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Costs of Taxing Sodium: A Lunch Meat Application[1]

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Abstract

The current American diet contains excessive amounts of sodium and saturated fat, which are high risk factors for cardiovascular disease (US Dietary Guidelines for Americans 2010). Recently, the Centers for Disease Control and Prevention (CDC) reported lunch meats to be the second highest source of sodium in American diets. Using 2006 Nielsen Homescan data and an AIDS framework, this study estimates the demand for eight disaggregated lunch meat products to determine the welfare costs associated with consuming these meat products. The estimated welfare analysis revealed that a tax rate that increases the price of the highest-sodium lunch meat (pepperoni) by 25 percent can reduce lunch meat consumption as well as lower the intake of lunch meat sodium by 20 percent.

Keywords: lunch meats, sodium, welfare costs

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[1] The views expressed here are those of the authors, and may not be attributed to the Economic Research Service or the U.S. Department of Agriculture.

Introduction

According to the Centers for Disease Control and Prevention (CDC), the foods with the highest sodium content are not the so called "junk foods," but breads, followed by lunch meats (CDC 2012). Lunch meats are defined as processed, prepackaged meats made from turkey, pork, beef, chicken and other meats that are often molded, sliced, and served cold. Most lunch meats are relatively high in sodium and often contain nitrates, which studies have shown to be cancer-causing additives (Preston-Martin et al. 1982; Peters et al. 1994). The average person in the United States consumes about 3,300 milligrams (mg) of sodium per day (CDC, 2012). According to the U.S. Department of Agriculture's Agricultural Research Service, U.S. Department of Health and Human Services, and CDC, the daily recommended sodium intake for adults is 2,300 mg. According to the CDC (2012) consuming over 2,300 mg of sodium can lead to hypertension, expenses health-care bills, and death.

Improving diets and health has become a national priority (WHTF 2010). One intervention policymakers may consider is taxing some food products. The growing worldwide incidence of health problems related to food choice and over consuming has led to calls for taxes on foods perceived to be unhealthy (Fletcher, Frisvold and Tefft 2010; Kuchler, Tegene and Harris 2004; Jacobson and Brownell 2000) and for promoting greater health and nutrition awareness. One downside to taxing unhealthy foods is that the taxes will increase consumers' costs of living by increasing the price of purchased products. As price increases, consumers' economic welfare decrease and the benefits of an improved diet are expected to balance out against the increased costs of food. Because food taxes are regressive, what impact will a tax increase have on consumers' consumption of lunch meats?

The first objective of this study is to measure how a tax on sodium would affect lunch meat demands. We use lunch meat because it is high in sodium and it accounted for 26.3% of all fixed-weight meat sales in 2009 (based on scanner data from Information Resources Inc. and Freshlook Alliances). The second objective is to measure how these sodium taxes on lunch meats will affect consumers' economic welfare. Thus, a third objective is to measure the accuracy of the tax-effect estimates related to the sodium in lunch meats.

Related Studies Measuring Consumer Welfare Cost

Numerous studies have examined consumer welfare costs for retail foods and other products (Townsend, Roderick and Cooper1994; Godfrey and Maynard1988; Säll and Gren 2012; Harding and Lovenheim 2012; Kuchler, Tegene and Harris 2004; Mytton et al. 2007), but this study is the first to evaluate sodium associated with disaggregated lunch meat products. A disaggregated analysis is beneficial because it allows examination of consumers' preference for one type of lunch meat over another with different levels of sodium.

Taxation involving price increases in order to reduce consumption of unhealthy products has been one approach economists and policymakers have used to help address issues related to unhealthy food and product purchases. For example, studies have shown that increasing the price of alcoholic beverages and tobacco through taxes could reduce consumption (Townsend, Roderick, Cooper 1994; Godfrey and Maynard 1988; Institute of Alcohol Studies Alcohol and

Tax 2003). A Swedish study evaluating the environmental impact from a tax on meat consumption, particularly poultry, pork, and beef (Säll and Gren 2012) discovered that imposing a tax on the three meat products can reduce consumer demand, while simultaneously reducing the emission of greenhouse gases, and the amounts of nitrogen and phosphorus dispersed in waterways and aquifers.

However, it is often questioned whether taxing consumer purchases of unhealthy foods can actually improve individual physical conditions (Jacobson and Brownell 2000; Fletcher, Frisvold, and Tefft 2010). In examining the effects of nutrient-specific taxes on shopping behavior, Harding and Lovenheim (2012) found that a sugar tax could lead to reductions in sugar purchases, and consequently—caloric intake, and salt consumption. Kuchler, Tegene, and Harris (2004) conducted a study of taxing snack foods in an attempt to address issues related to obesity in the United States. Their findings suggest that relatively low tax rates of one cent per pound (of salty snack food) and 1% of the value would have little effect on consumers' diet quality or health outcomes but would produce millions of dollars in tax revenues. Mytton et al. (2007) found that taxing unhealthy foods led to a reduction in consumption of those foods while lowering consumers' salt intake, which could potentially save about 2,300 lives in the United States per year.

Similarly to Mytton et al. (2007), this study will evaluate a sodium tax on eight different types of lunch meats, particularly roast beef, ham, chicken breast, turkey, bologna, pepperoni, salami, and other lunch meats. The tax rates for lunch meats will vary depending on their sodium levels. This study explores the impacts a low (1%), medium (5%), and high (25%) tax rate will have on consumer expenditures for lunch meats. These tax rates are similar to those used by Jacobson and Brownell (2000) and Kuchler, Tegene, and Harris (2004). Like studies conducted by Harding and Lovenheim; Kuchler, Tegene, and Harris; and Säll and Gren, we expect a tax designed to reduce the consumption of lunch meats, would work as it did for salty snack foods, sugar products, and meats.

The AIDS Demand Model

A tax on sodium would change the prices of foods. Those foods with high levels of sodium would get a higher tax. To measure how sodium taxes would affect lunch meat consumption, we need to know how demand for each lunch meat changes in response to its own and other prices. We used an Almost Ideal Demand System (AIDS) to estimate these effects.

One of the advantages of using the AIDS is that it is based on a cost function. Economists use a concept called "compensating variation" (CV) to translate price changes into estimates of economic welfare effects. The cost function is defined as the minimum cost of achieving a given level of utility with a given set of prices. Typically, economists adopt a given set of prices and consumer expenditures as a baseline. We also assume that consumers make purchases to maximize their utility. If we then change prices, we can use the cost function and the baseline utility to calculate how much additional expenditure would be needed to maintain a baseline utility level. The difference between the minimum cost expenditure and the baseline expenditure is the CV that will be a positive value when all the prices increase.

The AIDS model was developed by Deaton and Muellbauer (1980). It can be derived from a cost function:

(1) $\ln(x) = A(P) + v_0 B(P)$,

where$x$ is consumer total cost, P is a vector of prices andv_0 is some target level of utility. The cost function in (1) can be rearranged to give a maximum level of utility, given $P$and x. That function is the indirect utility function. For our welfare analysis, we can take baseline expenditures and prices and find v_0, then use our estimates to get the costs associated with a new set of prices.

A(P) and B(P) are functions of prices:

(2) $A(P) = \sum_i a_i \ln(p_i) + \frac{1}{2}\sum_i \sum_j c_{ij} \ln(p_i) \ln(p_j)$,

(3) $B(P) = \prod p_i^{b_i}$.

In (2) and (3),p_i is the price of item "i." The "a", "b," and "c" are model coefficients.

Cost functions have to be homogenous of degree 1 in prices. (Doubling all the prices will double the cost.) These conditions are ensured if the coefficients meet the following restrictions:

(4) $\sum_i a_i = 1$,

(5) $\sum_i b_i = 0$,

(6) $\sum_i c_{ij} = \sum_j c_{ij} = 0, \forall i, j$.

Deaton and Muellbauer demonstrated that if the c_{ij}[2]are symmetric, then these coefficients are unique:

(7) $c_{ij} = c_{ji}, \forall i, j$.

In theory, cost functions have to be negative, semidefinite (NSD) in prices. NSD is an inequality restriction. If the estimated cost function is not NSD, then it will be possible to increase all the prices and decrease total costs, yielding an illogical outcome. Some Economists often focus on the equality restrictions in their demand models and occasionally ignore or fail to check NSD.

Deaton and Muellbauer demonstrate that the AIDS is a locally flexible form; that is, one can take a set of prices, quantities, and expenditure and demand elasticities and find a set of AIDS parameters that will reproduce the demands and elasticities. The cost function being NSD implies that the matrix of compensated demands is also NSD. There are no equality conditions that will guarantee that the AIDS estimates are NSD; we can check a set of estimates to see if they are.A potential issue with the AIDS approach is that it can be NSD at one point and not at others. If the "c" and b" coefficients are all 0 and the "a" coefficients are all positive, then the AIDS will be globally NSD. In this extreme case, the AIDS implies the Cobb-Douglass utility

[2] Deaton and Muellbauer started their development of the AIDS with no restrictions on the c_{ij}. They noted that the c_{ij} show up in the demand equations as ½ (c_{ij}+c_{ji}). Imposing symmetry on the c_{ij} identifies these terms on the function A(P) and imposes symmetry on the AIDS demand equations.

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Deaton and Muellbauer derive the following demand equation from the cost function:

$$(8) \qquad w_{i,t} = a_i + \sum_j c_{ij} \ln\left(p_{i,t}\right) + b_i[\ln(\mathrm{x_t}) - \mathrm{A(P_t)}] + \mathrm{e_{i,t}}.$$

$w_{i,t}$ is the budget share for product "*i*" in week "*t*" and the term $e_{i,t}$ is a random error term. By virtue of the model's construction, the sum of the error terms in each time period is 0. As a result, an equation must be dropped to estimate the model. If the model is estimated using maximum-likelihood methods, the model estimates are independent of the dropped equation.

Data

Lunch meats make up a significant category of all meats sold in supermarkets. Using scanner data (from Information Resources Inc. and Freshlook Alliances), we found that the lunch meat share of meat expenditures on lunch meats in 2009 was 7.8%, while the share of fixed-weight packaged lunch meats of all fixed-weight meat sales was 26.3%.

For this study, we estimate a demand system of eight lunch meat products and assume them to be weakly separable from each other. Nielsen 2006 Homescan retail data are used to estimate U.S. demand for lunch meats. The 2006 data are used because that is the last year for which Nielsen included the random weight category for meats and poultry products. Other grocery store scanner data do not disaggregate lunch meats using random and fixed weight purchases. From Nielsen Homescan data, a sample of the U.S. population was used in selecting consumers who agreed to scan the Universal Product Code (UPC) of purchased grocery items and to input prices paid for items over a 12-month period. Using the descriptions of the UPC and designated codes for each item, eight lunch meat categories were identified and included in this study: roast beef, ham, chicken breast, turkey, bologna, pepperoni, salami, and other lunch meats (which include pastrami, specialty meats, other cold cuts, coppa, and Canadian bacon). Each household's quantities and prices are reported for all eight products. Expenditures and shares are derived from observed quantities and prices after accounting for any coupons or promotions that were in effect. There are 25,123 households represented in this study, each of which purchased at least one of the eight lunch meat products in 2006. The data for all households were aggregated for each week, which provided 52 observations for use in the model estimation. Purchases of all eight lunch meats over 52 weeks were then estimated using the AIDS model.

Estimation Results

We estimated parameters for the AIDS-model using what would be Full Information Maximum-Likelihood if the errors were normally distributed. Many of the b and c coefficients were statistically insignificant. We aggressively restricted the model by eliminating insignificant b and c coefficients. (A discussion of the restrictions applied and the results are shown in the Appendix). One of the interesting side effects of restricting the AIDS coefficients was that after these restrictions, the AIDS model estimates were NSD at all the points in the sample. The unrestricted estimates implied that demands were generally not NSD. Those statistically insignificant terms, that should have been 0, were also causing demand equations to violate economic theory.

Sodium Tax Analysis

According to the CDC, American's second largest source of sodium is lunch meats (after bread). Table 1 shows the sodium content of various types of lunch meat products. Based on the Agricultural Research Service online search tool, *"What's in the foods you eat"*, pepperoni has the highest sodium content of all eight lunch meat products. Ham has the second to the highest sodium per serving. The least amount of sodium per serving was found in turkey followed by bologna and chicken breast. The 2010 Dietary Guideline for Americans recommends only about 2,300 milligrams of sodium consumption per day; one serving of pepperoni will account for over 70% of the daily sodium allowanced (Dietary Guidelines for Americans, 2010). This information is useful to retail store managers because it identifies the lunch meats that potentially could be targeted the most due to their high level of sodium per serving.

Table 1. Average sodium found in lunch meat products

Variable	Serving	Milligrams
Quantities (sodium per serving)		
Bologna[1]	1	997
Chicken breast	1	1015
Ham	1	1330
Pepperoni	1	1653
Roast beef	1	1117
Salami[2]	1	1140
Turkey	1	772

Source. USDA-ARS.
[1] Bologna is made of chicken, pork, and beef.
[2] Salami is made of beef.

Our analysis does not include any measure of the benefits of sodium reduction. According to Bibbins-Domingo et al. (2010), a reduction in the mean population sodium consumption by 400 mg is estimated to help prevent about 28,000 deaths and save $7 billion in health care expenditures annually. Since many lunch meats contain a significant percentage of the recommended daily allowance of sodium, measures to reduce consumption of those with higher sodium content may be considered by policymakers.

For this analysis, we assume that a tax on sodium in lunch meats will have no supply side effects. We assume that the post-tax price of lunch meat will be the pre-tax price plus the sodium tax. This assumption is typical used in studies of this type. The studies we cited on food-tax analysis all use this assumption. This type of relationship will exist as long as the supply of each lunch meat is perfectly elastic. If supplies are not perfectly elastic, then processors will response to the sodium tax by lowering the price of their products. Any supply-side response will mitigate the effects of the tax on consumers. Our measures of welfare losses are an upper bound on the total losses to consumers.

In order to evaluate the effects of sodium taxes on lunch meat consumption, we have to assume some level of taxation. Table 2 shows three different levels of sodium tax, low (1%), medium (5%), and high (25%) used to analyze changes in lunch meats consumption. These three tax rates are set to raise the price of pepperoni by 1%, 5%, and 25%. Pepperoni is both the highest sodium and the highest priced lunch meat. For our analysis, we assume that the "other" lunch meat category has the average sodium of the seven other identified lunch meats. We set our taxes based on the total amount of sodium in each serving of the lunch meat. Thus Pepperoni, with the highest sodium content, also has the highest tax per pound (Table 2), while turkey, with the lowest sodium content, has the lowest.

Table 2. Sodium taxes per pound and as a percentage of the average price

			Sodium tax per pound of lunch meat[3]			**Sodium tax as a percentage of the average price of lunch meat (tax rate)**		
	Average price per Pound[1]	MG sodium per serving[2]	Low	Middle	High	Low	Middle	High
Bologna	$2.646	997	$0.034	$0.170	$0.849	1.3%	6.4%	32.1%
Chicken	$3.495	1,015	$0.035	$0.173	$0.864	1.0%	4.9%	24.7%
Ham	$4.156	1,330	$0.045	$0.226	$1.132	1.1%	5.4%	27.2%
Pepperoni	$5.629	1,653	$0.056	$0.281	$1.407	1.0%	5.0%	25.0%
Roast beef	$4.577	1,117	$0.038	$0.190	$0.951	0.8%	4.2%	20.8%
Salami	$4.031	1,140	$0.039	$0.194	$0.971	1.0%	4.8%	24.1%
Turkey	$3.659	772	$0.026	$0.131	$0.657	0.7%	3.6%	18.0%
Other	$4.274	1,146	$0.039	$0.195	$0.976	0.9%	4.6%	22.8%

[1] Source—average price from Nielsen Homescan® data.
[2] Other lunch meat sodium per serving set to the average value of the seven specific products.
[3] Low, middle, and high taxes were set so as to increase pepperoni prices by 1%, 5%, and 25%.

As shown in Table 2, our taxes are in dollars per pound/sodium per serving. Pepperoni is the saltiest of the eight lunch meats, while turkey has the least amount of sodium per serving. Pepperoni also had the highest average price per pound among all lunch meat products followed by roast beef. The lowest average price per pound of lunch meat was held by bologna. The tax on the non-pepperoni lunch meats is pepperoni's tax times the sodium per serving of the lunch meat divided by pepperoni's sodium per serving. For example, bologna has only 60.3% (997/1653) of the sodium per serving of pepperoni, and thus its tax per pound is 60.3% of the pepperoni tax per pound. Tax per pound of turkey, having the least amount of sodium per serving, is 46.7% of the pepperoni tax per pound.

Sodium tax per pound of lunch meat is also calculated and presented in Table 2. Ham had the second highest tax per pound at $0.045 (low), $0.226 (middle), and $1.132 (high). The sodium tax per pound of chicken was the second lowest at $0.035 (low), $0.173 (middle), and $0.864 (high). We made the low tax rate increase pepperoni's price by 1%. Thus, the medium and high rates increase pepperoni's price by 5% and 25%, and increase turkey's price by 0.7%, 3.6%, and 18.0%. Bologna has the second lowest sodium of the eight lunch meats and the lowest price. The tax on sodium has a larger percentage effect on bologna price than it does on pepperoni price. The low, medium, and high taxes on bologna are 1.3%, 6.4%, and 32.1% of its average price.

Statistical Properties of the Welfare Estimates

Our analysis of the effects of a sodium tax on lunch meat demands, sodium intake, and economic welfare is based on the AIDS system estimates. These estimates will vary randomly from the actual AIDS parameters. The random errors in the AIDS estimates will cause our welfare analysis to have random errors as well. Our tax impacts are nonlinear functions of the AIDS parameters.

Were the tax effects a linear function of the AIDS estimates, we could easily calculate the mean and variance of the tax effects using the means and variances of the AIDS coefficients. There are no simple functions for turning the randomness of the coefficients into randomness of the tax effects. For example, nonlinearities can and usually do induce bias in our estimates. The tax effects could be generally overstated or understated. It is also possible that the tax-effect estimates have large variances even if the coefficient estimates do not. Large variances imply that our analysis is likely to inaccurate and less useful for setting or evaluating policy. The randomness of our welfare measures means that we cannot be entirely certain about how a sodium tax is going to affect consumer health and economic welfare. We can improve our analysis by explicitly including information on the statistical distribution of the estimated welfare effects.

Previous research has dealt with the issue of nonlinear functions of demand system parameter estimates. Green, Rocke, and Hahn (1987) examined the statistical properties of elasticity estimates. They noted that there are large-sample approximations that allow one to calculate variances for nonlinear functions. They compared these large-sample results to small-sample results—they used bootstrapping to get the small-sample distributions of the nonlinear functions. We decided to use Monte-Carlo analysis.

For the Monte-Carlo analysis, we used the AIDS estimates as if they were the true values of the coefficients. We also used the estimated covariance matrix of the error as the true covariance matrix. We assumed normally distributed errors. We then simulated a new set of error terms for the equations and estimated the AIDS coefficients with the simulated data. The coefficient estimates were stored for later use. We ran 5,000 iterations of the model. We used the 5,000 sets Monte-Carlo coefficients to run our sodium tax analysis and saved those 5,000 sets of results. In this way, we were able to translate the variations in model estimates into variations in the welfare analysis. Monte-Carlo or other types of numerical analysis can be applied to other problems where econometric estimates are used to evaluate business or public policy.

Sodium Tax Effects

Table 3 shows how the different levels of the sodium tax will affect the demand for the lunch meats and total sodium consumption from lunch meats. We express these effects in terms of the percent change from their baseline values. The columns headed by the term "estimate" are the changes in demand implied by our constrained AIDS model estimates. We also calculated 95% confidence intervals for these estimates using the 5,000 Monte-Carlo iterations.

Table 3. Changes in Consumption as a result of the sodium tax

	Low			**Middle**			**High**		
		95% Confidence Interval			95% Confidence Interval			95% Confidence Interval	
	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Bologna	-1.23%	-2.39%	0.03%	-5.86%	-6.96%	-4.67%	-23.71%	-24.65%	-22.74%
Chicken	-1.12%	-3.25%	0.96%	-5.35%	-7.43%	-3.33%	-22.05%	-24.00%	-20.15%
Ham	-1.01%	-3.52%	1.51%	-4.87%	-7.28%	-2.42%	-20.39%	-22.42%	-18.29%
Pepperoni	-0.82%	-3.29%	1.64%	-3.99%	-6.36%	-1.60%	-17.14%	-19.29%	-14.93%
Roast beef	-0.79%	-3.56%	2.01%	-3.84%	-6.50%	-1.13%	-16.65%	-18.92%	-14.29%
Salami	-1.07%	-5.40%	3.11%	-5.14%	-9.36%	-1.13%	-21.32%	-25.04%	-17.77%
Turkey	-0.74%	-2.74%	1.22%	-3.59%	-5.53%	-1.68%	-15.70%	-17.42%	-14.03%
Other	-0.94%	-3.14%	1.27%	-4.54%	-6.66%	-2.40%	-19.21%	-21.06%	-17.38%
Sodium	-1.01%	-1.17%	-0.84%	-4.84%	-5.00%	-4.68%	-20.22%	-20.33%	-20.10%

Data Source. Author calculations based on Nielsen Homescan® data. 95% confidence intervals based on 5,000 Monte Carlo iterations

Our AIDS model estimates imply that a sodium tax will decrease the demands for all eight lunch meats. The higher the tax rate, the lower the demand for each of the lunch meats. Higher taxes also lower sodium consumption from lunch meats (Table 3). At the low tax rate (1%), salt consumption drops by slightly more than 1%. The high tax rate (25%) is associated with a 20% drop in sodium consumption.

According to Table 3, changes in lunch meat consumption resulting from a 1% (low), 5% (middle), and 25% (high) increase in sodium tax, will cause bologna to decline by the most (-1.23%, -5.86%, -23.71%) and turkey by the least (-0.74%, -3.59%, -15.70%). Chicken had the second largest decrease in consumption due to a sodium tax of 1%, 5%, and 25%, followed by salami. Retail store managers may leverage potential impacts of a sodium tax by stocking their deli sections and coolers with more of the lunch meats for which consumption decline the least, namely turkey and roast beef. In addition, media advertisement may be used as a marketing strategy for retail store managers and the food industry to help improve consumers' awareness of the nutritional benefits of eating lunch meats.

Economic theory implies that the demand for a product is driven by its price relative to other product prices. A pure tax on sodium will raise bologna's relative price more than that of other lunch meats. This has the ironic effect of reducing the demand for one of the lowest- sodium lunch meats by more than the reduction in demand for the other lunch meats (Table 3). Because pepperoni has a higher base price and a lower percentage change in its price due to the tax, its demand shifts less than bologna's under all the tax scenarios. Thus, these empirical findings inform retail store managers of the potential impacts a sodium tax will have on selective lunch meat prices. Given consumers' sensitivity to changes in price, retail store managers will be able to appropriately stock their deli sections and coolers based on projected increases in certain lunch meat prices.

The confidence intervals in Table 3 show that our estimated lunch meat demand shifts may not be that accurate. In the low-tax scenario, the AIDS estimates imply that the demand for all eight lunch meats will decline. However, the confidence intervals for the eight lunch meats in the low-tax scenario include actual increases in demand. Given that the expenditure for lunch meats is fixed, it is impossible to increase the consumption of all eight lunch meats when all eight lunch meats prices increase. An increase in the consumption of one lunch meat product has to be offset by decreases in the consumption of other lunch meats. A surprising outcome of the analysis is that the estimates of the effect of the sodium tax on salt consumption seem more accurate than those for the individual lunch meats.

Table 3 also has estimates of how much the taxes will reduce total lunch meat sodium consumption. These sodium reductions are calculated by comparing the pre-tax demands to the estimated post-tax demands. Our estimates show that the total sodium intake figures are more accurately estimated than the individual lunch meat's consumption changes. At the 95% confidence interval for the low tax, sodium is 1.17 to 0.84%, a range of 0.33%. Bologna is the lunch meat with the tightest confidence intervals. A 1% tax rate will place bologna's confidence interval at a 2.42% wide. The low tax rate reduces sodium consumption by slightly over 1%, while the high tax rate reduces sodium by about 20%.

Table 4 shows the results of our consumer cost analysis. A sodium tax that increases the prices of all lunch meats has the same effect as a reduction in consumer income. We used the estimated AIDS parameters to translate these price increases into income lost. In Table 4, this income loss is expressed as a percentage of the total market expenditure on lunch meats. For example, a 1% sodium tax increase will be equivalent to a 0.99% reduction in consumer expenditure on lunch meats. Likewise, a 25% sodium tax increase will amount to 24.70% less spending on lunch meats. To retail store managers, the implications of these findings translate into lower fixed-weight meat sales, for which lunch meats accounted for over one-fourth of all fixed-weight meat sales in 2009 (Information Resources Inc. and Freshlook Alliances).

Table 4. Economic welfare loss as a percentage of base lunch meat expenditures

	95% Confidence Interval		
Tax rates	Estimate	Lower	Upper
Low	0.99%	0.99%	0.99%
Middle	4.95%	4.94%	4.96%
High	24.70%	24.66%	24.74%

Data Source. Author calculations based on Nielsen Homescan® data. 95% confidence intervals based on 5,000 Monte Carlo iterations.

Because the welfare cost is a complicated, nonlinear function of the AIDS-parameter estimates, we expected that it would have "interesting" statistical properties such as large standard deviations and high bias. However, there was remarkably little variation in the welfare measure. It appears to be the most accurate estimate of all our effects. The confidence intervals for the costs are much narrower (on a percentage basis) than any of our other estimates. This set of econometric estimates does a better job of estimating the public policy impact of a sodium tax than it does the impact of the sodium tax on private companies.

Conclusion and Policy Implications

Although many studies have provided estimates of economic and demographic factors affecting the demand for meat, poultry, and fish, only one has focused on the consumption of specific lunch meat products (Davis et al., 2012). In this study, we analyze retail purchases of eight different lunch meat products: bologna, chicken breast, ham, pepperoni, roast beef, salami, turkey, and "other" lunch meats using Nielsen Homescan data. The objectives of this study are: (1) to measure how a tax on sodium would affect lunch meat demands; (2) measure how these sodium taxes on lunch meats will affect consumers' economic welfare; and (3) measure the accuracy of the tax-effect estimates.

We applied AIDS demand-system to estimate the effects of taxing sodium on lunch meat consumption and consumer costs. Food taxes will raise the prices of food and, consequently, consumers' cost of living. Costs are particularly a concern for consumers, so the regressive nature of food taxes should be kept in mind. The low tax rate raises pepperoni's price by 1%, and decreases lunchmeat-related sodium consumption by more than 1%. The 25% tax rate only decreases sodium from lunch meat consumption by 20%. Our estimates show that the ratios of sodium reduction to consumer costs are better at the lower tax rate. Policymakers may be more interested in sodium consumption effects than the effects on individual lunch meats, and the relative accuracy of the sodium consumption measures would support the use of these estimates for policy analysis.

One of the other objectives was to determine that accuracy of the welfare measures based on the sodium tax on lunch meats. We surprised by the accuracy of the welfare based measures. The 95% confidence intervals for the reduction in sodium consumption were narrower than the confidence intervals for any of the eight lunch meats. At the highest tax rate (25% of the value of peperoni) the width of the sodium tax confidence interval is 0.23%. The narrowest confidence interval for a lunch meat's consumption at the high tax rate is bologna (1.91%). Tax-rate equivalent costs are even more accurately measures. Given the high tax rate, the width of the tax-effect confidence interval is 0.08%.

The cost and benefit effects are invariably based on estimated consumer demands. It would be interesting to see if this type of accuracy holds for other types of welfare analysis. If it does, it will boost our confidence in the advice we provide to policymakers.

An unexpected result of our study is that sodium taxes will, in some cases, reduce the consumption of lower-sodium alternatives by more than the high-sodium ones. Many of the high-sodium lunch meats also have high prices. Sodium taxes will increase the prices of all lunch meats. High-sodium items would have the largest taxes; however, because of their high initial prices, the percent increase caused by the tax is lower for high sodium items than for low-sodium items.

As noted, we do not include any supply-side effects in our analysis. If processors react to lower demand by cutting their prices, then our estimates will overstate the value of taxing sodium on consumers. Our analysis excludes the effects that these taxes may have on meat-processors and retail stores profits. Sodium taxes will lower the demand for lunch meats. This lower demand can translate into lower processor and retailer profits and less employment. The profits and wages from sales of lunch meats are another part of economic welfare. Lost profits and employment due to sodium taxes are economic costs that need to be balanced against the potential health benefits of reduced sodium consumption. While the supply-side effects may mitigate the effects of sodium taxes on consumers, they do so by transferring costs to the lunch meat producers and marketers.

Processors may react to sodium taxes by changing their lunch meat formulas to include less salt. To the extent that consumers find the low-sodium alternatives just as good as the saltier ones, a reformulation may lead to lower economic losses for both producers and consumers. Evaluating the effects of product-reformulation is outside the scope of this analysis. However, economists have used cost functions or compensating variation to evaluate new products or improvements in old ones. Future work could expand on our analysis to account for these potential reformulation effects.

A reduction in sodium intake is likely to lower the number of people who suffer from strokes and acute myocardial infarctions (Smith-Spangler et al., 2010). A sodium tax will impose costs on those who consume healthy amounts of lunch meats as well as those who over consume. A sodium tax, therefore, addresses the over-consumption problem by taxing even healthy consumption levels. Further, lunch meats are not the only source of sodium in consumers' diets. An evaluation of the effectiveness of sodium taxes would require expanding the scope of foods analyzed.

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Appendix A

Developing the Restricted AIDS Model

As noted above, many of the *b* and *c* coefficients of the freely-estimated AIDS model were statistically insignificant. The free-model estimates were also not negative, semi-definite. We used a double-loop procedure to eliminate coefficients from the model.

We tested the coefficients one at a time. The computer selected the least-significant coefficient and set it to 0 for the following runs. With that least-significant term set to 0, we then retested the remaining coefficients, setting the least significant of coefficients to 0, and so on until we had eliminated all the c_{ij} and b_i from the model. We used likelihood ratio tests to test the coefficients. The asymptotically distribution of the likelihood ratio tests are chi-square. Table A shows the statistically insignificant tests.

Because of the symmetry $c_{ij}=c_{ji}$ we only tested the upper-triangle of the c_{ij}. These two sets of coefficients are also estimated subject to equations (5) and (6). We could have two coefficients go out at the same time when the rest of the terms in their “group” are already 0. For instance, at the 29th step, the c_{ij} for (turkey, ham) and (turkey, pepperoni) both go out at the same time because all the other six (turkey, whatever) c_{ij} are already 0.

We have two measures of statistical significance in Table A: step tests and cumulative tests. The step test shows the effect of dropping that last coefficient on the model’s likelihood. These are 1-degree-of-freedom tests. The other is the cumulative test and compares the likelihood with all the terms dropped to date to the free model. The cumulative tests’ degrees of freedom are “step.” We have 30 insignificant coefficients in Table A, so that the last test has 30 degrees of freedom.

The step-test area has a column labeled Holm–Bonferroni level. The more hypotheses one tests, the more likely one is to see significance levels that are smaller than the 5% level. Statisticians have developed procedures to deal with the problem of multiple hypothesis tests; here, a version of the Holm-Bonferroni procedure is used. In the Holm-Bonferroni method, the tests are arranged from least to most significant. For a 5% significance level, the least significant test is compared to the 5% value, the second least to ½ of 5%, the third to 5% divided by 3, and so on. If the nominal significance level is lower than the Holm-Bonferroni level, one rejects the hypothesis. While not shown in Table A, both the step and cumulative tests are significant in the 31st step.

