The Effects of a CO_2 Emissions Tax on American Diets

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Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2

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Introduction

U.S. food-related energy use was about 14 quadrillion British thermal units (Btu) in 2002 (Canning, et.al. 2010). This level is roughly equal to all energy use (food and nonfood related) for India in 2002, the World's 6th leading primary energy consumer that year, and exceeded that years combined energy budgets of all African nations (EIA, International Energy Statistics). In turn, energy costs have represented a substantial and highly variable share of food costs, growing from 3.5 cents of each dollar spent in U.S. grocery stores in 1998 up to 7.5 cents in 2008, and down to 5.7 cents in 2013 (ERS food dollar statistics; www.ers.usda.gov/data-products/food-dollar-series.aspx). This large intersection of food and energy commodity markets portend a strong relationship between diet outcomes and energy policy. We will assess whether a fossil fuel CO_2 tax influences dietary choice through cost and price affects?

Background

A systematic allocation of food system energy use becomes increasingly complicated when processes are interconnected. The input-output table typically reveals these interconnections and input-output material flow analysis, also called environmental input-output (EIO) analysis can be used to allocate fossil fuel consumption systematically from production processes to final products (Bullard & Herendeen, 1975). In 2003, the United Nations, the European Commission, the International Monetary Fund, the Organisation for Economic Co-operation and Development, and the World Bank jointly issued a handbook that provides economic accounting guidelines for member nations and recommends the EIO approach as a best practice for achieving "a consistent analysis of the contribution of the environment to the economy and of the impact of the economy on the environment" (United Nations et al., 2003, p. iii). This study employs an environmental input-output analysis using the newly compiled Food

Environment Data System (FEDS). A detailed description of FEDS is provided in a companion technical appendix, available from the authors upon request.

The U.S. food system is one source of greenhouse gas emissions (GHGE) among many others. GHGE in the United States totaled 6,673 million metric tons CO_2 equivalents[1] (CO_2e) in 2013 (U.S. Environmental Protection Agency, 2013). Additionally, the World Meteorological Organization (2015) reports that the global average CO_2 concentration has now surpassed the 400 parts per million threshold. In late 2015, the UN Climate Summit (COP21) in Paris brought together almost 200 countries to discuss climate change mitigation in response to increasing emissions both in the U.S. and abroad.

One policy instrument designed to curb emissions is a carbon tax. First, a tax rate is determined based on the additional cost to society not reflected in market prices due to increased carbon emissions, such as changes in net agricultural productivity, human health, property damages from increased flood risk, and reduced value of ecosystem services due to climate change (Interagency Working Group on the Social Cost of Carbon (IWGSCC), 2015). Fossil fuels are then taxed proportional to the quantity of carbon emitted when burned (Baranzini, Goldemberg, & Speck, 2000). A carbon tax can be easily translated to a CO_2 emissions tax[2] and using a 5 percent average discount rate (IWGSCC, 2015), current estimates range from $11 per ton of CO_2 to $220 per ton (Moore & Diaz, 2015) in 2015. The tax raises the price of polluting and provides an economic incentive to reduce emissions by producing differently (i.e. substituting towards cleaner fuel sources) or producing less. In France, carbon taxes effectively

[1] A CO_2 equivalent is a standardized measurement unit for GHGs that accounts for differences in global warming potential.
[2] Carbon and CO_2 emissions are proportional: 1 ton of carbon = 3.67 tons of CO_2 (Baranzini, Goldemberg, & Speck, 2000).

reduced CO_2 emissions by 2 percent between 1990 and 1999 (Bruvoll & Larsen, 2004). Currently, there is neither a global carbon tax nor a nationwide carbon tax in the United States as other countries have adopted (World Bank, n.d.).

One can easily imagine a demand response to increased fuel prices, but fossil fuels are also embodied in consumer goods such as food. Symons, Proops, and Gay (1994) measure the distributional effect of a carbon tax on the economy in the United Kingdom. In their study, the authors first use an input-output framework to model the effects of a fossil fuel carbon tax on economic sectors and then estimate the effects of the tax on consumer demand, fossil fuel use, and CO_2 emissions. They consider five scenarios that reduce CO_2 emissions by approximately 20 percent and find that food prices increase in four of the five scenarios, but other goods, such as household energy or transport, are affected more than food by the tax. Following the same approach using a different demand system, Cornwell and Creedy (1996) study the effects of a carbon tax in Australia and find a relatively large price increase in food compared to other sectors due to a 10 percent tax rate. Creedy and Sleeman (2006) also find that a carbon tax increases food prices in New Zealand.

Rather than assessing an emissions tax, Wirsenius, Hedenus, and Mohlin (2011) research the effect of a GHGE-weighted consumption tax on animal-based foods in the European Union. Using a tax base of €60 per ton of CO_2e, the authors estimate the effect of a tax on foods based on the average production emission intensities. The results indicate that GHGE could be reduced by 32 million tons CO_2e due to the tax and shifts in demand between the foods.

Linking CO_2 emissions from fossil fuels to current American diets

Table 1 reports total food-related fossil fuel consumption in 2007 by U.S. States. This data is from the FEDS 2007 benchmark database and multiregional environmental input-output model (MEIO). The analysis is done at the State level in order to identify the primary fuel sources used for electric power generation. The primary fuels used for electric power generation vary substantially across different regions of the country. For example, in 2012, 97 percent of electric power generation in West Virginia came from coal, whereas in Rhode Island 98 percent came from natural gas, in Vermont 76 percent came from nuclear power, and in Idaho 75 percent came from hydroelectricity (EIA, State Energy Data System). The data in table 1 represents the aggregated energy consumption data linked to 83 distinct food-related expenditure categories. These expenditure categories are reported in Table 2, and they include 74 food and beverage commodities and 9 expenditure categories linked to household kitchen operations.

[insert table 1]

[insert table 2]

Next, conversion factors are needed to translate fossil fuel consumption into tons of CO_2 emissions. The national CO_2 conversion factors for each sector, such as transportion, commercial and electric power, by primary fossil fuel are reported in table 3. For coal and natural gas, national average emission coefficients across all commodity types and end-user is applied. For petroleum products, each end-user's emission coefficient is computed as a weighted average from more detailed fuel uses, where the weights are the 2007 consumption totals by detailed petroleum fuels and end-user. For example, the residential petroleum coefficient (153.44) is the weighted average of butane/propane mix (141.1), home heating and diesel (161.3), and kerosene

(159.4). The weights are the shares of 2007 residential Btu consumption by fuel: 0.386, 0.579, and 0.035 for butane/propane mix, home heating and diesel, and kerosene, respectively.

[insert table 3]

A complete accounting of all 2007 food-related CO_2 emissions from fossil fuels is computed for each agri-foodchain stage and across all 83 benchmark year food-related final demand categories. Table 4 reports the combined results for the consumption of coal, natural gas, and petroleum products. The results in table 4 are compiled from summations of Appendix equation B.10 (Appendix is available from the authors upon request). Results are reported in emission units (metric tons of CO_2). Total food-related CO_2 emissions reach almost 817 million metric tons per year with 332 million from coal, 282 million from natural gas, and 202 million from petroleum productions.

[insert table 4]

We find that food-related CO_2 emissions from fossil fuels accounted for 13.6 percent of the 5.99 billion metric tons of CO_2 emissions from fossil fuel consumption in the United States (see table 12.1 in www.eia.gov/totalenergy/data/monthly/pdf/sec12.pdf). A closer look at the findings in table 4 provides some useful insights. While fossil fuels account for 93 percent of total food-related energy use, they only account for 86 percent of the 2007 national energy budget. Higher than average reliance on fossil fuel sources helps to explain the higher than expected CO_2 emission totals. Within the fossil fuel category, CO_2 emissions from natural gas consumption in the food system are nearly a quarter (23 percent) of the 1.24 billion metric tons (bmt) emitted nationally from natural gas. This disproportionate reliance on natural gas among fossil fuels serves to mitigate the emission impacts of the food system's fossil fuel reliance. For coal, the food system share was 15 percent of the 2.17 bmt national emissions from coal in 2007 and, for petroleum products, the food system's share was 8 percent of the 2.58 bmt national emissions associated with petroleum products.

Figure 1 shows the spatial distribution of annual CO_2 emissions down to U.S. counties indicating from where food-system emissions stem. This figure depicts data that is based on an assumption that electric power generation in each county derives the same shares of power by fossil fuel sources as the State-wide average, and also assumes that statewide energy use by type of industry is spatially distributed to counties in proportion to the share of that industry's labor force in each county. Finally, the county emissions data allocates emissions from the commercial transportation industry to the counties where the vehicles/vessels/railcars are most likely to have been launched and terminated. These are strong assumption that will misallocate a small percentage of the overall emission locations but it is expected to be representative of the spatial disposition of overall 2007 food system CO_2 emissions from fossil fuel consumption.

[insert figure 1]

Both total CO_2 emissions (panel A of figure 6) and per capita CO_2 emissions (panel B) are depicted and the 10 highest emitting counties list differs across the two metrics. In terms of total emissions, 8 of the 10 highest emitting counties are also among the top 10 most populated counties and the other two top emitting counties are among the top 20 most populous U.S. counties. These results are not surprising given household foodservices and transportation along with commercial foodservices account for about half of total food-related energy use (figure 1). Thus, the most populated counties will also have the largest number of home kitchens and be likely to have more commercial kitchens (foodservice establishments).

The story is very different on a per capita basis (panel B). Of the 10 highest per capita emitting counties, 8 are in Kansas (5) or Texas (3), 6 are in counties with population totals in the bottom 10 percent nationally, and all 10 are in counties with population totals in the bottom 20 percent. These counties are disproportionately farming and/or food processing intensive areas, and are more fossil fuel intensive than other farming and processing areas.

Would a CO_2 emissions tax influence dietary choice through cost and price effects?

Prices paid for a food or beverage product reflect the total value added by all industries that participate in making this product available for final market purchase. Value added represents the compensation for the use of materials and services from primary factors such as labor, capital, and resources like fossil fuels. This compensation to primary factors typically must at least cover the costs to the owners of those factors for making their materials and services available for use. In addition, factor owners will charge an economic rent that reflects market value to the purchaser from the use of that factor in production. The outcome of this market structure is that for any primary factor, unit price equals unit supply costs plus a unit rental cost.

Like other primary factors, fossil fuels are associated with environmental externalities whose costs are not reflected in this 'costs plus rent' price formulation. One of these externalities from fossil fuels is the emission of carbon dioxide into the atmosphere. Worldwide emissions are occurring at higher rates than are the natural rates of assimilation that remove these gasses from the atmosphere. The net impact of this situation is increasing accumulations of CO_2 (and other greenhouse gases) into the atmosphere, thus contributing to the greenhouse effect of rising temperatures worldwide (Karl, Melillo, and Peterson, 2009). Climate scientists studying this affect produce measures of economic costs from rising temperatures and these costs are substantial (Interagency Working Group on the Social Cost of Carbon, 2015). However, the cost plus rent price formation mechanism for primary factors described above does not factor these societal costs into the formation of market prices.

Economists have long recognized that the internalization of external costs through taxation can lead to more efficient market outcomes if the government can accurately gauge the social cost (Pigou, 1920). For example, consider an industries decision to purchase fossil fuels at a price that does not reflect external costs. Like other inputs, the industry will purchase the amount of this fuel that maximizes the expected profits from its use. Next, suppose the industry is charged for the societal costs of its use of fossil fuels. This charge will offset the expected profits such that the industry will be able to increase net profits by decreasing its use of fossil fuels, since this will reduce costs faster than it will reduce gross profits. This reduction in use will continue until the point where both costs and gross profits fall by the same amount. If all users of fossil fuels are accurately charged for the true external costs, one can analytically show that fossil fuel use will occur at its social optimum level. Both the measurement of social costs from fossil fuel use and the appropriate mechanism for internalizing this cost in energy markets are the two great challenges facing the U.S. and other nations seeking to reduce their carbon emissions.

In our research, we broaden the consideration of what constitutes the socially-optimal cost of fossil fuel use by assessing the potential spillover effects of higher fuel costs on American diet outcomes. Current estimates of the social costs of CO_2 emissions in the U.S. were recently published by the IWGSCC (Interagency Working Group on the Social Cost of Carbon, 2015), and in the current U.S. Congress there are at least four bills that propose the implementation of a

Federal carbon tax on fossil fuel use.[3] We consider a hypothetical implementation of a fossil fuel CO_2 tax that reflects current estimates of social cost and measure the food costs and relative commodity price effects of this tax.

In 2010, the IWGSCC developed its original estimates on the social costs of carbon (SCC) in order to allow agencies to incorporate the social benefits of reducing carbon dioxide emissions into cost-benefit analysis regulatory actions that impact cumulative global emissions. In July of 2015, the original 2010 estimates were revised (IWGSCC, 2015). Here, we consider a hypothetical CO_2 tax on fossil fuel use set at $31 per metric ton of CO_2 emissions[4], which is the current SCC estimate in calendar year 2010 based on an average discount rate of 3 percent.

Modeling the price impacts and behavioral adjustments along the U.S. agri-foodchain from a hypothetical CO_2 tax is a complex research challenge. For example, a recent study of alternative CO_2 taxes on electric power generation in the United States found that if such a tax were based on the IWGSCC 2010 cost estimates it would induce the industry to substitute natural gas or wind and nuclear fuel sources for coal, depending on whether the tax rate is based on the lower or higher costs estimates of the IWGSCC (Paul, Beasley, and Palmer, 2013). Industries facing the new tax reduce their use of the higher-priced energy source to mitigate price impacts. Similar behaviors are anticipated for non-electricity energy markets such as natural gas and petroleum products, both of which have substantial roles in the U.S. food system. Further, any tax-induced price impacts that do get passed onto consumers in the form of retail food prices

[3] These are (i) the Managed Carbon Price Act of 2015 (H.R. 972), introduced on February 13, 2015; (ii) the Tax Pollution, Not Profits Act (H.R. 2202), introduced May 1, 2015; (iii) the American Opportunity Carbon Fee Act of 2015 (S. 1548), introduced June 10, 2015; and (iv) the Climate Protection and Justice Act (S. 2399), introduced on December 10, 2015.

[4] In 2007 dollars.

will likely cause consumers to adjust their food purchasing behaviors in order to further mitigate the cost impacts of the tax.

Rather than accounting for all of the behavioral changes that are induced by the introduction of a tax on fossil fuel CO_2 emissions, we trace the total cost of such a tax that would be passed onto food consumers. This assumes that no behavioral adjustments occur and that all tax burdens levied to fossil fuel users are completely passed onto buyers of the energy using industry outputs. Therefore, our estimates are an upper bound. Using our estimates on food-related CO_2 emissions (table 4), we repeat these computations for each individual food commodity expenditure (see items 01 to 74 listed in table 2).

In a companion paper to this study (Rehkamp and Canning, 2016), the diet outcomes of all Americans ages 2 and above are measured using the 2007-2008 National Health and Nutrition Examination Survey (NHANES). In our sample, there are 4,067 unique food or beverage items consumed. Each item is mapped to one or more of the 74 food expenditure categories, and the measured annual total grams consumed that are mapped to each expenditure item tell us the aveage Btu per gram consumed, by type of fossil fuel. Also in the companion paper (Rehkamp and Canning, 2016), an alternative diet denoted 'Realistic Healthy' is estimated as a mathematical optimization problem, using an objective function that minimizes the changes from baseline consumption patterns in order to meet Calorie goals, nutriet and food pattern consumption targets, and expenditure limits. Figure 2 describes the sources for the baseline and realistic healthy diets, and figures 3 and 4 report the caloric composition and embedded primary energy (Btu) of the two diets across 10 broadly defined food and beverage groups.

[insert figure 2]

[insert figure 3]

[insert figure 4]

Using our estimates on food-related CO_2 emissions (table 4), we repeat these computations for each individual food commodity that was mapped to the individual diet components in the dietary analysis. With the measures of embodied CO_2 emissions already in metric ton units and multiplying by the $31 per unit tax produces a measure of the total potential tax burden on each food commodity market (IWGSCC, 2015). Then, dividing this figure through by total grams consumed in each commodity group produces an average CO_2 tax per gram consumed for each of the 4,000 plus food items consumed in each of the diets examined in this study.

Table 5 reports the potential tax burdens of the $31/metric-ton CO_2 tax on the Baseline Diet and the Realistic Healthy Diet. In the first 2 columns, the total annual potential tax burden is reported under the assumption that each of the two diets represent the annual average diet of all Americans in the study period of 2007. The numbers indicate that total diet expenditures of all Americans in 2007 (row 1) would have generated about $15.7 billion in CO_2 taxes under baseline diets, and $15.2 billion under the Realistic Healthy Diet scenario.

[insert table 5]

Columns 3 to 4 translate these total tax burdens into percentages of their pre-tax retail costs. Viewed in this way, the numbers indicate that an average meal would cost about 1.25 percent more with the CO_2 tax for both the Baseline Diet and the Realistic Healthy Diet (row 1). For example, for each $100 spent on food and beverages, the CO_2 tax would add $1.25 to the meal tab. Rows 2 through 10 of table 7 report the total taxes (columns 1 to 2) and average tax rates (columns 3 to 4) for different food groups. For both diets, eggs and egg products have the highest tax rates, ranging from 1.7 percent in the Baseline Diets to 1.9 percent in the Realistic Healthy Diet respectively. Sugars, sweets and beverages are the second highest taxed category in the baseline diet in terms of total tax revenues, but have the lowest tax rate, at 1.13 percent.

Row 11 of table 5 reports the potential CO_2 tax burden on home kitchen operations and household food-related transportation. Note that these agri-foodchain stages are not associated with the alternative diet since we do not have sufficient information to determine how kitchen operations would change under the alternative diet scenarios. The data indicates that the CO_2 tax comes down hard on home kitchen operations, with an average tax rate of about 7.5 percent of the pre-tax cost to operate these home kitchens. But whether this result would encourage households to eat out more often depends on how households view the value of their efforts spent on home food preparation. To explain, consider an identical meal that is one day prepared at home and the next day purchased at a restaurant. It is likely that the embodied energy and by extension the total CO_2 tax bill of the two meals will be very similar. However, the cost of the meal eaten away from home will likely be higher as well, such that the tax rate (tax as a percent of pre-tax cost) on the meal away from home will be lower. Thus whether the consumer views the roughly equal total tax on both meals as an incentive to increase or decrease the number of times they eat out depends on the value each consumer places on their home kitchen services (including their own time and effort). If they equate this value to the extra cost of purchasing the meal at a restaurant they will likely view the tax rate as equal and so the CO_2 tax will be neutral in terms of the eating at home verse eating out decision.

Related to this issue, our research does not account for any changes in the amount of home kitchen services that are associated with the healthy diet scenario. If the mix of food products in the healthy diet outcomes include far less processed foods, healthier diets might require more post purchase processing and thus more home kitchen services. However, this logic may not hold up to a closer examination. For this reason, this study does not attempt to predict how a CO_2 tax or nutrition promotion might affect decisions about food preparation.[5]

Although the rates of taxation on different food groups have clear differences, the rate of taxation on the typical baseline meal and the typical Realistic Healthy meal are virtually the same. In addition, after markets react to the tax, price and cost impacts will be lower. To gauge by how much, consider that without market reactions, our calculations represent 13.6 percent of total tax revenues since the food system accounts for that percentage of total CO_2 emissions from fossil fuels economywide. This implies that the total annual tax revenue would have been $186 billion ($25.3/0.136). Economists at Resources for the Future studied this issue and concluded that a tax of $25 per ton of CO_2 would raise approximately $125 billion annually after factoring in market reaction.[6] If we scaled our analysis to a $25 dollar tax rate we would expect approximately $150 billion in annual tax revenues (186 * 25/31). This 'back of the envelope' calculation suggests that market reactions to the tax would lower overall tax revenues by about 17 percent. Therefore, we reject the hypothesis that a tax on CO_2 would encourage healthier diets.

Summary

The findings from this research can be used to inform discussion and evaluate proposed policies at the intersection of health, diet, energy, and environmental issues. We trace the total

[5] We recognize that this may not be a realistic assumption, but this is an empirical question that is left for future research.

[6] See analysis summarized on the Resources for the Future website at www.rff.org/blog/2012/considering-carbon-tax-frequently -asked-questions .

cost that would be passed onto food consumers from a $31 per metric ton CO_2 emissions tax on fossil fuel use. We do so under the assumption that no behavioral adjustments occur and that all tax burdens levied to fossil fuel users are completely passed onto buyers of the energy using industry outputs. Our research indicates that an average meal would cost about 1.25 percent more with the CO_2 tax for both the Baseline Diet and the Realistic Healthy Diet. This cost is viewed as an upper bound since both producers and consumers would adjust their behaviors in order to mitigate the costs of this new tax. Tax rates on food items across the major food groupings vary, as do tax rates on the same food groupings across baseline and healthy diet outcomes. Even so, all tax rates fall between 1 and 2 percent of the pre-tax retail costs. Our findings do not provide compelling evidence of a clear relationship between a CO_2 tax and diet outcomes. Although the rates of taxation on different parts of the two diets have clear differences, the differences are small and the rate of taxation on the typical baseline meal and the typical 'realistic healthy' meal are virtually the same.

Future research could consider other sustainability metrics in addition to energy use. For example, water, land, and other greenhouse gases also have major roles in the U.S. food system. Food system water withdrawals, soil erosion, and other greenhouse gas emissions are also likely to change under alternative U.S. diet outcomes. Each of these important natural resources and production byproducts are the subject of many current and proposed federal policies. Just as it would be considered incomplete to study only one of the many dietary recommendations in the Dietary Guidelines for Americans, the same can be said for a consideration of only one of the metrics of food system sustainability.

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Table 1—Food-Related Annual Fossil Fuel Consumption by State, 2007

	Fossil Fuel Consumption						
			PETROLEUM PRODUCTS				
	COAL	NATURAL GAS	INDUSTRIAL	COMMERCIAL	HOUSEHOLD	TRANSPOR-TATION	ELECTRIC POWER
STATE	*(million Btu)*						
Alabama	75,392,269	84,343,997	19,284,842	957223	9690719	14713475	145533
Alaska	1,909,832	14,134,324	2,610,011	521470	2189071	3957876	25456
Arizona	55,043,250	93,597,446	10,509,732	1606812	13206366	17649449	137288
Arkansas	47,403,478	70,994,455	20,505,172	628119	5922005	17948591	57140
California	36,094,727	880,366,259	109,247,321	13354260	80933747	76417506	514262
Colorado	87,741,488	56,649,635	16,483,772	1454622	10304807	14128646	73886
Connecticut	11,033,739	76,770,705	4,414,168	2171446	9116942	5084610	68403
Delaware	18,218,424	10,575,916	3,932,027	430866	2054396	2418859	26905
District of Columbia	85,616	1,720,683	286,489	7015239	7823545	307342	117928
Florida	134,003,656	291,793,559	34,620,068	17923763	58033168	44655334	432480
Georgia	160,834,065	147,301,629	28,081,886	2488783	19977708	33351466	226792
Hawaii	5,190,041	8,886,337	5,642,169	8682002	13423688	4322387	148602
Idaho	2,657,248	24,369,913	13,936,339	303624	3100782	4996714	29528
Illinois	170,741,293	269,825,840	45,203,935	3685920	26946051	47260810	225364
Indiana	176,967,424	58,941,759	28,180,299	1532764	13307016	28953228	141277
Iowa	90,614,831	72,304,935	46,953,694	853430	6483858	16016424	75914
Kansas	64,801,852	52,082,371	32,912,525	758293	5965627	11854770	61406
Kentucky	119,153,475	36,557,984	21,185,587	1743750	10383621	20252511	98023
Louisiana	40,006,121	99,901,748	20,726,287	1924461	10819196	23445572	127218
Maine	2,622,020	34,214,220	5,372,272	571765	3340798	3152228	24379
Maryland	72,401,674	65,546,750	8,125,311	2324901	13294644	11670000	101288
Massachusetts	44,838,273	124,963,929	10,003,070	6001167	19304256	11572564	138270
Michigan	143,793,598	147,619,962	23,370,478	2560036	21690725	24053143	215194
Minnesota	98,380,902	108,439,622	34,816,200	1971872	11456381	18205332	116485
Mississippi	28,612,062	62,325,949	15,115,131	639353	6304375	9121134	74735
Missouri	135,844,787	74,835,401	24,294,754	1674969	12385137	23906335	129457
Montana	16,839,976	7,134,803	8,139,925	353536	2267629	3954237	29466
Nebraska	42,628,800	49,899,219	32,908,019	500738	3720552	15608326	2514
Nevada	16,270,416	44,756,891	3,349,611	776530	5375956	5728308	44284
New Hampshire	6,281,033	27,506,231	1,618,394	441435	3048551	1855180	32999
New Jersey	40,743,458	210,349,554	12,830,756	2744985	18703314	28444368	143560
New Mexico	33,674,483	17,129,439	6,334,949	374661	4112510	4557275	40979
New York	71,574,497	336,117,072	25,670,439	13361543	53473090	35151390	506106
North Carolina	142,395,059	138,642,117	32,796,666	2153829	19168484	25081274	190996
North Dakota	22,466,502	9,712,423	13,138,311	190141	1358862	3672532	27718
Ohio	267,585,205	125,836,344	34,350,382	3523383	25089736	38430090	252960
Oklahoma	47,067,515	62,018,059	16,605,481	853425	7574100	11749362	69339
Oregon	11,974,831	53,370,155	14,965,752	983052	7849124	12190519	69152
Pennsylvania	184,170,937	220,295,948	32,211,220	3675018	27131799	36899778	260003
Rhode Island	377,625	27,332,727	1,239,274	293053	2277815	1501721	7420
South Carolina	45,622,029	94,823,830	15,360,131	1021012	9322626	10975697	125903
South Dakota	12,264,464	10,270,029	13,912,238	241151	1764581	2805204	19597
Tennessee	106,281,653	104,422,111	17,105,236	1574760	12993007	29630181	24784
Texas	255,371,886	449,687,987	84,061,526	6565626	50406151	81140356	331400
Utah	54,636,659	24,059,736	6,693,133	667875	5504901	12798573	33604
Vermont	694,397	18,395,030	2,120,909	132296	1328476	1319475	19741
Virginia	88,207,351	124,436,164	16,119,936	3418084	18480359	21953754	160143
Washington	19,473,190	72,256,658	28,699,423	1574623	13679376	20852071	65735
West Virginia	53,845,912	10,619,847	8,275,389	358796	3830159	5618262	53447
Wisconsin	120,226,630	117,614,512	29,946,108	1948156	12745932	25807207	133070
Wyoming	16,868,586	4,776,815	5,283,527	120230	1102934	3902091	20840
United States	3,501,929,239	5,330,529,029	1,049,550,274	131,628,848	709,768,653	931,043,537	6,198,973

Source: Authors calculations

Table 2—FEDS Benchmark Food Related Final Demand Categories

fd0_Benchmark	Representative Products in Category
01	Rice and Packaged Rice Products
02	Flour, Cornmeal, Malt, Dry and Refrig/Frozen Flour Mixes (biscuts pancakes cakes etc) Made in Mill
03	Breakfast Cereals and Oatmeal
04	Macoroni and Noodle Products with Other Ingredients and Nationality Foods (not canned or frozen)
05	Noodle Pasta and Dry Soup Mixes with Other Ingredients Plus Fresh Pasta and Packaged Unpopped Popcorn
06	Popcorn Wild Rice (not canned or processed)
07	Grits and Soyflour
08	Dry Pasta Dry Noodles and Flour Mixes from Purchased Flour
09	Bread Rolls Cakes Pies Pastries (Including Frozen)
10	Cookies Crackers Biscutts Wafers Tortillas (Except Frozen)
11	Beef and Veal (fresh or frozen/not processed canned or sausage)
12	Pork (fresh or frozen/not canned or sausage)
13	Boxed Cooked and Processed (lunch) Meats plus Lamb & Other Meats (incl.game)
14	Fresh Frozen or Processed Poultry (except soups)
15	Fresh Frozen or Prepared Fish & Shellfish (incl. caned and soups)
16	Fresh Milk
17	Natural and Processed Cheese
18	Dry Condensed and Evaporated Dairy
19	Ice-cream Custards Frozen Yogurt Sherbets Frozen Pudding
20	Cottage Cheese Yogurt Milk Substitutes Sour Cream Butter Milk Eggnog
21	Shell Eggs
22	Dried Frozen or Liquid Eggs
23	Corn Oils
24	Margerine Shortning Oilseed Oils
25	Peanut Butter
26	Mayonnaise Salad Dressings Sandwich Spreeds
27	Oilseed Oils and Other Oilseed Products
28	Butter and Butter Oils
29	Lard and Other Animal Oils
30	Fresh Fruits
31	Fresh Vegetables
32	Mushrooms and other Vegetables Grown Under Cover
33	Fresh Herbs and Spices
34	Fruit Flours made in Grain Mills
35	Frozen Fruits and Vegetables
36	Canned or Dried & Dehydrated Fruits or Vegetables
37	Processed Vegetables and Fruits Packaged with Other Products (e.g., noodles)
38	Dry Beans and Peas (not canned)
39	Corn Sweetners (e.g., Karo syrup & sugar substitutes)
40	Sugar and Chocolate Products, Non-Chocolate Bars Gums and Candies
41	Jams Jellies and Preserves
42	Desert Mixes Sweetning Syrups Frostings
43	Almonds and Other Fresh Tree Nuts
44	Fresh Peanuts
45	Granola
46	Frozen Diners, Nationality Foods, Other Frozen Specialties (excl seafood)
47	Catsup and Other Tomato Sauces (eg spaghetti sauce)
48	Pickles and Pickled Products
49	Canned Soups and Stews (excl. frozen or seafood) and Dry Soup Mixes
50	Dry and Canned Milk plus Dairy Substitutes
51	Nuts and Seeds
52	Chips and Pretzels
53	Vinigar Condiments Sauces (excl. tomato based) Semi-Solid Dressings and Spices
54	Baking Powder and Yeast
55	Refrigerated Lunches
56	Refrigerated Pizza (Fresh, not frozen)
57	Bagged Salads
58	Value Added Fresh Vegetables
59	Fresh-cut Fruits
60	Fresh Tofu
61	Coffee Tea and Related Beverage Materials
62	Soft Drinks and Ice
63	Bottled Water
64	Frozen and Canned Fruit Drinks
65	Frozen and Canned Vegetable Drinks
66	Spirits Flavorings and Cocktail Mixes
67	Wine and Brandy
68	Beer
69	Food on Farm, Vegetables
70	Food on Farm, Fruits and Tree Nuts
71	Food on Farm, Dairy
72	Food on Farm, Beef
73	Food on Farm, Meats except Beef and Poultry
74	Salt, Fatty Acids, and Organic Chemical Food Flavorings
75	Household: Natural Gas
76	Household: Electricity
77	Household: Petro for Cooking
78	Household: Appliances
79	Household: Kitchen Equipment
80	Household: Motor Vehicles and Parts
81	Household: Auto Repair and Leasing
82	Household: Auto Insurance
83	Household: Auto Fuels Lubricants and Fluids
84	All Other Final Demand

Table 3—Pounds of CO_2 Emissions per Million Btu by Type of Fossil Fuel

End User	Coal	Natural Gas	Petroleum
Transportation sector		117.00	158.62
Commercial sector	210.20	117.00	158.59
Electric power sector	210.20	117.00	185.41
Industrial sector		117.00	157.11
Coke plants	210.20		
Organic chemicals	210.20		
Residential sector	210.20	117.00	153.44

Source: U.S. Energy Information Administration: www.eia.gov/environment/emissions/co2_vol_mass.cfm

Note. Coal and natural gas are national averages while petroleum is broken out by end-user.

Table 4—Food-Related Annual Carbon Dioxide Emissions

	Fossil Fuel CO2 Emissions		
	COAL	NATURAL GAS	PETROLEUM PRODUCTS
STATE	(metric tons)		
Alabama	7,140,311	4,452,626	3,198,043
Alaska	181,133	746,388	665,556
Arizona	5,217,768	4,939,806	3,083,260
Arkansas	4,503,610	3,757,851	3,223,317
California	3,434,307	46,589,665	20,059,107
Colorado	8,335,716	2,997,343	3,036,253
Connecticut	1,047,872	4,058,537	1,491,644
Delaware	1,726,750	558,975	632,844
District of Columbia	8,024	90,581	1,109,282
Florida	12,724,726	15,428,140	11,138,992
Georgia	15,255,857	7,785,691	6,015,207
Hawaii	492,306	469,971	2,302,085
Idaho	253,127	1,290,791	1,597,287
Illinois	16,217,505	14,273,913	8,822,924
Indiana	16,796,018	3,120,979	5,157,721
Iowa	8,609,478	3,830,017	5,025,692
Kansas	6,154,179	2,756,611	3,681,566
Kentucky	11,309,907	1,936,277	3,838,384
Louisiana	3,791,735	5,277,365	4,079,684
Maine	249,515	1,810,996	890,807
Maryland	6,873,974	3,465,190	2,541,123
Massachusetts	4,259,535	6,609,397	3,364,164
Michigan	13,642,007	7,801,216	5,138,659
Minnesota	9,342,991	5,737,534	4,755,945
Mississippi	2,712,518	3,291,612	2,232,363
Missouri	12,892,366	3,960,338	4,461,701
Montana	1,595,581	377,441	1,052,939
Nebraska	4,063,130	2,647,610	3,771,474
Nevada	1,544,414	2,365,208	1,092,964
New Hampshire	595,548	1,451,991	499,599
New Jersey	3,869,922	11,122,790	4,502,165
New Mexico	3,192,005	904,754	1,101,770
New York	6,790,534	17,752,481	9,161,597
North Carolina	13,513,560	7,329,874	5,673,934
North Dakota	2,126,930	514,164	1,311,826
Ohio	25,396,614	6,658,621	7,269,038
Oklahoma	4,467,458	3,278,940	2,634,295
Oregon	1,137,981	2,824,390	2,578,268
Pennsylvania	17,479,383	11,646,085	7,164,118
Rhode Island	35,949	1,447,958	381,101
South Carolina	4,323,164	5,005,769	2,627,568
South Dakota	1,164,900	543,802	1,337,395
Tennessee	10,124,133	5,538,057	4,397,638
Texas	24,263,287	23,792,296	15,922,367
Utah	5,191,802	1,273,950	1,841,378
Vermont	66,055	970,261	351,044
Virginia	8,372,429	6,576,760	4,301,975
Washington	1,852,908	3,828,490	4,641,615
West Virginia	5,091,976	561,312	1,294,961
Wisconsin	11,419,252	6,225,552	5,046,775
Wyoming	1,592,677	252,487	745,165
United States	332,444,827	281,928,853	202,246,579

Source: Authors calculations

Table 5—Potential Annual Tax Revenues and Average Tax Rates from a $31 per metric ton CO_2 Tax on Fossil Fuel Use

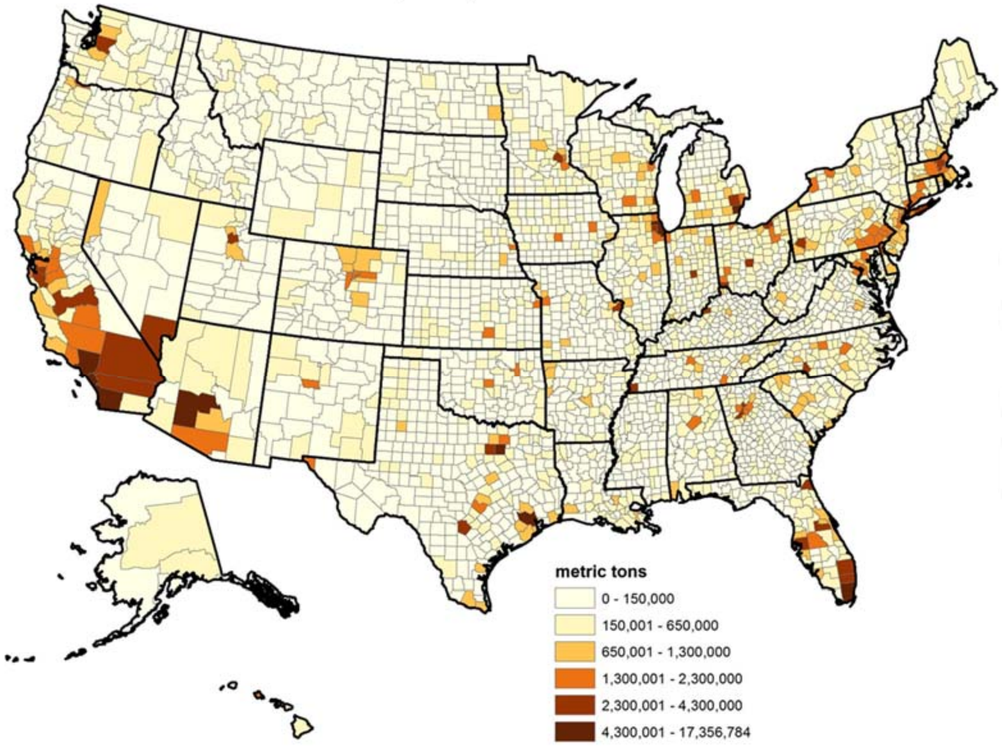
Item	Baseline Diet	Realistic Healthy Diet	Baseline Diet	Realistic Healthy Diet
	CO_2 tax revenues (dollars)		*Average CO_2 tax rate (percent)*	
Total Diet	**15,671,808,112**	**15,248,412,906**	**1.254**	**1.250**
Milk and milk products	1,537,140,389	2,312,329,574	1.319	1.548
Meat, poultry, fish, and mixtures	4,276,411,150	4,600,403,856	1.261	1.113
Eggs and egg products	239,249,998	293,970,899	1.700	1.882
Legumes, nuts, and seeds	273,026,588	461,330,351	1.337	1.277
Grain products	3,195,334,122	2,304,812,361	1.377	1.415
Fruits	862,689,940	1,456,855,630	1.245	1.192
Vegetables	988,695,268	1,720,308,252	1.255	1.215
Fats, oils, and salad dressings	123,890,935	7,603,555	1.248	1.141
Sugars and sweets	403,711,334	35,493,494	1.447	1.427
Beverages	3,771,658,387	2,055,304,933	1.105	1.175
Kitchen Operations & Grocery Trips	**9,644,405,298**	*	**7.466**	*

***** Kitchen operations and grocery trips are indeterminate under the "Realistic" and "Efficient Energy" healthy diet scenarios.

Source: Authors calculations

Figure 1--Food-Related Carbon Dioxide Emissions by County, 2007

Panel A—Total CO2 Emissions by County



Panel B—Per capita CO2 Emissions by County

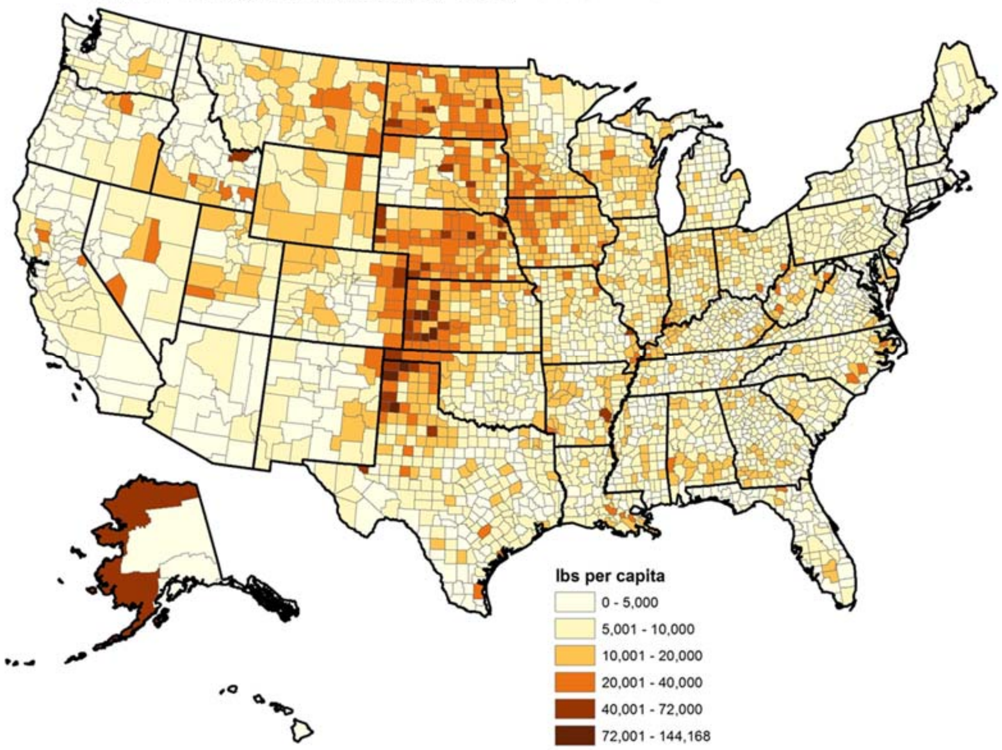


Figure 2—Description of Baseline and Realistic Healthy Diets

Figure 3—Caloric Composition of Baseline and Realistic Healthy Diets

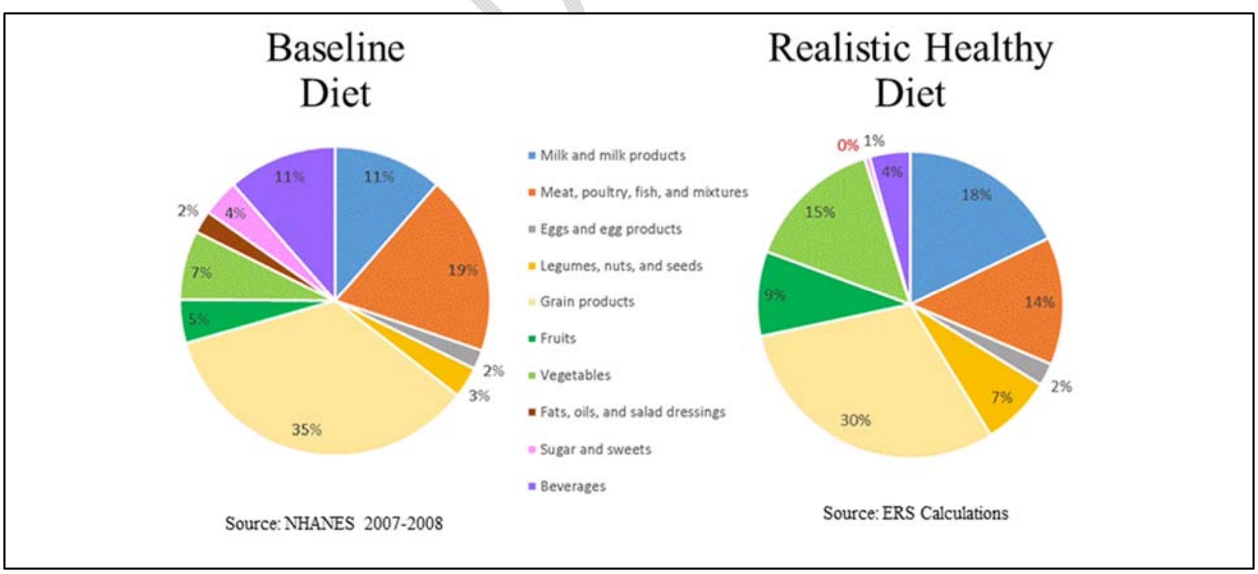


Figure 4—Primary Energy (Btu) Composition of Baseline and Realistic Healthy Diets