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Evidence from Bans in Restaurants in New York

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Abstract

This paper analyzes the impact of trans fat bans in restaurants on cardiovascular disease (CVD) mortality rates. Evidence from the medical community indicates that even low levels of artificial trans fat consumption increases the incidence of CVD such as heart disease. New York City and six New York State county health departments have responded to this public health concern by mandating that all food service establishments limit the amount of trans fat contained in their food products. Our analysis exploits the within-county variation over time in the trans fat content in the local food supply resulting from the policy mandate and the differential timing of its rollout across counties to estimate the mortality effects of reducing the amount of artificial trans fat in food away from home. The results indicate that trans fat bans cause a 4% reduction in CVD mortality rates, which translates into a reduction of about 12 CVD deaths per 100,000 persons per year. Using recent estimates of the Value of a Statistical Life-Year, we estimate that the fatal heart attacks prevented by trans fat bans, even if they extend life by only one year, can be valued at about \$3 million per 100,000 persons annually.

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 trans fat 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.

In this paper, we contribute to the literature by analyzing whether there is a causal effect of 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

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.

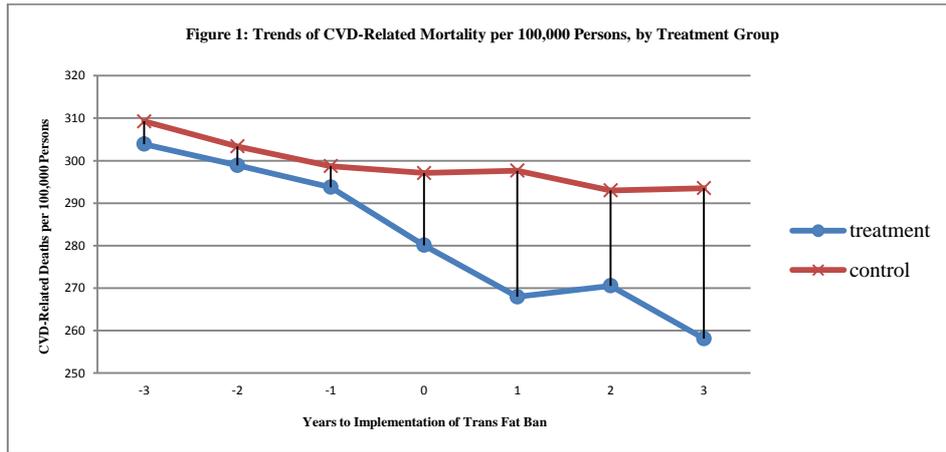
² Visit the following link for the statement by Patrice A. Harris, MD, an AMA Board Member, “AMA: Trans Fat Ban Would Save Lives”: <http://www.ama-assn.org/ama/pub/news/news/2013/2013-11-07-trans-fat-ban-would-save-lives.page>. Accessed online May 30, 2014.

reduction in the amount of trans fat in the local food supply. The policy, which is commonly referred to as a “trans fat ban”, imposes an upper limit to the amount of industrially produced or artificial trans fat that is allowed in food on all food service establishments that require a permit to prepare and serve food. 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 New York City (NYC) and six other counties in the same state.

We use panel data on NYS county mortality rates for the period 2002 to 2012 for our analysis. 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 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 between the treated and control counties, these differences are stable and the trends were very similar 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.

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.



Note: Each county's trans fat ban implementation year is normalized to zero.

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-related 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 a battery of robustness checks, including changes in the control group to address the potential for treatment spillovers, a variety of changes in model specification, and addressing several 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.

Our analysis reveals that mortality caused by heart disease and stroke responds quickly after the implementation of a ban on trans fat. These results suggest that cardiovascular health and mortality respond quickly to reductions in the consumption of trans fat. This is consistent with evidence in the medical literature that 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 the CVD-related mortality risk (Law *et al.*, 2003).⁴ It is also consistent with evidence in the economics literature that CVD-related mortality rates fall 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 find evidence indicating that, in addition to the contemporaneous effect on CVD-mortality, trans fat bans also have a lagged effect. This result suggests 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 our estimates indicate that trans fat bans have the potential to lead to substantial reductions in the loss of life as a result of the consumption of 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.

⁴ 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.

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 dynamics of the treatment effects. Fifth, we explore a variety of mechanisms that could underlie our results. Sixth, we discuss the magnitude and plausibility of our estimates. 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) indicated 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. 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 inexpensive, and it increases the shelf life, flavor stability, 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 all fats—there is no known health benefit of consuming artificial trans fat. 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).⁵ Trans fat is generally considered

⁵ 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.

worse than other fats (*e.g.* saturated fat) because, unlike other fats, it does not raise HDL cholesterol (Eckel *et al.*, 2007). 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 very little evidence to support a link between natural trans fat and the risk of developing CVD (Mozaffarian *et al.* 2006).⁶

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.^{7,8} 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. For example, between 2007 and 2011 the health departments of NYC and six counties implemented laws that place upper limits on the amount of trans fat that is allowed in a serving of food from

⁶ 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.”

⁷ 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.

⁸ 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.

food service establishments.⁹ 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 most 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 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 find that the amount of saturated fat in French fries decreased by about 10.5%. A more recent study analyzing transaction data

⁹ New York City initially launched an education campaign to encourage restaurant owners to use oils free of trans fat on a voluntary basis. However, the campaign was found to be ineffective (Tan, 2009).

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 partially hydrogenated vegetable oils (PHVO), 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.

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.

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 representative of other food service establishments, so it is difficult to know the true size of the reduction in trans fat in the local food supply of the counties that implemented the ban.

Nonetheless, the results in Agnell *et al.* (2009, 2012) indicate that trans fat bans have led to substantial reductions in the amount of trans fat contained in restaurant food 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 substituting with other oils, is very costly for firms. For example, in 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 their stores nationwide and report 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-related 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

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 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

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.

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 implemented a ban on trans fat in restaurants. Interestingly, 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 not ban trans fat over the study period, we also 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 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

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.

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.

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-related 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 affect CVD-related mortality rates in all NYS counties equally over time, such as mandatory trans fat labeling being 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.

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 factors 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 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-related 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. An alternative strategy, which we also describe in greater detail below, is to drop counties in years that coincide with the hospital intervention. We find that it produces very similar results.

b. Main Results

In Table 2, we present our main estimates, which reveal strong evidence that bans on artificial trans fat have 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

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).

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 time trends 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 county-specific linear time trends instead of treatment-group-specific ones. 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

¹⁷ This calculation uses the average CVD mortality rate in our sample period $((e^{-0.043}-1)*288.204= 12.130)$.

to the period over which CVD-related 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 shown 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-related mortality rates caused by the hospital interventions affecting these rates in 2010-2012. Thus, we proceed with using our preferred specification (column 5 in Table 2) throughout the remainder of the analysis.

In Table 3, we investigate 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 causes a decrease in 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.

A natural question to ask 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-related 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, and model specification. We also examine whether trans fat bans reduced CVD-related morbidity and whether trans fat bans affected non-CVD-related 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-related mortality rates may have been differentially affected by economic conditions in the treatment counties. We examine this possibility by allowing county unemployment rates and personal per capita income 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 the timing of the policies across counties 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 to 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-related 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-related 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 that 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-related mortality rates by about 3%.

Fourth, not all CVD-related events are fatal. We analyze the impact of trans fat bans on hospitalizations, which also include non-fatal events. We obtained data on CVD-related hospitalizations from the NYS Department of Health but, an important caveat with this part of the analysis, is that 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 greatest in an individual's county of residence and we cannot observe potentially important commuting patterns between treatment and control counties. 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

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

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.

Lastly, we analyze the impact of trans fat bans in restaurants on causes of death that are less likely to be affected by changes in trans fat content in restaurant food. The results are grouped according to the likelihood that the mortality outcome is linked to the consumption of trans fat. As we describe in greater detail below, because we examine the impact of the trans fat bans on many mortality outcomes individually, we address potential concerns with multiple hypothesis testing.

In Table 5, there is no systematic pattern of impacts on a wide variety of causes of death other than CVD. The estimates associated with the trans fat ban dummy are, in many cases, statistically insignificant, and are often small in magnitude. Two of the specifications produce marginally statistically significant reductions in mortality (those in which diabetes and pneumonia mortality rates are dependent variables). The specification involving diabetes is interesting because the medical community has found weak but inconclusive evidence that trans fat consumption increases the risk of diabetes (Mozaffarian *et al.*, 2006). It has also found similarly weak but inconclusive evidence that the consumption of trans fat raises the risk of developing some cancers and, while we find a negative impact of trans fat bans on cancer mortality rates, the estimate is not statistically significant at conventional levels. There is some evidence in the literature indicating that pneumonia triggers acute cardiac events (Corrales-Medina *et al.*, 2011). The estimated impact on pneumonia mortality rates of trans fat bans may stem from the association between pneumonia and heart health.

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 the 5% level. However, the estimate is “wrong signed” and seems implausibly large in magnitude. While the mortality reductions attributable to diabetes, pneumonia, and cancer might be linked to reductions in cardiovascular health, the mortality increase attributable to accidents

raises the concern that multiple hypothesis testing may be causing us to over-reject some hypotheses.

We attempt to control for multiple hypothesis testing by grouping all non-CVD-related mortality outcomes, and examining whether the overall impact of trans fat bans on this family is statistically different from zero (Gibson *et al.*, 2011). In particular, we apply Hochberg's (1988) modification of the Bonferroni method, which ranks n outcomes in increasing order of their p-values and rejects null effects for all outcomes $i \leq j$ if $p_j \leq \alpha/(n - j + 1)$ for any $j = 1, 2, \dots, n$, where α is the family-wise error rate. Among the non-CVD-related mortality outcome regressions, the smallest p-value we obtain is the one in which accident mortality is the dependent variable (p-value 0.025). If $\alpha = 0.10$, the adjusted p-value associated with the impact on fatal accidents is 0.011. Thus, we can neither reject null effects of trans fat bans on accident-related mortality nor reject null effects of trans fat bans on any of the other non-CVD-related mortality outcomes. When we include CVD mortality rates in the family with all the other non-CVD-related mortality outcomes, we can reject a null effect of trans fat bans only for CVD mortality. Thus, after adjusting for multiple hypothesis testing, the results suggest that trans fat bans affect CVD-related mortality outcomes, and not other mortality outcomes.

d. The Importance of 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 countywide 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. We examine whether changes in health-related behaviors explain the mortality reductions caused by trans fat bans by controlling for county-level rates of obesity (a proxy for diet-related behavioral change), physical activity, smoking, and drinking. 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.

These results also address other concerns regarding potential policy endogeneity. Previous studies have analyzed morbidity and mortality effects of anti-smoking regulations, and have found that tobacco taxes and smoking bans in public places affect heart disease mortality (Moore, 1996; Shetty et al., 2011; Adams et al., 2013). NYC has a different cigarette excise tax rate to other NYS counties, and NYC increased its tax rate by \$1.50 in 2002. The timing of this tax change affects only one year of the study period and does not coincide with the timing of trans fat bans. A comparison between the estimate in column 4 and that in column 1 of Table 6 confirms that policy endogeneity due to anti-smoking regulations is not likely to account for our results.

Another important 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. However, while trans fat bans affected 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 and menu labeling laws could have independent effects on mortality. A comparison of the estimates in columns 1 and 2 of Table 6 suggest that policy endogeneity due to menu labeling laws is not likely to account for our results, and that mechanisms other than changes in obesity are likely to be important for explaining the CVD-related mortality impacts of trans fat bans found here.

e. 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 7, 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.

f. Discussion

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 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 fast food chains in all NYS counties that implemented trans fat bans. In the U.S., about one-third of daily calories come from food consumed away from home (Lin and Guthrie, 2012). Second, assume that New Yorkers eat 1 out of 3 meals per day at fast food restaurants. Thus, trans fat bans would reduce the consumption of trans fat from fast food restaurants by 2.4g, which is a reduction of about 1.08% of energy intake for individuals on a 2000-calorie daily diet ($2.4\text{g} \times 9 \text{ calories} \div 2000$).²⁰ 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.²¹ Thus, our rough calculation implies that we might expect the reduction in trans fat intake from fast food restaurants to prevent between 518 to 1,037 deaths due to heart disease in NYS.²²

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

²⁰ 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.

²¹ 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.

²² 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.

county-level trans fat ban reduces mortality by between 2 and 17 per 100,000 persons.²³ Given that NYS had 50,470 heart-disease-related deaths in 2006, we estimate that, on average, implementation of trans fat bans saved between 353 and 3,482 lives per year. Note that this 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 fast food restaurant meals. For example, it may capture the mortality impact operating through dietary changes or the consumption of food at other restaurants, which may have had even higher levels of trans fat in their foods. In any case, the mortality impacts in NYS that we obtained from the rough calculation above are within our range of estimated mortality impacts.

Of course, this back-of-the-envelope calculation may overestimate the mortality reductions because changes in trans fat content 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 restaurants. That said, 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 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.

Another way to assess the plausibility of our estimated mortality reductions is to compare them to the mortality reductions caused by statin therapy. In a meta-analysis of 164 randomized placebo-controlled trials, Law *et al.* (2003) find that a daily intake of statins

²³ These calculations use the average heart disease mortality rate in our sample (*e.g.* $(e^{-0.007}-1)*255.041= 1.78$).

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.

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

There are several avenues for further research. First, we cannot separately identify the effect of eliminating trans fat from substituting for healthier fats. The health benefits of reducing trans fat content is likely to highly depend on the type of substitution behavior followed by restaurants in the counties studied. 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 trans fat in restaurant food seems to be a relatively easy and cost-neutral 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 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 (GRAS) database, which is likely to eliminate it from the U.S. food supply in the coming years. The findings in this study suggest that CVD-related mortality may fall as a result of reductions in trans fat in the food supply throughout the nation in the years to come.

VI. References

- Adams S, Cotti C, and Fuhrmann D. (2013). "The Short-Term Impact of Smoke-Free Workplace Laws on Fatal Heart Attacks." *Applied Economics*, 46(11): 1381-1393.
- Aldy, JE and Viscus WK. (2008). "Adjusting the Value of a Statistical Life for Age and Cohort Effects." *The Review of Economics and Statistics*, 90(3): 573-581
- Al-Samarrai T, Madsen A, Zimmerman R, Maduro G, Li W, Greene C, and Begier E. (2013). "Impact of a Hospital-Level Intervention to Reduce Heart Disease Overreporting on Leading Causes of Death." *Preventing Chronic Disease*, 10:120210.
- Angell S, Silver LD, Goldstein GP, Johnson CM, Deitcher DR, Frieden TR, and Basset MT. (2009). "Cholesterol Control Beyond the Clinic: New York City's Trans Fat Restriction." *Annals of Internal Medicine*, 151(2): 129-134.
- Angell S, Cobb L, Curtis C, Konty K, and Silver L. (2012). "Change in Trans Fatty Acid Content of Fast-Food Purchases Associated With New York City's Restaurant Regulation: A Pre-Post Study." *Annals of Internal Medicine*, 157(2): 81-86.
- Ascherio A, Katan MB, Stampfer MJ, and Willett WC. (1999). "Trans Fatty Acids and Coronary Heart Disease." *The New England Journal of Medicine*, 340(25):1994-8.
- Bordi P, Stokols J, Hack D, Rager M, and Hessert SM. (2007a). "Sensory Evaluation of Salted Trans Fat-Free French Fries vs. Salted Trans Fat French Fries." *Journal of Foodservice*, 18(5): 198-205.
- Bordi P, Hack D, Rager M, and Hessert SM. (2007b). "Sensory Comparison of Doughnuts Fried in Trans Fat-Free Oil to those Fried in Oil Containing Trans Fats." *Journal of Foodservice*, 18(6): 227-237.
- Brouwer IA, Wanders AJ, and Katan MB. (2010). "Effect of Animal and Industrial Trans Fatty Acids on HDL and LDL Cholesterol Levels in Humans – A Quantitative Review." *PLoS ONE*, 5(3): e9434.
- Corrales-Medina, VF, Suh, KN, Rose, G, Chirinos, JA, Doucette, S, Cameron, DW, and Fergusson, DA. (2011). "Cardiac Complications in Patients with Community-Acquired Pneumonia: A Systematic Review and Meta-Analysis of Observational Studies." *PLoS Medicine*, 8(6): e1001048.
- Danaei G, Ding E, Mozaffarian D, Taylor B, Rehm J, Murray C, and Ezzati M. (2009). "The Preventable Causes of Death in the United States: Comparative Risk Assessment of Dietary, Lifestyle, and Metabolic Risk Factors." *PLoS ONE*, 6(4): e1000058.
- Doell D, Folmer D, Lee H, Honigfort M, and Carberry S. (2012). "Updated Estimate of Trans Fat Intake by the U.S. Population." *Food Additives & Contaminants: Part A*, 29(6): 861-874.
- Eckel R, Borra S, Lichtenstein A, and Yin-Piazza S. (2007). "Understanding the Complexity of Trans Fatty Acid Reduction in the American Diet." *Circulation*, 115: 2231-2246.

Evans, WN and Moore TJ. (2011). "The Short-term Mortality Consequences of Income Receipt." *Journal of Public Economics*, 95(11): 1410-1424.

———. (2012). "Liquidity, Economic Activity, and Mortality." *The Review of Economics and Statistics*, 94(2): 400-418.

Food and Drug Administration. (2003). "Trans Fatty Acids in Nutrition Labeling." *Federal Register*, 68(133): 41433-41506.

Fryar C and Ervin R. (2013). "Caloric Intake From Fast Food Among Adults: United States, 2007-2010." NCHS data brief, no 114. Hyattsville, MD: National Center for Health Statistics.

Gibson J, McKenzie, D, and Stillman, S. (2011). "The Impacts of International Migration on Remaining Household Members: Omnibus Results from a Migration Lottery Program." *The Review of Economics and Statistics*, 93(4): 1297-1318.

Hochberg Y. (1988). "A Sharper Bonferroni Procedure for Multiple Tests of Significance." *Biometrika*, (75): 800-803.

Law, MR, Wald, NJ, and Rudnicka AR. (2003). "Quantifying Effect of Statins on Low Density Lipoprotein Cholesterol, Ischaemic Heart Disease, and Stroke: Systematic Review and Meta-analysis." *British Medical Journal*, 326:1423.

Lin B, and Guthrie J. (2012). "Nutritional Quality of Food Prepared at Home and Away From Home, 1977-2008." EIB-105, U.S. Department of Agriculture, Economic Research Service.

Lueck TJ and Severson K. (2006). "Big Brother in the Kitchen? New Yorkers Balk." *New York Times*.

Madsen, A and Begier, E. (2013). "Improving Quality of Cause-of-Death Reporting in New York City." *Preventing Chronic Disease*, 10:130227.

Moore M. (1996). "Death and Tobacco Taxes." *The Rand Journal of Economics*, 27(2): 415-428.

Mozaffarian D, Katan MB, Ascherio A, Stampfer MJ, and Willett WC. (2006). "Trans Fatty Acids and Cardiovascular Disease." *The New England Journal of Medicine*, 354:1601-1613

Restrepo B. (2014). "The Effects of Calorie Labeling in Chain Restaurants on Body Mass Index and Obesity: Evidence from New York." Working paper, European University Institute.

Ruhm C. (2000). "Are Recessions Good for Your Health?" *The Quarterly Journal of Economics*, 115 (2): 617-650.

Ruhm C. (2003). "A Health Economy Can Break Your Heart." *Demography*, 44(4): 829-848.

Shetty K, DeLeire T, White C, and Bhattacharya J. (2011). "Changes in U.S. Hospitalization and Mortality Rates Following Smoking Bans." *Journal of Policy Analysis and Management*, 30(1): 6-28.

Stender S, Dyerberg, J, and Astrup A. (2006). "High Levels of Industrially Produced Trans Fat in Popular Fast Foods." *The New England Journal of Medicine*, 354:1650-1652.

Tan A. (2009). "A Case Study of the New York City Trans-Fat Story for International Application." *Journal of Public Health Policy*, 30(1): 3-16

Unnevehr L and Jagmanaitė E. (2008). "Getting Rid of Trans Fats in the US Diet: Policies, Incentives and Progress." *Food Policy*, 33(6): 497-503.

Table 1: Sample Summary Statistics

	(1) All NYS Counties (No. Counties = 62)		(2) Trans Fat Ban Implemented Over Sample Period (No. Counties = 10)		(3) Trans Fat Ban Not Implemented Over Sample Period (No. Counties = 52)	
	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
<i>2002-2012 NYS Vital Statistics</i>						
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
<i>2002-2012 county level Information</i>						
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.

^aThese are mortality rates per 100,000 persons in the county.

^bNet deaths equal total deaths minus deaths attributed to cardiovascular disease.

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*** (0.021)	-0.101*** (0.025)	-0.071*** (0.024)	-0.060** (0.023)	-0.043*** (0.016)
County Unemployment Rate		-0.022* (0.012)	-0.02 (0.013)	-0.02 (0.013)	0.008 (0.015)
Ln(County Personal Income Per Capita)		0.359 (0.235)	0.382 (0.230)	0.37 (0.233)	0.306* (0.182)
1 if NYC × 1 if Year 2010-2012			-0.114*** (0.030)	-0.107*** (0.033)	-0.122*** (0.040)
Adjusted R-squared	0.867	0.870	0.874	0.873	0.896
Estimated Reduction per 100,000 Persons	-25.332	-27.687	-19.753	-16.784	-12.130
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*** (0.016)	-0.038** (0.016)	-0.082** (0.035)
Adjusted R-squared	0.896	0.887	0.719
Estimated Reduction per 100,000 Persons	-12.130	-9.510	-2.611
All Covariates Included	x	x	x
County and Year FE	x	x	x
County Dummies \times 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	<u>Ln (CVD Deaths Per 100K)</u>
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	<u>Ln (CVD Deaths Per 100K)</u>
1 if County Implemented Trans Fat Ban	-0.048* (0.025)
(3) County Population Weighted Regression	<u>Ln (CVD Deaths Per 100K)</u>
1 if County Implemented Trans Fat Ban	-0.033** (0.015)
(4) Using Age-Sex Adj CVD Deaths as Dep Var	<u>Ln (CVD Deaths Per 100K)</u>
1 if County Implemented Trans Fat Ban	-0.040** (0.015)
(5) Using CVD Deaths Per 100K as Dep Var	<u>CVD Deaths Per 100K</u>
1 if County Implemented Trans Fat Ban	-11.686** (4.782)
(6) Poisson Regression^b	<u>CVD Deaths</u>
1 if County Implemented Trans Fat Ban	-0.023* (0.012)
(7) Negative Binomial Regression^b	<u>CVD Deaths</u>
1 if County Implemented Trans Fat Ban	-0.028** (0.013)
(8) Using Log CVD Hosp Adm Per 100K as Dep Var^c	<u>Ln (CVD Hosp Adm Per 100K)</u>
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: The Effect of Trans Fat Bans on Other Causes of Death

	(1)	(2)	(3)
<i>Plausibly Related to Trans Fat Consumption</i>			
Dep Var	Ln(Diabetes Deaths Per 100K)	Ln(Pneumonia Deaths Per 100K)	Ln(Cancer Deaths Per 100K)
1 if County Implemented Trans Fat Ban	-0.080* (0.041)	-0.122* (0.066)	-0.022 (0.017)
<i>Unlikely to be Related to Trans Fat Consumption</i>			
Dep Var	Ln(CLRD Deaths Per 100K)	Ln(AIDS Deaths Per 100K)	Ln(Cirrhosis Deaths Per 100K)
1 if County Implemented Trans Fat Ban	0.016 (0.038)	0.089 (0.073)	0.002 (0.085)
Dep Var	Ln(Accident Deaths Per 100K)	Ln(Homicides Deaths Per 100K)	Ln(Suicide Deaths Per 100K)
1 if County Implemented Trans Fat Ban	0.127** (0.055)	0.017 (0.124)	-0.165 (0.162)
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. Sample means, starting from the top left and proceeding rightward, then downward, then from the middle and proceeding rightward, and so on, are 22.951, 22.829, 213.740, 54.908, 2.493, 8.686, 31.779, 2.312, 10.615.

Table 6: Accounting for Changes in Health-Related Behaviors

	(1)	(2)	(3)	(4)	(5)	(6)
Dep Var	Ln (CVD Deaths Per 100K)					
1 if County Implemented Trans Fat Ban	-0.043** (0.019)	-0.042** (0.019)	-0.043** (0.019)	-0.046** (0.019)	-0.044** (0.018)	-0.045** (0.018)
Adjusted R-squared	0.920	0.920	0.920	0.922	0.920	0.921
Obesity Rates ^a		x				x
Exercise Rates ^a			x			x
Smoking Rates ^a				x		x
Drinking Rates ^a					x	x
All Covariates Included	x	x	x	x	x	x
County and Year FE	x	x	x	x	x	x
County Dummies × Year	x	x	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 469. Note that the sample size is lower than in Table 2 because we do not observe obesity, exercise, smoking, and drinking rates for all counties and years. 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.

^a These are percentages of the county's (age 18+) population, which were drawn from the 2002-2012 Behavioral Risk Factor Surveillance System.

Table 7: 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*** (0.017)	-0.051** (0.019)
1 if County Has Implemented Phase II Trans Fat Ban (t)	-0.063*** (0.021)	-0.065*** (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.

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 $\geq 0.5g$ 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 $\geq 0.5g$ 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 $\geq 0.5g$ 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 artificial trans fat per serving.

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

	(1)		(2)		(3)	
	All NYS Counties		Trans Fat Ban Implemented Over Sample Period		Trans Fat Ban Not Implemented Over Sample Period	
<i>2006 NYS Vital Statistics</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>	<i>Mean</i>	<i>S.D.</i>
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
<i>2006 county level Information</i>						
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
Sample Size	62		11		51	
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 cardiovascular disease.

^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	CVD Deaths Per 100K			
1 if County Implemented Trans Fat Ban	-0.043*** (0.016)	-0.044** (0.019)	-0.049*** (0.016)	-0.052*** (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 Mortality Per 100K, by Age Group

	(1)	(2)	(3)	(4)
<i>Sample Mean</i>	17.707	31.061	150.950	693.568
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 (0.046)	0.044 (0.048)	0.007 (0.011)	-0.022** (0.010)
Adjusted R-squared	0.250	0.361	0.742	0.939
Estimated Reduction per 100,000 Persons	-0.643	1.397	1.060	-15.092
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.