Trans Fat and Cardiovascular Disease Mortality:
Evidence from Bans in Restaurants in New York

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Abstract.—This paper analyzes the impact of trans fat bans on cardiovascular disease (CVD) mortality rates. Several New York State jurisdictions have restricted the use of ingredients containing artificial trans fats in food service establishments. The resulting within-county variation over time and the differential timing of the policy's rollout is used in estimation. The results indicate that the policy caused a 4% reduction in CVD mortality rates, or 12 fewer CVD deaths per 100,000 persons per year. While the averted deaths can be valued at about $3.6 million per 100,000 persons annually, the costs associated with the policy are comparatively smaller.

Keywords: Trans fat, restaurant, ban, stroke, heart disease, cardiovascular disease, mortality

JEL Classification Codes: I12, I18

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I. Introduction

The medical community has reached a consensus on the link between the consumption of artificial trans fat and the risk of developing cardiovascular diseases (CVD) such as coronary heart disease (CHD). Previous work has estimated that a 2% increase in energy intake from artificial trans fat increases the incidence of CHD by between 23% and 29% (Mozaffarian *et al.*, 2006).[1] In November 2013, the American Medical Association (AMA) indicated that a substitution away from oils containing artificial trans fats toward healthier options such as extra virgin olive oil could prevent 30,000 to 100,000 premature deaths each year.[2] Danaei *et al.* (2009) estimate that high trans fat consumption is responsible for about 82,000 CVD-related deaths annually in the U.S.

The first major public policy response in the U.S. to the growing public health concern over trans fat consumption was in 2006 when the Food and Drug Administration (FDA) mandated trans fat labeling on packaged foods at the national level. The food industry reacted by reformulating its products to reduce the amount of trans fat contained in packaged foods (Unnevehr and Jagmanaite, 2008). While recent work has documented a marked reduction in the amount of trans fat in the American diet (Doell *et al.*, 2012), an analysis of the health effects of a nationwide policy such as mandatory trans fat labeling is hampered by the absence of geographical policy variation and meaningful treatment and control units.

[1] One gram of fat has 9 calories, so for an individual on a 2000-calorie daily diet this is approximately a 4.4g increase in trans fat consumption.

[2] Visit the following link for the statement by Patrice A. Harris, MD, an AMA Board Member, "AMA: Trans Fat Ban Would Save Lives": http://www.ama-assn.org/ama/pub/news/news/2013/2013-11-07-trans-fat-ban-would-save-lives.page, accessed online May 30, 2014.

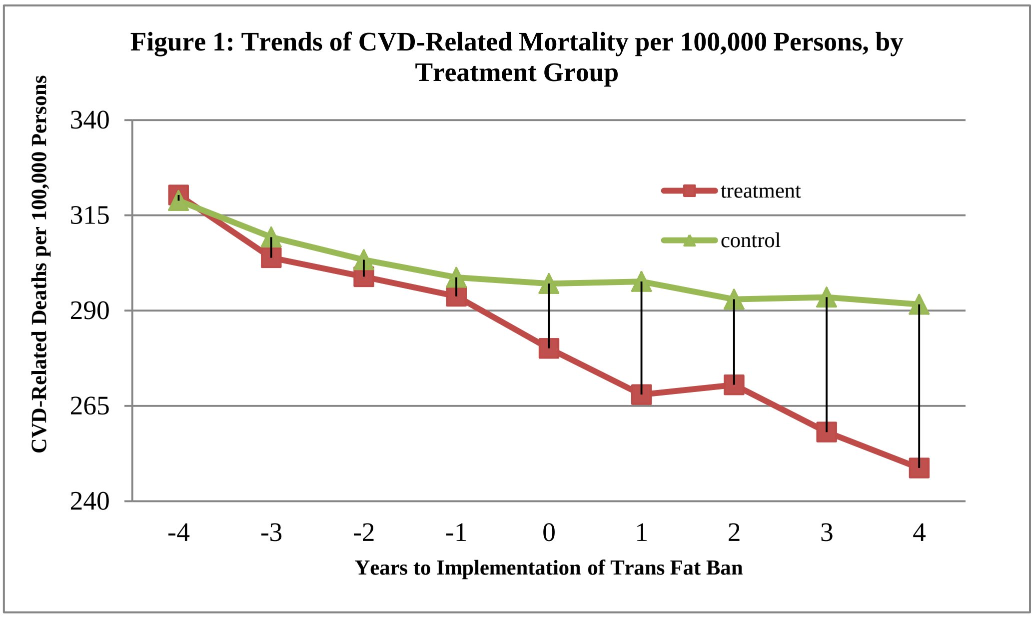
In this paper, we contribute to the literature by analyzing whether there is a causal effect of artificial trans fat consumption on CVD-related mortality. In particular, we evaluate a recent public policy response in some New York State (NYS) counties that mandated a substantial reduction in the amount of artificial trans fat in the local food supply. The policy, which is commonly referred to as a "trans fat ban", applies to all food service establishments that require a permit to prepare and serve food. The regulation imposes an upper limit on the amount of artificial or industrially produced trans fat allowed in food, which is generally 0.5g of trans fat per serving. Current estimates indicate that about one-third of daily calories come from food consumed outside the home (Lin and Guthrie, 2012), so this policy has far-reaching implications for nutrition and health.[3] Between 2007 and 2011, trans fat bans were implemented by the health departments of six NYS counties and New York City (NYC).

We use panel data on NYS county mortality rates for the 2002-2012 period. These data allow us to employ an empirical approach that controls for statewide time-varying determinants of mortality and permanent differences across counties. Trans fat bans and the resulting reductions in trans fat content in restaurant food were not randomly assigned across NYS counties. However, we make use of plausibly exogenous within-county variation over time in the artificial trans fat content in restaurant food resulting from the policy mandate and the differential timing of the policy's rollout to identify the CVD-related mortality effects of trans fat bans.

As Figure 1 illustrates, prior to the implementation of trans fat bans, both treated and control counties followed very similar downward-sloping trends in CVD mortality rates. While there are differences in mortality rates

[3] In 2005-2008, about 20% of daily calories were consumed at restaurants and fast food outlets and 12% of daily calories were consumed at other establishments away from home (Lin and Guthrie, 2012). Because most of the calories consumed away from home are from restaurants and fast food outlets, we often use the term "restaurants" to refer to the establishments targeted by the policy for ease of exposition.

between the treated and control counties, these differences are stable before the period in which trans fat bans were implemented. After the bans were implemented, we see a clear downward break in the trend in treated counties, and a relatively stable trend in control counties.



Note: Each county's trans fat ban implementation year is normalized to zero. Each point -4, -3,…, 4 corresponds to a mean for the control group that was taken over various years because of the variation in implementation years across treatment counties. For example, the control group mean at point 0 was taken over the years 2007, 2008, 2009, 2011, and 2012, which correspond to the different implementation years of the treatment counties.

Our regression analysis indicates that mandating low upper limits on the content of artificial trans fat in restaurant food prevents a substantial number of CVD deaths. In particular, in our preferred specification, we find evidence indicating that implementation of a ban on the use of artificial trans fat in restaurants caused, on average, a 4% reduction in CVD mortality rates, which translates into a reduction of about 12 CVD-related deaths per 100,000 persons per year. An analysis of the impacts on the major components of CVD mortality reveals that trans fat bans reduce mortality caused by diseases of the heart by about 10 per 100,000 persons per year and reduce mortality due to cerebrovascular disease (stroke) by about 3 per 100,000 persons per year.

Our results are robust to excluding NYC counties from the analysis, changes in the composition of the control group to address the potential for policy spillovers to neighboring counties and comparability concerns with treatment counties, a variety of changes in model specification, and addressing policy endogeneity concerns (*e.g.* hospital-level interventions in NYC counties to increase the accuracy of cause-of-death reporting and menu labeling laws). Placebo analyses indicate that trans fat bans have much weaker impacts on mortality outcomes that are less likely or unlikely to be associated with the consumption of artificial trans fat. We also find evidence suggesting that the impact of trans fat bans on CVD-related mortality is concentrated among senior citizens who have, after all, the highest risk of mortality from CVD.

The analysis reveals that mortality caused by heart disease and stroke responds within a year to reductions in the amount of artificial trans fat in the local food supply. This is consistent with evidence from diet-related randomized control trials in the medical literature. For instance, the incidence of CVD-related events and mortality falls soon after individuals at high CVD risk switch to a Mediterranean diet and consume healthier fats (Estruch *et al.*, 2013).[4] Similarly, for individuals with CVD, the impact of statin therapy on low-density lipoprotein (LDL) cholesterol levels—the main channel through which trans fat consumption raises the risk of developing CVD—quickly reduces LDL cholesterol levels and CVD-related mortality risk (Law *et al.*, 2003).[5] Our results are also consistent with evidence in the economics

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[4] In a large randomized control trial in Spain, individuals with high CVD risk, but no CVD at baseline, were randomly assigned to be either (a) counseled to follow a Mediterranean diet and given extra-virgin olive oil or a mixture of nuts for free on a weekly basis, or (b) advised to reduce fat intake. The study found that the incidence of major CVD-related events including deaths responded quickly to an increased consumption of healthier fats (Estruch *et al.*, 2013).

[5] In a meta-analysis of 164 randomized placebo-controlled trials with median duration of 8 weeks, Law *et al.* (2003) find that a daily intake of statins lowered LDL cholesterol levels by 1.8 mmol/l, and 58 randomized trials revealed that a 1 mmol/l reduction in LDL cholesterol resulted in an 11% reduction in fatal heart disease events in the first year.

literature that cardiovascular health is sensitive to changes in the environment or health-related behavior. For example, there is evidence that CVD-related mortality falls shortly after increases in cigarette taxes (Moore, 1996), the implementation of smoke-free workplace laws (Adams *et al.*, 2011), changes in macroeconomic conditions (Ruhm, 2003), and income receipt (Evans and Moore; 2011, 2012). In an analysis of the dynamics of the treatment effects, we provide evidence that, in addition to the effect on CVD-mortality occurring within one year, trans fat bans also have a lagged effect. This result gives reason to believe that the impact of the policy on prevented deaths or increased longevity may grow over time.

Heart disease is the leading cause of death in NYS, and we find that trans fat bans have the potential to lead to substantial reductions in the loss of life as a result of the consumption of artificial trans fat, which has no known health benefits. Given that the NYS counties that implemented trans fat bans over our study period had 34,215 heart-disease-related deaths in 2006, we estimate that, on average, implementation of trans fat bans prevented about 1,300 heart-disease-related deaths per year. Assuming a discount rate of 3%, Aldy and Viscusi (2008) find that the cohort-adjusted Value of a Statistical Life-Year is about $302,000. Even if fatal heart attacks cause only 1 year of life to be lost, the fatal heart attacks prevented by trans fat bans can be valued at about $393 million annually. In a cost-benefit analysis below, we calculate that these health benefits are likely to outweigh the costs to the food service industry and inconveniences to consumers.

The rest of the paper is organized as follows. First, we provide some background on the health effects of trans fat consumption and discuss related studies in the literature. Second, we describe the data used in the analysis. Third, we outline the empirical strategy and discuss the main results. Fourth, we explore the heterogeneity of impacts across counties. Fifth, we explore the dynamics of the treatment effects. Sixth, we test for a variety of mechanisms that could underlie our results. Seventh, we discuss the magnitude and plausibility of our estimates and perform a rough cost-benefit analysis. Finally, we conclude.

II. Background and Previous Literature

There are two main sources of dietary trans fatty acids (trans fat) in the U.S. food supply. Natural trans fat occurs through biohydrogenation in ruminant animals and is found in meat and dairy products. However, Eckel *et al*. (2007) estimates that approximately 80% of the trans fat in the U.S. diet is artificial or industrially produced, and it is found in foods that contain partially hydrogenated oil (PHO). Artificial trans fat is created through a process called partial hydrogenation, whereby hydrogen gas is added to liquid vegetable oil, which converts it into semi-solid fat. Artificial trans fat is commonly used in the food production and service industries because it is less expensive than other fats, it increases the shelf life of products, and it may enhance the flavor and texture of food. Foods that typically contain artificial trans fat include shortenings, margarines, fried fast foods, baked goods, and snack foods (Eckel *et al*., 2007).

Aside from its caloric value—which is the same as for all fats—there is no known health benefit of consuming artificial trans fats. The consumption of artificial trans fat raises levels of low-density lipoprotein (LDL), or "bad" cholesterol, and decreases high-density lipoprotein (HDL), or "good" cholesterol (Brouwer *et al*., 2010). Thus, artificial trans fat consumption increases the total-to-HDL cholesterol ratio, which increases the risk of cardiovascular diseases (CVD) such as coronary heart disease (CHD).[6] Trans fat is generally considered worse than other fats (*e.g.* saturated fat) because, unlike other fats, it does not raise HDL cholesterol (Eckel *et al*., 2007).

[6] Consumption of saturated fat also increases the risk of heart disease, but to a much lesser extent than trans fat. A review by Ascherio *et al.* (1999) finds that a 2% increase in energy intake from industrially produced trans fat increases the LDL to HDL ratio by 0.1, which corresponds to a 5.3% increase in the risk of CHD; a 5% increase in energy intake from saturated fat is needed to result in the same increase in the risk of developing CHD.

Evidence from the epidemiology and medical communities indicates that adverse health effects are present at intake levels as low as 1 to 3% of total energy, which is only 20 to 60 calories for those on a 2000-calorie daily diet. In contrast, there is comparatively less evidence to support a link between natural trans fat and the risk of developing CVD (Mozaffarian *et al.* 2006).[7]

On January 1, 2006, the FDA implemented a nationwide policy, which mandated that trans fat content per serving be included on the "Nutrition Facts" label found on all packaged foods.[8,9] Recent work has documented that the amount of trans fat contained in the American diet fell substantially after 2006. For example, Doell *et al.* (2012) estimate that trans fat intake in 2009 was 1.3g per person per day, which is only about 28% of the estimated daily intake of trans fat in 2003. While this policy affected food products available at supermarkets and grocery stores, it had no impact on restaurant foods because restaurants are not subject to nutrition labeling requirements.

Recent local legislation has addressed the fact that consumers are generally not able to determine the trans fat content in the foods that they consume away from home. The New York City (NYC) health department initially launched an education and awareness campaign to encourage restaurant owners to use oils free of artificial trans fat on a voluntary basis. However, the campaign was found to be ineffective (Tan, 2009). The NYC

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[7] Mozaffarian *et al.* (2006) indicate that the lack of association between natural trans fat and heart disease risk "may be due to lower levels of intake (typically less than 0.5% of total energy intake), different biologic effects (ruminant and industrial trans fats share some, but not all, isomers), or the presence of other factors in dairy and meat products that balance any effects of the small amount of trans fats they contain."

[8] Denmark was the first country to implement a nationwide policy to limit the amount of trans fat in the food supply. Since 2004, Denmark has prohibited the sale of oils and fats that contain more than 2 grams of industrially produced trans fatty acids per 100 grams of oil or fat. Canada was the first country to implement trans fat labeling on packaged foods, which it did in 2005.

[9] The FDA allows food manufacturers to label products with less than 0.5g of trans fat per serving as containing 0g of trans fat. Thus, some products whose label indicates that they are free of trans fat might contain negligible amounts of trans fat.

health department deemed it appropriate after the failed campaign to regulate the amount of artificial trans fat in its food supply, and other NYS jurisdictions quickly followed suit. In particular, between 2007 and 2011 the health departments of NYC and six other NYS counties implemented laws that place upper limits on the amount of trans fat that is allowed in a serving of food from food service establishments. This policy applies to *all* food service establishments that are required to hold a permit from health departments to serve food, including restaurants (large chains and single-owner establishments alike), school and business cafeterias, caterers, mobile food vendors, soup kitchens, and food stands at street fairs, etc. Thus, the policy is far-reaching and affects the trans fat content in nearly all food consumed away from home.[10]

The main impetus behind the policy is the growth in calorie consumption from food away from home, and in particular restaurants. For example, between 1977-78 and 2005-08 the share of daily calories consumed in restaurants and fast food establishments increased from 6% to 20%, while the share of daily calories consumed at home fell from 82% to 68%. Over the same time period, the share of total fat consumed on a daily basis provided by restaurants and fast food establishments increased from 7% to 23% (Lin and Guthrie, 2012).

To the best of our knowledge, only a handful of studies have attempted to quantify the reduction in the amount of trans fat in restaurant food after the

[10] It is important to note that trans fat bans do not *fully* eliminate the existence of trans fat in food away from home. As mentioned above, meat and dairy products contain naturally occurring trans fat, so it is virtually impossible to totally eliminate the presence of trans fat in restaurant food. Instead, these policies place a low upper limit on the amount of trans fat per serving of foods containing PHOs, shortenings, and margarines. In addition, these policies do not apply to packaged goods because they are under the jurisdiction of the FDA (Tan, 2009). Thus, pre-packaged potato chips or candy, for example, are permitted to be sold even if the trans fat content per serving is higher than 0.5g.

bans were implemented in restaurants.[11] Angell *et al.* (2009) show that in four major fast food chains in NYC, the amount of trans fat contained in French fries fell from an average of 4g before the ban to about 0.1g after the ban, or a reduction of about 98%. They also find that the amount of saturated fat in French fries decreased by about 10.5%. A more recent study analyzing transaction data from 11 NYC fast food chains found that, on average, trans fat per purchase fell by 2.4g and saturated fat increased by 0.55g after trans fat bans were implemented (Angell *et al*., 2012); however, the mean trans fat plus saturated fat content decreased by 1.9g. These studies are useful because they confirm that the policy was effective, *i.e.* that restaurants complied with the law and reduced the amount of trans fat in restaurant food, but it is important to note that they did not compare the change in the content of trans fat in fast food chains in NYC to chains in areas not subject to a ban. In addition, chains are not necessarily representative of other food service establishments, so it is difficult to know the true size and distribution of the reduction in the amount of artificial trans fat in the local food supply of the counties that implemented the ban.

Nonetheless, the results in Agnell *et al.* (2009, 2012) point to substantial reductions in the amount of trans fat contained in restaurant food due to the bans and there is no evidence that restaurants make substitutions that fully offset these reductions with increases in saturated fat content, which also has adverse health effects. Moreover, as best as we can tell, there is no evidence that compliance with trans fat bans, which involves replacing trans-fat-containing oils with other oils, is very costly for firms. For example, in

[11] Between November 2004 and September 2005, Stender *et al.* (2006) calculated the content of industrially produced trans fat in French fries and chicken nuggets purchased at McDonald’s and KFC. They analyzed a total of 43 servings bought in 20 countries, and found that 50% contained more than 5 grams of trans fat per serving. Interestingly, there was substantial geographical variation in the share of trans fat as a percentage of total fat. For example, in a large serving of McDonald’s French fries the share was 23% in NYC, 19% in Atlanta, 15% in France, and 1% in Denmark.

2006 Wendy's started cooking with oil that contains 0g of trans fat per serving and has reported that the change was cost neutral (Lueck and Severson, 2006). Starbucks, Dunkin' Donuts, and the International House of Pancakes have also eliminated the use of trans-fat-containing oils in all of their stores and reported no loss in earnings after doing so (Tan, 2009).

III. Data

This paper goes one step further than the aforementioned studies on trans fat and cardiovascular health by analyzing whether there is a causal impact of trans fat on CVD mortality rates. To this end, we obtained publicly available data on mortality rates over the period 2002 to 2012 from the NYS Annual Vital Statistics files, which are provided by the NYS Department of Health. The NYS Annual Vital Statistics files give mortality rates by county of residence, year of death, and the primary cause of death. Our main dependent variable of interest is the (log) number of deaths per 100,000 persons residing in a county caused by CVD. We also analyze the major components of this variable, including diseases of the heart and cerebrovascular disease (stroke).[12] To complement our main analysis, we obtained comparable data for the NYS Metropolitan Area from the CDC Wonder Database, which we use to test the sensitivity of our results to changes in the composition of the control group.

The NYS Department of Health provided us with information on the effective dates of trans fat bans in restaurants for each county.[13] We verified this information by reviewing local laws from health department websites. Appendix Table 1 shows the timing of trans fat bans in restaurants for each county that has implemented such a policy over the sample period. We

[12] We define the sum of the mortality counts from "diseases of the heart" and "stroke" as the mortality attributable to CVD. The ICD-10 codes for diseases of the heart are I00-I09, I11, I13, and I20-I51; the ICD-10 codes for stroke are I60-I69.

[13] NYC is composed of 5 counties (Bronx, Kings, New York, Queens, and Richmond), so a total of 11 of the 62 NYS counties have implemented policies that reduce the amount of trans fat in restaurant food.

consider a county to have a ban on trans fat if the law has been effective for at least 6 months in a given year. Notice that NYC and three other counties implemented their ban on trans fat over two phases. In some counties, some food service establishments were allowed to continue using oils and shortenings containing trans fat for deep frying cake batter and yeast dough until Phase II; however, the preparation of all other foods was affected by the policy in Phase I. If the ban was implemented over two phases, we use the earliest date of the ban. Later, we distinguish between the two Phases, and show that the estimated impacts of the bans in Phase I and Phase II are similar.

Table 1 shows county population-weighted summary statistics for the full sample and by whether a county implemented a ban on trans fat over the sample period. Averages over the sample period show that there were 288 CVD-related deaths per 100,000 persons, most of which are attributed to diseases of the heart. CVD-related deaths per 100,000 persons are lower (283) in the treatment counties than in the control counties (299). The number of deaths per 100,000 persons not attributable to CVD—to which we refer as net deaths—is also higher in the control counties (607) than in the treatment counties (419). However, CVD is responsible for a substantial share of deaths in both treatment (33%) and control (40%) counties. Economic conditions, as measured by unemployment rates and per capita personal income, are similar in the treated and control counties.[14]

Appendix Table 2 shows additional summary statistics for the year 2006, the latest year before any county in our sample implemented a ban on trans fat in restaurants. Mortality caused by CVD was slightly higher in counties that implemented a ban over the study period relative to counties that did not. To examine the overall "healthiness" of counties that banned and did

[14] We obtained county-level unemployment rates from the 2004-2011 Local Area Unemployment Statistics series of the Bureau of Labor Statistics, and county-level personal per capita income from the 2004-2011 Bureau of Economic Analysis Regional Economic Accounts. Using the consumer price index, we inflated personal per capita income to 2012.

not ban trans fat over the study period, we obtained data on major CVD risk factors from the 2002-2012 waves of the Behavioral Risk Factor Surveillance System.[15] Counties that implemented a trans fat ban over the sample period were "healthier" in 2006 than other counties, as measured by lower rates of obesity, smoking, and drinking, but "less healthy" as measured by lower rates of physical activity. As we discuss in greater detail in the next section, so long as these differences across counties are fixed over time, our empirical model will account for them by controlling for county fixed effects in the regression analysis. Later, however, we also explore whether *changes* in health-related behaviors, which could be a component of the policy's impact on health, explain the reductions in CVD-related mortality.

IV. Empirical Analysis and Results

a. Empirical Model

To estimate the impact of trans fat bans on CVD mortality rates, we estimate the following model:

$$ln(M_{ct}) = \beta_0 + \beta_1 TFB_{ct} + X'_{ct}\beta_2 + \gamma_c + \gamma_t + \gamma_c \times t + \varepsilon_{ct} \quad (1)$$

where *M* is the number of CVD-related deaths per 100,000 in county *c* in year *t*. *TFB* is a dummy variable equal to 1 if county *c* has implemented a ban on trans fat in year *t*, and zero otherwise. Time-varying county-specific factors that may affect mortality rates (*e.g.* unemployment rates) are grouped in matrix *X*. In order to account for unobservable county characteristics that may affect CVD mortality rates and are fixed over time, we control for a county fixed effect (γ_c). A county fixed effect would, for example, net out from the model differences in mortality that result from differences in the accuracy of cause-of-death reporting across counties, so long as these differences are constant over time. The year fixed effect (γ_t) accounts for factors that may

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[15] This information includes a county's (age 18+) population who were obese, engaged in physical activity over the past 30 days, were smokers, and drank alcohol in the past 30 days. Information on these variables is not available for every county and every year, which explains why the sample size is smaller for these descriptive statistics.

affect CVD mortality rates in all NYS counties equally over time, such as mandatory trans fat labeling laws that were implemented nationwide in 2006 or bans on smoking in bars and restaurants implemented statewide in 2003. To account for trends in mortality rates that may vary across counties, we also include county-specific linear time trends in the model ($\gamma_c \times t$). Finally, ε_{ct} is an idiosyncratic error term. Standard errors are clustered at the county level to allow for arbitrary correlation of observations within counties over time.

Figure 1 adds confidence to the empirical strategy, which assumes that pre-treatment trends in the outcome variable are parallel or similar in both treatment and control counties. The empirical model outlined above is powerful because it controls for observable and unobservable factors, both time-constant and time-varying, that might affect mortality rates and whether a county implements health-related policies such as a ban on trans fat in restaurants. However, there remains the concern that counties may implement several policies around the same time that affect mortality rates, which makes it difficult for the analyst to isolate the impact of a single policy.

An important concern for policy endogeneity that we account for is that the NYC health department implemented interventions in some hospitals with the goal of reducing the over-reporting of deaths caused by heart disease. The first hospital-level intervention was conducted between July and December of 2009 and affected mortality statistics starting in 2010. This intervention involved physician and hospital staff training and occurred in 8 hospitals located in Brooklyn, the Bronx, Queens, and Staten Island.[16] These hospitals accounted for only 10% of all deaths in NYC in 2008, but Al-Samarrai *et al.* (2013) find that the intervention caused a substantial decrease in deaths attributed to heart disease. A similar intervention was performed in

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[16] These are Kings, Bronx, Queens, and Richmond Counties, respectively. No hospital located in Manhattan or New York County was affected by the intervention conducted in 2009 (Al-Samarrai *et al.*, 2013).

12 additional hospitals across all 5 NYC counties in 2011 and 2012, yielding similar results (Madsen and Begier, 2013).

It is important to note that the timing of these interventions does not coincide with the timing of trans fat bans in NYC, but they may cause us to overestimate the impact of trans fat bans on CVD mortality rates. Thus, as we discuss in greater detail below, we also include in matrix *X* a dummy variable for NYC interacted with a dummy variable equal to one for the years 2010-2012 to account for the structural break in NYC mortality rates as a result of the hospital-level interventions that occurred over this period. Two alternative strategies, which we describe in greater detail below, are (1) to drop counties in years that coincide with the hospital intervention or (2) to drop all observations from NYC. We find that both analyses produce similar results.

b. Main Results

In Table 2, we present our main results, which reveal strong evidence that bans on artificial trans fat led to a sizeable and statistically significant decline in CVD mortality rates. We begin by estimating a stripped-down version of equation (1) that controls for only county and year fixed effects. We find that implementation of a ban on trans fat reduces CVD mortality rates by about 9% (see column 1). In column 2, we control for unemployment rates and (log) personal income per capita. In line with Ruhm (2000, 2003), we find evidence of a procyclical relationship between economic conditions as measured by unemployment rates and personal income and CVD mortality rates. However, adding controls for measures of economic conditions only slightly increases (in absolute magnitude) the coefficient estimates of the trans fat ban effects. In column 3, we account for the structural break in CVD mortality rates caused by hospital-level interventions that affected mortality statistics in 2010-2012 in NYC by controlling for a dummy variable for NYC interacted with a dummy variable for the years 2010-2012. We find evidence suggesting that the NYC hospital-level interventions causes us to overestimate the impact of trans fat bans by about 30%, but the estimate of the CVD-related mortality reduction (about 7%) of trans fat bans remains statistically and economically significant.

We also want to rule out the possibility that we could be over- or under-estimating the treatment effect due to slow-moving trends (*e.g.* demographic changes or dietary habits) that may vary across counties. We examine this by adding to the regression model a linear time trend, which is allowed to vary according to whether a county implemented a trans fat ban in restaurants over the sample period. Controlling for a time trend specific to the treatment group reduces the coefficient associated with the trans fat ban dummy to about 6% (column 4). We present the estimates of our preferred specification in column 5. Here, we control for a county-specific linear time trend instead of a treatment-group-specific one. We find that trans fat bans reduce CVD mortality rates by about 4%, which implies that implementation of a ban on trans fat reduces CVD-related mortality by about 12 per 100,000 persons.[17]

In Appendix Table 3, we show the results from an alternative way of addressing the hospital-level interventions in NYC. In particular, we find that restricting the analysis sample to the period over which CVD mortality rates were not affected by the intervention (2002-2009) produces a very similar estimate of the impact of trans fat bans on CVD-related mortality to the one delivered by our preferred specification discussed previously (compare column 1 to column 2). When we add mortality data from 2010 and 2011 but exclude mortality data from counties that were affected by the hospital-level interventions, we also find similar results to those in the main analysis (compare columns 3 and 4 to column 1). We conclude from this analysis that including the interaction between a NYC dummy and the hospital-intervention period in the regression model appropriately accounts for the structural break in CVD mortality rates caused by the hospital interventions in 2010-2012.

[17] This calculation uses the average CVD mortality rate in 2006 ($(e^{-0.043}-1)*293.742 = 12.363$).

Thus, we proceed with using our preferred specification (column 5 in Table 2) throughout the remainder of the main analysis.

In Table 3, we analyze the impact of trans fat bans on the major components of CVD-related mortality. The magnitudes of the estimated effect of the trans fat ban on deaths caused by diseases of the heart and strokes are both negative and quantitatively important. Column 1 reproduces the estimate shown in column 5 of Table 2. The estimate shown in column 2 of Table 3 implies that implementation of a ban on trans fat in restaurants decreases deaths attributed to heart disease by about 10 per 100,000 persons, and the corresponding estimated reduction in deaths attributed to strokes is about 3 per 100,000 persons. Thus, about 80% of the impact of trans fat bans on CVD is attributable to diseases of the heart, and the remainder is due to cerebrovascular diseases.

A natural question that comes to mind is whether the mortality reductions caused by trans fat bans are driven by the oldest segment of the population, since the risk of developing CVD increases with age, and thus those at the highest risk of dying from CVD-related health conditions are older individuals. The public-use mortality files provided by the NYS Department of Health do not disaggregate mortality data by cause of death, county of residence, and age group, but they do disaggregate *all* deaths by county of residence and age group. In Appendix Table 4, we estimate the impact of trans fat bans on all-cause mortality rates for the following age groups: 0-24, 25-44, 45-64, and 65 and over. The estimated impacts for the younger three age groups are all statistically insignificant and are small in magnitude. In contrast, we find that trans fat bans reduced all-cause mortality rates among senior citizens by about 2%, which implies a reduction of about 15 deaths per 100,000 persons. This estimated reduction is quite close to the one we found for CVD-related mortality (column 5 of Table 2). These results suggest that trans fat bans reduce mortality among senior citizens and not younger individuals, and most of the reduction in all-cause mortality is driven by a reduction in CVD mortality rates. In the next section, we will also investigate whether trans fat bans impact other causes of death.

c. Robustness Checks

We conduct a variety of robustness checks relating to spillover effects, the timing of the financial crisis and the implementation of the trans fat bans, as well as model specification. We also examine whether trans fat bans affected CVD-related morbidity, as well as unrelated mortality outcomes.

First, the residents of control counties may commute to treated counties. The resulting spillover patterns that are unrelated to trans fat bans and are time-invariant are captured by county fixed effects. However, it is plausible that commuting patterns may change in response to the implementation of trans fat bans. Residents in counties that have not banned trans fat in restaurants may choose to eat in the counties that have implemented such bans in order to consume healthier meals. This would result in control group contamination and could cause us to underestimate the mortality effects of the ban on trans fat. The reverse is less plausible, *i.e.* that residents from treatment counties commute to control counties with the purpose of consuming food that contains trans fat. For example, in the case of frying oils, there is evidence suggesting that individuals prefer foods fried in oils that are free of trans fat to oils that contain trans fat (Bordi *et al.* 2007a, 2007b). These spillover effects are most likely an issue in the case of counties that are immediately adjacent to treatment counties, so we examine whether omitting neighboring counties affects our results. When we do this, we find that the coefficient estimate on the trans fat ban dummy only slightly increases in magnitude (in absolute value), suggesting that treatment spillovers are not a major cause for concern in our analysis (row 1 of Table 4).

Second, since implementation of trans fat bans in restaurants coincided with the time period spanning the financial crisis, we address the concern that CVD mortality rates may have been differentially affected by economic conditions in treatment and control counties. We examine this possibility by allowing county unemployment rates and personal income per capita to have county-specific effects in the regression model. We find that the estimated impact of a ban on trans fat is little changed when we do this (row 2 of Table 4), suggesting that policy timing and the financial crisis are unlikely to account for our results.

Third, we assess the robustness of our results to a battery of specification checks. We have applied equal weights to each observation in our regression models throughout the analysis, so we test the sensitivity of our results to weighting the observations with the square root of a county's population. Row 3 of Table 4 shows that this weighting procedure produces smaller estimates than when we apply equal weights to all observations, but the results remain economically important and statistically significant. Throughout the analysis we have used crude mortality rates, so we test the sensitivity of our estimates to using age-sex-adjusted CVD mortality rates to account for differences in the age and sex distributions across counties. We show that accounting for the age and sex structures of the county populations only slightly reduces the estimated effect of trans fat bans (row 4 of Table 4).[18] Using CVD mortality rates in levels (instead of in logs as in the main analysis) as a dependent variable produces an estimate for the reduction in CVD-related mortality (row 5 of Table 4) that is very close to the one calculated using the results from the main regression model shown in column 5 of Table 2. Because the data we use in our analysis are based on mortality counts, we also examine whether using poisson and negative binomial regressions produces similar results, and rows 6 and 7 of Table 4 show that they do: exponentiating poisson and negative binomial regression coefficients provide incidence rate ratios indicating that trans fat bans reduce CVD mortality rates by about 3%.

Fourth, mortality is an extreme health event and not all CVD-related events are fatal. We analyze the impact of trans fat bans on hospitalizations,

[18] These age-sex-adjusted CVD mortality rates were standardized using the age-sex distribution from the United States 2000 Census.

which also include non-fatal events. We obtained data on CVD-related hospitalizations from the NYS Department of Health, but there is an important caveat with this part of the analysis. The mortality data are based on the deceased's county of residence whereas the hospitalization data are based on the county where the hospitalization took place. These data are not ideal because exposure to the treatment resulting from the policy is likely to be greatest in an individual's county of residence and we cannot observe the commuting patterns. Nonetheless, using our preferred specification, in row 8 of table 4 we estimate that trans fat bans reduce CVD-related hospital admissions by about 3%, an estimate that is statistically significant at the 10% level and quantitatively important. From a sample mean of 1,654 per 100,000 persons, this estimated reduction implies that implementation of trans fat bans reduces CVD-related hospitalizations by about 44 per 100,000 persons.[19] As expected, the estimated reduction in hospital admissions is larger than the estimated mortality reduction, given that not all hospitalizations result in deaths.

Lastly, we analyze the impact of trans fat bans in restaurants on major causes of death, some of which are unlikely to be affected by changes in the amount of trans fat in restaurant food. A caveat here is that our mortality data reflect the underlying or main cause of death, and any one single death is often attributed to multiple causes. Thus, we grouped the mortality outcomes according to the likelihood that the mortality outcome is linked to the consumption of trans fat, either directly based on medical research or because a mortality outcome has been strongly associated with cardiovascular health. In particular, we grouped together CVD, diabetes, cancer, and pneumonia. The first three have been shown to be associated with trans fat consumption in the medical literature (Mozaffarian *et al.*, 2006). And there is evidence in the

[19] Data on hospitalizations are unavailable for 2012, so this analysis relies on 2002-2011 data. The corresponding estimate (standard error) of trans fat bans on hospital admissions caused by diseases of the heart and stroke are -0.032 (0.014) and -0.009 (0.028), respectively.

medical literature that the cause-effect relationship between pneumonia and cardiovascular health is bi-directional (Corrales-Medina *et al.*, 2013), which opens up the possibility that deaths mainly attributed to pneumonia can fall as a result of improved cardiovascular health outcomes.

Table 6 shows results from an analysis that allows the error terms to be correlated across regression equations in a seemingly unrelated regression framework. Panel A displays the results for the group of outcomes that should be least likely to be associated with trans fat consumption, showing that, in most cases, estimates associated with the trans fat ban dummy are statistically insignificant, and are often small in magnitude. For example, estimated effects per 100,000 persons range from 0.015 to 2.933, while the corresponding reduction in CVD mortality is about -12. Only one specification, which involves accident mortality rates as a dependent variable, produces an estimate of the effect of trans fat bans that is statistically significant at conventional levels. However, we find that we cannot reject the null hypothesis that the estimates in Panel A are jointly equal to zero (p-value 0.124).

In contrast, in Panel B, we find that in addition to CVD, two other models produce statistically significant reductions in mortality, namely, those in which diabetes and pneumonia mortality rates are dependent variables. (We can strongly reject the null hypothesis that the estimates in Panel B are jointly equal to zero.) The specification involving diabetes is interesting because the medical community has found weak evidence that trans fat consumption increases the risk of diabetes (Mozaffarian *et al.*, 2006). It has also found similarly weak evidence that the consumption of trans fat raises the risk of developing some cancer. We find that the impact of trans fat bans on cancer mortality rates is negative, but the estimate is not statistically significant at conventional levels. Finally, the estimated impact on pneumonia mortality rates may stem from a bi-directional association between pneumonia and cardiovascular health (Corrales-Medina *et al.*, 2013).

In sum, we find that trans fat bans reduce CVD mortality rates and a few non-CVD-related mortality outcomes. Evidence from the medical community provides plausible mechanisms through which these latter effects might operate. However, relative to the estimated reduction per 100,000 persons, the largest impact of trans fat bans on mortality is for the outcome that is most strongly linked to the consumption of artificial trans fat, namely, CVD-related mortality.

d. Heterogeneous Impacts

Next, we address the question of heterogeneous treatment effects and, to save space, this section is coupled with an analysis that shows that our results are not driven by the composition of the control group.

Despite the fact that Figure 1 showed that treatment and control counties had similar trends in CVD mortality rates prior to the period over which trans fat bans were implemented, there may be a lingering concern about the comparability of the treatment and control counties. For example, all the counties that implemented trans fat bans are metropolitan counties, according to 2004 County Typology Codes provided by the U.S. Department of Agriculture's Economic Research Service (ERS). In Panel A of Table 5, we show results from analyses that examine the sensitivity of the results to changing the composition of the control group. Using the ERS metropolitan county classification system, we re-estimated our preferred specification using only metropolitan control counties (column 2) as well as using only non-metropolitan counties (column 3). The estimated effects are nearly identical and very close to the estimated impact we found in the main analysis (reproduced in column 1).

Most of the treatment counties in our sample are part of the NYS Metropolitan Area. One might argue that a more appropriate control group would consist of counties that are also a part of the NYS Metropolitan Area. To examine whether our results are sensitive to limiting the analysis sample to counties that belong to the NYS Metropolitan Area, we used supplementary data from the CDC Wonder database.[20] Using our preferred specification, analysis of this sample reveals that trans fat bans reduce CVD mortality rates by about 3.5% (column 2 of Panel B of Table 5), which is statistically significant at the 10% level. Again, this estimate is very similar in magnitude to the one we obtained in the main analysis. Overall, the analysis indicates that our results are robust to changes in the composition of the control group.

It is important to know whether a subset of the treatment counties is driving the results. For example, one might argue that NYC is a special case, given that it is often at the frontier of the health policy arena, so we drop all observations from NYC from the analysis. Panel A of Table 5 (columns 4, 5, and 6) and Panel B of Table 5 (column 5) show that the average estimated impact of trans fat bans on CVD mortality rates ranges between about 3.3% and 5.6%, with two of these estimates being statistically significant at the 10% level. However, estimates from models that include and exclude NYC observations are not statistically different from each other. For example, in Panel A, we fail to reject the null hypothesis that the estimates in column 1 (includes NYC observations) are equal to the estimates in column 4 (excludes NYC observations) with a p-value of 0.817.[21] Thus, overall, our results are robust to the concern that NYC drives impact of trans fat bans on CVD mortality rates.

Finally, we might expect heterogeneity in the effect of trans fat bans due to, for example, different pre-regulation levels of artificial trans fat in the local food supply. We examined this explicitly by estimating our preferred

[20] The latest year for which mortality information is available is 2011, so the sample period for this analysis is 2002-2011. In addition to the NYS jurisdictions that are in the NYS metropolitan area (see Appendix Table 1), Stamford, CT, which is in Fairfield County, CT, also implemented a trans fat ban over the sample period. In 2008, Stamford, CT implemented a law that is comparable to the second phase of the NYS county laws.

[21] Similarly, in Panel B, we fail to reject the null hypothesis that the estimate from the regression including NYC is equal to the estimate from the regression excluding NYC (p-value 0.223).

specification on the main analysis sample, using all the control counties and only one treatment county at a time. Figure 2 summarizes the results from these regressions, which suggests that the impact of the laws varies by county. While most estimates are negative in sign, we cannot reject the null hypothesis that the impact of trans fat bans on CVD mortality rates is zero for Albany, Nassau, Queens, Suffolk, and Westchester counties. However, we do find statistically significant and economically important reductions in CVD mortality rates for Bronx, Broome, Kings, New York, Richmond, and Rockland counties. Note that two of these counties are not NYC counties. This finding adds further empirical support for the conclusion we made above that the inclusion of NYC observations does not drive all of our main results.

e. Health Behaviors and other Policy Endogeneity Concerns

We now turn to analyzing the importance of changes in health-related behaviors that may be driving our results. A ban on trans fat can affect health and mortality risk through improvements in health-related behaviors. Major risk factors for CVD include unhealthy eating habits, lack of physical activity, smoking, and excessive alcohol consumption. In Table 7, we show results from an analysis that is similar to our preferred specification, except that we use county-level obesity rates (a proxy for diet-related behavioral change), physical activity rates in the past month, current smoking rates, and drinking rates in the past month as dependent variables. We cannot reject the null hypothesis that the impact of trans fat bans on these health-related behaviors is zero. Thus, it does not appear to be the case that changes in these major CVD risk factors explain the impact of trans fat bans on CVD mortality rates.[22] This suggests that other behaviors associated with cardiovascular health, such as

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[22] In an unreported analysis, we also examined whether changes in health-related behaviors explain the mortality reductions caused by trans fat bans by directly controlling for them in CVD mortality regressions. Neither controlling for each one of these variables individually nor controlling for them all at once reveal any evidence that changes in health-related behaviors are driving our results. Coefficients on the trans fat ban dummy are unchanged when controlling for each individually or all behaviors simultaneously.

various dimensions of food consumption, might be important channels underlying the CVD mortality reductions. To our knowledge, detailed food consumption data by county over time do not exist, so we are unable to determine and rank the importance of a myriad of channels related to food consumption that could underlie the policy's effect on CVD mortality rates. The policy's effect may be a result of a combination of several factors, such as changes in trans fat content in food away from home, changes in the quantity of food consumed away from home, and other changes in the quality of food offered by food service establishments.

A remaining policy endogeneity concern is that many counties that implemented bans on trans fat in restaurants also implemented menu labeling laws, which require chain restaurants to post calorie counts on menus. It is important to note, however, that while trans fat bans applied to all restaurants, only chains with 15 or more locations nationwide were required to comply with menu labeling laws. Nonetheless, Restrepo (2014) finds evidence that implementation of menu labeling laws caused a reduction in the probability of obesity and, since obesity is a risk factor for CVD-related disease, both trans fat bans and menu labeling laws could have independent effects on mortality.

In an unreported analysis, we controlled for obesity rates in CVD mortality regressions, and found that trans fat ban estimates were virtually identical with (coefficient -0.042, standard error 0.019) and without controls for obesity rates (coefficient -0.043, standard error 0.019). This suggests that changes in obesity rates following menu labelling laws are not the driving the impacts we find of trans fat bans on CVD mortality rates. Fortunately, two counties in our sample, Broome and Rockland, implemented trans fat bans but did not implement menu labeling laws, which allows us to shed more light on this policy endogeneity concern. In the analysis summarized in Figure 2, we found economically important and statistically significant reductions in CVD mortality rates in Broome and Rockland counties. Thus, overall, the analysis indicates that policy endogeneity due to the similar timing in the rollout of trans fat bans and menu labeling laws is unlikely to account for our main results.

f. Dynamics of the Treatment Effect

Thus far, we have focused on the contemporaneous effect of a ban on trans fat in restaurant food on CVD-related mortality. However, a reduction in trans fat consumption may also have lagged effects on mortality rates if, for example, the cardiovascular health benefits of reduced trans fat consumption grow over time. Over our study period, a ban on trans fat was effective for at least two years for all but one county (see Appendix Table 1), so we estimate a model allowing for one lag. Leads of the trans fat ban variable are also included in the model to examine whether there is evidence that the treatment effects anticipate implementation of the policy mandate.

Here, it is necessary to distinguish between the Phase I and Phase II implementation dates to account for the different lag structures of the counties that implemented a ban on trans fat in one phase and the counties that did so over two phases. We also drop all NYC observations from the NYC hospital-intervention period to avoid confounding the lagged estimated effect of the trans fat ban with the hospital-level interventions.

In column 1 of Table 8, we show results from a model that is comparable to the specification in column 5 of Table 2. As in Table 2, we find that trans fat bans contemporaneously reduce CVD mortality rates, with Phase II of the ban having a larger estimated impact than Phase I. The estimates, however, are not statistically different from each other (p-value 0.216). In column 2, we show estimates from a model including the leads and lag of the trans fat ban variable. The leads are not statistically significant, and F-tests of joint significance allow us to fail to reject the null hypothesis that the leads are jointly equal to zero. In contrast, we reject the null hypothesis that the contemporaneous and lagged effects are jointly equal to zero. In sum, these results imply that trans fat bans affect CVD-mortality quickly after implementation, and their effects may accumulate over time.

V. Discussion

Plausibility of the Size of the Estimated Reduction in CVD

We have found strong evidence that trans fat bans in restaurants caused a reduction in mortality attributable to diseases of the heart and stroke. Is the size of the mortality effect we estimate in line with predictions based on evidence from the medical literature? Below, we perform a back-of-the envelope calculation to examine the plausibility of our estimates, which is based on several assumptions.

First, assume that the estimates in Angell *et al.* (2012) of the reduction in the amount of trans fat per purchase (2.4g) caused by trans fat bans in NYC fast food chains also applies to all food service establishments in all NYS counties that implemented trans fat bans. In the U.S., about one-third of daily calories (or about 1 out of 3 meals) come from food consumed away from home (Lin and Guthrie, 2012). Thus, trans fat bans would reduce the consumption of trans fat from food service establishments by 2.4g, which is a reduction of about 1.08% of energy intake for individuals on a 2000-calorie daily diet (2.4g*9 calories ÷ 2000).[23] The FDA estimates that a 0.04% decrease in energy intake from trans fat would prevent between 240 and 480 fatal heart attacks nationally every year (FDA, 2003). Thus, a 1.08% reduction in energy intake from trans fat is estimated to prevent between 6,480 and 12,960 fatal heart attacks per year. In 2006, NYS accounted for about 8% of all U.S. deaths attributable to heart disease.[24] Thus, our rough calculation implies that we might expect the reduction in trans fat intake from food

[23] Stender and Dyerberg (2006) show that when it comes to fast food "it is possible to consume 10 to 25 g of these trans fatty acids in one day and for habitual consumers of large amounts of this food to have an average daily intake far above 5 g." Thus, the reduction in trans fat intake is likely to be much larger for certain individuals.

[24] This figure was obtained by dividing the total number of deaths in NYS in 2006 due to heart disease (50,470) by the total number of deaths in the U.S. due to heart disease (631,636). These figures were obtained from the Centers for Disease Control and Prevention (CDC) Wonder database.

service establishments to prevent between 518 to 1,037 deaths due to heart disease in NYS.[25]

In column 2 of Table 3, our 95% confidence interval of the estimated reduction in mortality due to heart disease is [-0.069 , -0.007], which implies that, on average, a NYS county-level trans fat ban reduces mortality by between 2 and 17 per 100,000 persons.[26] Given that NYS had 50,470 heart-disease-related deaths in 2006, we estimate that, on average, statewide implementation of trans fat bans would save between 353 and 3,482 lives per year.

There are three important points to bear in mind before comparing the two ranges above. First, our regression estimate captures the impact of a trans fat ban on mortality caused by heart disease that may operate through a variety of channels, not only through reduced trans fat intake from food away from home. For example, it may also capture the mortality impact operating through dietary changes made in response to increased awareness of the harmful consequences of consuming artificial trans fats. Second, changes in the amount artificial trans fat in NYC fast food chains after bans on trans fat were implemented may not be representative of corresponding changes in fast food chains in other areas of NYS, let alone the fact that fast food chains may not be representative of all food service establishments. Third, the FDA's estimates of the heart disease mortality impact of reducing trans fat consumption are based on medical evidence that trans fat consumption increases the risk of developing heart disease because trans fat increases LDL-to-HDL cholesterol levels. However, Mozaffarian *et al.* (2006) indicate that trans fat consumption also influences other risk factors for CVD. Thus, the

[25] If we instead assume that the mortality impact is equal across states, the corresponding range of prevented deaths in NYS that we might expect is between 130 and 259. This is also within our range of estimates of the impact of a trans fat ban on mortality caused by coronary heart disease.

[26] These calculations use the average heart disease mortality rate in 2006 (*e.g.* $(e^{-0.007}-1)*260.843 = -1.82$).

FDA's estimates of the mortality impact of a reduction in trans fat intake may underestimate the total impact of trans fat intake on heart disease mortality. Despite these caveats, it is comforting that the mortality impacts in NYS that we obtained from the rough calculation above are within our range of estimated mortality impacts.

Another way to assess the plausibility of our estimated mortality reductions is to compare them to the mortality reductions caused by statin medication therapy. In a meta-analysis of 164 randomized placebo-controlled trials, Law *et al.* (2003) find that a daily intake of statins lowered LDL cholesterol levels by 1.8 mmol/l and 58 randomized trials revealed that a 1 mmol/l reduction in LDL cholesterol resulted in an 11% reduction in fatal heart disease events in the first year. In a meta-analysis of controlled dietary trials, Mozaffarian *et al.* (2006) find that substituting 1% of dietary energy from unsaturated fats with trans fat increases LDL by between 0.04 and 0.07 mmol/l. Assuming that trans fat bans also caused a substitution towards unsaturated fats equal to 1% of dietary energy implies a reduction in fatal heart disease events of about 0.44% to 0.77%, which is in line with the lower end of our 95% confidence interval. However, again, trans fat intake affects cardiovascular health through channels other than increases in LDL cholesterol (Mozaffarian *et al.*, 2006), *e.g.* they promote inflammation, so this back-of-the-envelope calculation may account for only part of the policy's effect on cardiovascular health.

Are Trans Fat Bans a Cost-Effective Policy?

The financial costs associated with trans fat bans include all the costs related to compliance including substituting PHOs with healthier oils, creating new recipes without PHOs, training food preparers to cook without PHOs, *etc*. There is also a loss in consumer surplus if consumers value foods containing artificial trans fats because of taste or cost concerns. Higher food production and service costs would be passed on to consumers in the form of higher prices. We do not have information on the price of food away from home by county over time,[27] but we conduct a rough cost-benefit analysis to assess whether trans fat bans would be welfare improving if they were implemented in all NYS counties.

To our knowledge, there is no evidence in the literature showing positive health effects of consuming artificial trans fats, and we have documented that trans fat bans cause a statistically and economically important reduction in CVD-related deaths. In 2006, there were 60,421 CVD-related deaths in NYS, so we estimate that 2,598 (60,421*0.043) fewer deaths may have been attributed to CVD if there were a statewide ban in place in 2006. Suppose each prevented death results in one more year of life. If we use a recent estimate of the VSLY ($302,000) to value each prevented death (Aldy and Viscusi, 2008), the benefit of trans fat bans amounts to $785 million.

Regulation of the amount of trans fat used by food service establishments is accompanied by three main costs. First, there will be a cost for restaurants because of mandatory substitutions towards healthier cooking oils, which may involve changes to recipes. Also, since artificial trans fats increase the shelf-life of foods, foods free of them might spoil faster. In 2005 before the ban, food service sales in NYS amounted to $21.4 billion (selling period March 2005 – February 2006, excluding retail sales). The National Restaurant Association (NRA) estimates that the cost of food and drinks amounts to one-third of sales.[28] Existing evidences indicates that the cost of going trans fat free is small (*e.g.* Lueck and Severson, 2006; Tan, 2009), but

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[27] We obtained Big Mac prices for three NYS counties (Bronx, Queens, and New York) as well as three other cities (Atlanta, Chicago, and San Francisco) from Landry (2013) for the 2001-2011 period. In an unreported analysis, we used synthetic control methods to examine whether Big Mac prices changed after trans fat bans were implemented in NYC, relative to a control group of cities that did not implement similar regulations. Our unreported results reveal that Big Mac prices in NYC fell slightly between 2007 and 2011, relative to the price of the weighted average of the three non-NYC cities.

[28] See the NRA's 2013-2014 Restaurant Operations Report at http://www.restaurant.org/News-Research/Research/Operations-Report, accessed October 15, 2014.

we conservatively assume that these costs amount to 2%. Suppose that, on average, restaurants need 24 hours to modify recipes, and that one hour of time is valued at $31.[29] There are roughly 45,000 restaurants in NYS.[30] Thus, in sum, annual costs to restaurants would amount to $176 million (⅓*$21.4 billion*0.02 + 24*$31*45,000).

Second, there are administrative costs of implementation and enforcement of regulations such as trans fat bans. For example, NYC spent $75,000 communicating the new regulations to food service establishments, and the NYC Health Department reported that they do not face any additional or ongoing costs to implement the regulation because food safety inspectors have incorporated trans fat inspections into their regular annual inspections.[31] If we assume that the administrative cost is the same for the other 57 NYS counties, this cost is $4.4 million (58*75,000).

Third, there may be a loss in consumer surplus because individuals may enjoy the taste of foods containing artificial trans fats. This is hard to estimate. However, we can calculate the minimum size of the "taste costs" to break even with the benefits.[32] The benefits net of financial costs amount to $605 million ($785-$180 million). About 20 million people live in NYS and 1 out of 3 meals are eaten away from home per person and day, which amounts to about 7.3 billion meals per year. If we divide $605 million by 7.3 billion

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[29] See the Bureau of Labor Statistics News Release on Employer Costs for Employee Compensation at http://www.bls.gov/news.release/pdf/ecec.pdf, accessed on October 15, 2014.

[30] See the NRA's 2014 Restaurant at a Glance at http://www.restaurant.org/Downloads/PDFs/State-Statistics/2014/new-york, accessed October 15, 2014.

[31] See NYC's report entitled "Best Practice: Restriction of Trans Faat in Restaurant Food" at http://www.nyc.gov/html/ia/gprb/downloads/pdf/NYC_Health_TransFat.pdf, accessed October 15, 2014.

[32] For a similar calculation and logic see the discussion of trans fat bans on a blog by Becker and Posner (2006) at http://www.becker-posner-blog.com/2006/12/the-new-york-city-ban-on-trans-fats--posner.html, accessed October 18, 2014.

meals, then the consumer "taste costs" should not be larger than $0.08 per meal.

The maximum cost to consumers to break even seems small, however, existing evidence underlines that consumers do not place a very high value on consuming artificial trans fat. For example, Doell *et al.* (2012) document that following trans fat labeling laws implemented nationwide in 2006, trans fat consumption decreased by 72%. This can be taken as an indication that consumers value the health benefits of lower artificial trans fat consumption higher than any associated taste costs. There is also reason to believe that consumers are not likely to notice the difference in the taste of food that has been purged of artificial trans fat. For example, Dunkin Donuts started testing alternatives to trans fat-containing oils in 2003 and sold 50 million donuts without receiving any negative feedback from consumers.[33] It has also been found in sensory evaluations that individuals prefer doughnuts fried in trans fat free oil (Bordi *et al.* 2007b).

In sum, the potential benefits are quite large relative to the financial costs of implementing bans on artificial trans fat. The loss in consumer surplus would have to be much larger than the financial costs to outweigh the benefits in terms of monetized mortality reductions. The food service industry has an incentive to improve any loss in flavor associated with substituting PHOs with healthier oils, so taste costs, even if they are large at the outset, are likely to diminish over time.

VI. Conclusion

We have exploited plausibly exogenous variation in artificial trans fat content in restaurants due to the implementation of trans fat bans in some counties in New York State to examine whether it affects mortality due to cardiovascular diseases (CVD) in a "difference-in-difference" empirical

[33] See the article entitled "Can You Taste the Difference of No Trans Fat? Probably Not" at http://www.huffingtonpost.com/2013/11/07/trans-fat-ban_n_4234831.html, accessed on October 15, 2014.

framework. The results indicate that harmful macronutrients with no established health benefits such as artificial trans fats can have significant repercussions on population health and longevity. In particular, we have shown that artificial trans fat consumption has a strong impact on mortality caused by heart disease and stroke. The estimated mortality impacts of banning trans fat in restaurant food are economically important, and the range of effect sizes overlaps with predictions by the public health and medical communities. We find that CVD mortality rates responded within a year after the implementation of trans fat bans, and patterns in the data indicate that the number of prevented CVD-related deaths may increase in the years to come.

There are several avenues for further research. First, we cannot separately identify the effect of eliminating artificial trans fats from substituting for healthier fats. The health benefits of reducing the amount of artificial trans fat in food away from home is likely to highly depend on the type of substitution behavior followed by restaurants. Analysis of detailed restaurant-level data sets would be useful to shed light on these issues. Second, the analysis could be enriched by using survey data on CVD-related health conditions, cholesterol levels, and dietary habits and patterns of eating away from home. These data would allow a detailed investigation of some of the channels and heterogeneities that might underlie the mortality impacts we have estimated in this study.

Reducing the amount of artificial trans fat in restaurant food appears to be cost-effective way of improving diets on a large scale. However, bans on trans fat should be considered a complement to rather than a substitute for other ways of promoting healthier behaviors. Trans fat consumption is only one of the many risk factors associated with CVD, many of which are behavioral. That said, our evidence does indicate that even small changes in the quality of macronutrients can lead to significant improvements in population health.

Many local and state jurisdictions outside of New York State have also passed laws restricting the amount of trans fat in restaurants. In 2013, the FDA made a preliminary determination to remove artificial trans fat from the FDA’s Generally Regarded as Safe database, which is likely to eliminate it from the U.S. food supply in the coming years. The WHO recently made a call to Europe to become free of artificial trans fats in the near future. The findings in this study suggest that CVD-related mortality may fall as a result of reductions in the amount of artificial trans fats in the food supply throughout the globe.

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Table 1: Sample Summary Statistics

	(1) All NYS Counties (No. Counties = 62)		(2) Trans Fat Ban Implemented Over Sample Period (No. Counties = 11)		(3) Trans Fat Ban Not Implemented Over Sample Period (No. Counties = 51)	
2002-2012 NYS Vital Statistics	*Mean*	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*
Cardiovascular Disease (CVD)[a]	288.204	55.925	282.674	48.187	298.851	67.365
Diseases of the Heart (HD)[a]	255.041	51.404	256.989	45.960	251.289	60.583
Cerebrovascular Disease (Stroke)[a]	33.163	14.328	25.684	8.483	47.562	12.146
Net Deaths[a,b]	483.389	114.342	419.146	64.893	607.085	83.157
2002-2012 county level Information						
County Unemployment Rate	6.631	2.061	6.819	2.201	6.270	1.722
Log(County Per Capita Inc in $2012)	10.756	0.360	10.855	0.399	10.565	0.139
Log(County Population)	11.732	1.263	13.664	0.844	11.315	0.899
Sample Size	682		121		561	

Note: All variables except for county population are weighted by county population. County level unemployment rates and personal per capita income were drawn from the 2002-2012 Local Area Unemployment Statistics series of the Bureau of Labor Statistics and Bureau of Economic Analysis Regional Economic Accounts, respectively.

[a] These are mortality rates per 100,000 persons in the county.

[b] Net deaths equal total deaths minus deaths attributed to CVD.

Table 2: The Effect of a Ban on Trans Fat on Cardiovascular Disease Mortality

	(1)	(2)	(3)	(4)	(5)
Dep Var	Ln(CVD Deaths Per 100K)				
1 if County Implemented Trans Fat Ban	-0.092***	-0.101***	-0.071***	-0.060**	-0.043***
	(0.021)	(0.025)	(0.024)	(0.023)	(0.016)
County Unemployment Rate		-0.022*	-0.02	-0.02	0.008
		(0.012)	(0.013)	(0.013)	(0.015)
Ln(County Personal Income Per Capita)		0.359	0.382	0.37	0.306*
		(0.235)	(0.230)	(0.233)	(0.182)
1 if NYC × 1 if Year 2010-2012			-0.114***	-0.107***	-0.122***
			(0.030)	(0.033)	(0.040)
Adjusted R-squared	0.867	0.870	0.874	0.873	0.896
Estimated Reduction per 100,000 Persons	-25.818	-28.219	-20.133	-17.106	-12.363
County and Year FE	x	x	x	x	x
Treatment Dummy × Year				x	x
County Dummies × Year					x

Note: Standard errors are clustered at the county level, and are in parentheses below OLS coefficients. *,**, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively. Sample size is 682.

Table 3: The Effect of a Ban on Trans Fat on Cardiovascular Disease Mortality, by Type of Disease

	(1)	(2)	(3)
Dep Var	Ln(CVD Deaths Per 100K)	Ln(HD Deaths Per 100K)	Ln(Stroke Deaths Per 100K)
1 if County Implemented Trans Fat Ban	-0.043***	-0.038**	-0.082**
	(0.016)	(0.016)	(0.035)
Adjusted R-squared	0.896	0.887	0.719
Estimated Reduction per 100,000 Persons	-12.363	-9.726	-2.590
All Covariates Included	x	x	x
County and Year FE	x	x	x
County Dummies × Year	x	x	x

Note: Covariates include the county level unemployment rate and log personal income per capita, and a dummy for NYC interacted with a dummy for years 2010-2012. Sample size is 682. Standard errors are clustered at the county level, and are in parentheses below OLS coefficients. *,**, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Table 4: Robustness Checks

(1) Dropping Neighbor Counties from Control Group[a]	Ln (CVD Deaths Per 100K)
1 if County Implemented Trans Fat Ban	-0.048***
	(0.017)
(2) Allowing for County-Specific Impacts of County Unemployment Rates and Per Capita Income	Ln (CVD Deaths Per 100K)
1 if County Implemented Trans Fat Ban	-0.048*
	(0.025)
(3) County Population Weighted Regression	Ln (CVD Deaths Per 100K)
1 if County Implemented Trans Fat Ban	-0.033**
	(0.015)
(4) Using Age-Sex Adj CVD Deaths as Dep Var	Ln (CVD Deaths Per 100K)
1 if County Implemented Trans Fat Ban	-0.040**
	(0.015)
(5) Using CVD Deaths Per 100K as Dep Var	CVD Deaths Per 100K
1 if County Implemented Trans Fat Ban	-11.686**
	(4.782)
(6) Poisson Regression[b]	CVD Deaths
1 if County Implemented Trans Fat Ban	-0.023*
	(0.012)
(7) Negative Binomial Regression[b]	CVD Deaths
1 if County Implemented Trans Fat Ban	-0.028**
	(0.013)
(8) Using Log CVD Hosp Adm Per 100K as Dep Var[c]	Ln (CVD Hosp Adm Per 100K)
1 if County Implemented Trans Fat Ban	-0.027*
	(0.015)
All Covariates Included	x
County and Year FE	x
County Dummies × Year	x

Note: Covariates include the county level unemployment rate and log personal income per capita. Standard errors are clustered at the county level, and are in parentheses below OLS coefficients. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively. Sample size is 682 unless otherwise indicated.

[a] Sample size is 550.

[b] This regression also controls for county population.

[c] Sample size is 620.

Table 5: Estimating the Impact of Trans Fat Bans on CVD Mortality using Various Treatment and Control Groups

	(1)	(2)	(3)	(4)	(5)	(6)
Dep Var	Ln (CVD Deaths Per 100K)					
Panel A: Main Analysis Sample						
1 if County Implemented Trans Fat Ban	-0.043***	-0.041**	-0.042**	-0.040	-0.052*	-0.033
	(0.016)	(0.017)	(0.017)	(0.026)	(0.027)	(0.030)
Adjusted R-squared	0.896	0.925	0.870	0.891	0.919	0.851
Treatment Group	All	All	All	Non-NYC	Non-NYC	Non-NYC
Control Group	All	Metro	Non-Metro	All	Metro	Non-Metro
Sample Size	682	379	429	627	319	374
Panel B: NYS Metropolitan Area Sample						
1 if County Implemented Trans Fat Ban		-0.035*			-0.056*	
		(0.019)			(0.032)	
Adjusted R-squared		0.936			0.929	
Treatment Group		All			Non-NYC	
Control Group		All			All	
Sample Size		300			260	

Note: The specification is the same as in column 5 of Table 2. Standard errors are clustered at the county level, and are in parentheses below OLS coefficients.

*,**, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Table 6: The Effect of Trans Fat Bans on Major Causes of Death (Seemingly Unrelated Regressions)

	(1)	(2)	(3)	(4)	(5)
Panel A	*Unlikely to be Related to Trans Fat Consumption*				
Dep Var [Ln(X Deaths per 100,000 Persons)]	CLRD	Cirrhosis	AIDS	Accidents	Homicides
1 if County Implemented Trans Fat Ban	0.016	0.002	0.089	0.127***	0.017
	(0.034)	(0.076)	(0.065)	(0.049)	(0.111)
Estimated Effect per 100,000 Persons	0.527	0.015	0.704	3.127	0.084
P-Value of Joint Test of Significance			**0.124**		
Panel B	*Plausibly Related to Trans Fat Consumption*				
Dep Var [Ln(X Deaths per 100,000 Persons)]	CVD	Diabetes	Cancer	Pneumonia	
1 if County Implemented Trans Fat Ban	-0.043***	-0.080**	-0.022	-0.122**	
	(0.014)	(0.037)	(0.016)	(0.059)	
Estimated Effect per 100,000 Persons	-12.363	-1.534	-3.968	-2.919	
P-Value of Joint Test of Significance			**0.000**		
All Covariates Included	x	x	x	x	x
County and Year FE	x	x	x	x	x
County Dummies × Year	x	x	x	x	x

Note: Estimates from seemingly unrelated regressions model. Covariates include the county level unemployment rate and log personal income per capita, and a dummy for NYC interacted with a dummy for years 2010-2012. Sample size is 682. Standard errors are clustered at the county level, and are in parentheses below coefficients. *,**, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Table 7: Estimating the Impact of Trans Fat Bans on Health-Related Behaviors

	(1)	(2)	(3)	(4)
Sample Mean	0.266	0.746	0.203	0.577
Dep Var	1 if Obese	1 if Exercise in Past Mo	1 if Current Smoker	1 if Drank in Past Mo
1 if County Implemented Trans Fat Ban	-0.019	0.015	-0.017	-0.013
	(0.013)	(0.016)	(0.019)	(0.036)
Adjusted R-squared	0.308	0.291	0.334	0.255
Percentage Reduction from Sample Mean	-0.071	0.020	-0.084	-0.023
All Covariates Included	x	x	x	x
County and Year FE	x	x	x	x
County Dummies × Year	x	x	x	x

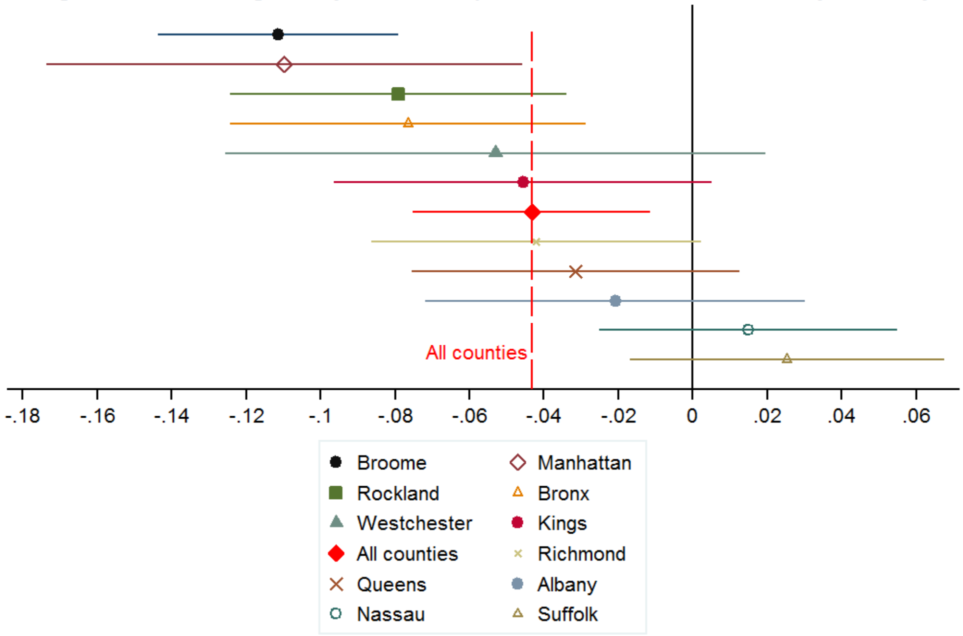
Note: Covariates include the county level unemployment rate and log personal income per capita. Sample size is 469. Standard errors are clustered at the county level, and are in parentheses below OLS coefficients. *,**, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Table 8: The Dynamics of the Effect of Trans Fat Bans on Cardiovascular Disease Mortality

	(1)	(2)
Dep Var	Ln(CVD Deaths Per 100K)	
1 if County Has Implemented Trans Fat Ban (t+2)		-0.025
		(0.028)
1 if County Has Implemented Trans Fat Ban (t+1)		0.004
		(0.022)
1 if County Has Implemented Phase I Trans Fat Ban (t)	-0.046***	-0.051**
	(0.017)	(0.019)
1 if County Has Implemented Phase II Trans Fat Ban (t)	-0.063***	-0.065***
	(0.021)	(0.023)
1 if County Has Implemented Trans Fat Ban (t-1)		-0.039*
		(0.020)
Adjusted R-squared	0.893	0.892
P-Value of Test that Leads are Jointly Equal to Zero		0.339
P-Value of Test that Contemporaneous and Lagged Estimated Effects are Jointly Equal to Zero		0.002
County and Year FE	x	x
County Dummies × Year	x	x

Note: Covariates include the county level unemployment rate and log personal income per capita. Sample size is 667. Note that the sample size is lower because we drop 2010 observations from 4/5 NYC counties and all NYC observations from 2011-2012. Standard errors are clustered at the county level, and are in parentheses below OLS coefficients. *,**, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Figure 2: Heterogeneity in the Impact of Trans Fat Bans, by County



Appendix Table 1: The Timing of Bans on the Use of Artificial Trans Fat in Restaurants

NYS County	Effective Dates of Trans Fat Bans	Notes
Albany	Phase I 1/1/2009; Phase II 7/1/2009	
Bronx	Phase I 7/1/2007; Phase II 7/1/2008	
Broome	12/2011	No cooking oils, shortenings or margarines can be used for frying that contain ≥ 0.5g of artificial trans fat
Kings	Phase I 7/1/2007; Phase II 7/1/2008	
Nassau	Phase I 4/1/2008; Phase II 4/1/2011	Original Phase II date was 4/1/2009
New York	Phase I 7/1/2007; Phase II 7/1/2008	
Queens	Phase I 7/1/2007; Phase II 7/1/2008	
Richmond	Phase I 7/1/2007; Phase II 7/1/2008	
Rockland	1/1/2011	No food item with ≥ 0.5g of artificial trans fat can be stored, used, or served
Suffolk	Phase I 10/28/2010; Phase II 10/28/2011	
Westchester	4/9/2008	No cooking oils, shortenings or margarines can be used for frying that contain ≥ 0.5g of artificial trans fat

Note: Phase I bans the use of partially hydrogenated vegetable oils (PHVO), shortenings, and margarines for frying, grilling or as spread unless the manufacturer's label shows that it contains < 0.5g of artificial trans fat per serving. The use of trans fat-containing oils and shortenings for deep frying cake batter and yeast dough was allowed until Phase II. Phase II prohibits storing, using, or serving any food item containing PHVO oils, shortenings, or margarines if it contains more than or equal to 0.5g of artifical trans fat per serving.

Appendix Table 2: Summary Statistics Before Trans Fat Bans (2006)

	(1) All NYS Counties (No. Counties = 62)		(2) Trans Fat Ban Implemented Over Sample Period (No. Counties = 11)		(3) Trans Fat Ban Not Implemented Over Sample Period (No. Counties = 51)	
2006 NYS Vital Statistics	*Mean*	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*
Cardiovascular Disease (CVD)[a]	293.742	46.754	294.882	37.405	291.570	62.407
Diseases of the Heart (HD)[a]	260.843	45.928	268.560	37.428	246.135	57.786
Cerebrovascular Disease (Stroke)[a]	32.899	12.633	26.322	8.709	45.435	9.328
Net Deaths[a,b]	474.579	111.463	412.811	67.097	592.303	81.984
2006 County Information						
County Unemployment Rate	4.681	0.798	4.681	0.926	4.681	0.584
Log(County Per Capita Inc in $2012)	10.758	0.382	10.867	0.438	10.550	0.140
Log(County Population)	11.730	1.269	13.655	0.878	11.315	0.905
Obesity Rates[c]	0.219		0.208		0.248	
Exercise Rates[c]	0.725		0.711		0.764	
Smoking Rates[c]	0.165		0.153		0.200	
Drinking Rates[c]	0.568		0.554		0.606	

Note: All variables except for county population are weighted by county population. County level unemployment rates and personal per capita income were drawn from the 2006 Local Area Unemployment Statistics series of the Bureau of Labor Statistics and Bureau of Economic Analysis Regional Economic Accounts, respectively.

[a] These are mortality rates per 100,000 persons in the county.

[b] Net deaths equal total deaths minus deaths attributed to CVD.

[c] These are percentages of the county's (age 18+) population, which were drawn from the 2006 Behavioral Risk Factor Surveillance System. The sample size in column 2 is 11. Due to missing information, the percentages in column 3 are for only 17 of the 51 counties that did not implement a trans fat ban over the sample period.

Appendix Table 3: Alternative Way of Addressing the Hospital-Level Interventions in NYC

	(1)	(2)	(3)	(4)
Dep Var	Ln(CVD Deaths Per 100K)			
1 if County Implemented Trans Fat Ban	-0.043***	-0.044**	-0.049***	-0.052***
	(0.016)	(0.019)	(0.016)	(0.017)
1 if NYC × Year 2010-2012	-0.122***			
	(0.040)			
Time Period	2002-12	2002-09	2002-10	2002-12
Sample of Counties	All	All	Excluding NYC Observations	
			All Except Manhattan in 2010	Same as in Column (3) + All in 2011-12
Adjusted R-squared	0.896	0.894	0.898	0.893
Sample Size	682	496	554	667
All Covariates Included	x	x	x	x
County and Year FE	x	x	x	x
County Dummies × Year	x	x	x	x

Note: Covariates include the county level unemployment rate and log personal income per capita. Standard errors are clustered at the county level, and are in parentheses below OLS coefficients. *,**, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Appendix Table 4: Heterogeneity in the Impact of a Ban on Trans Fat on All-Cause Mortality Per 100K, by Age Group

	(1)	(2)	(3)	(4)
Sample Mean	17.659	31.121	152.365	675.999
Dep Var	Ln(Deaths per 100K)			
	Aged 0-24	Aged 25-44	Aged 45-64	Aged 65 and Over
1 if County Implemented Trans Fat Ban	-0.037	0.044	0.007	-0.022**
	(0.046)	(0.048)	(0.011)	(0.010)
Adjusted R-squared	0.250	0.361	0.742	0.939
Estimated Reduction per 100,000 Persons	-0.641	1.400	1.070	-14.710
All Covariates Included	x	x	x	x
County and Year FE	x	x	x	x
County Dummies × Year	x	x	x	x

Note: Covariates include the county level unemployment rate and log personal income per capita, and a dummy for NYC interacted with a dummy for years 2010-2012. Sample size is 682. Standard errors are clustered at the county level, and are in parentheses below OLS coefficients. *,**, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.