M.S. COMPREHENSIVE EXAMINATION

21 June 2019

You have four hours, after a 20 minute reading period. You do not need to use the whole time period. You need to answer all three questions, which will be weighted equally.

Watch the time carefully. The logic used to answer each question is important, so be sure to specify your reasoning with full sentences. You may support your answers using diagrams or mathematical derivations where appropriate. If you use graphs, make sure that they are large enough. We are expecting precise and concise answers. Also make sure your writing is legible: if we cannot read it, your answer will be assumed wrong.

1 Adverse selection in the market for insurance

We consider the market for insurance. There are many individuals indexed by $i = 1, \ldots, \mathcal{N}$, each facing a possible loss $L > 0$. Individuals differ in their "riskiness," that is, the probability of the loss $0 < \pi_i < 1$ depends on the individual, but individuals are otherwise identical. Notably, they have the same initial wealth $W_0 > L$ and the same von-Neumann-Morgenstern preferences, representable by the *ex post* utility function $u(w) = \ln(w)$. Losses occur independently across individuals.

The contractual setting is different from what we saw in class. Here, we assume that the insurance contract has a price $P > 0$, and that it is a take-it-or-leave-it option. That is, the choices of the individual are to either fully insure against the loss for a total price of P, or to not insure at all (and not pay anything).

Note: Harder questions have a star before them. You may proceed and answer them at the end.

Demand

[0.2] 1. Define and compute the coefficient of absolute risk aversion.

[0.3] 2. Write down the two lotteries that individual i can choose from when offered an insurance contract at price P. For each lottery, indicate the payoffs and the probabilities of occurrence in each state. Also indicate the expected utility under each lottery. (Hint: one of these lotteries is degenerate.)

[0.5] 3. Using part 2, derive individual i's willingness to pay for insurance, denoted P_i and defined as the highest price that will induce individual i to choose insurance over no insurance. What is P_i if $\pi_i = 0$? If $\pi_i = 1$? Are higher-risk individuals willing to pay more for insurance than lower-risk individuals?

[0.4] 4. On a figure (label it Figure 1), draw the willingness to pay P_i as a function of the loss probability π_i (with π_i on the horizontal axis). Be sure to get the shape right.

The distribution of π_i amongst the $\mathcal{N}$ individuals follows a uniform distribution over the segment $[0, 1]$. That is, the share of individuals with loss probability less than or equal to any value $0 < \pi < 1$ is precisely π, and the total number of such individuals is thus $\pi\mathcal{N}$.

[0.5] 5. ⋆For insurance prices in the range $0 \leq P \leq L$, show that the number of insured individuals is

$$Q(P) = \mathcal{N}\left[1 - \frac{\ln(W_0) - \ln(W_0 - P)}{\ln(W_0) - \ln(W_0 - L)}\right].$$

(Hint: An individual purchases insurance if and only if their willingness to pay for it exceeds the insurance contract price.)

[0.2] 6. Show that the insurance demand function in part 5 is concave in P.

[0.4] 7. On a new figure (Figure 2) with insurance price (P) on the vertical axis and total market quantity (Q) on the horizontal axis, represent the insurance demand function. Indicate the value of the vertical intercepts at $Q = 0$ and $Q = \mathcal{N}$, and make sure your demand function has the right shape.

Supply

There are two insurance firms competing *à la* Bertrand (i.e., by choosing price P taking the other firm's price as given). Firms have zero administrative costs of providing insurance, so that their only costs are the costs of claims filed by their customers incurring the loss L. On the revenue side, insurance firms charge a flat price for each contract sold (they cannot charge higher prices to higher-risk customers, either because of regulation or because they cannot observe individuals' riskiness). Firms are risk-neutral.

[0.2] 8. If a firm sells a contract to individual i (with loss probability π_i), what is the firm's expected claims cost from that particular contract? On Figure 1, depict the expected contract cost as a function of π_i.

[0.5] 9. Carefully explain why in equilibrium, each insurance firm must make zero expected profit and charge the same price for the insurance contract. (Hint: Assume this is not the case, and find contradictions. You are not asked to compute the equilibrium price!)

Since each firm charges the same price, it is natural to assume that each firm gets half of the insured customers, and that the composition of the customer base in terms of riskiness is the same for each firm. Given part 9, in equilibrium the price of the contract must then be equal to the *average expected cost of a contract in the insured population*.

[0.5] 10. *Using your answers to part 3 and part 8, compute the total expected claims cost for the insured population as a function of the contract price P.

[0.3] 11. *Using part 5 and part 10, show that the average expected claims cost for the insured population (hereafter "average contract cost") is

$$\text{AC} = \frac{L}{2}\left[1 + \frac{\ln(W_0) - \ln(W_0 - P)}{\ln(W_0) - \ln(W_0 - L)}\right]$$

(Hint: You will get partial credit if you explain how to combine the results of part 5 and part 10 to answer the question.)

[0.2] 12. Now using part 11 and part 5, express the average contract cost AC as a function of the insured population Q rather than the contract price P. Check that $\text{AC}(0) = L$ and that $\text{AC}(\mathcal{N}) = \frac{L}{2}$.

[0.2] 13. On Figure 2, draw the average contract cost function $\text{AC}(Q)$.

[0.2] 14. Using Figure 2, show the equilibrium contract price. On the figure, identify the individuals who are not insured in equilibrium, if any.

Welfare analysis

It is socially desirable to insure individual i whenever their willingness to pay for insurance P_i exceeds the expected claim cost from the insurance contract.

[0.2] 15. Based on Figure 1, is it socially desirable to insure every individual in this population? Explain.

[0.2] 16. Does competition among insurance firms lead to a socially desirable outcome? Explain.

2 Advertising

A study of total advertising effort by a cross-section of firms was conducted, by examining the monthly revenues of various media outlets, along with firms' total sales in the same month.

Advertising by firm i was measured as the firm's total expenditure on advertising in the current month, expressed in dollars.

Sales by firm i in the current month were also collected and expressed in dollars.

1. One equation considered for estimation (using Ordinary Least Squares) was

$$\text{SALES}_i = \beta_1 + \beta_2 \text{ADV}_i + v_i, \tag{1}$$

with $v_i \sim N(0, \sigma_v^2)$.

However, the observed SALES variable is measured with error:

$$\text{SALES}_i = \text{SALES}_i^* + w_i, \tag{2}$$

with $w_i \sim N(0, \sigma_w^2)$, where SALES_i^* denotes the unobserved actual sales for firm i.

Errors v_i and w_i are independent from each other and across firms.

State any consequences for the regression model. Would you be willing to use OLS to estimate β_1 and β_2? What properties would you claim for your estimates? State any assumptions you require for the results you claim.

Would your answer change if v_i and w_i were correlated with each other for each firm i, remaining independent across firms?

2. Since the advertising variable was constructed using revenue sources for media outlets in the market of interest, only large firms are included in the data set. Smaller firms' expenditures are not disclosed, because they tend to use fewer media outlets.

This means that you will observe data only from firms whose total advertising budget exceeds \$100,000 per month. As a simplification, you may now assume that the SALES variable is correctly measured for those firms (i.e., $w_i = 0 \,\forall\, i$).

State any consequences for the regression model. Would you be willing to use OLS to estimate β_1 and β_2? What properties would you claim for your estimates? State any assumptions you require for the results you claim.

For the rest of this question, you may ignore any of the estimation problems considered above.

3. Suppose that the model now under consideration is

$$\begin{aligned} \text{ADV}_i &= \beta_1 + \beta_2 \text{SALES}_i + \beta_3 \text{SIZE}_i + u_i \\ \text{SALES}_i &= \gamma_1 + \gamma_2 \text{ADV}_i + v_i \end{aligned}$$

The added variable SIZE_i represents the size of firm i, measured by its total number of employees in the current month.

Demonstrate formally that OLS is not appropriate for either equation.

4. Comment on the identification status of each equation. If feasible, indicate how you would obtain consistent estimates of the parameters, stating any assumptions you make. If it is not feasible to do so, explain why.

5. How does your answer to the previous part change if the first equation includes each firm's lagged sales (i.e., sales of firm i in the previous month), not current-period sales? Do you require any additional assumptions?

6. Finally, continuing to assume that it is lagged sales (LSALES) and not current sales that should appear in the advertising equation, you would like to test the hypothesis that lagged sales and overall firm size are not the only determinants of advertising; you believe that the number of employees who are administrative also matters.

   Assuming that

   $$\text{SIZE}_i = \text{ADMIN}_i + \text{NONADMIN}_i,$$

   where ADMIN_i denotes the number of administrative employees in firm i and $\text{NONADMIN}_i = \text{SIZE}_i - \text{ADMIN}_i$, compare your advertising equation to the two models below, and indicate how you would test the hypothesis that the share of employees in administration has no effect on advertising. Answer the question assuming that only equation (3) is available for comparison to the original equation, and then assuming that only equation (4) is available for your comparison:

   $$\text{ADV}_i = \beta_1 + \beta_2 \text{LSALES}_i + \beta_3 \text{NONADMIN}_i + \beta_4 \text{ADMIN}_i + v_i \tag{3}$$

   $$\text{ADV}_i = \beta_1 + \beta_2 \text{LSALES}_i + \beta_3 \text{NONADMIN}_i + \beta_4 \text{SIZE}_i + v_i \tag{4}$$

   Is there any reason to prefer using (3) or (4)? If so, why?

3 Sugar tax

Many people blame sugar-sweetened beverages (SSBs) for growing obesity and related problems in rich and poor countries alike. Many places have imposed taxes on SSBs in an attempt to remedy these problems. Read the attached 'Research Letter' by Cawley, Willage and Frisvold published in the *Journal of the American Medical Association*, then address the following questions.

1. Use a simple supply and demand graph to demonstrate the basic determinants of the pass-through of a tax on SSBs to consumers. Explain the economic factors that determine this tax pass-through rate.

2. Is the fact that the location of this study is a single airport an empirical advantage or disadvantage? Explain carefully.

3. What assumption(s) must hold for a difference-in-differences (DID) estimator to identify causal impacts? Use your answer to assess the authors' use of a DID regression model to identify the causal effect of the SBB tax on retail prices: How convincing or credible do you find this use of DID? Be as specific as possible.

4. What does it mean to cluster standard errors? Why do the authors in this case cluster standard errors at the store level? In this analysis, would you expect standard errors clustered in this way to be larger or smaller than non-clustered standard errors? Justify your reasoning.

5. The authors report a p-value of 0.002 for their February DID estimate. In the clearest and most complete terms possible, explain the statistical meaning of a p-value of 0.002 in the context of this problem.

6. Why do you think the authors discuss 93% as the key pass-through rate finding from their study rather than their DID estimate of 55.3%? Does this reveal a general limitation of DID estimation or something specific to this problem? Explain.

7. Economists ask and try to answer "and then what?" questions. Suppose that the entire state of Pennsylvania adopted a 1.5 cent/oz SSB tax and that the pass-through of this tax was indeed 93%. Now, answer the "and then what?" question. Specifically, use economic concepts from consumer demand theory to predict the health effects of this SSB tax for Pennsylvania residents.

Letters

RESEARCH LETTER

Pass-Through of a Tax on Sugar-Sweetened Beverages at the Philadelphia International Airport

Taxes on sugar-sweetened beverages (SSBs) have been proposed as a possible approach to prevent obesity and improve diets.[1,2] These taxes have recently been implemented in Berkeley, California, and Philadelphia, Pennsylvania. A goal of the taxes is to increase prices and dissuade consumption, but the taxes are levied on beverage distributors, and it is unclear how much of the tax is passed through to consumers as higher retail prices vs being paid by distributors or manufacturers. This study estimated the extent to which the tax of 1.5 cents per ounce on SSBs in Philadelphia (implemented on January 1, 2017) raised retail prices.

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Methods | The Philadelphia International Airport straddles the city border, with some terminals in Philadelphia that are subject to the beverage tax, and other terminals in Tinicum that are not. Retailers in the airport were visited once before the tax (December 21, 2016) and twice after the tax took effect (January 14, 2017, and February 5, 2017). On each visit, a 20-ounce bottle of regular Coke or Pepsi was purchased, with fountain drinks purchased at 4 stores that did not sell bottles. To ensure that stores on the taxed and untaxed sides of the airport were similar, only retail chains (including bakeries, restaurants, and newsstands) that had locations on both sides of the airport were examined.

Data were pooled from before and after implementation of the tax for all stores. Stata (StataCorp), version 15.0, was used to estimate (1) mean price per ounce by city and time and (2) difference-in-difference regressions with standard errors clustered at the store level. Because of concerns that stores in the untaxed side of the airport would raise their prices once their taxed competitors had done so, additional analyses focused on the change in prices in taxed stores. Two-sided hypothesis tests were conducted, with a P value of less than .05 considered significant.

Results | The study included 31 stores: 21 on the taxed side of the airport (Philadelphia) and 10 on the untaxed side (Tinicum).

The mean price per ounce of SSBs in December 2016 (before the tax) was 12.37¢ per ounce in the untaxed side and 12.53¢ per ounce in the taxed side; in February 2017 (after the tax), it had risen to 12.93¢ per ounce in the untaxed side and 13.92¢ per ounce in the taxed side (**Table 1**). By February, prices had risen 0.83¢ per ounce (95% CI, 0.33¢-1.33¢; P = .002) more in taxed than untaxed stores. Based on this difference-in-differences model, 55.3% (95% CI, 22%-89%; P = .002) of the tax was passed on to consumers.

Stores on the untaxed side of the airport might have raised their prices at the same time or soon after those on the taxed side did, so the change in prices within the taxed stores was estimated. The taxed stores increased their prices by 0.91¢ per ounce (95% CI, 0.60¢-1.23¢; P<.001) by January and 1.39¢ per ounce (95% CI, 1.20¢-1.58¢; P<.001) by February (Table 1). Using only data for taxed stores, the percentage of the tax passed on to consumers was 61% (95% CI, 40%-82%; P<.001) in January and 93% (95% CI, 80%-105%; P<.001) in February.

Discussion | Thirty-six days after the Philadelphia tax on SSBs was levied on beverage distributors, stores subject to the tax in the Philadelphia airport raised their prices of SSBs by 93% of the tax. Moreover, stores on the untaxed side of the airport may have raised their prices in response.

Limitations of the study include the assessment of only 1 size of soda (20-oz bottles), 2 brands of soda (Coke and Pepsi), and 1 location (the Philadelphia International Airport). No control beverages were included, historic price data were not available, and the change measured was short-term. Although prices were collected from airport retailers, which limits generalizability, airport vendors are required by their leases to charge no more than prices elsewhere in Philadelphia to prevent price gouging.

Table 1. Mean Price and Mean Change in Price of Sugar-Sweetened Beverages (SSBs) at the Tinicum Side (Untaxed) vs Philadelphia Side (Taxed) of the Philadelphia International Airport[a]

	Tinicum Side Price		Philadelphia Side Price		
Time Point	Mean (95% CI), ¢/oz (n = 10 Stores)	Mean Change vs December 2016 (95% CI), ¢/oz	Mean (95% CI), ¢/oz (n = 21 Stores)	Mean Change vs December 2016 (95% CI), ¢/oz	Difference in Mean Change (95% CI), ¢/oz
Before new tax on SSBs					
December 2016	12.37 (10.83-13.91)		12.53 (11.80-13.25)		
After new tax on SSBs					
January 2017	12.78 (11.07-14.48)	0.41 (−0.08 to 0.89)	13.44 (12.59-14.29)	0.91 (0.60 to 1.23)	0.51 (−0.01 to 1.03)
February 2017	12.93 (11.21-14.64)	0.56 (0.03 to 1.09)	13.92 (13.18-14.66)	1.39 (1.20 to 1.58)	0.83 (0.33 to 1.33)

[a] Standard errors are clustered at store location level.

The pass-through of the tax on SSBs in the Philadelphia airport (93%) was higher than that found in Berkeley, California, which previous studies estimated was in the range of 43% to 69%.[3,4] Future studies should investigate explanations for this difference and examine how the Philadelphia tax affected the purchase and consumption of SSBs and the health of consumers.

John Cawley, PhD
Barton Willage, MA
David Frisvold, PhD

Author Affiliations: Department of Policy Analysis and Management, Cornell University, Ithaca, New York (Cawley); Department of Economics, Cornell University, Ithaca, New York (Willage); Department of Economics, University of Iowa, Iowa City (Frisvold).

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Corresponding Author: John Cawley, PhD, Department of Policy Analysis and Management, Cornell University, 2312 MVR Hall, Ithaca, NY 14853 (jhc38@cornell.edu).

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Concept and design: Cawley, Frisvold.
Acquisition, analysis, or interpretation of data: Cawley, Willage.
Drafting of the manuscript: Cawley.
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COMMENT & RESPONSE

Axillary vs Sentinel Lymph Node Dissection in Women With Invasive Breast Cancer

To the Editor Dr Giuliano and colleagues[1] analyzed 10-year survival and disease-free survival data for women with breast cancer who had breast-conserving surgery followed either by sentinel lymph node dissection (SLND) alone or axillary lymph node dissection (ALND). The study was designed to assess whether SLND was noninferior to ALND with a noninferiority hazard ratio margin of 1.3. How such a large margin for assessing noninferiority can be justified is not clear.

The observed hazard ratio (SLND vs ALND) was 0.85, and the upper bound of the 1-sided 95% CI was 1.16. That is, the hazard of SLND could be 16% higher than that of ALND. It is not clear how to translate this large margin value to claim SLND would not have a clinically meaningful difference from ALND. The issues and concerns of using an hazard ratio as the group difference measure for a noninferiority study have been discussed.[2]

The hazard is not a probability or chance measure. The observed upper bound of 1.16 does not mean SLND might have a 16% increased risk over ALND. Moreover, without a hazard estimate from ALND as a reference value, how a decision can be made based on a hazard ratio alone is unclear.

An alternative summary measure is the restricted mean survival time to quantify the group difference.[2-4] Generally, hazard ratio is not an intuitive tool when weighing risk against benefit. A clinically interpretable summary measure, such as the difference in restricted mean survival times, would be a better choice for evaluating noninferiority or equivalence.

Hajime Uno, PhD
Michael J. Hassett, MD
Lee-Jen Wei, PhD

Author Affiliations: Department of Medical Oncology, Dana-Farber Cancer Institute, Boston, Massachusetts (Uno, Hassett); Department of Biostatistics, Harvard University, Boston, Massachusetts (Wei).

Corresponding Author: Lee-Jen Wei, PhD, Department of Biostatistics, Harvard University, 655 Huntington Ave, Boston, MA 02115 (wei@hsph.harvard.edu).

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In Reply In principle, we agree with Dr Uno and colleagues that restricted mean survival time has the potential for being a more clinically interpretable summary. At this time, few people, especially clinicians, know what this measure is and would need to be educated with respect to its meaning before it would be considered more interpretable.