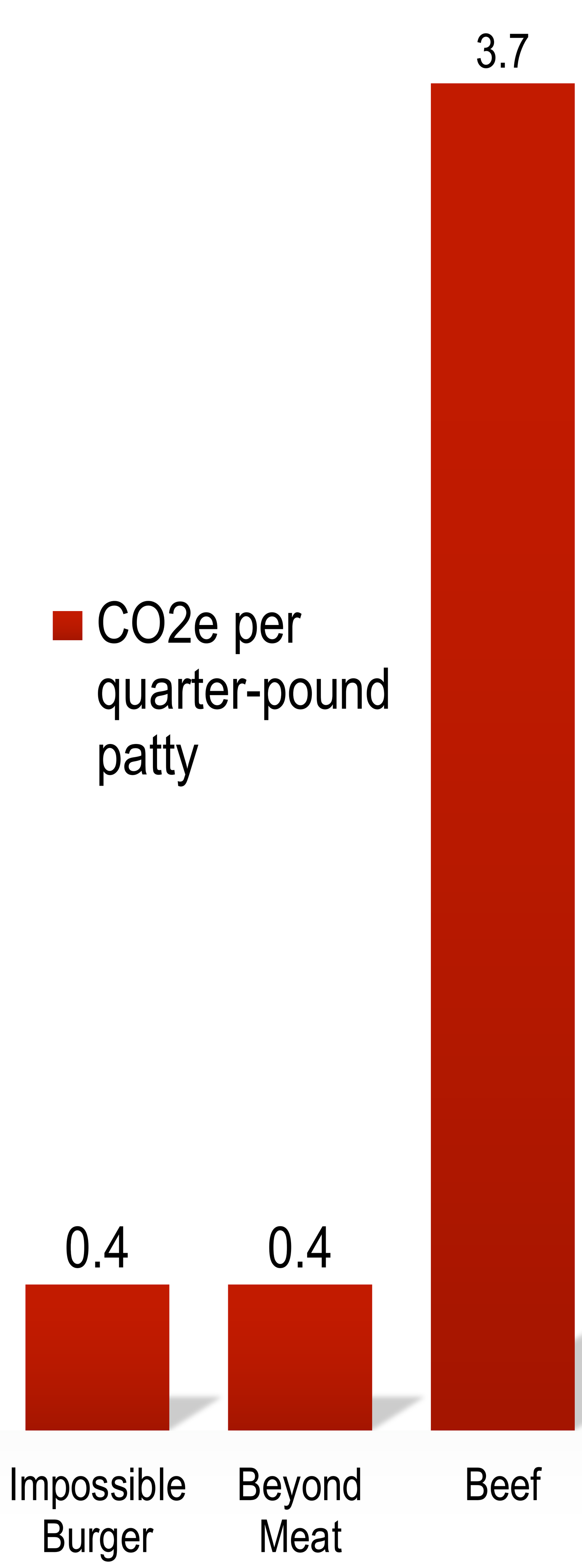
Fast Facts

- 3,500+ U.S. economists, including 27 Nobel Laureates, believe a carbon tax is the best way to mitigate climate change.[1]
- Emissions from global livestock production are 14.5% of all anthropomorphic emissions. Cattle, raised mainly for beef, represent 65% of the livestock sector's emissions.[2]
- U.S. beef consumption per capita is 2nd highest in the world.[3]
- U.S. plant-based meat market grew 38% from 2017 to 2020.[4]



Abstract

There exists potential to reduce U.S. GHG emissions by shifting consumer preferences of beef and plant-based substitutes (PBS) due to the disparity in their global warming potential.[5] Market intervention to create new incentive structures using Pigouvian taxation of externalities and price distortion is one method. The second method is to fund a public information campaign to raise awareness on beef's negative impact on climate change and to advocate consideration of PBS as a similar, but more sustainable option. Effective public policy can be interpreted differently, including consumers' elasticities to each method and net change in global warming potential per cost of implementation. The administration of both methods together is possible, or even ideal[6], but is not explored due to assumed limited budget. To determine optimal tax and optimal information, a welfare model is used that is inclusive of consumer utility, global warming potential externalities, and government revenue.[6] Utility is maximized with respect to consumer gratification from using the consumption bundle to lower their carbon footprint.

Market Intervention

- A Pigouvian tax is enforced
- To counter the regressive nature of a flat tax, consumers receive discounts on purchases of plant-based substitutes
- Government revenue from tax is used to fund discount program, and remaining revenue is used to fund R&D in PBS products.

Information

- Public funding of an information campaign using modern media accessible to wide audiences, such as AdCouncil.org
- Government receives no income but funds information campaign, therefore revenue is negative

- $\frac{u}{\lambda}\frac{\theta}{B}$ = gratification
- w = tax administration and enforcement
- α = discount as % of tax
- $\frac{\rho'}{\lambda}$ = marginal monetary utility of PBS R&D
- B = beef
- P = plant-based substitutes
- MEC = marginal external cost
- q = information administration
- L = per unit information
- τ = per unit tax
- G = government revenue
- I = budget
- p = price of beef
- $\frac{\varphi'}{\lambda}$ = government ROI

Market Intervention		Information
$(p+\tau)B+P = I+\alpha G$	**Budget Constraint**	$pB+P = I$
$G = (\tau\text{-}w)B$	**Government Revenue**	$G = -(L+q)B$
$\max u[B, P, \theta(\tau,B)]+\lambda[I+\alpha G-(p+\tau)B-P]-\delta(D)+\rho[(1-\alpha)G]$	**Indirect Utility Function**	$\max u[B, P, \theta(L,B)]+\lambda[I-pB-P]-\delta(D)+\varphi[G]$
$I+\alpha G-(p+\tau)B-P = 0$	**First-order Conditions:** $u_B-\lambda(p+\tau) = 0$; $u_P-\lambda = 0$	$I-pB-P = 0$

$$\tau^* = \frac{\frac{u\theta}{\lambda B}\varepsilon_{\theta,\tau}-\left[w\left(\alpha+\frac{\rho'}{\lambda}(1-\alpha)\right)+MEC_B\right]\varepsilon_{B,\tau}-MEC_P\frac{P}{B}\varepsilon_{P,\tau}}{1-(1+\varepsilon_{B,\tau})(\alpha+\frac{\rho'}{\lambda}(1-\alpha))}$$

set $\frac{\partial IUF}{\partial\tau}\frac{1}{\lambda}\frac{\tau}{B}\left(\frac{\partial IUF}{\partial L}\frac{1}{\lambda}\frac{L}{B}\right) = 0$, solve for τ (L) to get τ^* (L^*)

$$L^* = \frac{\frac{u\theta}{\lambda B}\varepsilon_{\theta,L}-\left[q\frac{\varphi'}{\lambda}+MEC_B\right]\varepsilon_{B,L}-\frac{P}{B}MEC_P\varepsilon_{P,L}}{\frac{\varphi'}{\lambda}(1+\varepsilon_{B,L})}$$

Proposition 1: If $q = w = \frac{u}{\lambda}\frac{\theta}{B} = 0$, $\alpha = \frac{\rho'}{\lambda} = \frac{\varphi'}{\lambda} = 1$, $\varepsilon_{B,\tau} = -\varepsilon_{P,\tau}$, $\varepsilon_{B,L} = -\varepsilon_{P,L}$, then:

$$\tau^* = MEC_B - \frac{P}{B}MEC_P$$

In equilibrium, optimal tax is equal to net externality, which is beef externality minus adjusted PBS externality. $\tau^* < 0$ indicates a subsidy on beef is optimal.

Using the graph to the left as the marginal external costs, an optimal tax (and optimal information) equal to zero is achieved when $\frac{P}{B} = 9.25$.

In equilibrium, optimal information is equal to net externality multiplied by responsiveness per unit of funding. $L^* < 0$ indicates defunding information is optimal.

$$L^* = \frac{-\varepsilon_{B,L}}{(1+\varepsilon_{B,L})}\tau^*$$

$\varepsilon_{B,\tau}=-\varepsilon_{P,\tau}$ (and $\varepsilon_{B,L}=-\varepsilon_{P,L}$) implies a 1-for-1 substitute between beef and PBS as a response to tax or information.

Carbon Dividend

Suppose now that government revenue is rebated as a flat "carbon dividend" back to consumers. Let $\frac{\sigma'}{\lambda}$ denote marginal monetary utility of the dividend, and transform all parameters to express a new model:

$$\tau^* = \frac{\frac{u\theta}{\lambda B}\varepsilon_{\theta,\tau}-\left[w\frac{\sigma'}{\lambda}+MEC_B\right]\varepsilon_{B,\tau}-\frac{P}{B}MEC_P\varepsilon_{P,\tau}}{1-\frac{\sigma'}{\lambda}(1+\varepsilon_{B,\tau})}$$

- The more effective use of government revenue will depend on the relative size of $\frac{\sigma'}{\lambda}$ and $(\alpha + \frac{\rho'}{\lambda}(1-\alpha))$
- Given proposition 1, optimal tax is the same
- In the default model, tax and discount both provide incentive to increase demand for PBS, which spurs R&D to innovate advancement in PBS industry, thus furthering demand. This positive feedback loop may become a marginal external benefit due to further reduction in emissions. This benefit is not available if revenue is used for dividends.

Corollary 1:

Given Proposition 1, $\tau^* = L^*$ ⬌ $\varepsilon_{B,L} = \frac{-1}{2}$

Optimal tax and optimal information are equal if and only if elasticity of beef demand to information is exactly negative one-half. If greater (but less than 0), the magnitude of optimal tax is greater than the magnitude of optimal information. The converse applies.

Corollary 2:

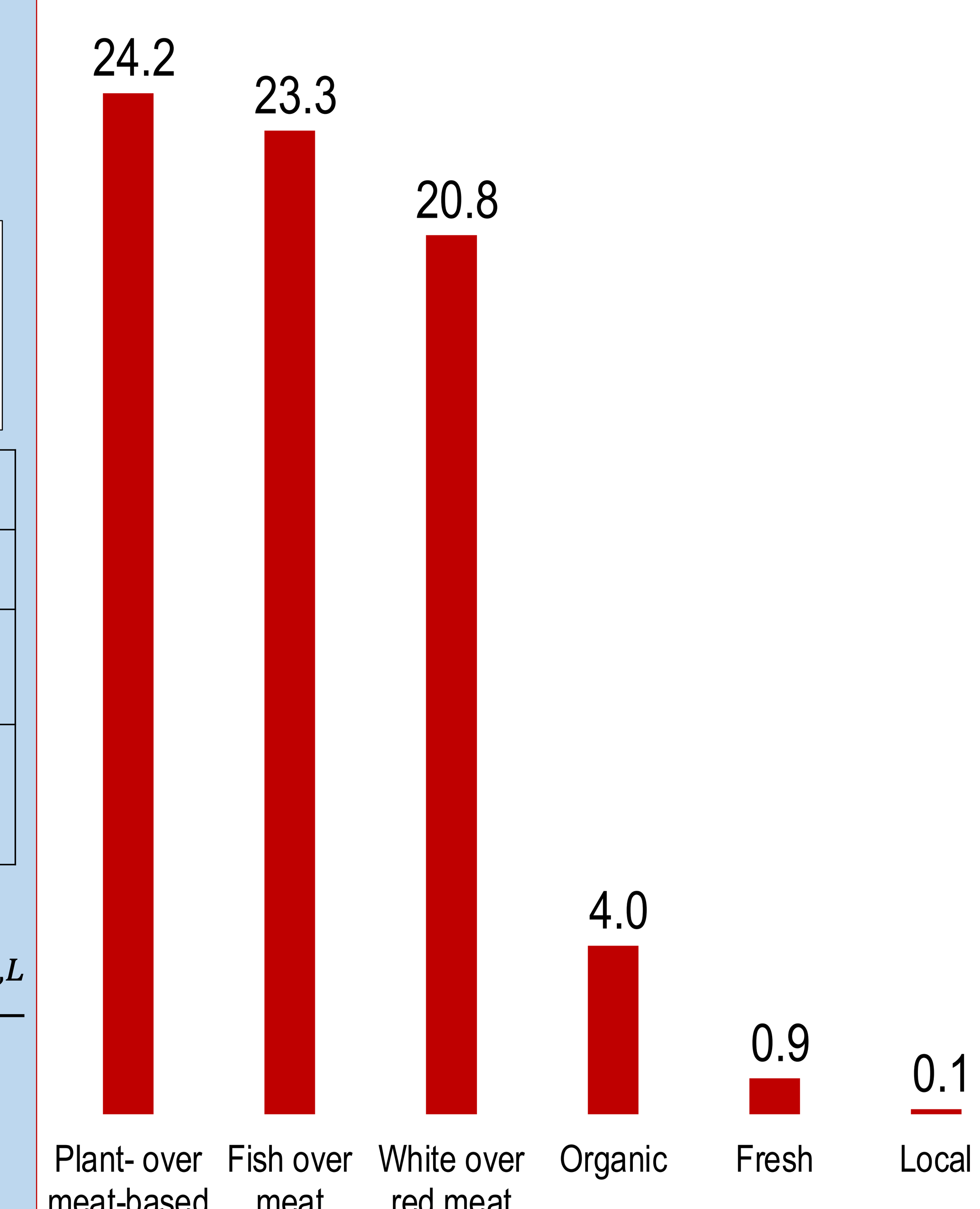
Given Proposition 1, if $\varepsilon_{B,L} < -1$ and $\tau^* > 0$, then $L^* < 0$.

This implies that if beef demand is elastic to information and subsidy isn't optimal, then funding an information campaign becomes ineffective.

Future Work

- Additional improvements to the model
- Collect data, or run survey experiment to create data to use the model
- Analysis to determine per unit optimal tax and per unit information funding to compare efficacy
- Synthesis with existing literature
- A culmination of all research will be documented and concluded in a final thesis

Food-Buying Decisions and Kilograms of GHGe Saved



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Graph to the Left

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2. Quantis. (2019). Comparative Environmental LCA of the Impossible Burger with Conventional Ground Beef Burger. https://impossiblefoods.com/mission/lca-update-2019/

Graph Above

Kause, A., Bruine de Bruin, W., Millward-Hopkins, J., & Olsson, H. (2019). Public perceptions of how to reduce carbon footprints of consumer food choices. *Environmental Research Letters*, *14*(11), 114005. https://doi.org/10.1088/1748-9326/ab465d

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Math proofs, supplementary research materials, and thesis (upon completion), are available upon request.