For Online Publication

Appendix

Environmental Engel Curves

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1. Introduction

Environmental Engel Curves (EEC) show the relationship between households' incomes and the pollution embodied in the goods and services consumed by those households. The key challenge to estimating EECs is assigning a level of pollution to each household based on annual consumption. To do this we combine two broad types of information: i) pollution intensity coefficients that show the per-dollar amount of pollution created in order to produce goods from a certain industry, and ii) itemized consumer expenditure data that show the dollar-value of expenditure in a given category for each household. Then the general outline is simple. We start with a list of household consumption expenditure and multiply each item by its individual pollution intensity of production. Because we want to include upstream emissions, we also use the BEA benchmark input-output tables to calculate emission intensity coefficients that include pollution from manufacturing the inputs to each household's final consumption (and inputs-to-inputs, on up the supply chain).

There are three types of data we use to calculate household pollution: consumer expenditure, industry-level emissions and output, and input-output tables. One of the primary data-related challenges is that each of these groups of data rely on a different coding system to categorize products or industries. The Consumer Expenditure Survey (CEX) tracks household income and expenditure in approximately 850 separate universal classification codes (UCC). The EPA National Emissions Inventory facility summary tracks emission from individual facilities based on NAICS industry codes, and the BEA input-output tables use yet another categorization of industries.[1] In order to calculate EECs, we need to match consumption, production, and input-output tables across three separate coding systems. In addition, harmonizing information across these datasets requires subjective judgments about which production processes correspond to each consumption category.

The broadest classification system is the IO codes used by the BEA input-output tables.[2] Each IO code can encompass several six-digit NAICS codes and several UCC codes. To address this, we aggregate both CEX consumption data and pollution data to match the BEA IO

[1] NAICS is the standard classification system used by Federal agencies to identify industries in the US. The system groups common establishments into NAICS industries based on their production processes and supply functions. These individual industries are characterized by a six-digit NIACS Code. The NAICS is hierarchical, drilling down from 24 two-digit sectors to 1065 individual six-digit industries. A complete list of NAICS codes can be downloaded from the US Census Bureau (Census Bureau, 2015) and more information on NAICS is available in Murphy (1998).
[2] Detailed information about the BEA IO tables can be found in Horowitz and Planting (2009).

classification system. Figure A.1 summarizes the data synthesis process to calculate household-level pollution.

The second component necessary to estimate EECs is household income. We measure gross household income and after-tax income using the Consumer Expenditure Survey. We use the CEX rather than other income-related sources (such as the Current Population Survey) in order to maintain consistency between our sources for income and pollution. Once we have household income and an estimate of household-level pollution, along with demographic information from the CEX, it is straightforward to estimate the relationship between household income and the pollution embodied in the goods and services consumed by each household—the environmental Engel curves.

2. Calculating direct pollution intensity coefficients (by BEA IO industry)

To calculate the per-dollar pollution intensity of production we calculate the total amount of emissions associated with each industry and divide by the total sales for those industries. We rely on the EPA National Emissions Inventory for a measure of air pollution emissions and the Economic Census and Census of Agriculture for sales data. All three of these sources are organized by NAICS industries, but we aggregate sales and pollution to match the BEA IO industries before calculating pollution intensities. NAICS industries are hierarchical, with each 4-digit industry encompassing a set of 5-digit industries, and each 5-digit industry encompassing a set of 6-digit industries, each with increasing specificity. The BEA IO codes map to individual 6-digit NAICS codes, so we aggregate sales and NEI emissions to 6-digit NAICS industries.

Both the 2002 Economic Census and the 2002 Census of Agriculture list the value of sales for individual NAICS industries and together the two sources cover all formal production in the United States.[3] With the exception of hog and pig farming (1122) and animal aquaculture (1125), industries in the Census of Agriculture are classified by 5- or 6-digit NAICS. When the Census lists only 4- or 5-digit NAICS industries, we evenly split the remaining sales across subordinate 6-digit industries. The Economic Census also lists total sales by 6-digit NAICS industry. Occasionally, total sales for some 6-digit industries in the Economic Census are not reported because the number of firms is too small. In these cases, we find the portion of the parent 5-digit

[3] For agricultural-related industries (NAICS 111 and 112) sales is measured as the "market value of agricultural products sold" from the Agricultural Census (U.S. Department of Agriculture, 2004). Other industries' sales are measured as total "sales, shipments, receipts, and revenue" from the Economic Census (U.S. Census Bureau, 2014).

NAICS industry's sales that hasn't been accounted for in 6-digit NAICS and we allocate it across the remaining 6-digit industries in proportion to the number of establishments.

Industry level pollution estimates are based on the facility summaries of the EPA National Emissions Inventory (NEI). The NEI is collected every three years, but we rely on the 2002 summaries because they are the most recent set that are also contemporaneous to the Economic Census and Benchmark IO tables (both released every five years). The facility-level summary provides information on all point sources in the 2002 NEI, including, in most cases, a NAICS industry code associated with the facility.[4] There are 98,500 records in the 2002 NEI facility summary, and we calculate industry-level emission by aggregating the facility-level data by NAICS industry. Only point sources in the NEI are assigned NAICS codes, so our pollution intensity coefficients do not include area or mobile sources, or any other source not included in the facility summary.

Not all facilities included in the NEI summary are assigned NAICS codes. In 2002 there are 1,368 records in the NEI that are not assigned to a NAICS industry. Some of these facilities (587) are assigned an SIC code, and in those cases we rely on the SIC-NAICS concordance provided by the Census Bureau to allocate emission to corresponding NAICS industries.[5] The remaining 781 facility records that do not indicate a NAICS or SIC industry are dropped from the analysis. These unassigned facilities represent only a fraction of a percent of total emissions.[6]

Occasionally, facilities in the NEI report 4- or 5-digit NAICS. Before aggregating facility-level pollution to industry level, we allocate the emissions from these facilities to subordinate 6-digit NAICS industries in proportion to value shipped from the Censuses for each industry. We then calculate total emissions for each NAICS industry as the sum of all facility-level emissions within each industry. The result is a full set of 6-digit NAICS industries with information on total facility-sourced pollution from the NEI and total sales from the Censuses for each industry.

Aggregating emissions and total sales from NAICS industries to match the IO industries used by the BEA input-output tables is straightforward because BEA provides a concordance between

[4] See the EPA NEI website (https://www.epa.gov/air-emissions-inventories/national-emissions-inventory) for more information about the NEI and to download the raw data.
[5] The SIC-NAICS concordance is available for downloaded from the Census Bureau website: https://www.census.gov/eos/www/naics/concordances/concordances.html.
[6] For example, these orphan facilities collectively reported only 5.38 tons of PM10 in 2002.

the two systems.[7] Some IO codes are matched directly to five or six-digit NAICS codes; this is particularly common in the manufacturing sector. But most IO codes represent groups of related NAICS codes of varying sizes. For example, the IO code 221100 encompasses all NAICS codes that begin with 2211, which includes ten separate six-digit NAICS industries related to electrical power generation and transmission.[8] We use the BEA concordance to assign each NAICS industry to the appropriate IO industry and then calculate the sum of all emission and total sales for each IO industry.

A key difference between the NAICS and IO system is that the BEA classifies agriculture, real estate, and construction industries based on activities rather than establishments. For example, construction is classified by the type of activity, such as the construction of new highways and streets, rather than by the type of construction contractor, such as heavy construction contractors who pave asphalt roads (Lawson et al., 2002). For agriculture and real estate industries, this does not interfere with assigning NAICS codes to IO codes. But the BEA does not assign specific NAICS codes to any construction-related IO industry. Instead, all construction-related IO codes are assigned a NAICS code of "23*," corresponding to the general NAICS construction industry. To address this, we aggregate all construction-related IO codes to a single code "230000" and use the overall average pollution intensity of all construction-related NAICS codes. Similarly, the BEA input-output tables do not distinguish between types of wholesale trade, so we consolidate all wholesale-trade-related NAICS into a single industry 420000.

After calculating total emission and total sales by IO code, we calculate per-dollar pollution intensity coefficients by taking the ratio of total emission to total sales. The coefficients are rescaled to represent the amount of emissions in tons associated with $1 million in sales for each IO industry, assuming a linear relationship between sales and emissions. We refer to these coefficients as direct coefficients because they only include the emission directly associated with each industry. In the following section, we also calculate total coefficients that include pollution from upstream production.

[7] This concordance is available from the BEA in Stewart et al. (2007) or http://www.bea.gov/industry/io_benchmark.htm.

[8] NAICS code 2211 includes eight electric power generation industries of various fuel sources under NAICS 22111 and two electric transmission and distribution industries under NAICS 22112.

3. Calculating total pollution intensity coefficients

The direct coefficients calculated above include emissions associated with each industry's output, but do not include upstream emissions associated with producing inputs to production. The BEA input-output tables provide a means of calculating total coefficients that represent the pollution created by each industry, including all pollution created to produce inputs to that industry, inputs to those inputs, and so on up the supply chain. We derive these total pollution coefficients that include upstream production by combining our direct pollution coefficients with the BEA Total Requirements Table.

Benchmark input-output tables are published by the BEA every five years and are used to map the flow of goods and services throughout the US economy. One of the benchmark tables, the Industry-by-Industry Total Requirements Table, shows the dollar value of inputs from each industry, both directly and indirectly, that is necessary to create one dollar of output for every other industry. This Total Requirements Table can be derived from the Direct Requirements Table, an $n \times n$ matrix $\mathbf{C}$ where each element c_{ij} contains the dollar amount of input industry i necessary to produce one dollar's worth of output industry j, using a Leontief input-output calculation. All we see in the CEX is final goods being consumed by households, an n-element vector $\mathbf{y}$. But what we really want to know is the amount that needs to be produced in order for households to consume $\mathbf{y}$. This amount of total production can be represented by an n-element vector $\mathbf{x}$.

Leontief noted that a simple linear production function implies that the relationship between $\mathbf{x}$ and $\mathbf{y}$ can be written

$$\mathbf{x} = \mathbf{C}\mathbf{x} + \mathbf{y}\,.$$

Total output ($\mathbf{x}$) is the sum of all production used as input ($\mathbf{Cx}$) and all production consumed as final products ($\mathbf{y}$). We observe $\mathbf{y}$ and want to know $\mathbf{x}$. To solve for $\mathbf{x}$, rewrite the equation as

$$\mathbf{x} = [\mathbf{I} - \mathbf{C}]^{-1}\mathbf{y}$$

where $\mathbf{I}$ is the identity matrix. Each element of the matrix $\mathbf{T} = [\mathbf{I} - \mathbf{C}]^{-1}$ (called the Leontief total requirements matrix) contains the dollar amount of industry i necessary to produce one dollar of output industry j, including all of the upstream industries used as inputs to j, the inputs to those industries, etc. The BEA reports estimated values for $\mathbf{T}$ in the Total Requirements Table. If we see $\mathbf{y}$ reported in the CEX as being consumed, the vector $\mathbf{x} = \mathbf{Ty}$ represents the total amount of manufactured goods necessary to produce that consumption $\mathbf{y}$.

We use the total requirements matrix to generate *total* pollution intensity coefficients. If **z** represents a vector of industry-specific pollution intensities, derived from the NEI data but transformed to match the IO industries, then

$$\tilde{\mathbf{z}} = \mathbf{z}'\mathrm{T}$$

represents a vector of total pollution intensity coefficients, including that upstream pollution.[9]

In this calculation, we pay special attention to the construction-related IO codes, which we consolidated into a single IO code (230000). The BEA input-output table lists the original (unconsolidated) IO codes both as input and final industries, which means that the construction industries show up as both row headings and column headings in the Total Requirements Table. To account for this, we first find the amount of each input industry required by the average construction industry by averaging the construction columns of the Total Requirements Table (creating the column IO 230000). Then we find the total value of construction inputs used for all other industries by summing the construction rows (creating the row IO 230000). With this consolidation, the input-output table matches our IO-level pollution coefficients and we calculate total coefficients. These total coefficients represent the amount of pollution created in order to produce $1 million in sales for each IO industry, including upstream pollution, based on 2002 production technology.

4. Matching consumption expenditure from the CEX to IO-level pollution intensity coefficients

To measure consumption expenditure on specific goods we rely on the Consumer Expenditure Survey (CEX) interview surveys, which include information on 80 to 95 percent of household consumption expenditure (U.S. Bureau of Labor Statistics, 2008).[10] Interviews for the CEX are conducted over five consecutive quarters; the initial interview collects demographic and family characteristics and the second through fifth interviews collect expenditure information.[11] Each survey round includes households in all stages of the five-quarter process, and new

[9] See Leontief (1970) for the original or Miller and Blair (1985) for a textbook explanation.
[10] Additional detailed information on the CEX is available from the Bureau of Labor Statistics (http://www.bls.gov/cex/home.htm).
[11] Expenditure information form the first interview are not used by the BLS for expenditure estimation and are not included in the public use microdata (U.S. Bureau of Labor Statistics, 2013).

households are introduced each quarter as old households leave the survey.[12] For example, the Q1 2012 survey includes total 6,838 consumer units, 1,733 of which are completing their second of five interviews and reporting expenditure information for the first time. Likewise, the Q2 2012 survey includes 6,715 consumer units, of which 1,641 are reporting expenditure for the first time and 5,074 are continuing through various steps of their five-quarter interview cycle.

In order to capture annual consumption, we consolidate expenditure across survey rounds and group households according to the date of their second interview. For example, we assign all households that completed their second (of five) interviews during the first quarter of 2012 to a Q1 2012 cohort. Expenditure information for these households is based on their responses to surveys conducted from Q1 to Q4 of 2012.[13] Thus we have a new set of households for each quarter, but each quarterly round of data captures a full calendar year of expenditures. The raw sample of 2012 households includes 8,782 households (2,230 entering in Q1, 2,208 entering in Q2, 2,201 entering in Q3, and 2,143 entering in Q4).

The CEX also includes descriptive demographic information, including household composition and estimates of before- and after-tax income. We exclude student households and households that did not respond to all four consecutive expenditure questionnaires. Excluding these households substantially reduces the sample (from 236,605 to 95,512) and may introduce attrition bias as young renters are less likely to complete all five surveys. We account for this by reweighting the sample based on age groups and homeowner/renter status.[14] We also exclude households with nursing home expenditure (0.5 percent of the raw sample) and trim the top and bottom one percent of households based on after-tax income.

[12] The CEX is organized based on consumer units, rather than households. A consumer unit is smaller than a household and consists of "(1) All members of a particular household who are related by blood, marriage, adoption, or other legal arrangements; (2) a person living alone or sharing a household with others or living as a roomer in a private home or lodging house or in permanent living quarters in a hotel or motel, but who is financially independent; or (3) two or more persons living together who use their incomes to make joint expenditure decisions" (US Bureau of Labor Statistics, 2008). For convenience the terms "households" and "consumer units" are sometimes used interchangeably, and we follow suit.

[13] Household interviews collect expenditure information for the prior three months. We group households based on the dates of the surveys, not the dates of the actual expenditures.

[14] We follow the same procedure used for the NBER CEX extracts to create a "usable sample" and adjusted weights: "First, the respondents must have met the BLS "complete income reporter" requirement. Second, the household must have completed all four quarterly [follow-on] interviews... Finally, student households are dropped. Excluding households using the above criteria (about half) introduces substantial attrition bias, most notably, young renters tend not to complete the survey. Therefore, an attrition adjustment based on six age groups and renter/homeowner status is used to reweight the sample" (Harris and Sabelhaus, 2000).

Incomes and expenditures in the CEX are categorized based on the Universal Classification Code (UCC) system. The UCC system was developed in the 1970s in an effort to harmonize the Consumer Price Index with the CEX (Smith and Schmidt, 2001). The coding system groups consumption into roughly 850 categories such as “gas, bottled or tank,” “boys underwear,” and “electrical system repair.”[15] Unlike NAICS industries, there is no official concordance between UCC codes and IO codes. Instead, we manually assign each UCC code to an individual IO industry based on comparing the descriptions of consumption categories and production industries. Then by summing the UCC-based expenditure within a given IO industry, we find the total consumption for each IO industry based on the CEX data.

The challenge to matching CEX expenditure data to BEA industries is that the BEA classifies industries based on their production, whereas the CEX classifies expenditure based on types of consumption. Many of the consumption categories clearly correspond to a specific IO industry. For example, UCC code 339992 (music instruments/accessories) clearly matches IO industry 339992 (musical instrument manufacturing). But not all consumption items are unambiguous; many require a subjective decision about which production industry most closely corresponds to the consumption category. For example, we match UCC code 680904 (dating services) to IO industry 5111A0 (database, directory, and other publishers).

There are many more consumption categories in the CEX than there are IO industries in the input-output tables.[16] As a result, a single IO industry often encompasses several UCC consumption items.[17] In addition, not all IO codes are relevant for household consumption. In those cases there are no UCCs assigned to the IO industries and the pollution coefficients from those industries do not affect household pollution (directly).

Finally, we classify each item’s IO industry as core consumption, electricity, food and beverages, gasoline, or gas/oil. This is so that we can apply separate price deflators to these five broad consumption categories.

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[15] A complete list of UCC codes and their descriptions are included in the documentation for each round of the CEX data, available at http://www.bls.gov/cex/csxmicrodoc.htm.

[16] There are 858 unique UCC codes used in the CEX between 1984 and 2014 while there are 417 production-related IO codes used by the BEA in the benchmark input-output tables. Further, many of the 417 IO codes do not correspond directly to a UCC category.

[17] For example IO industry 513300 (telecommunications) includes eight separate consumption categories ranging from residential telephones and pay phones to global positioning services.

5. Finding the total pollution associated with each household's consumption

We calculate the total amount of pollution associated with each household's consumption based on 2002 production technology. For any given household we multiply the itemized IO-level consumption by the IO-level total pollution coefficient to find the amount of pollution associated with each individual category of consumption. Then by summing pollution from all categories within a given household's annual consumption, we find the total amount of pollution attributable to each household.

In order to compare consumption expenditure in various years to per-dollar pollution intensity coefficients from 2002, we discount all expenditure to real 2002 dollars using the Consumer Price Index. But the price trends for various categories of products—such as food, energy, and core consumption—followed disparate trends over the 30 year period from 1984 to 2014. For example, figure A.2 shows the CPI for each of those categories from 1984 to 2014. Since we don't want our estimate of household pollution to be driven by price changes, we separately discount food and beverages, electricity, gasoline, fuel oil, and core consumption using category-specific CPIs.

After discounting consumption to 2002 dollars, we match consumption in each year to 2002 pollution intensity data in order to hold production technology constant. We repeat this process for every household in all relevant years of the CEX and find a single value for each household that represents the total pollution associated with that household's consumption. This amount of pollution reflects the pollution created using 2002 production technology and can be compared to household income and other demographics to estimate environmental Engel curves across households and over time.

6. Household income, after tax income, and total consumption expenditure

The income measure we use is after-tax income from the CEX. While consumer expenditure data are elicited over the course of four consecutive quarters (rounds two through five of the survey), the income information is only collected during the second and fifth rounds and covers the 12-month period prior to the specific survey round.[18] Since we want our income measure to correspond contemporaneously to household expenditure, we rely on annual income reported during the fifth survey round, covering the same 12 months as the expenditure data.

[18] For more details see, for example, the 2012 CEX Public Use Micro Dataset documentation.

Income measured in the CEX tends to be lower than income measured in other surveys (Garner, McClelland, and Passero, 2009). Figure A.3 compares the after-tax income we use from the CEX to that reported by the Congressional budget Office (CBO), as well as income measured in the Current Population Survey (CPS).

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8. Tables

Table A.1. Parametric EECs for Other Air Pollutants
(Full version of Table 3)

Dependent variable (pounds):	VOC		NO_x		SO_2		CO	
	1984	**2012**	**1984**	**2012**	**1984**	**2012**	**1984**	**2012**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
After-tax income (10,000 2002 dollars)	2.281	1.857	6.720	6.020	10.45	9.527	5.961	4.622
	(0.337)	(0.161)	(0.838)	(0.470)	(1.479)	(0.840)	(0.685)	(0.417)
After-tax income squared	0.00335	-0.0349	-0.00649	-0.125	0.0362	-0.188	-0.0396	-0.0920
	(0.0256)	(0.0106)	(0.0658)	(0.0278)	(0.116)	(0.0494)	(0.0545)	(0.0252)
Household size	3.105	1.997	14.14	11.45	23.11	18.70	6.900	4.048
	(0.508)	(0.308)	(1.368)	(1.268)	(2.355)	(2.374)	(1.152)	(0.848)
Household size squared	-0.215	-0.0962	-0.935	-0.587	-1.600	-0.939	-0.553	-0.201
	(0.0559)	(0.0361)	(0.150)	(0.169)	(0.254)	(0.328)	(0.126)	(0.0988)
Age	0.455	0.230	1.714	1.100	2.700	1.806	1.084	0.524
	(0.0749)	(0.0541)	(0.198)	(0.186)	(0.345)	(0.347)	(0.168)	(0.148)
Age squared	-0.00440	-0.00189	-0.0149	-0.00767	-0.0238	-0.0124	-0.0104	-0.00401
	(0.000714)	(0.000490)	(0.00190)	(0.00184)	(0.00328)	(0.00348)	(0.00158)	(0.00134)
Married	1.799	2.175	4.664	5.165	7.672	7.706	4.147	5.357
	(0.573)	(0.403)	(1.633)	(1.205)	(2.841)	(2.127)	(1.430)	(1.071)
Race = Black	-3.788	-2.030	-9.941	-3.178	-16.65	-3.953	-8.550	-4.582
	(0.570)	(0.567)	(1.661)	(1.485)	(2.921)	(2.625)	(1.381)	(1.519)
Race = Asian	0.898	-3.249	-6.717	-10.34	-15.77	-17.37	-2.791	-7.876
	(2.678)	(0.625)	(4.486)	(2.041)	(6.947)	(3.582)	(4.650)	(1.653)
Race = Other	-4.349	-0.583	-13.37	-2.109	-22.08	-3.359	-10.99	-2.194
	(1.414)	(1.231)	(4.859)	(3.383)	(8.295)	(5.958)	(3.311)	(3.206)

(continued)

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High school	1.942	1.633	7.949	7.503	13.25	12.97	2.893	4.398
	(0.642)	(0.442)	(1.745)	(1.407)	(3.096)	(2.565)	(1.491)	(1.259)
Some college	2.788	2.224	10.82	9.051	16.28	15.15	5.279	5.636
	(0.677)	(0.412)	(1.847)	(1.403)	(3.164)	(2.570)	(1.726)	(1.184)
College	2.704	2.693	12.71	10.25	21.53	16.95	4.511	6.983
	(0.917)	(0.547)	(2.718)	(1.739)	(5.010)	(3.261)	(2.381)	(1.645)
Graduate	2.469	3.430	12.44	13.10	20.62	20.99	4.984	8.036
	(0.892)	(0.755)	(2.576)	(2.332)	(4.411)	(4.027)	(2.302)	(2.096)
Midwest	0.525	-1.592	2.942	-2.997	2.874	-4.126	1.951	-2.800
	(0.719)	(0.555)	(1.845)	(1.360)	(3.157)	(2.386)	(1.577)	(1.290)
South	1.284	-0.668	10.00	7.140	22.70	15.92	4.979	0.196
	(0.718)	(0.531)	(1.909)	(1.362)	(3.240)	(2.359)	(1.595)	(1.250)
West	0.390	-0.701	-4.063	0.270	-7.885	1.006	2.232	-0.170
	(0.691)	(0.578)	(1.841)	(1.514)	(3.013)	(2.724)	(1.801)	(1.393)
Rural	-0.117	-0.0781	5.328	0.693	15.29	2.985	1.328	0.000931
	(0.708)	(0.592)	(2.036)	(1.825)	(3.647)	(3.469)	(1.762)	(1.844)
Constant	-8.524	-3.741	-37.52	-22.61	-59.21	-34.66	-21.73	-9.606
	(1.871)	(1.365)	(5.115)	(4.398)	(9.140)	(7.918)	(4.526)	(3.751)
Income elasticity at median	0.402	0.382	0.311	0.270	0.308	0.254	0.437	0.393
	(0.0354)	(0.0230)	(0.0226)	(0.0161)	(0.0247)	(0.0171)	(0.0304)	(0.0266)
F-test on income coefficients	126.9	205	184.8	216.8	160.8	168.6	161.7	154.8
Observations	3,184	3,538	3,184	3,538	3,184	3,538	3,184	3,538
R-squared	0.413	0.361	0.555	0.473	0.521	0.430	0.403	0.313

See notes for table 2.

9. Figures

Figure A.1: Summary of Data Procedure

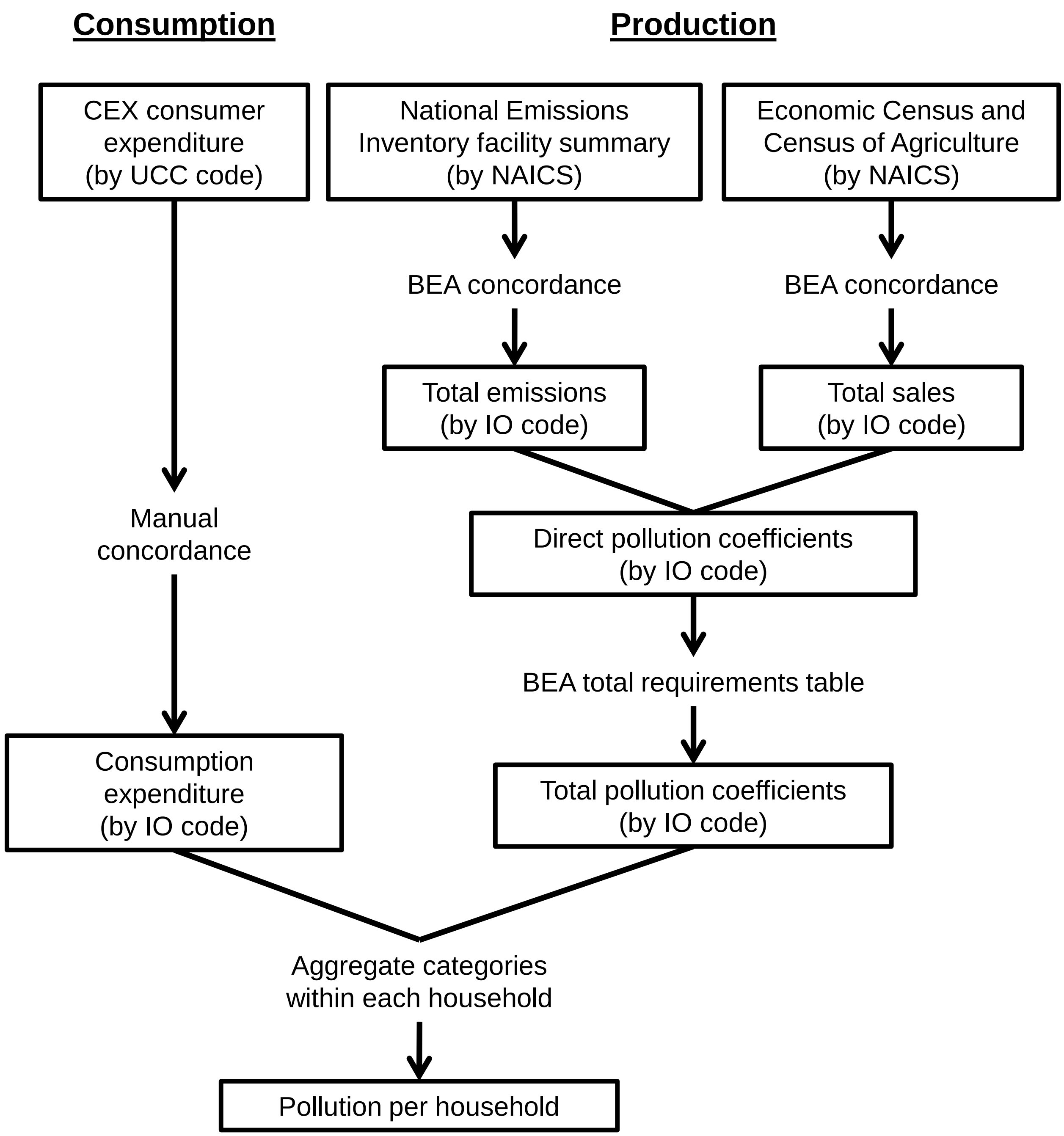
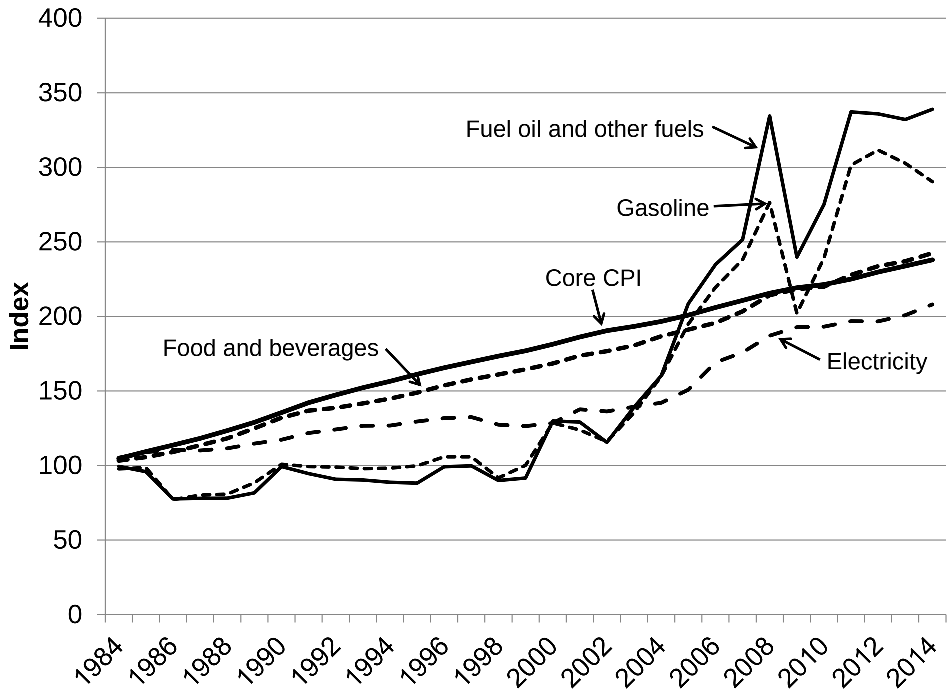
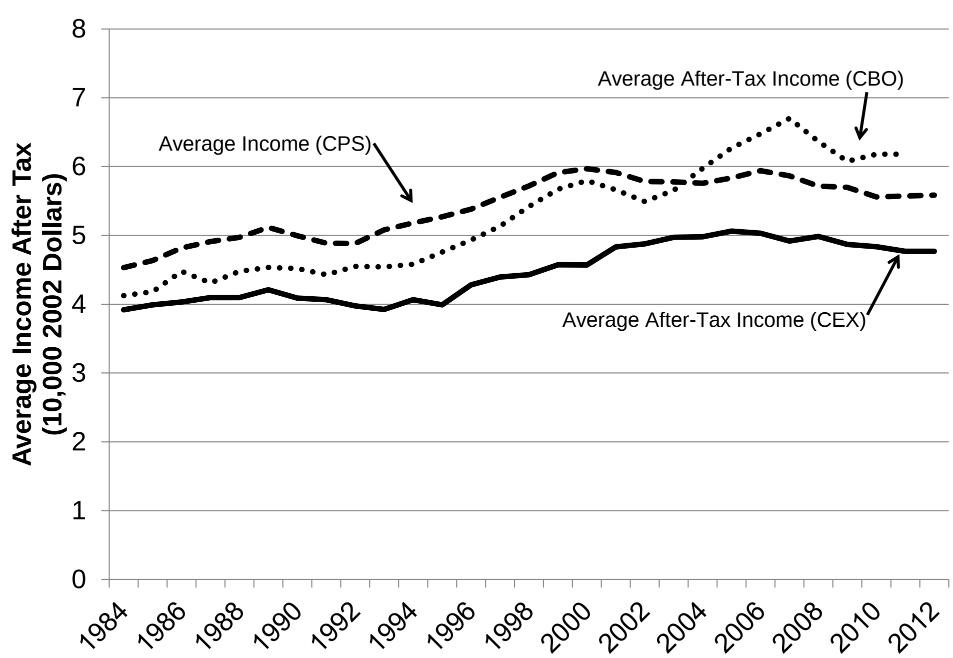


Figure A.2: Components of the Consumer Price Index, 1982-2014



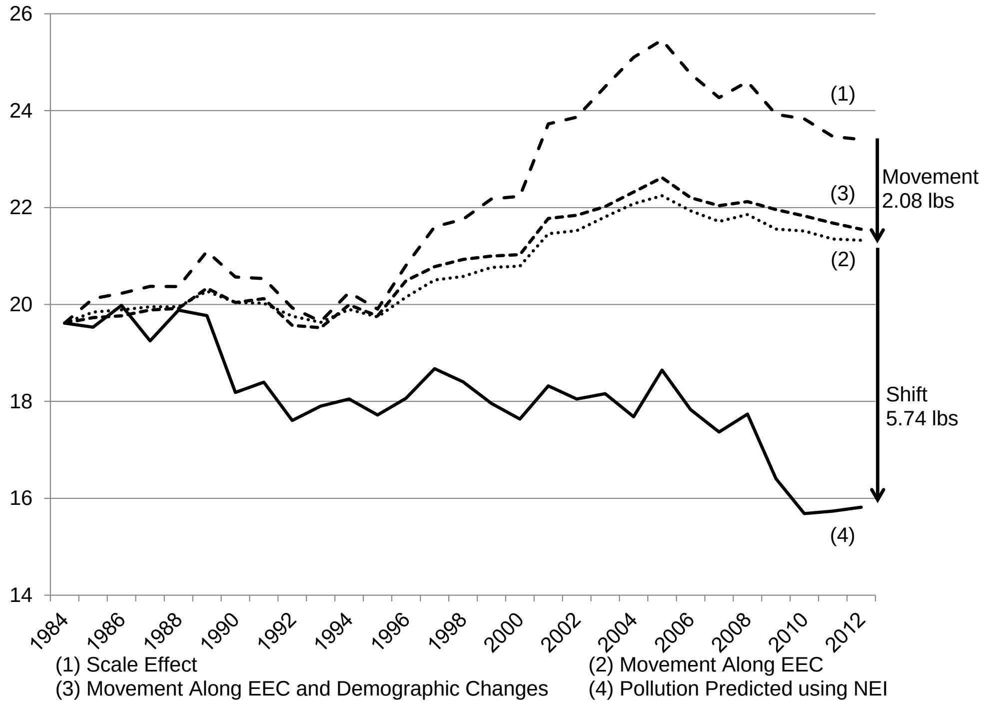
Note: Core CPI includes all items, less food and energy.
Source: Bureau of Labor Statistics, Consumer Price Index (available at http://www.bls.gov/cpi/)

Figure A.3: Income Measured in Household Surveys



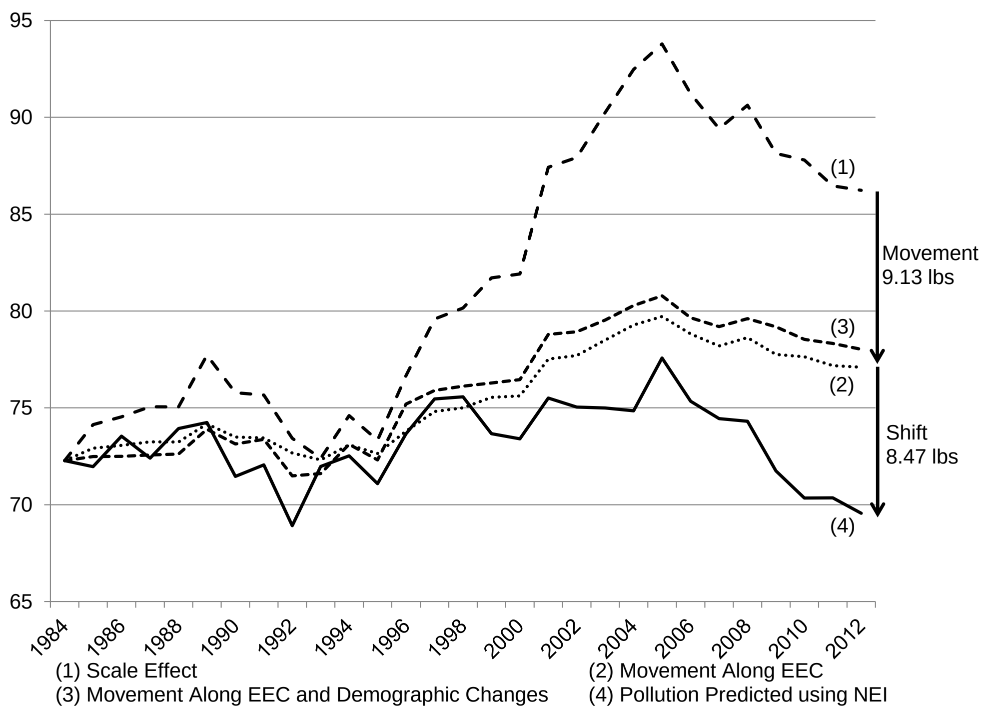
Sources: Bureau of Labor Statistics, 2016; Congressional Budget Office, 2014; U.S. Census Bureau, 2016.

Figure A.4. Decomposition of Predicted Pollution from Household Consumption: VOC



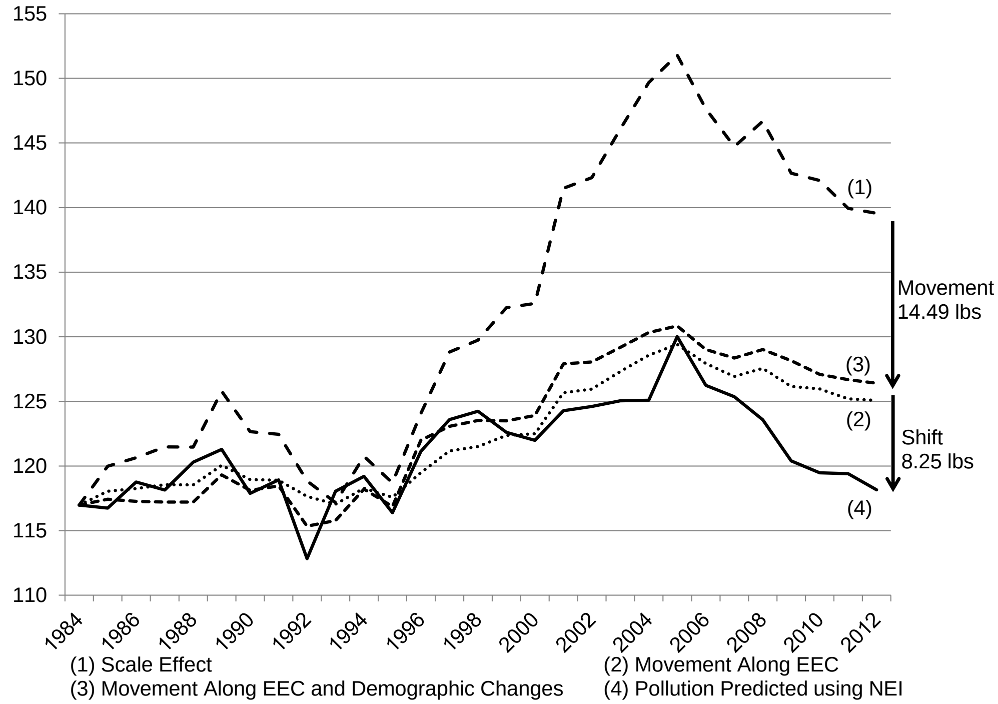
Notes: The scale effect is calculated by increasing pollution in proportion to real after-tax income growth. Movements along and shifts in the EEC are calculated by estimating pollution in each year using the 1984 EEC coefficients. Pollution predicted using NEI-based pollution coefficients is estimated by matching itemized consumption expenditure in each year with the corresponding industry's 2002 pollution intensity.

Figure A.5. Decomposition of Predicted Pollution from Household Consumption: NO_x



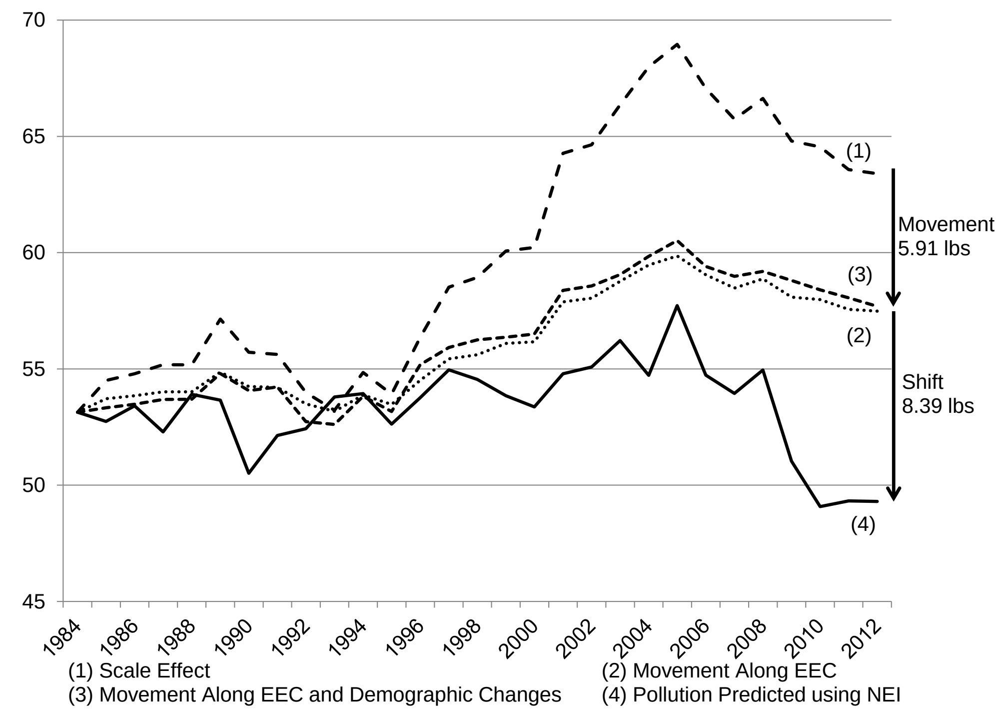
See notes to figure A.4.

Figure A.6. Decomposition of Predicted Pollution from Household Consumption: SO_2



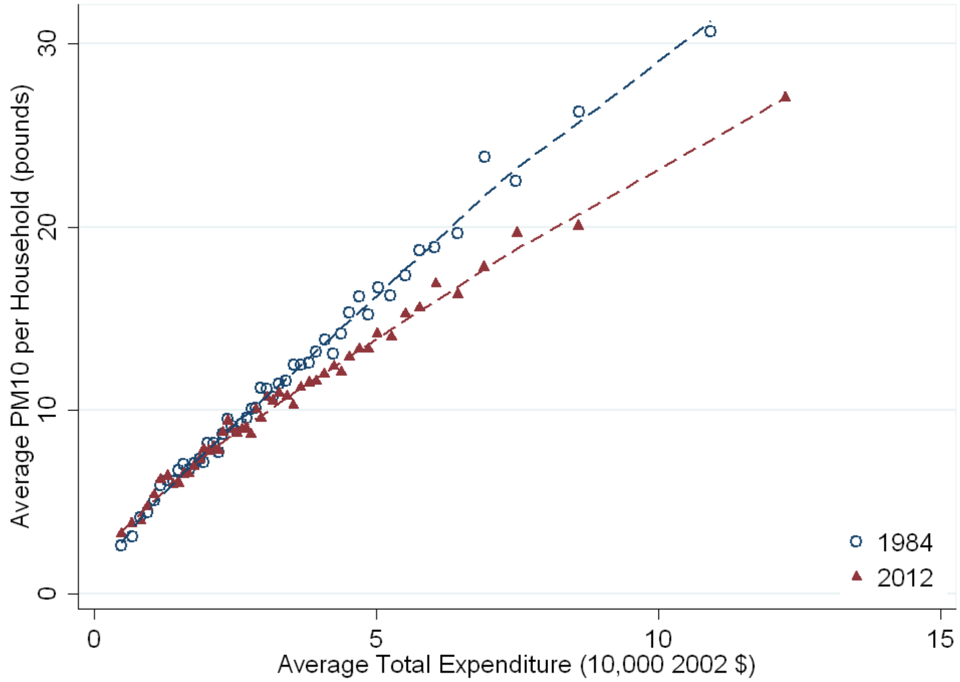
See notes to figure A.4.

Figure A.7. Decomposition of Predicted Pollution from Household Consumption: CO



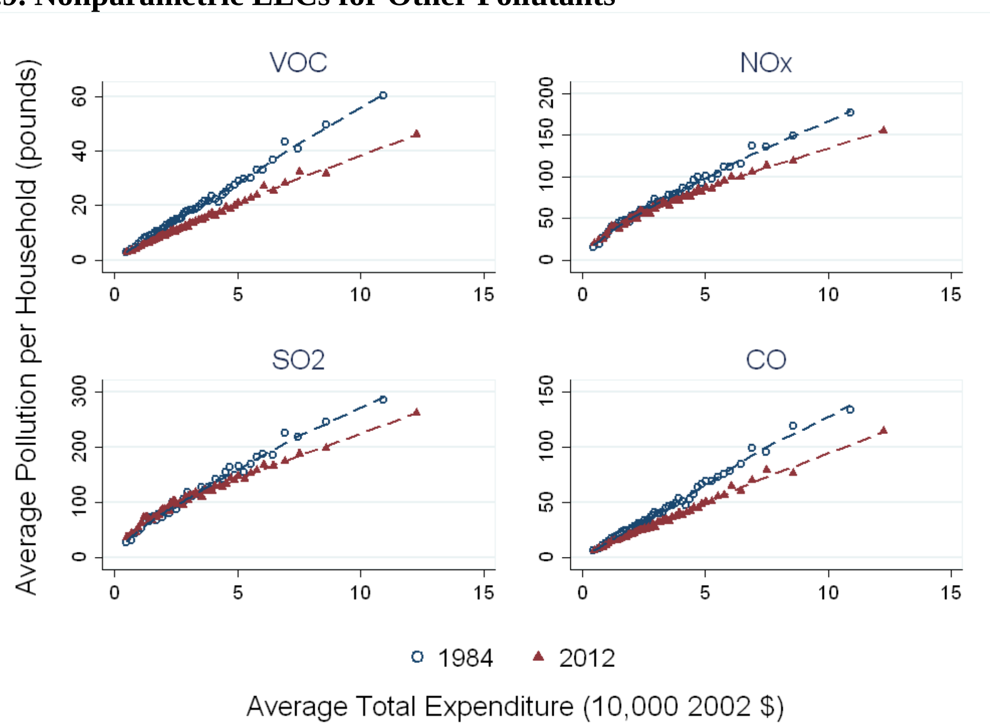
See notes to figure A.4.

Figure A.8. EECs Based on Total Expenditure – PM10



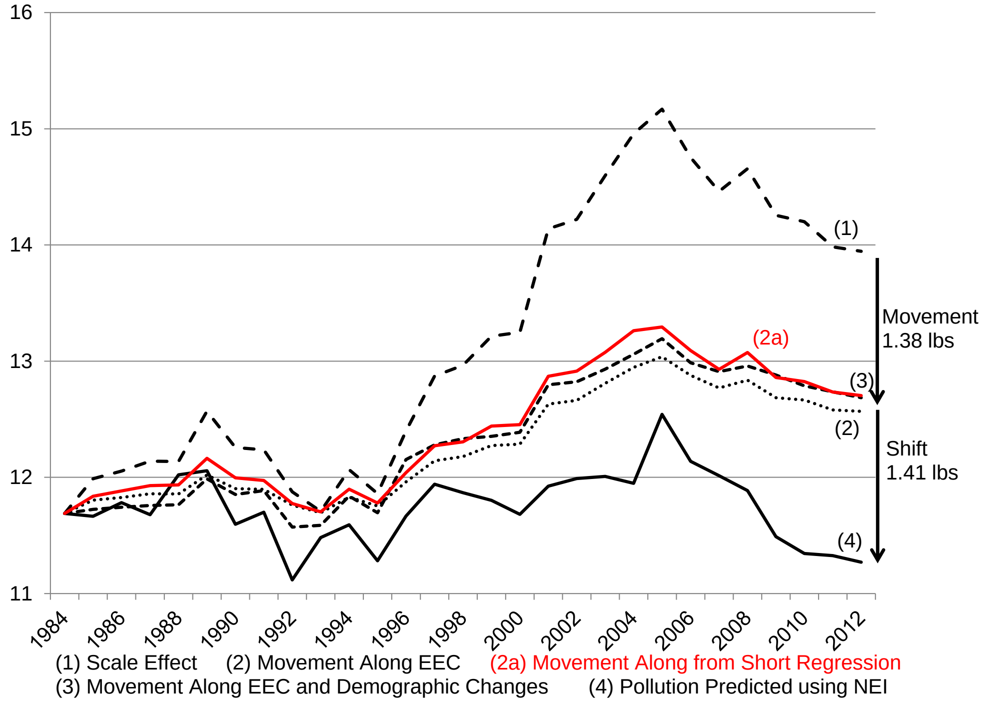
Total expenditure is adjusted for inflation using the all-items CPI. Itemized consumption expenditure is adjusted using the core CPI with food, fuel, gasoline, and electricity adjusted separately using the corresponding CPI. Each pair of dots represents an income level corresponding to 2 percent of the 1984 CEX sample, with the highest and lowest one percent of households trimmed based on after-tax income. The top income bin includes all remaining households with real annual after-tax income higher than $110,529.

Figure A.9. Nonparametric EECs for Other Pollutants



See notes to figure A.8.

Figure A.10. Decomposition of Predicted Pollution from Household Consumption



This is a version of figure 6 in the paper, with line 2a added. Line 2a plots changes to predicted PM10 changes from movement along an EEC estimated using a quadratic in income alone, with no covariates.

Figure A.11. Income coefficients over time—PM10

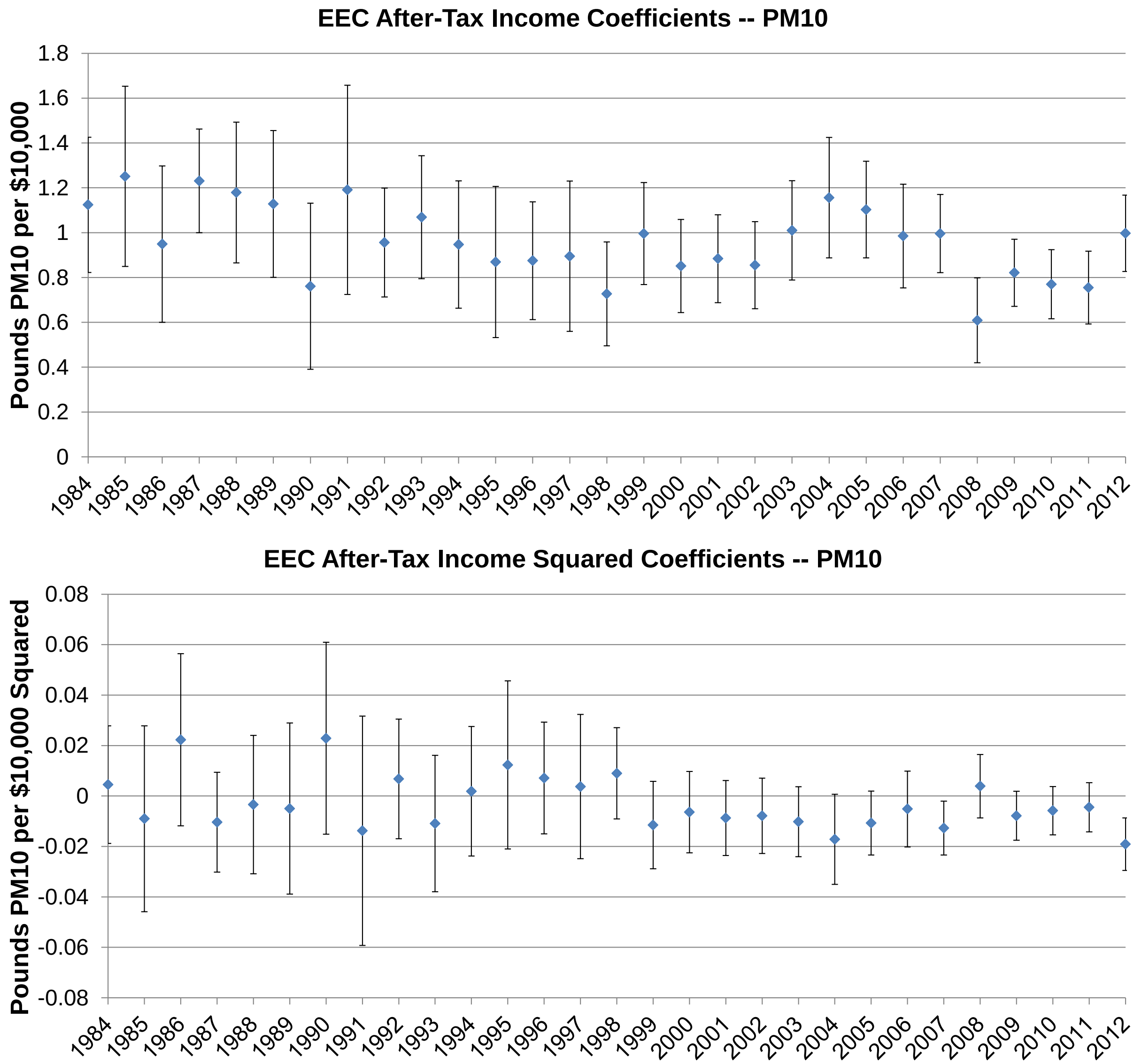


Figure A.12. Share of Households in Each Income Bin from Figures 1 through 3

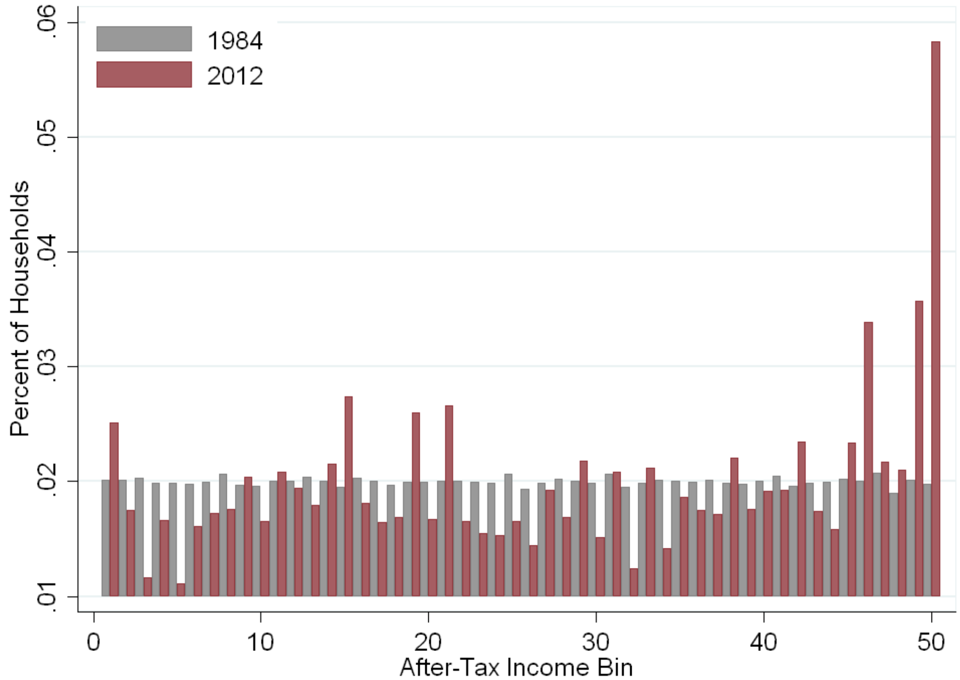
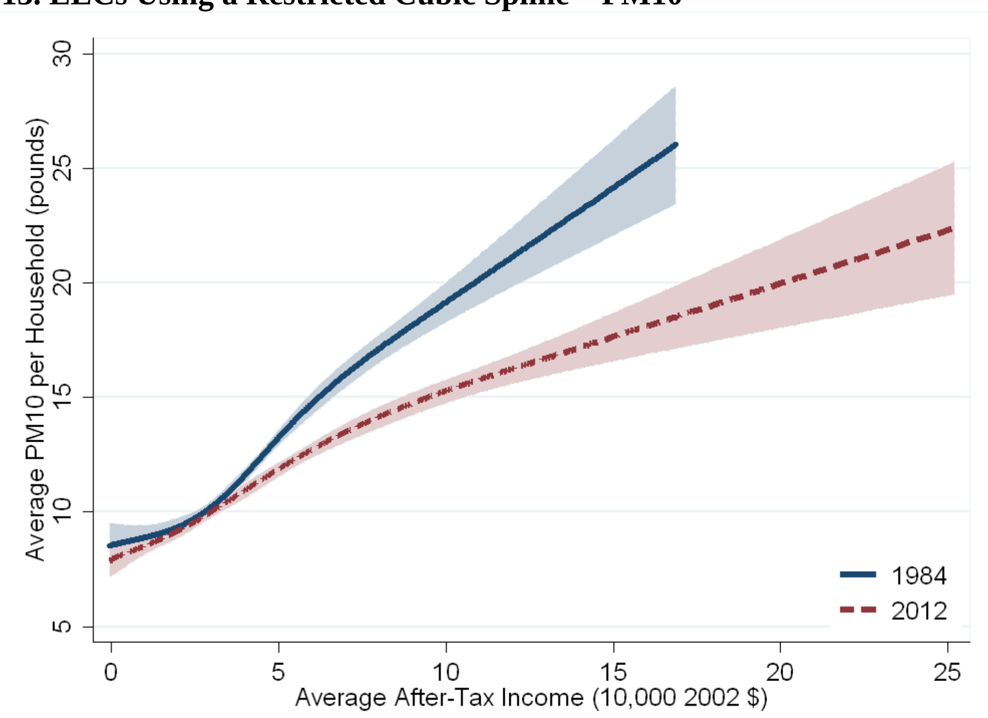
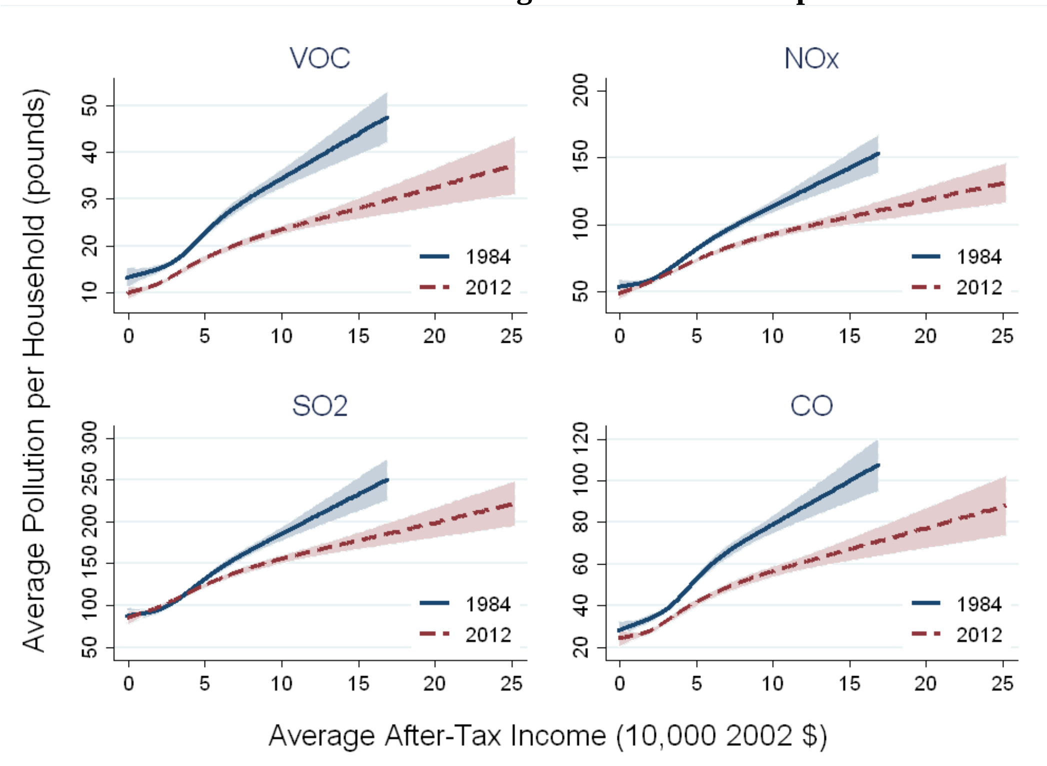


Figure A.13. EECs Using a Restricted Cubic Spline – PM10



Inflation adjustments as in figure 1. All other covariates are fixed at their mean values. Estimation is based on five knots placed at percentiles as suggested in Harrell (2001). Standard errors for pollution intensity of production are not estimated, so 95 percent confidence intervals (shaded) reflect variation in household spending.

Figure A.14. EECs for Other Pollutants Using Restricted Cubic Splines



See notes to figure A.13.