Engel Curves on Outsourcing and Foreign Environmental Taxes: A Valued-Added Approach *

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Abstract

This paper estimates Engel curves on the foreign content (outsourcing) and the foreign environmental taxes embedded in the consumption of final goods and services in the United States (U.S.). We estimate Engel curves using U.S. household income and consumption information from 1996 to 2011 and find that they are concave, shift down over time on the foreign content of goods, and shift up over time on foreign environmental taxes. Our results suggest that the foreign content in U.S. household consumption bundles decreased over time primarily because the significant income increase has led to a shift in consumption towards goods with greater domestic content. This effect represents then a movement along the Engle curve. On the other hand, we find that the greater share of U.S. household consumption of goods using foreign inputs sourced by countries with higher environmental taxes is due to other factors besides income. Thus, these factors are responsible for the upward shift in this Engel curve.

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1 Introduction

The integration of the world economy has achieved unprecedented levels during the 2000s.[1] It has essentially reshaped the global economy linking markets and consumers at a scale unimaginable just a few decades ago. An important facet of this integration process is the fragmentation of the production process across national borders (Koopman et al., 2014; Antràs and Helpman, 2004), a phenomenon better known as global sourcing. This important phenomenon is consequential in many dimensions, an essential one being the challenge of linking consumption decisions to the domestic production of goods using national input-output tables. By definition, the presence and growth of foreign outsourcing mean that domestic consumption choices may be related to imports of foreign-sourced inputs used in producing domestic goods and services for final consumption. In this paper, we investigate the relationship between U.S. household incomes and the foreign content of the final goods and services they consume. Moreover, we also study the relationship between household incomes and the associated foreign environmental taxes embedded in their consumption bundles. We rely on the concept of Engel curves to study these relationships since our focus is the effects of consumption decisions. In the former case, we call this relationship the Engel curve on the foreign content of goods, while, in the latter case, we label it the Engel curve on the foreign environmental taxes.

The numbers on the fragmentation of production processes leave no margin for doubts about the importance of this topic. Johnson and Noguera (2017) show that the ratio between value-added and gross exports fell by 20 percentage points in manufacturing sectors between 1970 and 2009.[2] This finding implies that countries increasingly rely on foreign inputs to produce exported goods and services. Importantly, Antràs and Staiger (2012) indicate that most of the growth in international trade flows occurred through dif-

[1] Bagwell et al. (2016) show that the most-favored-nation tariffs applied by developed countries on manufactured products decreased, on average, by 85 percent. Likewise, Nicita et al. (2018) argue that the average tariff faced by world exporters averaged around 2.6 percent in 2006. See their column at "https://cepr.org/voxeu/columns/trade-war-will-increase-average-tariffs-32-percentage-points".

[2] Wolszczak-Derlacz and Parteka (2018) confirm a substantial rise in offshoring in recent decades. The manufacturing offshoring intensity in 40 countries measured as the ratio of imported intermediate inputs to the value-added rose from 0.24 in 1996 to 0.30 in 2008.

ferentiated inputs. Thus, they confirm the importance of process fragmentation across borders and highlight that the uniqueness of inputs being traded challenges the multilateral trade system since bilateral negotiations may be needed to overcome holdup problems. Most recently, policy concerns with international integration have resurfaced, primarily since the election of former U.S. President Donald J. Trump.[3] These concerns with production fragmentation have also become intertwined with environmental policy. The U.S. Inflation Reduction Act of 2022 promotes the consumption of fuel-efficient vehicles (e.g., electric and hybrid cars) while promoting domestic production (or imports from preferential U.S. partners) of auto batteries and their components.[4] It then represents a key recent policy where economic integration and environmental policies intertwine. Notice that a central pillar of these policies is consumption behavior, where policy makers try to influence with various policy tools, which we study in this paper via estimation of Engel curves.[5]

Our econometric strategy to estimate these Engel curves follows the approach adopted by Levinson and O'Brien (2019). Our source of information about U.S. household incomes, expenditures, and demographic characteristics is the Consumer Expenditure Survey (CEX) from the Labor Bureau of Statistics, which is also used in their study. Instead, information on the production of final goods and services and input-output linkages is provided by the World Input-Output Database (WIOD). In this case, we can map the U.S. production of final goods and services to their foreign input sources, a point not explored in Levinson and O'Brien (2019). Notice that this mapping strategy allows us to measure the U.S. household exposure to the foreign content of the final goods and services they consume. Importantly, we can also use these production linkages to relate foreign

[3] It is well documented that former President Trump initiated various trade skirmishes, some multilateral (e.g., tariffs on steel and aluminum) and some geared towards specific countries (e.g., tariffs on Chinese products via U.S. Section 301). For a timeline of these events, see https://www.piie.com/blogs/trade-and-investment-policy-watch/trumps-trade-war-timeline-date-guide.

[4] For more information, see U.S. President Joseph Biden's statement on electric vehicles and battery manufacturing at https://www.whitehouse.gov/briefing-room/statements-releases/2022/10/19/fact-sheet-biden-harris-administration-driving-u-s-battery-manufacturing-and-good-paying-jobs/

[5] Chai and Moneta (2010) find that Engel's work contains some interesting features in juxtaposition to both modern and classical literature. Then, they offer a few thoughts about the contemporary literature spawned by Prais and Houthakker (1955) and how it built upon Engel's research. Their paper does not include a discussion about foreign content.

inputs to their country of origin's environmental taxes by using the OECD Environmentally Related Taxes (ERT) database. This strategy enables us to measure U.S. households' exposure to foreign environmental taxes. This matter is undoubtedly vital since the acceleration of international trade has led to concerns about the potential adverse effects of international trade on the environment (Bombardini and Li, 2020; Tosun and Knill, 2009).

We use non-parametric and parametric econometric strategies to estimate these two Engel curves yearly, covering the period from 1996 to 2011. Their main characteristics are very robust regardless of the econometric strategy and whether or not we control for other household characteristics besides their income. The estimated Engel curves are concave and display a quadratic shape relative to income. Thus, their shape implies that high-income U.S. households may consume a bundle of goods and services with lower foreign content intensity than middle-income households. Likewise, high-income U.S. households consume more products that rely on foreign inputs from countries with lower environmental taxes than middle-income households. Importantly, we show that the Engel curve on foreign content shifts downwards over time while the Engel curve on foreign environmental taxes moves upwardly over the years. These shifts suggest that U.S. household consumption decisions have moved in the opposite direction to globalization by choosing goods with lower foreign content intensity over time. Instead, the results imply that the same decisions have favored goods and services relying on foreign inputs from countries with more lenient environmental policies, as signaled by their lower taxes.

The factors explaining these results borrow heavily from the literature investigating the evolution of U.S. pollution emissions. For example, in a seminal paper, Levinson (2009) decomposes and measures the evolution of U.S. pollution into a scale effect, a composition effect, and a technique effect.[6] His results show that despite an increase in income, which produces a positive scale effect, the change in consumption choices towards cleaner goods (negative composition effect), and, primarily, because of decreases in pollution intensity (negative technique effect), emissions of major pollutants due to U.S.

[6] This decomposition is originally proposed in Copeland and Taylor (1995).

manufacturing activity have been reduced, on average, by twenty-five percent from 1987 to 2001. Besides, Shapiro and Walker (2018) confirm the prominence of the technique effect in explaining the reduction in the emission of major pollutants during manufacturing activity. But, most importantly, they show that the implicit cost of environmental regulations is primarily responsible for these significant emission reductions. In contrast, increases in firm-level productivity and reductions in trade costs do not play important roles in explaining this phenomenon.

Our paper focuses on the contribution of consumption decisions in explaining the foreign content and environmental taxes embedded in the consumption of goods and services. For this reason, we keep the input-output linkages and foreign environmental taxes at their 2002 levels. This decision essentially mutes the technique effect discussed above, corresponding to a decision also present in Levinson and O'Brien (2019). Notice that our measure for the average (across U.S. households) exposure to foreign content on consumption bundles decreases by about 9 percent over the years, while its counterpart involving exposure to foreign environmental taxes increases by about 2 percent. These effects seem economically meaningful. In addition, we find that changes in the composition effect cause 60 percent of the effect related to foreign content, i.e., as U.S. household incomes grew, they shifted to consuming goods with lower foreign content (negative composition effect). This effect represents a movement along the Engel curve. On the contrary, most of the impact related to the increase in exposure to foreign environmental taxes is driven by other (non-income effects) factors causing a shift in the Engel curve. Moreover, we consider the effects of income redistribution on consumption decisions. We conclude that income redistribution may lead to a shift in imports of inputs towards countries with higher environmental taxes. At the same time, it may lead to more economic integration as measured by the foreign content used to produce final goods and services.

Our paper is strongly related to the literature that uses the concept of Engel curves to study different economic phenomena.[7] As suggested above, Levinson and O'Brien

[7]Dunbar et al. (2013) use Engel curves to identify how total household resources divided up among household members. They find that large shares of resources are devoted to children, and the share increases

(2019) use Environmental Engel curves to study how U.S. consumption decisions have affected pollution emissions.[8] They conclude that the composition effect and other non-income factors[9] (price changes and availability of goods) are equally responsible for the reduction in average emissions embedded in U.S. household consumption bundles. Sager (2019) estimates Environmental Engel curves to relate U.S. household incomes to the (carbon dioxide) CO_2 emissions embedded in their consumption choices. He can then estimate the effects of redistribution of income on CO_2 emissions, concluding that it may lead to greater emissions and create an "equity-pollution dilemma." A vast literature has studied the effects of aggregate (national) income on aggregate pollution levels across countries using Kuznets curves.[10] The general finding is that pollution emissions increase to a certain income point and then decrease. This relationship then displays an inverted U-shaped form. More recently, Kacprzyk and Kuchta (2020) used a novel dataset[11] to proxy for development levels and estimate this curve for CO_2 emissions using data from 1992 to 2012. They find that the income threshold, beyond which increases in income lead to declines in pollution, is smaller and more stable than the previous thresholds discussed in the literature. Notice that these papers neither focus on household exposure to the foreign content of consumption bundles nor rely on the WIOD to link household consumption to the sourcing countries accurately nor control foreign environmental taxes.[12]

The rest of the paper unfolds as follows: section 2 describes the data and methodology; section 3 presents the nonparametric estimates; section 4 explains the empirical

with the number of children.

[8]They estimate separate Engel curves for five main pollutants, namely: particulates smaller than 10 microns (PM10), volatile organic compounds (VOCs), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and carbon monoxide (CO).

[9]Non-income factors cause shifts in the Engel curve. On the contrary, income changes cause a movement along the curve.

[10]Torras and Boyce (1998) bring 'political and social economy' in environmental Kuznets curve and find that the growth of per capita income can be accompanied by improvements in at least some important dimensions of environmental quality in the developing countries. Hettige et al. (2000) suggest that the evidence on the inverted-U relationship only applies to a subset of environmental measures. By measuring the effect of income growth on three determinants of industrial water pollution, the environmental Kuznets curve rises rapidly through middle-income status and remains roughly constant thereafter.

[11]They use the Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS) nighttime light imagery as a proxy for the income level.

[12]Cole et al. (2014) combines production data with international environmental outsourcing data for Japanese firms. They conclude that Japanese firms outsource the dirtier stages of production to minimize domestic environmental regulation costs.

strategy and discusses the results for parametric estimation of the Engel Curves; section 5 discusses the average decomposition of the average index values over time, and applies the estimated Engel curves to evaluate the effects of income redistribution efforts. Finally, section 6 concludes.

2 Data and Methodology

2.1 Data

Our key objective is to understand the relationship between household income, consumption, and the degree to which U.S. production of final goods relies on foreign-sourced inputs. These datasets enable us to estimate the Engel curve on the foreign content of goods. Likewise, we want to relate the U.S. consumption of final goods to the environmentally related taxes of the countries exporting inputs used in the U.S. production of final goods. This information enables us to estimate the Engel curve on foreign environmental taxes. Essentially, this effort requires detailed information on individual household consumption, the use of foreign-sourced inputs in the U.S. production of final goods, and foreign environmentally related tax rates of countries exporting inputs to the U.S. Importantly, our data on consumption and incomes cover the years from 1996 and 2011.

Our data with detailed information on household consumption choices and income is provided by the Bureau of Labor Statistics (BLS) in two quarterly surveys: the Interview Survey for major and recurring items and the Diary Survey for more minor or frequently purchased items. The CEX provides information on itemized household expenditures, incomes, and demographic characteristics. Following Levinson and O'Brien (2019), we exclude households with expenditures on nursing homes, students, and the top and bottom 1 percent of households based on after-tax income. In addition, the sample is reweighted by age groups and homeownership status to deal with the potential bias caused by the sample size reduction. The CEX captures around 80 to 95 percent of total household expenditures and is categorized by about 850 universal classification codes (UCCs).

The estimated Engel curves relate household income over time to foreign outsourcing and foreign environmental tax indexes derived from the U.S. production of final goods and services. Notice that input-output matrixes allow researchers to connect the production value of domestic goods to the value added from inputs originating from different industries. The World Input-Output Database (WIOD) extends it to consider value-added from inputs originating domestically and from different countries and industries. Thus, it enables us to trace the contribution of foreign inputs (outsourcing) to the U.S. production of final goods. Information from CEX allows us to relate household income to house expenditure across industries. The combination of both datasets allows us to relate household income to foreign inputs embedded in U.S. household consumption. A similar rationale can be extended to the relation between U.S. household consumption and foreign environmental taxes as detailed below.

This strategy requires us to concord UCCs to the industries used in the World Input-Output Database (WIOD). This concordance proceeds in two steps. First, we follow Levinson and O'Brien (2019)'s strategy to concord UCCs to the industries in the U.S. Input-output (IO) matrix. Second, we expand on their work by constructing a concordance connecting IO codes to the WIOD codes, thus bridging the linkage between CEX and WIOD codes.[13] Numerous IO codes may correspond to the same WIOD code owing to the restricted number of sectors (35 sectors and 40 countries) in the World Input-Output Database.[14] The WIOD provides a set of national input-output tables connected by bilateral international trade flows. Then, the WIOD provides for a given user, defined at the country and industry level, the information about the distribution of the output of different industries across countries. Therefore, the gross output of each U.S. industry is equal to the sum of the uses of foreign countries and the uses of other U.S. industries.

[13] We provide further details on the concordance between the UCCs and the WIOD industries in the supplemental appendix.

[14] See Timmer et al. (2015) for details on the WIOD.

Our approach focuses on the relationship between household income levels and their consumption decisions. For this reason, we maintain technology and foreign environmental taxation constant for our baseline results while accommodating discussions on potential technology changes and income redistribution as extensions. Notice that Levinson and O'Brien (2019) estimates EECs using a similar assumption.[15] Our strategy to keep technology constant during the baseline analysis allows us to discern whether shifts in consumption patterns are affected by factors like consumer preferences or policy alterations. Our analysis then uses the WIOD and ERT databases to incorporate the more realistic and important assumption that technology and environmental taxes vary across countries. This strategy allows us to consider the potential impact of (different) foreign environmental tax policies on U.S. household consumption via the usage of imported intermediate products.

It is well understood that aggregate pollution levels generated by U.S. production have decreased over time (Levinson, 2009; Shapiro and Walker, 2018). At the same time, the usage of imported intermediate products (foreign outsourcing) has become more critical for the U.S. economy and across the globe. For instance, basic manipulation of the WIOD suggests that the foreign content share (i.e., the ratio between the value of imported inputs over the value of shipments) for U.S.-produced goods rose from 8 percent to 14.3 percent between 1996 and 2011. In the case of pollution, the main channel leading to reductions in the emission of the main pollutants has been the technique effect. This effect represents reductions in pollution intensity via increases in productivity across firms and policies that directly affect the decision of firms to control their emission intensity via abatement investments.[16] Instead, we are primarily interested in how U.S. household income affects consumption and, consequently, relies on imports of outsourced foreign inputs whose foreign environmental taxes are embodied in them. We follow Levinson

[15] Technology changes are an important extension of our baseline results. For instance, Duarte et al. (2013) argue that technology changes can influence consumption patterns, production processes, and trade dynamics, affecting environmental outcomes.

[16] Shapiro and Walker (2018) show that the implicit taxes on pollution via U.S. regulatory norms doubled on average between 1990 and 2008. Thus, their paper explains the bulk of the U.S. pollution reduction through the technique effect.

and O'Brien (2019) by keeping the technology (the technique effect) constant by using the 2002 WIOD-based I-O linkages for our analysis. Notice that this strategy still captures any production-oriented taxes that may affect consumption decisions through price changes and goods availability.

Figure 1 shows the foreign content share by industry using the 2002 WIOD. It is clear that, within a particular industry, the prevalent dependence on a notable proportion of intermediate goods can be ascribed to the sector's inherent attributes and intricate production procedures.[17] According to the figure, the largest foreign share in 2002 was 37.42 percent for "Coke, Refined Petroleum and Nuclear Fuel." This conclusion is a direct result of the fact that Energy-Intensive Trade-Exposed (EITE) manufacturing industries are heavily fossil-fuel-reliant and very reliant on international trade. Chen et al. (2018) argue that global economic integration allowed the transfer of the less-environmental friendly (dirtier) segments of these EITE industries to relocate across borders, enabling then firms located in developed countries to meet stringent domestic environmental targets. This process of international fragmentation explains the high foreign share for EITE industries. The second greatest foreign content share applies to the industry "Electricity, Gas and Water Supply" with 19.26 percent. In this case, Feenstra and Hanson (1996) indicate that many utility companies are choosing to outsource their information technology (IT), distribution, and even their manufacturing operations to lower operating costs and increase the quality of service. Based on Feenstra and Hanson (1996), companies can save up to 30 percent when delegating parts of their operation to foreign suppliers, which explain the relatively high foreign share for this sector. On the other hand, the sector "Private Households with Employed Persons" only sources domestically.

As discussed above, we also want to examine the evolution of the foreign environmental tax embedded in the U.S. household consumption of goods produced in the U.S. economy. The ERT measures used in this study are part of the Policy Instruments for

[17] We use the word outsourcing to refer to the share of foreign content on an industry's shipment value. A more accurate definition refers to the share of imported inputs by firms that originate in the same sector that these firms operate. Hummels et al. (2014) use a similar definition of foreign outsourcing.

the Environment (PINE) database, which serves as a repository, systematically aggregating quantitative and qualitative data from 3,200 distinct instruments adopted across OECD countries and numerous other nations (OECD, 2023). Environmentally related taxes within this database are pivotal in signaling market dynamics capable of shaping the conduct of both producers and consumers. Constituting approximately one-third of the instruments cataloged in the PINE database, environmentally related taxes manifest in a diverse array, exceeding 1,400 in variety (Ancapi, 2021). We measure environmental tax rates by taking the ratio between the tax revenue and the value added to each country and industry.[18] These environmental taxes aim to capture and elucidate the impact of environmentally related taxes on consumption patterns.

Environmental policies have experienced a growing momentum propelled by heightened awareness and the gravity of environmental issues. Our data on ERT reveals that the U.S. revenue related to environmental taxes witnessed a 10.94 percent increase (from $120,741.69 to $133,954.08 million) from 1996 to 2011.[19] Likewise, China's environmentally related tax revenue experienced a substantial growth of 30.14 percent during the same period. Since our analysis focuses on household consumption and its evolution over time, we rely on the 2002 ERT information and, therefore, we keep environmental taxes constant in our analysis. Figure 2 shows that several European Union members (e.g., Netherlands, Greece, Austria, Denmark) and Mexico reported the highest environmental-related taxes in 2002. These two trade entities represented two of the largest U.S. trading partners. Instead, according to the WIOD, Canada, Mexico, Great Britain, Japan, and China were responsible for the largest foreign content shares of U.S. imported inputs in 2002.

The case of Canada and Mexico is revealing since it is a member of the North Amer-

[18]The tax revenues for the sectors with missing information were computed by applying a weighted average approach to the tax rates of analogous industries in comparable countries, determined through the utilization of the Country Similarity Index (CSI), accessible at https://objectivelists.com/. Additional information can be referenced in the supplemental appendix.

[19]The values are expressed in millions of U.S. dollars (USD) adjusted for inflation and cost of living differences across countries using the Purchasing Power Parity (PPP) method, with the base year being 2015.

ican Free Trade Area (NAFTA).[20] Conconi et al. (2018) explain that NAFTA's rules of origin promote trade of intermediate products among its members, thereby diverting imports of inputs from the rest of the world and increasing the foreign content of Canadian-sourced inputs in the production of U.S. goods. To the extent that environmental taxes tend to be higher in the European Union members and Mexico, the significant contribution of inputs originating in Mexico and these developed countries represents a force propelling heightened environmental awareness and higher foreign environmental taxes embedded the U.S. production of final consumption goods. However, Ancapi (2021) explains that the composition changes to consumption bundles as income rises may counter the pure scale effect of income increases on consumption choices. Section 5 discusses these effects in detail.

In Figure 3, the environmentally related tax index by industry for the year 2002 is visually presented. Notably, the "Coke, Refined Petroleum, and Nuclear Fuel" sector stands out with the highest average foreign environmental tax. Huang et al. (2023) argue that this industry is characterized by resource-intensive processes and substantial energy consumption, leading to a heightened environmental impact, thereby leading to higher environmental taxes. The "Other Supporting and Auxiliary Transport Activities" ranks second in environmentally related tax revenue in Figure 3. Froehlich et al. (2009) suggest that this is due to its inherent connection to consumer travel, known for its environmental impact through emissions, waste, and resource consumption. Thus, environmental taxes are heightened in this sector to encourage sustainability and responsible practices, especially in transport services, which are primary emission sources.

2.2 Methodology

We estimate the Engel curves on the foreign content of final goods and foreign environmental taxes using two household-level exposure measures. Economic integration is

[20] As is well known, the Trump administration promoted the review of NAFTA's original agreement, and its updated version was then relabeled the USMCA.

usually not measured in terms of absolute total trade values. Instead, the degree of integration usually refers to trade values (or other measures) relative to specific variables such as aggregate income or production values.[21] As indicated in Figures 1 and 2, the fragmentation of production across countries is an emblematic sign of modern economies. Notice that Hofmann et al. (2019) and Laget et al. (2020) relate the intensity of trade in inputs across countries to the presence of global value chains and the formation of preferential trade agreements. As such, our measure of exposure to the foreign content of goods is the foreign content share. i.e., it represents the ratio between the value of imported inputs and the value of shipments by U.S. industry j. We use the I-O direct linkage requirements based on the 2002 WIOD to measure this share and label it FS_j. Likewise, we use the 2002 OECD ERT and denote the environmental tax applied by country c in industry j by ERT_{jc}.

The household i's index of exposure to outsourcing (EO_{it}) can be described by the following formula:

$$\frac{\sum_j (FS_j \times expenditure_{ijt})}{TOTexpenditure_{it}} = EO_{it} \tag{1}$$

where $expenditure_{ijt}$ corresponds to the household i's expenditure in industry j at year t. We notice that outsourcing exposure (EO_{it}) should be a positive number less than 1. Essentially, expression (1) corresponds to the household i's expenditure-weighted average of the foreign content shares.

We proceed with a two-step approach regarding exposure to foreign environmental taxes. First, we measure the average foreign environmental tax (FET_j) that goes into

[21] Some examples from popular media may shed light on the importance of relating trade values to aggregate income. For instance, recent material published by the Wall Street Journal (WSJ) suggests that the degree of globalization peaked in 2007 using total trade (sum of imports and exports) over the GDP. See their report at "https://www.wsj.com/story/the-messy-unwinding-of-the-new-world-order-b43d7e45?mod=Searchresults_pos1&page=1". Another measure of de-globalization is the fall between the value of foreign inputs on manufacturing production since 2011. Again, see WSJ's "https://www.wsj.com/articles/globalization-inflation-tariffs-buy-american-11638635122?mod=Searchresults_pos6&page=1".

foreign inputs used to produce a U.S. final good in industry j. Second, we calculate the household i's consumption index of exposure to foreign environmental taxes ($EFET_{it}$) using the composition of an individual i's consumption basket across industries.

The average industry level of exposure to foreign environmental taxes (FET_j) is obtained by the following expression:

$$\frac{\sum_c (ERT_{jc} \times s_{jc})}{FS_j} = FET_j \tag{2}$$

where we noticed that s_{jc} corresponds to the foreign content share specific to country c in U.S. industry j. This fact implies that $FS_j = \sum_c s_{jc}$. Thus, expression (2) corresponds to an industry-level weighted average of the foreign environmental taxes applied by country c in industry j, ERT_{jc}. Notice that expression (2) corresponds to the first step outlined above. Then, individual i's exposure to foreign environmental taxes ($EFET_i$) can be represented as an expenditure weighted-average of the industry level exposures according to the following expression:

$$\frac{\sum_j (FET_j \times expenditure_{ijt})}{TOTexpenditure_{it}} = EFET_{it} \tag{3}$$

Expression (3) ensures that industries with higher household i's expenses significantly impact the overall $EFET_{it}$ calculation, accurately reflecting the household's consumption patterns. The evaluation of $EFET_{it}$ is a significant tool used to gauge households' exposure to foreign environmental taxes based on their consumption patterns. This index is a composite measure that takes into account both the foreign content share in consumed goods and the environmental taxes associated with that foreign content. It is not a cardinal variable, meaning it does not represent an absolute quantity but provides a comparative exposure assessment. This weighted average approach aligns with the economic reality that households spend varying amounts on different industries, making it an appropriate method for assessing exposure to foreign environmental taxes concerning consumption patterns. In line with it, comparing the exposure regarding EO_{it} and $EFET_{it}$ across households measures the intensity with which their consumption bundles rely on foreign content (inputs) or foreign taxes rather than the value of foreign inputs or tax revenue embedded in their consumption.

Figure 4 provides the schematics for calculating the indexes expressed in (1) and (3) and some measures mentioned above. At the top, we can see the three primary sources of data: consumption (CEX), production (WIOD), and environmental-related taxes (ERT_{jc}). According to Figure 4, the information from CEX is used to obtain the expenditure by household across industries ($expenditure_{ijt}$). The WIOD provides information on domestic production (value of shipments) and I-O domestic and international linkages. In particular, it allows us to obtain foreign content shares (FS_j). At the leftward bottom of the graph, we notice that the interaction between household expenditures and foreign content shares yields the household index of outsourcing exposure (EO_{it}). Likewise, back to the right middle section of Figure 4, we notice that the interaction between the information on foreign content shares and the ERT_{jc} yields the average industry level of exposure to foreign environmental taxes (FET_j). We then interact this information with household expenditure across industries to obtain the index of household exposure to foreign environmental taxes ($EFET_{it}$).

Table 1 shows the average household i's values for the two exposure indexes described in expressions (1) and (3) in percentage points (multiplied by 100). In addition, this table provides crucial information on average household income and other household characteristics for 1996 and 2011, our series's first and last years. For example, the index of exposure to outsourcing (EO_{it}) decreased significantly between 1996 and 2011, from 7.746 to 7.039, and the exposure to foreign environmental taxes ($EFET_{it}$) rose slightly from 3.881 to 3.973. The decrease in the average value of EO_{it} is possible due to our keeping the technology used in our measures at their 2002 values since we have observed above that the share of production supplied by foreign countries increases over time.[22]

[22]Moreover, the average household became smaller, older, less likely to be married, better educated, more urban, more likely to live in the Northeast and West.

We explore the role of technology in household exposure as one of our extensions. As we explain below, the changes in the composition of U.S. consumer bundles of goods, price changes, and the changing availability of consumption goods over time also contribute to this trend. A similar explanation also applies to household exposure to foreign environmental taxes ($EFET_{it}$) since, in this case, we keep technology and foreign environmental taxes at their 2002 values.

In Figure A1, we plot the evolution of the Consumer Price Index (CPI) components from 1980 to 2014. It is clear that some CPI elements (fuel and gasoline) became cheaper during the first half of our sample (the mid-1990s and early 2000s) and became significantly more expensive during the commodity boom of the 2000s. On the other hand, the cost of electricity to U.S. households relatively falls substantially during our time frame. These trends allow for considerable changes to the composition of U.S. household consumption bundles, with consumers moving away from products heavily reliant on fossil fuels and moving towards products intensive in electricity, possibly cleaner goods whose foreign-sourced inputs are subject to higher environmental taxes. These trends seem broadly in line with the timid average increase in exposure to foreign environmental taxes, as suggested by Table 1.

3 Nonparametric Estimates

In this initial step, we plot the Engel curves on outsourced goods and foreign environmental taxation without controlling for other household characteristics. The former relates household income levels to their index of exposure to outsourcing (EO_{it}), while the latter relates household income levels to their index of exposure to foreign environmental taxes ($EFET_{it}$). This step approaches this problem (plotting the Engel curves) in a nonparametric way. First, we use the 1996 version of the CEX to split households into 50 groups based on after-tax income, which will not be influenced by tax policy. Second, we measure the average value of these two indexes for each of these 50 household groups.

The share of households in each income bin can be found in Figure A2. We can get a nonparametric Engel curve on the foreign content of goods by plotting 50 combinations of average after-tax income and the average value of the EO_{it} index per household group. This methodology can also be applied to measure this Engel curve for different years. Likewise, obtaining a nonparametric version of the Engel curve on foreign environmental taxes is similarly applicable.

Panel (a) of Figure 5 shows the nonparametric Engel curve on the foreign content of goods for 1996 and 2011. This panel reveals a consistent pattern:

1. Engel curves are concave, meaning that increasing household income will cause the exposure to the outsourcing index (EO_{it}) first increase and then decrease. In particular, this figure shows that middle-income households prefer to purchase goods and services more reliant on outsourced foreign inputs.

2. When the household income is relatively very high, households tend to consume more domestically produced goods that are less reliant on foreign inputs.

3. An important point is that this type of Engel curve tends to shift downward over time, as can be seen by comparing the curves for 1996 and 2011. The decrease in the outsourcing index over time for given income levels relates to changes in prices and availability of goods.

On the other hand, panel (b) of Figure 5 focuses on the nonparametric Engel curve on the foreign environmental taxes. This panel shows that this Engel curve shifts upward over time and indicates a concave shape. Its general message is that middle- and high-income households will tend to buy U.S.-produced goods and services that rely more on outsourced foreign inputs from countries with higher environmental taxes.

In Figure 5, we notice several evident outliers, raising the question of their origins and influence on the plotted Engel curve. Several factors contribute to the presence of these outliers. Firstly, within a designated income group, notable variability exists in the exposure to foreign content. This variability can be attributed to differing consumption patterns, preferences, or other unobserved factors, resulting in a deviation from the anticipated trend represented by the Engel curve.[23] Secondly, a typical consumption behavior among specific households within their income group can significantly impact the calculated Engel curve, leading to notable deviations. These variations might stem from unique consumption preferences or circumstances peculiar to those households.[24] In the subsequent analysis, we excluded these outlier observations and reestimated the Engel curves for both indexes. The outcomes of this reevaluation are detailed in Figure A3.[25] Notably, removing outliers did not unduly skew or distort the non-parametric Engel Curves and the subsequent parametric analysis.

We test the robustness of the nonparametric estimates shown in Figure 5 in different ways. The panels in Figures A4 and A5 plot Engel curves based on total household expenditure and household pre-tax income, respectively. The Engel curves in these figures maintain the same properties discussed for panels (a) and (b) of Figure 5. According to Harrell (2001), the location of changes in the curvature of Engel curves can be set at specific points known as knots. We re-estimate Engel curves based on five knots placed at equally-distanced percentiles.[26] Panels (a) and (b) of Figure A6 present the variation in

[23] To exemplify, in the year 2011, within the lowest income bin, after-tax income displayed a substantial range, spanning from \$94.5 to \$4,213 (using \$10,000 in 2002 dollars). Additionally, the age of households within this income group ranged from 19.5 to 87 years, further illustrating the multifaceted nature of this variation.

[24] An illustrative example can be found in the behavior of households within the lowest income bin. While the majority of these households typically allocate a significant portion of their income to "Food, Beverages, and Tobacco," there are exceptional cases, such as a household that deviates from this pattern by directing their expenditures toward "Mining and Quarrying." The unique preferences and priorities of this particular household drive this deviation.

[25] Mahalanobis distance was employed to assess the deviation of specific data points, representing income and exposure index values within different income bins, from the expected trend represented by an Engel curve. Mahalanobis originally introduced this distance measure in Mahalanobis (1930) as part of his investigations into racial similarity. Over time, it has matured into a pivotal and indispensable tool in statistics and data analysis, especially in situations involving diverse sets of measurements (McLachlan, 1999). By calculating the Mahalanobis distance for each data point, we can identify those income bins that exhibited substantial dissimilarities from the Engel curve, indicating potential outliers in the dataset.

[26] Harrell (2001) recommends placing knots at equally-spaced percentiles of the original variable's (after-tax income) marginal distribution. In this application, we choose the 5th, 27.5th, 50th, 72.5th, and 95th percentile as knots. When using a restricted cubic spline, one obtains a continuous smooth function that is linear before the first knot, a piecewise cubic polynomial between adjacent knots, and linear again after the last knot. By estimating Engel curves using restricted cubic splines (over income), we can observe the relationship between income and exposure index as a piecewise cubic polynomial.

household spending reflected by 95 percent confidence intervals (shaded area). Generally, the Engel curves displayed in these panels share similar characteristics and evolution over time with their counterparts shown in Figure 5.

The approach depicted in Figure 5 may not precisely explain the relationship between the household exposure indexes (EO_{it} and $EFET_{it}$) and household income due to the missing household characteristics. Lewbel and Pendakur (2009) show that the standard Engel curve varies with consumer characteristics, accounting for both shape and changes over time. Moreover, the law of one price may not hold across U.S. regions, given the continental dimension of its economy. For example, suppose some U.S. regions have considerably higher household incomes. In that case, it may present higher relative prices for goods that rely more heavily on foreign inputs imported from countries with higher environmentally related taxes. If this situation applies, then the shape of the Engel curve in panels (a) and (b) will be influenced by the combination of income elasticities and price differences. Likewise, if incomes and relative prices have changed over time at different rates across regions, the Engel curves may be biased by this price effect.

Thus, we now turn to parametric estimates to access the degree to which these demographic changes account for the shape and movements in the Engel curves.

4 Parametric Estimation

The main challenge in estimating the relationship between household income and the indexes of consumption exposure described in expressions (1) and (3) is that it may be affected by demographic characteristics with varying effects over the years. As a result, this relationship varies across years, producing shifts and changes in the form (concavity) of the Engel curves over time. This section describes our empirical strategy for addressing the difficulty mentioned above. In the next section, we investigate the variation in the average exposure indexes in terms of movements along the Engel curve and the shifts in this curve.

We can then estimate the relationship between exposure and household income in the following way, similar to the approach used by Levinson and O'Brien (2019). We estimate the following expression to measure the Engel curve on the foreign content of goods in year t:

$$EO_{it} = \alpha_t Y_{it} + \beta_t Y_{it}^2 + \delta_t X_{it} + \varepsilon_{it} \quad (4)$$

The dependent variable EO_{it} represents the exposure index described in expression (1). Y_{it} and Y_{it}^2 represent the after-tax income and its quadratic value in year t, respectively. X_{it} denotes the vector of household characteristics that control for demographics, among other factors. Estimation of expression (4) per year allows us to graph the Engel curve on a yearly basis. Notice that a similar process allows us to estimate its counterpart on the foreign environmental taxes. In this case, we replace the dependent variable in expression (4) with the exposure index $EFET_{it}$ described in expression (3).

Panel (a) of Figure 5 describes (different) Engel curves that share a strictly concave shape similar to the curves estimated by Levinson and O'Brien (2019). In column 1 of Table 2, we regress EO_{it} only on the value of income and its quadratic value. The estimated shape is concave since the coefficient for the variable measuring quadratic income is negative (-0.021) and statistically significant.[27] Notice that the estimated effects are economically relevant. The numbers in column 1 of Table 2 suggest that, on average, a one-standard-deviation increase in income (based on 1996 values) leads to an increase in EO_{it} of 0.009, corresponding to approximately 26 percent of a standard deviation (0.035 based on 1996 values) in this index according to Table 1.[28] Measuring the direct effect of income on exposure through standard deviation units facilitates straightforward comparison and interpretation, especially in scenarios involving variables with varying units or scales. It also provides a tangible measure of the impact of income changes on the index, aiding in informed policy decisions. This approach bridges the gap between statis-

[27]The joint test for income and its squared value is also statistically significant.

[28]Calculations use the standard deviations in the index and income for 1996.

tical significance and real-world relevance, enhancing the applicability of our research to policy-making (Vossler and Evans, 2009).

Still, since the specification used in column 1 does not control for other household characteristics, there may be endogeneity concerns related to missing variables. For instance, educational attainment correlates with income and also correlates with environmental awareness (consumption preferences), posing an endogeneity challenge to estimate the effects of household income on EO_{it}. Thus, the specifications used in columns 2 through 5 additionally control for household characteristics, such as age, household size, race, and region of residence. Furthermore, each specification focuses on a particular year, whose estimates allow us to plot the parametric version of the Engel curve for different years. For example, the specification used in column 2 focuses on CEX data for 1996, while the specifications used in columns 3 through 5 focus on CEX information for 2000, 2005, and 2011, respectively.

In column 2, the coefficients corresponding to educational attainment levels, specifically high school and some college, demonstrate a positive relationship. This implies that households with these levels of education tend to select consumption bundles characterized by a higher proportion of foreign inputs. Conversely, the coefficients demonstrate a negative association for higher educational levels, such as college and graduate degrees, signifying a preference for consumption bundles with a reduced proportion of foreign content. Furthermore, household size, age, marital status of the household head, and living in rural areas positively affect household exposure to the foreign content of goods.

Unsurprisingly, including controls for household characteristics affects the relationship between income and household exposure. The results in column 2 indicate that using CEX data for 1996, the linear coefficient on income and its quadratic value are statistically significant and point to a strictly concave Engel curve. Moreover, the income effects continue to be economically relevant: if income increases by one standard deviation, then the index of exposure to the foreign content of goods (EO_{it}) also increases by 0.006 on average, equivalently, 18 percent of a standard deviation. The effect of other household characteristics is meaningful as well. For instance, households residing in the Southern region, on average, exhibit an exposure to outsourcing that is 0.26 percentage points higher compared to households in the Midwest region. Differently, a one-standard-deviation increase in age (0.375 based on 1996 levels) leads to a slight increase in the index value of 0.004 or the equivalent of about 11 percent of its standard deviation.[29]

Similar conclusions apply to the specifications in columns 3 through 5 of Table 2. As explained above, these specifications rely on different years for the CEX information. In these cases, the coefficients for income and its quadratic value are positive and negative, respectively, and both are statistically significant. These results confirm the presence of strictly concave Engel curves across the years. Notice that the sign of coefficients used as controls coincide across columns 2 through 5. However, the size of these coefficients varies significantly across columns, suggesting potential important changes in the degree of concavity and shifts in the Engel curve across years. For example, if we focus on column 5, the results suggest that a one-standard-deviation increase in income (0.066 based on 2011 levels) leads to an increase in the index of exposure to the foreign content of goods of 0.0039 on average, which corresponds to 15 percent of its standard deviation based on the 2011 CEX (0.026 according to Table 1). The comparison with a similar analysis for column 2 reveals a decrease in the effect of income on the foreign content embedded in consumption. Figure 6 shows the estimated linear coefficient of income (upper section) and its squared value (lower section) yearly from 1996 to 2011. Notice that coefficients vary over the years but are statistically significant.[30]

Table 3 shows the estimation of expression (4) using the index of exposure to foreign

[29]People form consumption habits based on past consumption patterns. Therefore, as presented in Tables 2 and 3, age and age-squared variables are included in expression (4) as part of the vector of controls X_{it}. This strategy aims to control for problems caused by the "habit persistence" effect on consumption decisions.

[30]Following Sager (2019), we conducted a comparative analysis by juxtaposing equation (4) with more versatile semiparametric models. Specifically, we employed a Gaussian kernel-weighted local polynomial approach to model the influence of income while maintaining linear control over other covariates. In line with the test proposed by Hardle and Mammen (1993), for each polynomial degree, we test the null hypothesis that the adjustment of degree n+1 is appropriate. Our objective was to pinpoint the minimum polynomial degree where the null hypothesis remained unchallenged (failed to reject). The findings affirm that the quadratic model for 2011 emerges as the optimal choice. This result is available from the authors upon request.

environmental taxes ($EFET_{it}$) as the dependent variable. It follows the exact specifications across columns used in Table 2, except for the dependent variable. Generally, results tend to follow a similar pattern as described for the index EO_{it}. For instance, the linear effect of household income on $EFET_{it}$ tends to be positive, while its quadratic value displays a negative effect. Both coefficients are statistically significant even using the parsimonious model described in column 1 of Table 3. If we focus on column 2, when using the 1996 CEX data, on average, a one-standard-deviation increase (0.062 based on 1996 values) in income leads to an increase of 0.0017 in household exposure to foreign environmental taxes. This effect corresponds to an increase equivalent to 17 percent of the standard deviation of the exposure index (0.010 based on 1996 values, according to Table 1). As we move across columns, this effect is consistent with what we described in Table 2. If we focus on the 2011 CEX data, column 5 indicates that an increase of one standard deviation in income (0.066 based on 2011 values) causes an increase in the index $EFET_{it}$ of 0.0006 on average. This effect corresponds to 7 percent of the standard deviation of this index (0.009 based on 2011 values). Figure 7 indicates the yearly estimated linear and quadratic income coefficients from 1996 to 2011. These estimates confirm the statistical significance of the income-related coefficients in Table 3.[31]

Figure 8 presents the parametric Engel curves based on results in Table 2 (panel (a)) and Table 3 (panel (b)). It illustrates the relationship between income and the two indexes (EO_{it} and $EFET_{it}$) for 1996 and 2011 using the control variables outlined in expression (4) and represented by X_{it}. The two thick lines in panel (a) use the estimated coefficients displayed in columns 2 (1996 CEX) and 5 (2011 CEX) of Table 2. Likewise, the two thick lines in panel (b) are constructed using the results in columns 2 (1996 CEX) and 5 (2011 CEX) of Table 3. We also plot each Engel curve without matrix X_{it} covariates for comparison purposes. In sum, the parametric versions of Engel curves in Figure 8 are similar to their counterparts in Figure 5. First, all parametric Engel curves are concave.

[31] We can observe several outliers using the non-parametric estimates of the Engel Curves described graphically in both panels of Figure 5. Then, we consider the methodology suggested in Levinson and O'Brien (2019) to select and re-estimate expression (4) for the two indexes (EO_{it} and $EFET_{it}$) considered in Tables 2 and 3 while dropping these outlier observations. The results are listed in Table A1, they are qualitatively similar to those described in Tables 2 and 3.

Second, the curve related to exposure to foreign environmental taxes ($EFET_{it}$) tends to shift upward over the years, while the curve pertaining to exposure to outsourcing (EO_{it}) exhibits the opposite pattern. We investigate as an extension to which degree these shifts remain under technological progress. Last, the degree of concavity of Engel curves in panels (a) and (b) decreases from 1996 to 2011.

From Panel (a) of Figure 8, we observe that the low-income households' exposure to foreign content intensity in their consumption (left section of the graph) is greater than high-income households' exposure intensity. This feature is in line with expectations. Chan and Gruber (2010) argue that low-income households are more price-sensitive than their higher-income counterparts. Furthermore, Buxey (2005) and Miroudot et al. (2009) underscore the critical role of foreign intermediate goods in bolstering price competitiveness. These findings explain why price-sensitive low-income households consume lower-priced goods with greater foreign content intensity than their high-income counterparts. Likewise, Panel (b) exhibits similar patterns. de Groot (2003) illustrates that as consumers become wealthier, their consumption patterns tend to evolve. In the early stages of income growth, there's a shift towards manufacturing products characterized by larger emission intensity. As income continues to rise, consumers tend to favor services known for their smaller environmental footprint. Consequently, this implies that low-income households, as their income increase, might gravitate toward goods with higher environmental impact, therefore with potentially higher environmental taxes. In contrast, higher-income households may opt for goods with lower environmental impact and, possibly, lower environmental taxes.

Notice that the thin lines in Figure 8 plot the regression of expression (4) for the two indexes on income and income-squared alone. The baseline results remain the same, although adding the covariates in matrix X_{it} changes the shape of the Engel curves. Moreover, we conclude again that the Engel curves shift down for the index of exposure to outsourcing (EO_{it}). In contrast, they shift up for the exposure to foreign environmental taxes ($EFET_{it}$). The downward shift in Engel curves on the foreign content of goods can be attributed to policy changes and modifications in consumer behavior. Palley (2008) argues in favor of additional policies to address social concerns given the increase of foreign outsourcing, representing a new form of competition. The US-Central America and Dominican Republic Free Trade Area (CAFTA-DR) was signed into law in 2005. It was the first FTA involving the U.S. with enforceable labor requirements in line with the argument outlined in Palley (2008). Instead, Goldberg and Campa (2006) bring to the forefront that final consumption goods intensive in foreign intermediate inputs may have more volatile prices since their contents are more affected by exchange rate swings. As a result, consumers may switch to products with lower-foreign content and, therefore, less subject to price fluctuations.

On the other hand, Engel curves on the foreign environmental taxes shift upward, possibly due to increasing awareness of environmental issues. Gadenne et al. (2009) show that greater environmental awareness increases the environmental-friendly business practices and consumer options. Butler (2018) refers to a 2017 study on corporate social responsibility, revealing that 87% of consumers will have a more positive image of a company that supports social or environmental issues, and 87% of consumers would buy a product with a social and environmental benefit if given the opportunity. Thus, Americans increasingly expect companies to be engaged making an impact on social and environmental matters. Likewise, Acemoglu et al. (2012) show that regulatory and policy frameworks are pivotal in shaping a consumption trend. They argue that nations placing a greater emphasis on environmental considerations frequently implement incentives to encourage adopting eco-friendly practices. These incentives encompass tax reductions, subsidies, or other economic encouragements for enterprises employing cleaner and sustainable production approaches. Consequently, products originating from such countries are often perceived by consumers as more sustainable and environmentally responsible.

So far, we have presented the estimation of the Engel curves and have observed whether they shift upwards or downwards over time. Next, we will decompose the effects of changes in these indexes in terms of movements along the curve and shifts of the Engel curve.

5 Applications

5.1 Decomposing the Changes Over Time

Table 1 indicates that the average value of the index measuring household exposure to the foreign content of goods (EO_{it}) decreased by 0.707 points, the equivalent of about 9 percent, from 1996 to 2011. Instead, this table suggests that household exposure to foreign environmental taxes ($EFET_{it}$) increased by 0.092, representing a 2 percent rise. It is then important to explain the forces behind these average changes. These forces can be divided into two groups. First, some forces explain a movement along the Engel curve, while others cause shifts in each curve. Movements along the curve are related to changes in after-tax income and represent the combination of scale and composition effects following Levinson and O'Brien (2019)'s definitions. Below, we detail how to measure and explain these two specific effects. On the other hand, shifts in the Engel curve can be caused by changes in other household (demographic) characteristics over time or by unexplained factors not modeled in expression (4).[32]

As indicated above, we are trying to explain the evolution of the average values (across households) for our indexes described in expressions (1) and (3) over the years. We apply the Oaxaca-Blinder decomposition to separate components related to the movement along Engel curves and the shift in them. Then, focusing on the household exposure to outsourcing (EO_{it}), the average level of this index at year t can be described, with the assistance of expression (4), by the following expression:

[32] Levinson (2009) shows that the conventional way to explain the evolution of pollution emissions generated by producing goods and services is to decompose it in terms of scalar, composition, and technique effects. Our objective here is different as we aim to understand the foreign environmental taxes embedded in the foreign content of goods consumed by U.S. households. For instance, we keep technology constant at 2002 levels, meaning that we shut down the changes due to the technique effect.

$$\overline{EO}_t = \alpha_t \bar{Y}_t + \beta_t \bar{Y}_t^2 + \delta_t \bar{X}_t \tag{5}$$

Equation (5) relates the average level of EO_{it} to the after-tax average income and its squared value ($\bar{Y}_t$ and $\bar{Y}_t^2$) while controlling for the average of other included covariates ($\bar{X}_t$). By construction, the average OLS error is 0. Therefore the error term is not included in equation (5). We also adopt a similar strategy to investigate the factors behind the evolution of the average value for the index of exposure to foreign environmental taxes $EFET_{it}$.

We use expression (5) to measure changes in the average value of the exposure to outsourcing between 1996 and 2011 in the following way:

$$\begin{aligned}
\overline{EO}_{11} - \overline{EO}_{96} = {} & \alpha_{96}(\bar{Y}_{11} - \bar{Y}_{96}) + \beta_{96}(\bar{Y}_{11}^2 - \bar{Y}_{96}^2) && \text{(Term 1)} \\
& + (\alpha_{11} - \alpha_{96})\bar{Y}_{11} + (\beta_{11} - \beta_{96})\bar{Y}_{11}^2 && \text{(Term 2)} \\
& + \bar{X}_{11}(\delta_{11} - \delta_{96}) + (\bar{X}_{11} - \bar{X}_{96})\delta_{96} && \text{(Term 3)}
\end{aligned} \tag{6}$$

Term 1 of expression (6) considers changes in after-tax average income levels while holding constant the estimated coefficients (α_{96} and β_{96}). Thus, it reflects a movement along the Engel curve for 1996 prompted by the increase in income between that year and 2011. Term 2 represents changes in estimated parameters between 1996 and 2011 while keeping average incomes constant at their 2011 levels. Thus, it means shifts in the Engel curves. Finally, Term 3 captures the changes on the average index related to all other covariates.

Table 4 presents the decomposition results for the change in the average indexes $\overline{EO}_t$ (column 1) and $\overline{EFET}_t$ (column2) between 1996 and 2011. Term 1 of expression (6) is calculated by multiplying the change in average values of income (see column 3 of Table1) by the 1996 OLS coefficients (see column 2 of Tables 2 and 3). Term 3 follows a similar approach for other control variables. Thus, the summation of these effects across individual variables corresponds to Term 1 (movements along the Engel Curve) and Term 3 (changes due to other covariates) of expression (6). We know from Table 1 the value for the left-hand-side variable (e.g., $\overline{EO}_{11} - \overline{EO}_{96}$), and measuring Term 1 and Term 3 then allows us to obtain Term 2 as the difference between the left-hand-side change and the summation of Terms 1 and 3.

Focusing on column 1 of Table 4, we conclude that the increase in average after-tax income leads to a hypothetical increase of 0.110 in the average index value.[33] On the other hand, the average increase in the after-tax squared value of income is responsible for a decline in the average index of 0.133. Then, we can add up the two effects related to income to find that Term 1 in expression (6) contributes to an average decrease in the index ($\overline{EO}_t$) of 0.023. Similar analysis measures Term 3 of expression (6). In this case, the overall effects of changing demographic characteristics contribute to a hypothetical decrease of 0.0804 (see bottom of Table 4) in the average value of $\overline{EO}_t$ between 1996 and 2011. According to Table 1, the average value of the exposure index to the foreign content of goods and services ($\overline{EO}_t$) decreased by 0.707 between 1996 and 2011. The difference between 0.707 and the summation of Terms 1 and 3 is -0.6036 (i.e., $-0.707-(-0.023-0.0804)$). Thus, this amount corresponds to the contribution of Term 2 (shifts in the Engel curve) to the change in the average index. The contribution related to Term 2 (shifts in the Engel curve) is more significant than the contributions related to Term 1 (movements along the curve) and Term 3 (changes in other covariates).

Similarly, we use the results in column 2 of Table 4 to decompose the forces behind the change in the average exposure to foreign environmental taxes ($\overline{EFET}_t$). The summation of the effects related to the change in average income and its squared value tends to decrease the average index value by 0.0061 (equal to 0.026 - 0.032 following column 2), corresponding to Term 1 of expression (6). Likewise, the summation of the effect due to changes in the average value of demographic characteristics equals -0.0063 (Term 3

[33] This corresponds to the change in average income (0.512) found in column 3 of Table 1 times the 1996 OLS coefficient described in column 2 of Table 2 (0.214). A Similar analysis applies to other values.

in expression (6)). Therefore, it contributes to a potential decline in the average value of index $\overline{EFET}_t$. We know from Table 1 that the average value of this index increases by 0.092. As such, we conclude that shifts in the Engel Curve on the foreign environmental taxes (Term 2) lead to an increase in this index of 0.1044 (i.e., 0.092-(-0.0061-0.0063)). Again, shifts in the Engel curve (Term 2) are the main contributors to the average increase observed in $\overline{EFET}_t$.

Levinson (2009) and Shapiro and Walker (2018) use a well-established decomposition model to explain the evolution of pollution emissions from U.S. production of goods and services. These papers show that pollution emission is affected by scale, composition, and technique effects. The scale effect suggests that pollution tends to rise, as production grows given the same combination of goods produced and technology. On the contrary, the composition effect focuses on the evolution of the mix of goods produced over time. In our analysis, the technology effect is kept constant as explained before using the 2002 WIOD information. Still, we can uncover the influence of scale and composition effects by observing the evolution of our index when income changes, i.e., when we consider movements along the curve, as established by Term 1 of expression (6). Panels (a) and (b) of Figure 8 make it clear that the composition of goods consumed across households of different incomes must change since the household exposure varies among low-, middle-, and high-income households.

Following Levinson (2009), Shapiro and Walker (2018), and Levinson and O'Brien (2019), we can define the scale effect as a proportional change of the average exposure index in 1996 relative to income. More specifically, we can focus on the exposure to the foreign content of goods and services to express the scale effect (SC_t) for year t relative to 1996 in the following way:

$$SC_t = \overline{EO}_{96} \times [(\bar{Y}_t - \bar{Y}_{96})/\bar{Y}_{96}] \tag{7}$$

Next, we use the fact that Term 1 of expression (6) represents a movement along the curve, which, therefore, corresponds to the summation of the scale effect (SC_t) and the composition effect (CC_t). Accordingly, we can define the composition effect at year t relative to 1996, with the assistance of expression (7), in the following way:

$$\begin{aligned} CC_t &= \text{Term } 1_t - SC_t \\ &= \alpha_{96}(\bar{Y}_t - \bar{Y}_{96}) + \beta_{96}(\bar{Y}_t^2 - \bar{Y}_{96}^2) \\ &\quad -\overline{EO}_{96} \times [(\bar{Y}_t - \bar{Y}_{96})/\overline{Y}_{96}] \end{aligned} \tag{8}$$

Panels (a) and (b) of Figure 9 show the decomposition effects overtime for the average indexes $\overline{EO}_t$ and $\overline{EFET}_t$, respectively. Line 1 corresponds to the scale effect (SC_t) defined in expression (7). Instead, line 2 represents the effects of movements along the curve, or, equivalently, Term 1 of expression 6, which describes the sum of the scale effect (SC_t) and the composition effect (CC_t) described in expressions (7) and (8), respectively. Line 3 combines Terms 1 and 3 of expression (6), i.e., the sum of the effects related to movements along the curve (Term 1) and changes in demographic characteristics (Term 3). Instead, line 4 shows the sum of effects summarized by Terms 1, 2, and 3 over time. These joint effects equal the average change in indexes found in Table 1.

First, we focus on panel (a) of Figure 9. Table 1 suggests that household incomes have increased. Thus, the scale effect for $\overline{EO}_t$ described in line 1 increases, according to expression (7), as long as average income rises, which does happen until the financial crisis of 2007. However, line 2 lies significantly below line 1. The difference between these two lines is the composition effect (CC_t), according to expression (8), which, therefore, is substantially negative and tends to reduce the average index. Lines 3 and 4 lie below line 2, suggesting that the shifts in the Engel curve (Term 2) and changes due to demographic characteristics (Term 3) are negative and decrease the average index, as discussed above. The exact contribution of each of these factors can be found in Table 5. We can then use expressions 6, 7, and 8 to disentangle the different effects on $\overline{EO}_t$ based on Table 5 as follows:

$$
\begin{aligned}
\overline{EO}_{11} - \overline{EO}_{96} &= \text{Term } 1_{11} + \text{Term } 2_{11} + \text{Term } 3_{11} \qquad (9) \\
\overline{EO}_{11} - \overline{EO}_{96} &= SC_{11} + CC_{11} + \text{Term } 2_{11} + \text{Term } 3_{11} \\
-0.707 &= 0.9896 - 1.0125 - 0.6036 - 0.0805
\end{aligned}
$$

Expression (9) reveals the relative contribution of the different terms in expression (6) to the change in the average value of $\overline{EO}_t$ between 1996 and 2011. It confirms that shifts in the Engel curve (Term 2) are the main contributor to the reduction in this index between 1996 and 2011, as discussed above. However, expression (9) reveals that the small (net) contribution of movements along the curve represents strong opposing forces between the scale (SC_{11}) and composition (CC_{11}) effects. The former tends to (strongly) increase the exposure to outsourcing while the latter (strongly) decreases this exposure by shifting consumption choices towards goods with lower foreign content as income rises. This combination of effects highlights that the composition effect counters to a great extent in the scale effect, and is the main factor leading to an average decrease in the exposure to foreign content of goods and services.

Next, we use expressions (6), (7), and (8) to disentangle the contribution of the different effects on $\overline{EFET}_t$ according to the results displayed in Table 5. These effects can be outlined as follows:

$$
\begin{aligned}
\overline{EFET}_{11} - \overline{EFET}_{96} &= \text{Term } 1_{11} + \text{Term } 2_{11} + \text{Term } 3_{11} \qquad (10) \\
\overline{EFET}_{11} - \overline{EEFT}_{96} &= SC_{11} + CC_{11} + \text{Term } 2_{11} + \text{Term } 3_{11} \\
0.092 &= 0.4958 - 0.5020 + 0.1044 - 0.0063
\end{aligned}
$$

Expression (10) provides information about the relative contribution of the different terms to the change in the average value of $\overline{EFET}_t$ between 1996 and 2011. Similar to the results in expression (9), shifts in the Engel curve (Term 2) are an important contributor to the index's increase. The scale effect (SC_{11}) increases the exposure to foreign environmental taxes, while the composition effect (CC_{11}) has the opposite impact, leading to a small contribution of movements along the Engel curve. These findings point to shift factors (Term 2) as the primary contributor to the increase in the exposure to foreign environmental taxes as a direct comparison of the absolute value of the different elements in expression (10) indicates it.

Table 5 provides further details about the contribution of the different terms mentioned above to the change in the average value of the two indexes. Column 1 of Table 5 shows the changes in the average value of the two exposure indexes between 1996 and 2011 (see also Table 1), holding technology and foreign environmental taxes fixed at their 2002 levels. Column 2 presents the scale effects (SC_{11}). The difference between columns 1 and 2 (column 3) represents the value of each index changes net of scale effect. Following expressions (9) and (10), it can be explained by the composition effect (CC_{11}), changes in household demographics (Term 3), and shifts in Engel curves over time (Term 2).

For the index of exposure to foreign environmental taxes ($\overline{EFET}_t$), the total average positive change in column 1 is mainly explained by shifts in the Engel curve (Term 2) since the composition effect basically counters the size of the scale effect, while the changes due to demografics tends to decrease this index. On the contrary, for the index of exposure to outsourcing (EO_t), the value of the index decreased significantly, meaning that households tend to consume more domestically produced goods and services with less foreign content. The increasing household income will lead to substantial growth in consumption according to the scale effect (see column 2). Therefore, column 3 is partly offset by the composition effect (CC_{11}), which tends to decrease the consumption of goods more reliant on foreign inputs as income rises, and shifts in Engel curves (see column 8).

Instead, the difference is mostly unaffected by demographic changes, according to column 6. Based on Table 5, we observe that the composition effect explains about 60 percent of the reduction in the average value of the index (see column 5). In comparison, shifts in the Engel curve explain about 36 percent (see column 9) of this reduction.[34]

5.2 Income Redistribution

The U.S. government engages in a multitude of social programs, including insurance (e.g., Medicaid, unemployment, and disability), education (e.g., pre-schooling, job and vocational training, college), tax and in-cash transfers (e.g., earned-income tax credits, child tax credit), and in-kind transfers (e.g., housing and food stamps). Most of these programs transfer income (directly or indirectly) from U.S. high-income households to targeted household groups. For example, some programs benefit low-income households (e.g., Medicaid) or contain income thresholds that prevent segments of the U.S. middle class from taking up benefits (e.g., child tax credits). Hendren and Sprung-Keyser (2020) analyzes 113 U.S. social programs, some of which include layouts of hundreds of billions of dollars each year. This fact makes it evident that social programs and income redistribution play a significant role in advanced economies.

In this section, we apply our parametrically estimated Engel curves to measure the degree to which redistribution affects U.S. consumption decisions. In turn, these decisions may affect the foreign content (EO_t) and the foreign environmental taxes ($EFET_t$) embedded in the final consumption of goods and services. We focus on the coefficient estimates for 2011, which can be found in column 5 of Tables 2 and 3. Our first exercises involve targeted transfers from the rich- to the low- or average-income households in line with typical U.S. social programs since they may encompass transfers only to one of these household groups. Next, we consider economy-wide transfers involving all 3,624

[34] This conclusion can be seen by taking the value of the composition effect in expression (9) or Table 5 (-1.0125) and dividing it by the sum of its value with the value of shifts in the Engle curve (-0.6036 for Term 2) and changes due to demographic characteristics (-0.0805 for Term 3). A similar approach applies to finding the relative contribution of shifts in the Engle curve. The 4 percent remaining is due to changes in the average value of demographic characteristics.

(see Table 1) households in our sample. In this case, we consider partial and complete redistribution, where the latter involves transfers to keep all households at the average income level of $45,210 (see Table 1).

Our first redistribution plan considers transfers of $5,000 and $10,000 from the one hundred top households based on income to the two hundred households at the bottom of the post-tax income schedule. Alternatively, we consider transfers to the two hundred households at the middle of the income schedule. Our redistribution plan is a theoretical construct that mimics some redistribution proposals. For instance, Charles Murray's plan involves in-cash transfers of about $10,000, which can be interpreted as a Universal Basic Income (UBI).[35][36] Thus, the transfers used in our redistribution exercise were chosen strategically to align with the theoretical construct of a UBI and to facilitate a comprehensive exploration of the effects of wealth redistribution, serving as a reasonable representation within the context of our study. These redistribution plans then mimic U.S. social plans that mostly target low-income households (e.g., Medicaid) versus those more catered to middle-income households (e.g., college grants and college loan subsidies). They are also economically meaningful: The mean income for the two hundred lowest-income households is $4,163, implying that these transfers ($2,500 and $5,000 for each) would correspond to an increase between 60 percent and 120 percent relative to their average after-tax income.

Notice that Figure 8 indicates that the estimated Engel curve for the indexes EO and $EFET$ are concave and quadratic (inverted U-shaped). To the extent that lowest income households have greater income with transfers, their individual indexes tend to grow as we move from the left side to the center of the estimated Engel curve for each index.[37]

[35]Charles Murray, a scholar at the American Enterprise Institute, suggests converting federal spending on programs like Social Security and Medicare into direct payments of $10,000 annually or $13,000 with a $3,000 health insurance deduction until a person's annual income exceeds $30,000. Murray aims to simplify the system, ensuring direct financial assistance reaches individuals, potentially saving administrative costs.

[36]Kearney and Mogstad (2019) argues that this approach could be more effective in aiding the most financially vulnerable and have fewer work disincentives than current programs.

[37]Expression (1) controls for many household characteristics that can be correlated with income. Still, our lack of information about the same households over time may cause biases in our estimates due to missing variables. Thus, results in Section 5.2 are best viewed as conditional correlations between income and exposure measures rather than a casual relationship.

A similar fact happens to the richest households as we move from the right to the center of each panel in Figure 8 unless some of these wealthiest households have income below the peak of the estimated curve. Therefore, the graphical analysis suggests an average increase in these indexes with redistribution. Table 6 provides numerical confirmation for these graphical conclusions. The transfers of income from the rich to the poor households lead to an average increase in the EO index between 0.04 percent and 0.075 percent, while a similar analysis for the $EFET$ index causes an increase between 0.029 and 0.051 percent. This table also reveals that transfers from the rich- to the middle-income households yield similar albeit smaller average increases in these indexes.[38]

We have also investigated the consequences of income redistribution involving all households. In this case, we follow Sager (2019) and consider marginal (small) changes in income involving two randomly chosen households. Likewise, we also consider the case of full redistribution, where transfers ensure that all households have the same average income of $45,210. The effect of former transfers can be approximated by the expression $-2 \times \beta_2 \times \Psi$ where Ψ represents the dispersion of each index across households and β_2 describes the curvature of the Engel curve. The marginal redistribution mechanism increases the average EO index by 0.605 percent while it raises the $EFET$ index by 0.332 percent. The low value of the estimated Engel curve's curvature (β_2) is an important piece in explaining the limited effect of redistribution on both indexes. Instead, full redistribution increases the EO and $EFET$ indexes by 0.372 and 0.275 percent, respectively. In this case, several households with income just below the level that maximizes each index have to pay transfers to poorer households, thereby leading to individual decreases in their indexes. This fact limits the full redistribution effects on the estimated indexes.

In sum, income redistribution leads to movements along estimated Engel curves and, in our case, causes increases in the average foreign content of final goods consumed in

[38] The income range for high-income households is between $146,243 and $240,703, while the income level corresponding to the $EFET$'s Engel curve peak is $147,561. Instead, the estimated Engel curve for the EO index peaks at an income level of $97,576.

the U.S. Likewise, it causes an increase in the foreign environmental taxes embedded in U.S. final goods and services. In this case, redistribution and consumption decisions are in sync with governments that want to promote trade with countries with a more robust environmental agenda, as signaled by higher environmental taxes. However, redistribution also leads to greater foreign content in final consumption. This result sheds light on a possible use of income redistribution to promote economic integration and reverse some of the de-globalization taking place (less offshoring), a movement centered in our object of study, the United States of America.

5.3 Technological Change

In the preceding section, we examined the shifts in two indexes while maintaining technological factors (IO linkage) at a constant level. This section extends our discussion to the shifts in these indexes while using information from the WIOD across the years. Notice that we keep environmentally related tax revenues constant at 2002 levels. Otherwise, our methodology closely aligns with the parametric estimations used to plot the Engel curves, as depicted in Figure 8. These newly estimated Engel curves can be found in panels (a) and (b) of Figure 10, which maintain a consistent concave shape yet exhibit a differing shift pattern for the exposure to foreign content (panel (a)). Notably, for the outsourcing exposure index EO (panel (a)), the Engel curve shifts up over time, a contrasting pattern to the downward shift observed in Figure 8, panel (a). This shift implies a growing inclination among U.S. consumers to consume goods with a higher foreign content share as time advances. Compared to Figure 8, this contrasting pattern emphasizes technology's substantial role in influencing consumption patterns concerning the share of foreign content in goods.

The rise in the share of foreign content in domestically produced goods over time can be attributed to a host of critical technological factors. Thatcher (2011) argues that advances in communication technologies have greatly facilitated global business coordination and collaboration, streamlining supply chain management by seamlessly integrating foreign intermediate goods into domestic production processes. Likewise, Hummels (2007) discusses that transportation systems have witnessed significant advancements, enhancing ease and cost-effectiveness in moving goods across borders. Moreover, Baier et al. (2014) show that preferential trade agreements (e.g., NAFTA and CAFTA-DR) promote trade between members, while Johnson and Noguera (2017) link these agreements to the fragmentation of production processes. Essentially, all these policy and technological changes affect the IO coefficients over time in the sense of leading to a greater share of foreign content in domestic consumption. They explain the upward shift of the Engel curve in this case.

In contrast, the index reflecting exposure to foreign environmental taxes $EFET$ displays an upward shift like in the baseline results, as seen in panel (b) of Figure 10, but with a more pronounced shift magnitude. This upward trend in the index is influenced by the varying changes in foreign content shares over time, driven by distinct countries and industries. Figure 11 elucidates these shifts in foreign content share by country from 1996 to 2011 utilizing the time-variant WIOD. Notably, specific countries, such as China, Germany, and Mexico, have increased their contribution to the U.S. foreign share and exhibit substantial environmental-related taxes, as reflected in Figure 2. Consequently, the considerable rise in foreign content share associated with significant tax contributes to the average increase in the exposure to foreign environmental taxes, $EFET$. Conversely, Japan has shown the most significant decrease in U.S. foreign content share from 1996 to 2011.[39] The below-average environmental taxes in Japan, combined with the reduction in participation in the U.S. foreign content share, contribute to an increase in the index value.[40]

[39]The composition of Japan's intermediate goods imports by country underwent significant alterations between 1996 and 2011. According to data from the World Integrated Trade Solution (WITS) at https://wits.worldbank.org/CountryProfile/en/Country/JPN/Year/2011/TradeFlow/Import/Partner/all/Product/UNCTAD-SoP2, the proportion of intermediate goods from Japan imported by the United States constituted a substantial share, accounting for 19.47 percent in 1996. In contrast, China's share was notably lower at 7.69 percent. However, by 2011, the share of Japan's intermediate goods imported by China experienced a substantial increase to 20.67 percent, consequently reducing the percentage imported by the United States to 13.55 percent.

[40]The shift observed in the $EFET$ in panel (b) can be linked to alterations in foreign content share across industries over the temporal span, as depicted in Figure 12. Notably, the sectors of "Mining and Quarrying," "Electrical and Optical Equipment," and "Basic Metals and Fabricated Metal" display the most substantial

In Table 7, we delved into the outcomes of income redistribution in conjunction with technological changes. The findings exhibit a comparable pattern to those presented in Table 6. Specifically, redistributing income from wealthier to poorer households results in a minor increase in the EO index, ranging from 0.035 to 0.065 percent. A similar analysis applied to the $EFET$ index yields an increase ranging from 0.02 to 0.041 percent. When employing the marginal redistribution mechanism involving the entire sample, the average EO index experiences a rise of 0.54 percent, while the $EFET$ index sees an increase of 0.33 percent. Conversely, full-scale redistribution leads to a 0.23 percent increase in the EO index and a 0.18 percent increase in the EFET index. Hence, the effects of income redistribution are not qualitatively affected by the choice of maintaining the World Input-Output Database (WIOD) at the 2002 level, enabling a more consumption behavior-focused analysis. This approach facilitates a more evident determination of whether alterations in consumption patterns predominantly stem from technological advancements or are influenced by factors such as shifts in consumer preferences or policy changes.

6 Conclusion

In this paper, we contribute to understanding the interplay between after-tax income and two critical features of final consumption goods and services. First, notice that modern economies carry out critical levels of international trade, including the trade of inputs. Thus, we estimate Engel curves to better understand the relationship between household income and the foreign content of their consumption choices. Likewise, we are interested in better understanding how U.S. households are exposed to foreign environmental taxes via their consumption choices. Our strategy estimates Engel curves on the foreign content of goods and services and the foreign environmental taxes embedded in consumption. We find that Engel curves are concave, shift down for the exposure to outsourcing (EO), and shift up over time for the index of exposure to foreign environmental taxes

increases in foreign content share between 1996 and 2011. Morrissey and ODonoghue (2012) argue that marine resources have a role in climate change and food production, and there has been an increased focus on marine policy abroad, which may explain higher taxes in this sector .

($EFET$). Moreover, these Engel curve features are present using different methodologies (parametric and nonparametric) and income measures.

Our decomposition analysis based on Engel curves suggests that changes in the composition of consumption bundles (movement along Engel curves) account for about 60 percent of the exposure to outsourcing index (EO) reduction. Instead, the increase in the exposure to foreign environmental taxes ($EFET$) is caused primarily by shifts in this curve. These results may shed some light on potential income redistribution and outsourcing trade-offs. For example, suppose significant swats of income are redistributed from high-income to low-income households. In that case, that policy may increase the consumption of goods with greater foreign content, as shown in the previous section. Likewise, our estimated Engel curve on foreign environmental taxes suggests that substantial income redistribution to low-income households goes hand-in-hand with importing inputs from countries with more robust environmental taxes.

Our dataset does not allow a distinction between consumption of final goods produced in the U.S. or imported from abroad. Thus, our analysis assumes that imported final goods and services are produced using the same technology, including the choice of source for inputs, as final goods produced in the United States. Accounting for the relationship between U.S. household consumption of imported final goods and the content of third-country inputs used in the production of imported final goods is beyond the scope of this paper but an interesting question to pursue in the future.

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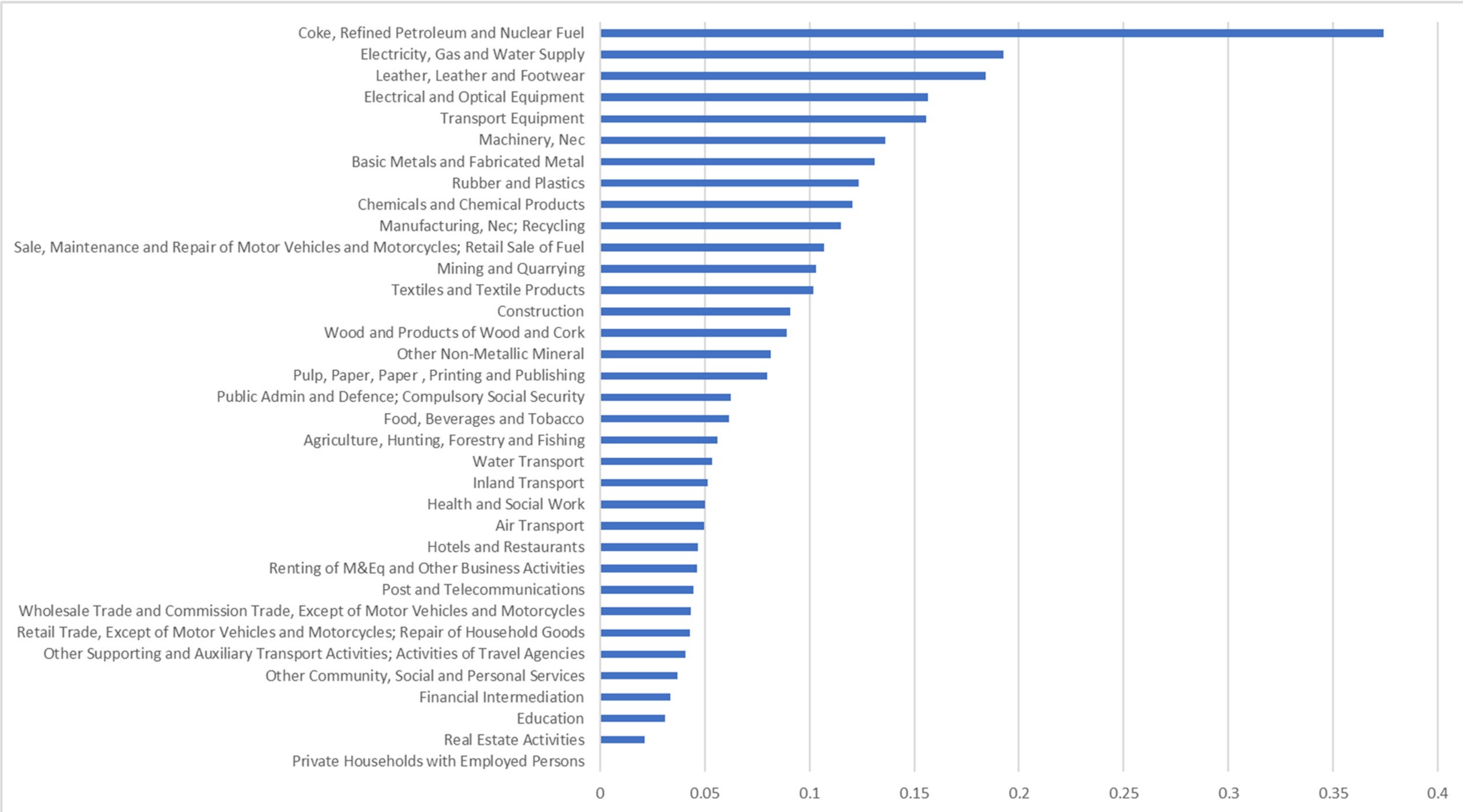
The data that supports the findings of this study are available from the corresponding author upon reasonable request.

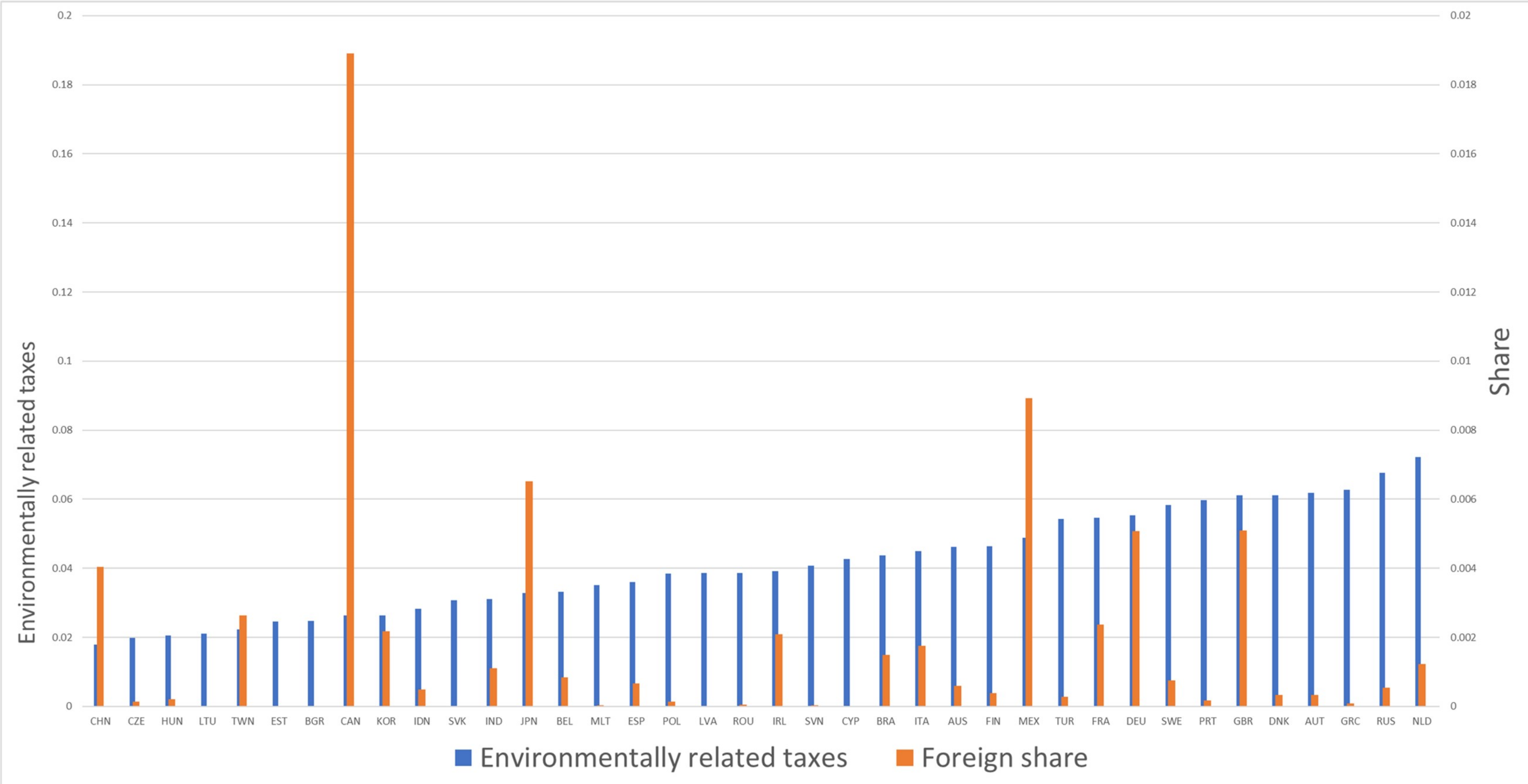
Figure 1: Foreign Content Share By Industry in 2002 WIOD



Note: The foreign content share within an industry is calculated by summing the values of intermediate goods sourced from foreign countries in that specific industry and dividing this sum by the value of shipments within the same industry.

Source: World Input-Output Database (available at https://www.rug.nl/ggdc/valuechain/wiod/?lang=en)

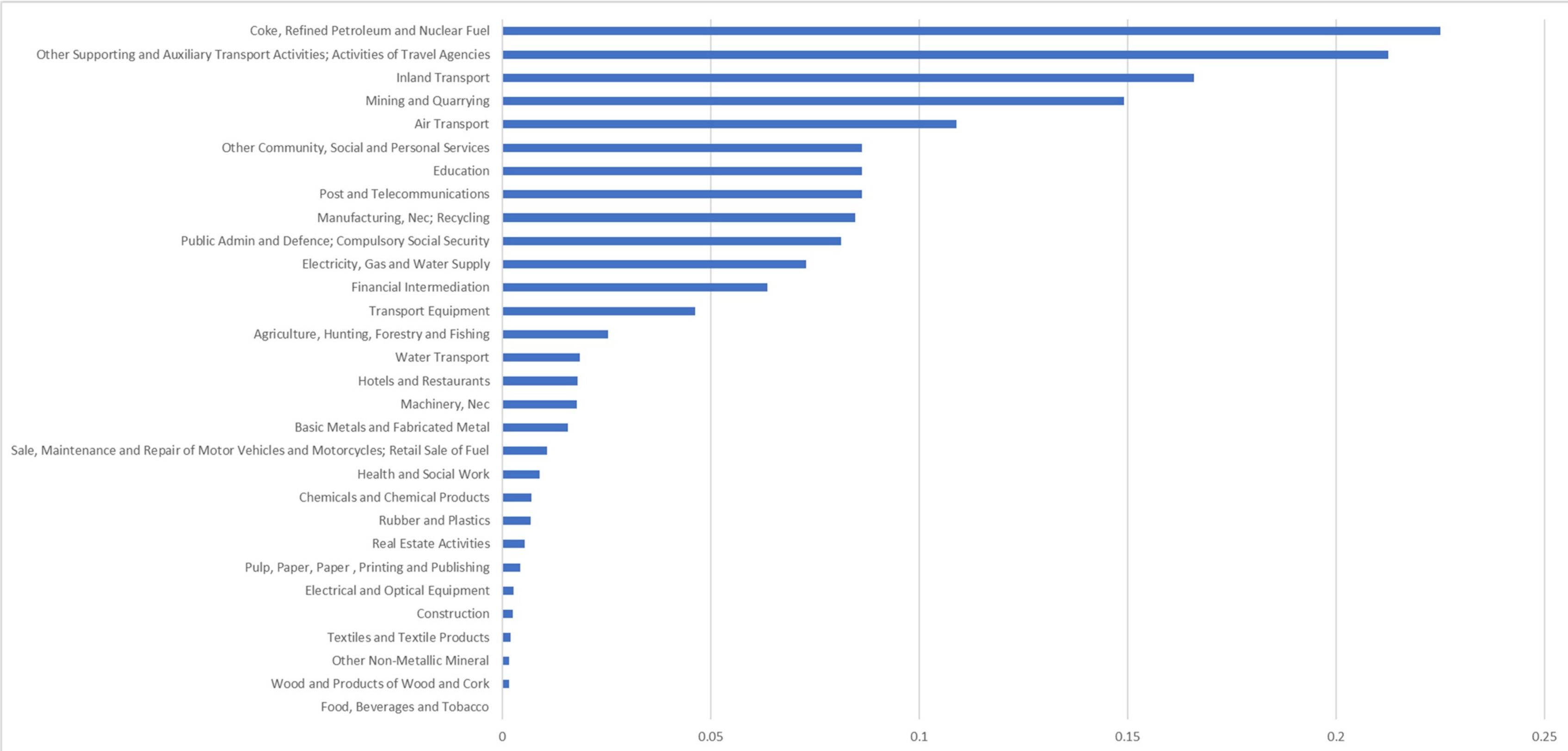
Figure 2: Average Environmentally Related Taxes and Foreign Content Share By Country in 2002



Note: The foreign content share by country is determined by summing the values of intermediate goods sourced from foreign countries and dividing this sum by the value of shipments.

Source: World Input-Output Database (available at https://www.rug.nl/ggdc/valuechain/wiod/?lang=en). Policy Instruments for the Environment Database (available at https://www.oecd.org/environment/indicators-modelling-outlooks/policy-instruments-for-environment-database/)

Figure 3: Environmentally Related Taxes in 2002 by industry



Source: Policy Instruments for the Environment Database (available at https://www.oecd.org/environment/indicators-modelling-outlooks/policy-instruments-for-environment-database/)

Figure 4: Summary of Data Procedure

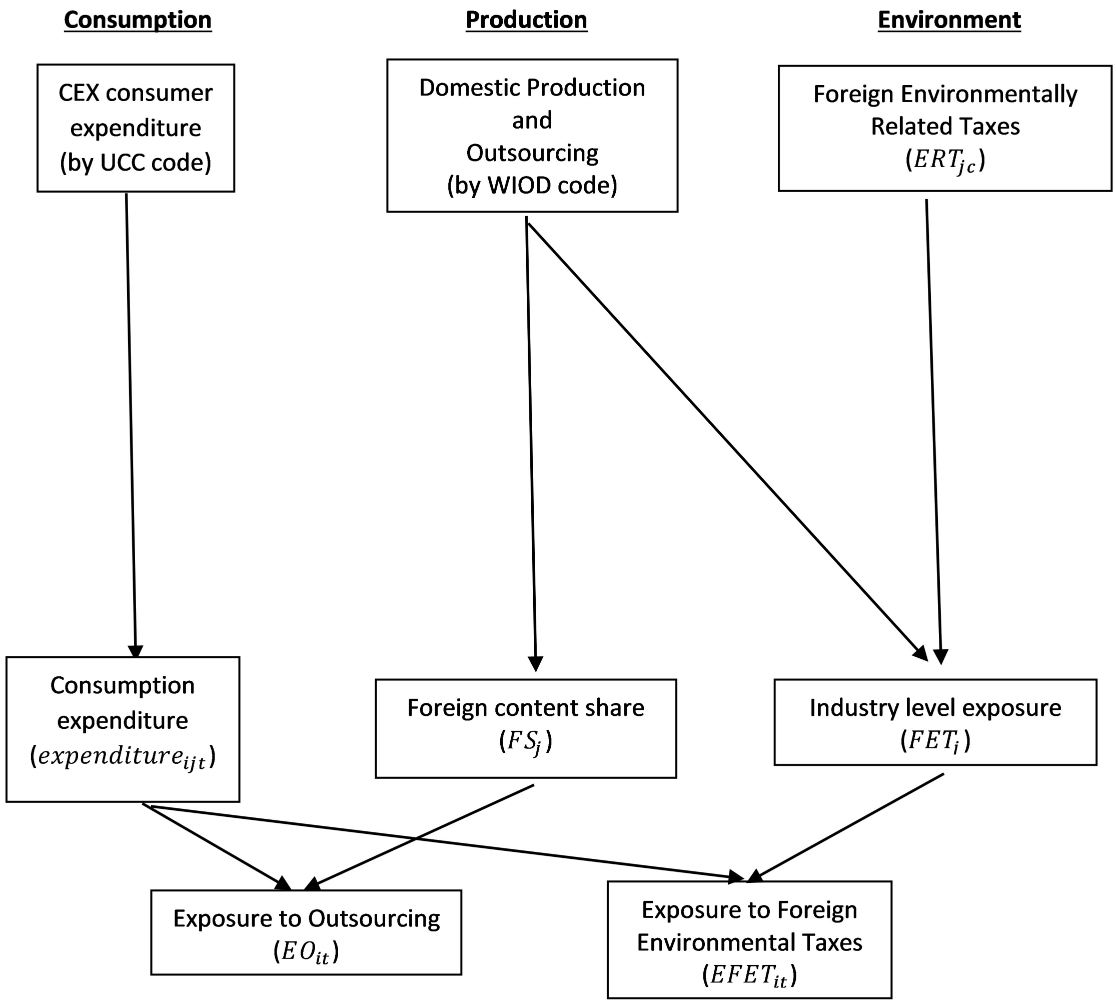
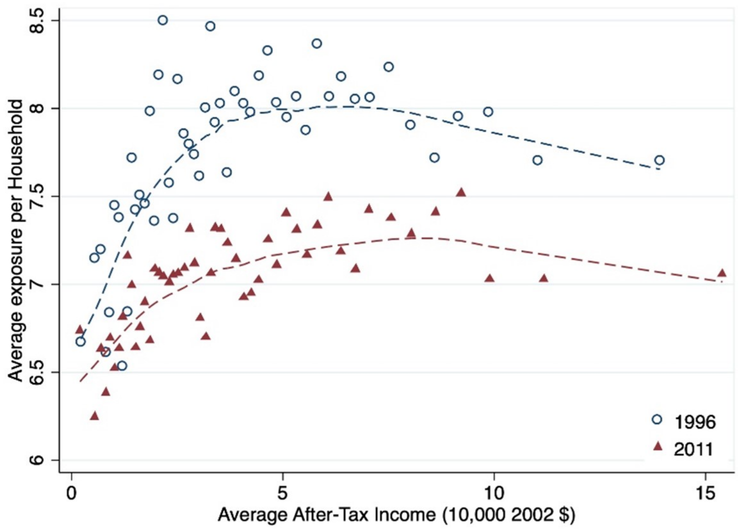


Figure 5a: Outsourcing Embodied in Household Consumption

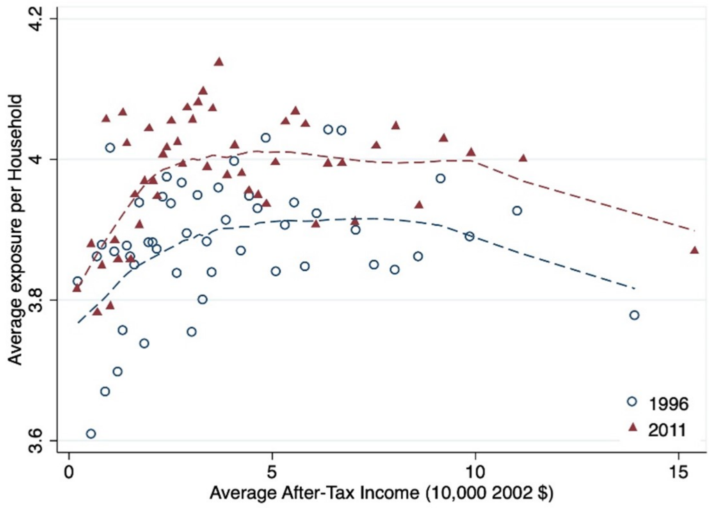
(Exposure to Outsourcing Index)



Income is adjusted for inflation using the all-items CPI. 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% of the 1996 CEX sample, with the highest and lowest 1% of households trimmed based on after-tax income.

Figure 5b: Foreign Environmental Taxes Embodied in Household Consumption

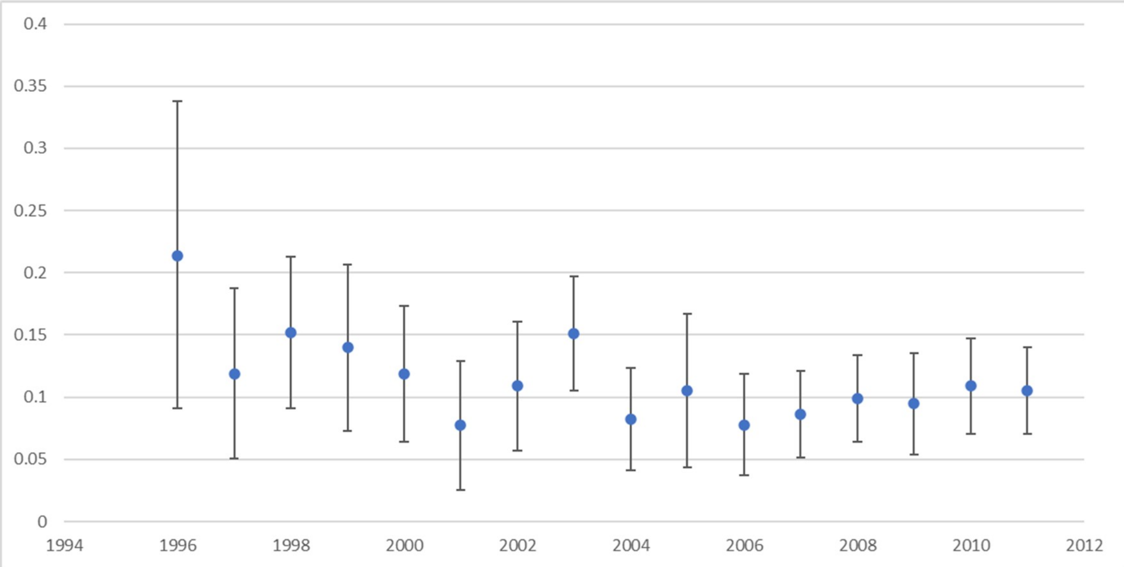
(Exposure to Foreign Environmental Taxes Index)



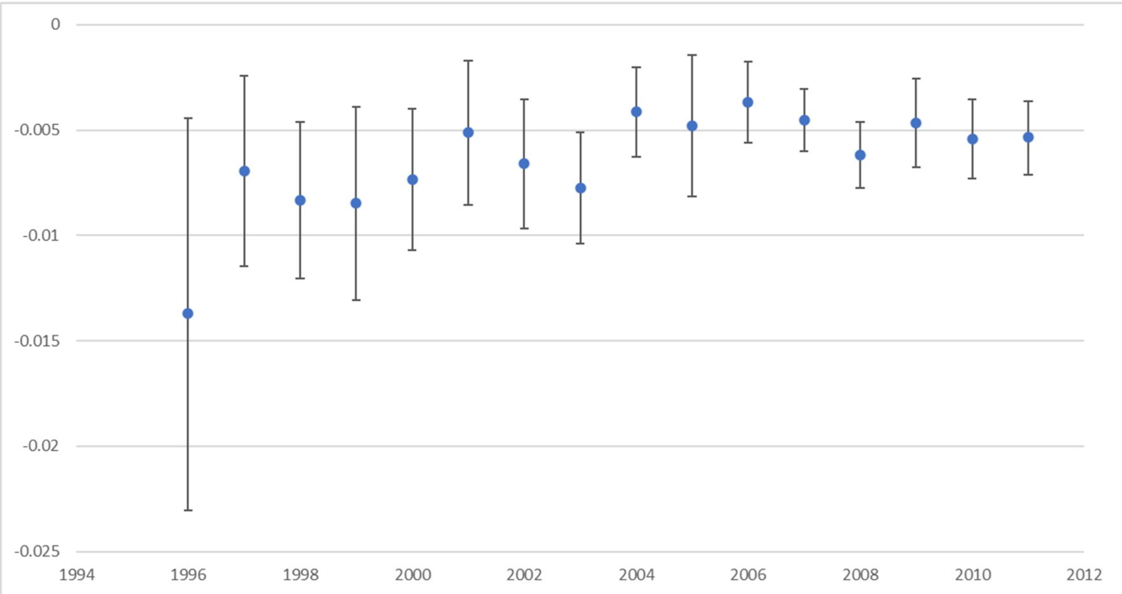
Income is adjusted for inflation using the all-items CPI. Consumption expenditure is adjusted using the core CPI with food, fuel, gasoline, and electricity adjusted separately using the corresponding CPI. Each pair of dots represents an income level corresponding to 2% of the 1996 CEX sample, with the highest and lowest 1% of households trimmed based on after-tax income.

Figure 6: Income coefficients over time – Exposure to Outsourcing

Engel Curve After-Tax Income Coefficients



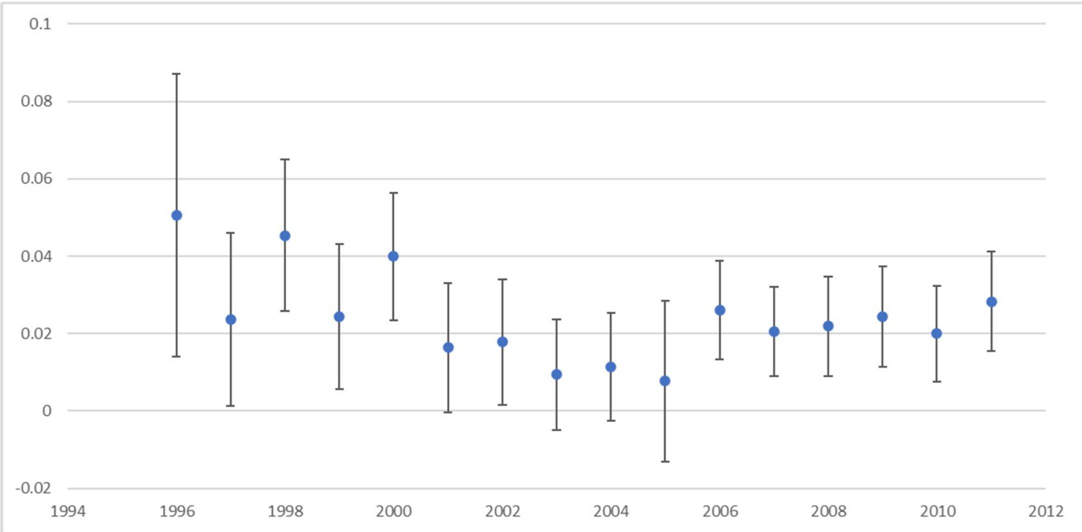
Engel Curve After-Tax Income Squared Coefficients



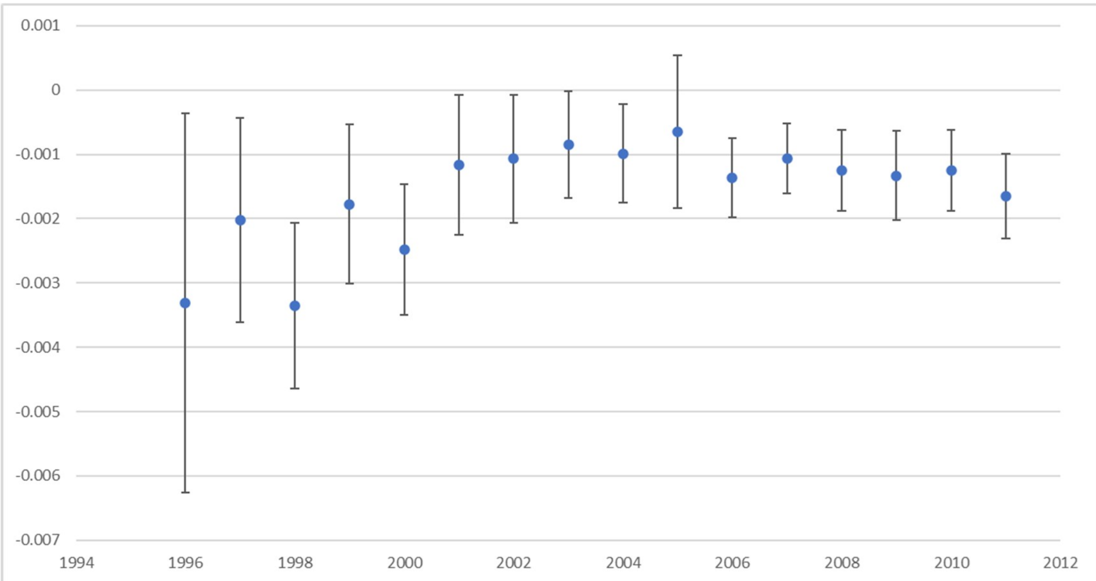
Note: The figure illustrates the regression analysis results examining the relationship between income quadratic terms and the value of exposure to the outsourcing index over time. The dot represents the estimated coefficients in Table 2, while the line indicates the corresponding confidence intervals.

Figure 7: Income coefficients over time – Exposure to Foreign Environmental Taxes

Engel Curve After-Tax Income Coefficients



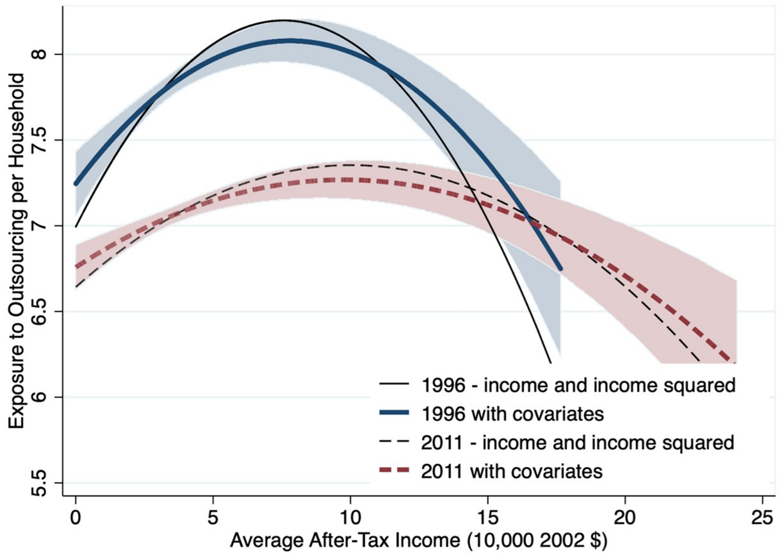
Engel Curve After-Tax Income Squared Coefficients



Note: The figure illustrates the regression analysis results examining the relationship between income quadratic terms and the value of exposure to foreign environmental taxes index over time. The dot represents the estimated coefficients in Table 3, while the line indicates the corresponding confidence intervals.

Figure 8a: Engel Curves Based on Parametric Estimates

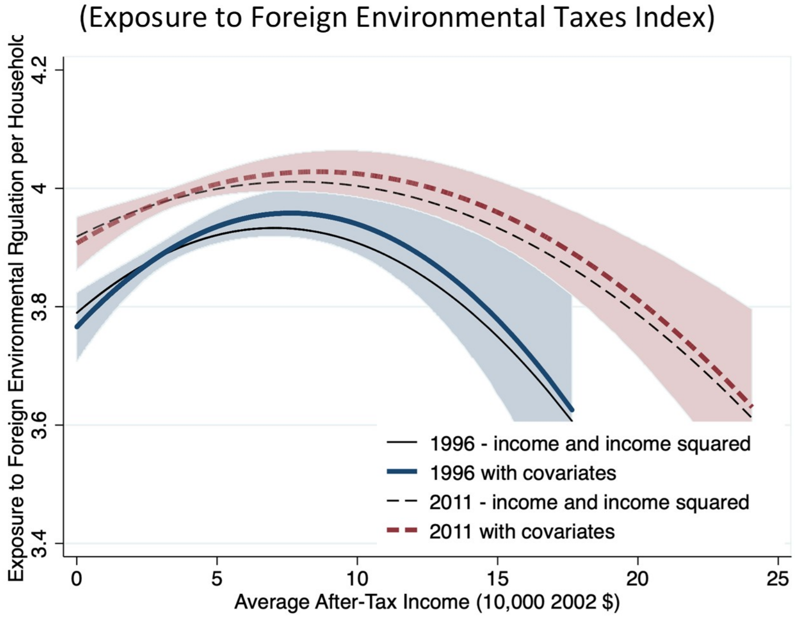
(Exposure to Outsourcing Index)



All other covariates are fixed at their mean values. Inflation adjustments as in Figure 5. Standard errors for the two outsourcing indexes are not estimated. So, 5% confidence intervals (shaded) reflect variations in household spending.

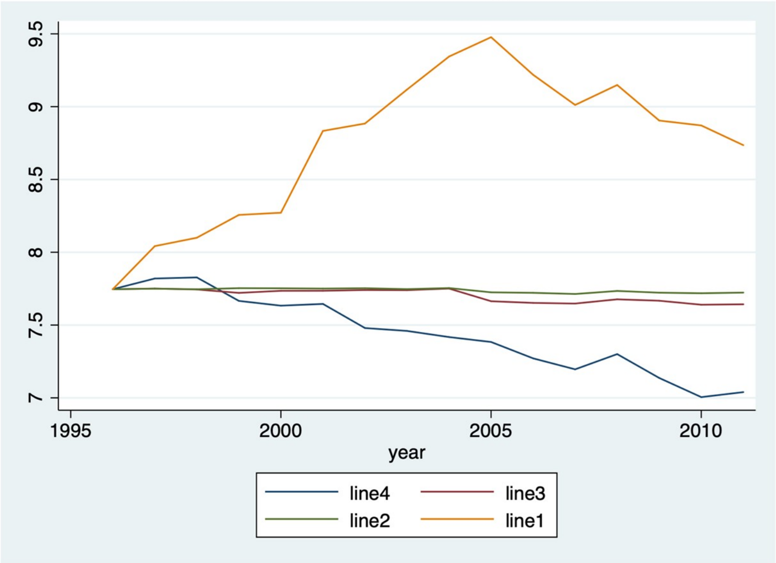
Figure 8b: Engel Curves Based on Parametric Estimates

(Exposure to Foreign Environmental Taxes Index)



All other covariates are fixed at their mean values. Inflation adjustments as in Figure 5. Standard errors for the two outsourcing indexes are not estimated. So, 5% confidence intervals (shaded) reflect variations in household spending.

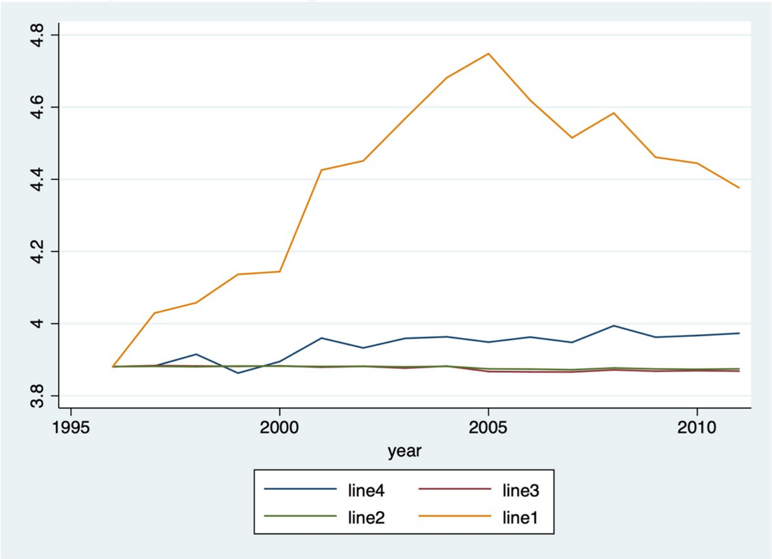
Figure 9a: Decomposition of Predicted Outsourcing Indexes from Household Consumption (Exposure to Outsourcing Index)



Line (1) Scale Effect
Line (2) Movement Along Engel Curve
Line (3) Movement Along Engel Curve and Demographic Changes
Line (4) Index Predicted

The changing index calculates the scale effect in proportion to real after-tax income growth. Movements are long and shifts in the Engel curve are calculated by estimating the value of indexes each year using the 1996 Engel curve coefficients. Household exposure is estimated by matching itemized consumption expenditure in each year with the corresponding industries' 2002 WIOD outsourcing index or foreign regulation index.

Figure 9b: Decomposition of Predicted Outsourcing Indexes from Household Consumption (Exposure to Foreign Environmental Taxes Index)

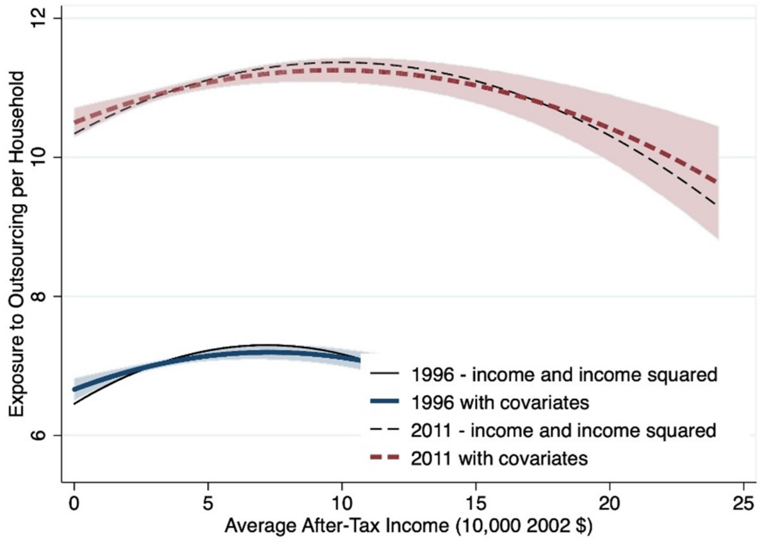


Line (1) Scale Effect
Line (2) Movement Along Engel Curve
Line (3) Movement Along Engel Curve and Demographic Changes
Line (4) Index Predicted

The changing index calculates the scale effect in proportion to real after-tax income growth. Movements are long and shifts in the Engel curve are calculated by estimating the value of indexes each year using the 1996 Engel curve coefficients. Household exposure is estimated by matching itemized consumption expenditure in each year with the corresponding industries' 2002 WIOD outsourcing index or foreign regulation index.

Figure 10a: Engel Curves Based on Parametric Estimates with Technology Changes

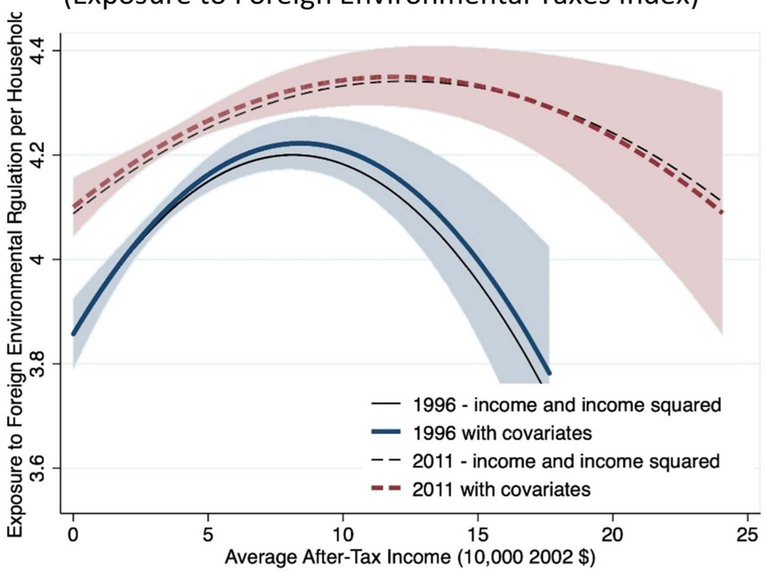
(Exposure to Outsourcing Index)



All other covariates are fixed at their mean values. Inflation adjustments as in Figure 5. Standard errors for the two outsourcing indexes are not estimated. So, 5% confidence intervals (shaded) reflect variations in household spending.

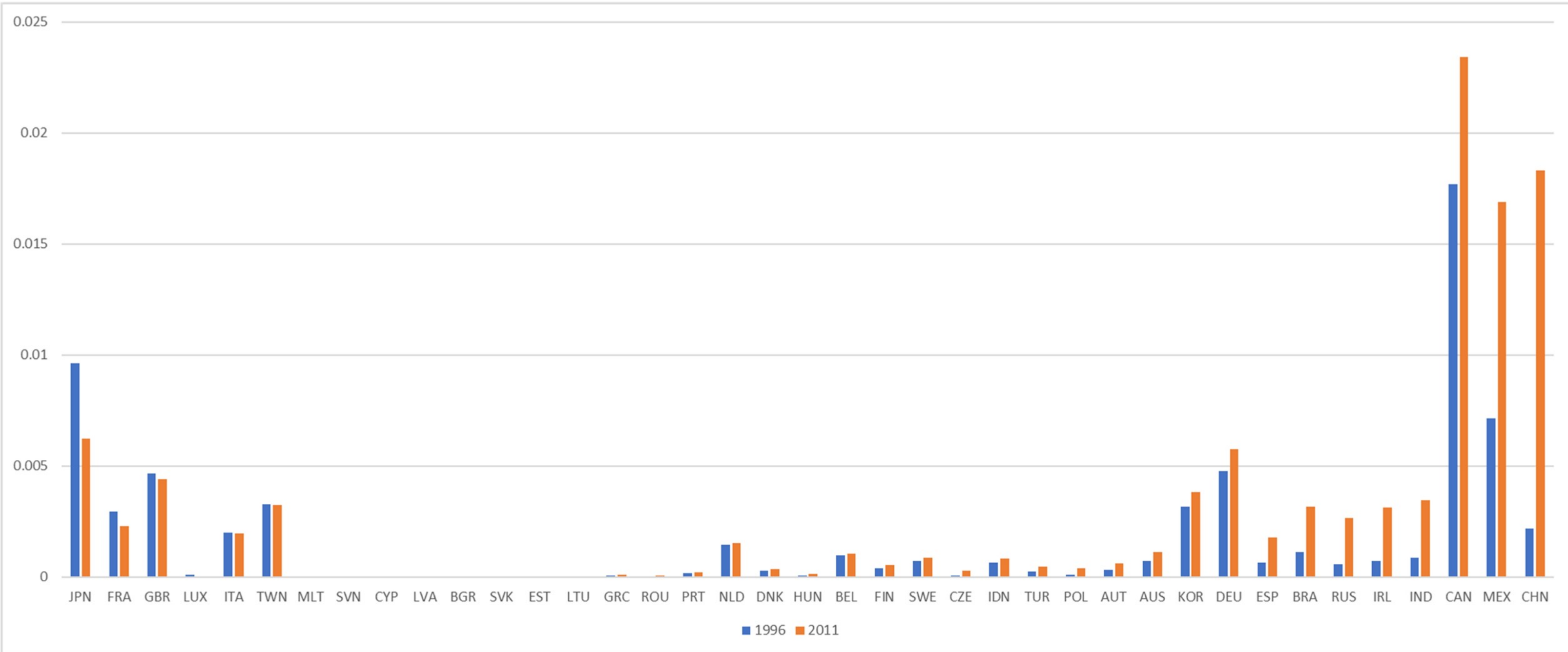
Figure 10b: Engel Curves Based on Parametric Estimates with Technology Changes

(Exposure to Foreign Environmental Taxes Index)



All other covariates are fixed at their mean values. Inflation adjustments as in Figure 5. Standard errors for the two outsourcing indexes are not estimated. So, 5% confidence intervals (shaded) reflect variations in household spending.

Figure 11: Foreign Content Share by Country between 1996 and 2011



Note: The foreign content share by country is determined by summing the values of intermediate goods sourced from foreign countries and dividing this sum by the value of shipments.

Source: World Input-Output Database (available at https://www.rug.nl/ggdc/valuechain/wiod/?lang=en). Policy Instruments for the Environment Database (available at https://www.oecd.org/environment/indicators-modelling-outlooks/policy-instruments-for-environment-database/)

Figure 12: Foreign content Share By Industry between 1996 and 2011

Note: The foreign content share within an industry is calculated by summing the values of intermediate goods sourced from foreign countries in that specific industry and dividing this sum by the value of shipments within the same industry.

Source: World Input-Output Database (available at https://www.rug.nl/ggdc/valuechain/wiod/?lang=en)

Table 1: Average Values for Selected Variables

	Cross Section		
	1996	2011	Difference
Variable	(1)	(2)	(3)
Outsourcing index (2002 technology)			
Exposure to Outsourcing	7.746	7.039	-0.707
	(0.035)	(0.026)	(0.044)
Exposure to Foreign Environmental Taxes	3.881	3.973	0.092
	(0.010)	(0.009)	(0.013)
After-tax income	4.009	4.521	0.512
($10,000 in 2002 dollars)	(0.062)	(0.066)	(0.091)
Household size	2.608	2.545	-0.063
	(0.032)	(0.027)	(0.042)
Age of household head	48.17	50.04	1.87
	(0.375)	(0.331)	(0.500)
Head is married (share of population)	0.556	0.523	-0.033
Race of head is black	0.117	0.111	-0.006
Education of head (share of population)			
Elementary only	0.182	0.135	-0.047
High school	0.292	0.252	-0.04
Some college	0.272	0.301	0.029
College	0.171	0.204	0.033
More than college	0.084	0.108	0.024
Region			
Northeast	0.180	0.185	0.005
Midwest	0.230	0.218	-0.012
South	0.367	0.354	-0.013
West	0.223	0.234	0.011
Rural	0.138	0.079	-0.059
Observations	2,571	3,624	

Values calculated using sample weights. Standard erros in parentheses. After-tax income measured in $10,000. Nominal income adjusted using the CPI for all items: nominal expenditures adjusted using the corresponding price series for food and beverages, gasoline, electricity, fuel oil, and core expenditure. Sample size for 1996 is small caused by the deletion of the observations that are students.

Table 2: Parametric Engel Curves for Exposure to Outsourcing

Dependent vairable:	1996		2000	2005	2011
Exposure per Household	(1)	(2)	(3)	(4)	(5)
After-tax income	0.319***	0.214***	0.119***	0.105***	0.105***
($10,000 in 2002 dollars)	(0.033)	(0.035)	(0.027)	(0.021)	(0.021)
After-tax income squared	-0.021***	-0.014***	-0.007***	-0.005***	-0.005***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Household size		0.289***	0.065	0.308***	0.244***
		(0.074)	(0.071)	(0.073)	(0.061)
Household size squared		-0.025***	-0.0006	-0.030***	-0.017**
		(0.008)	(0.009)	(0.009)	(0.007)
Age		0.059***	0.082***	0.037***	0.055***
		(0.013)	(0.011)	(0.011)	(0.009)
Age squared		-0.0005***	-0.0007***	-0.0003***	-0.0005***
		(0.0001)	(0.0001)	(0.0001)	(0.0001)
Married		0.255***	0.414***	0.324***	0.157**
		(0.087)	(0.071)	(0.074)	(0.064)
Race: Black		-0.596***	-0.365***	-0.285***	-0.336***
		(0.099)	(0.085)	(0.102)	(0.083)
Race: Asian		-0.429**	-0.616***	-0.428***	-0.623***
		(0.197)	(0.149)	(0.150)	(0.121)
Race: Other		0.596	0.523**	0.330*	0.143
		(0.438)	(0.247)	(0.181)	(0.234)
Education: High school		0.119	0.204**	0.354***	0.327***
		(0.102)	(0.090)	(0.103)	(0.090)
Education: Some college		0.069	0.208**	0.241**	0.303***
		(0.108)	(0.092)	(0.098)	(0.089)
Education: College		-0.209*	-0.163	-0.060	-0.023
		(0.114)	(0.101)	(0.107)	(0.102)
Education: Graduate		-0.498***	-0.196	-0.251**	-0.131
		(0.130)	(0.123)	(0.121)	(0.113)
Region: Midwest		0.458***	0.373***	0.216***	0.324***
		(0.098)	(0.080)	(0.080)	(0.075)
Region: South		0.722***	0.583***	0.589***	0.494***
		(0.092)	(0.077)	(0.081)	(0.072)
Region: West		-0.013	0.189**	0.067	-0.175**
		(0.100)	(0.083)	(0.083)	(0.077)
Rural		0.809***	0.789***	0.919***	0.488***
		(0.093)	(0.094)	(0.118)	(0.107)
Constant	6.993***	4.642***	4.434***	4.966***	4.344***
	(0.089)	(0.320)	(0.302)	(0.302)	(0.253)
F-test of income coefficients	49.40	18.83	10.05	12.98	13.33
Observations	2,571	2,571	3,714	3,703	3,624
R-squared	0.043	0.204	0.167	0.141	0.138

The dependent variable is Exposure to Outsourcing (EO_{it}) described in expression (1). Robust standard errors in parentheses. Household exposure calculated by multiplying itemized household consumption with 2002 WIOD outscourcing index or foreign environmental taxes index for each type of good and summing for each household. Ater-tax income measured in $10,000. Nominal incomes adjusted using the CPI for all items; nominal expenditures are adjusted using the corresponding core, food and beverage, gasoline, electricity, and fuel oil CPIs.
**** for 1%, ** for 5%, * for 10%*

Table 3: Parametric Engel Curves for Exposure to Foreign Environmental Taxes

Dependent vairable:	1996		2000	2005	2011
Exposure per Household	(1)	(2)	(3)	(4)	(5)
After-tax income	0.041***	0.051***	0.040***	0.008	0.028***
($10,000 in 2002 dollars)	(0.010)	(0.011)	(0.008)	(0.007)	(0.007)
After-tax income squared	-0.003***	-0.003***	-0.002***	-0.0006**	-0.002***
	(0.0008)	(0.0008)	(0.001)	(0.0003)	(0.0004)
Household size		-0.041	-0.036*	-0.043**	-0.020
		(0.026)	(0.021)	(0.021)	(0.021)
Household size squared		0.004	0.003	0.006**	0.0006
		(0.003)	(0.002)	(0.002)	(0.003)
Age		0.011***	0.008**	0.006*	0.012***
		(0.004)	(0.004)	(0.003)	(0.003)
Age squared		-0.001***	0.0001*	0.0003	0.0001***
		(0.00003)	(0.00003)	(0.00003)	(0.00001)
Married		0.009	0.051**	0.048**	0.044**
		(0.028)	(0.024)	(0.022)	(0.022)
Race: Black		-0.022	-0.003	0.065**	0.022
		(0.034)	(0.027)	(0.031)	(0.032)
Race: Asian		0.035	0.043	0.155***	0.063
		(0.068)	(0.062)	(0.054)	(0.041)
Race: Other		-0.023	0.095	-0.064	-0.022
		(0.159)	(0.079)	(0.065)	(0.062)
Education: High school		-0.046	0.033	0.050*	0.070**
		(0.031)	(0.028)	(0.030)	(0.030)
Education: Some college		-0.075**	0.012	0.051*	0.004
		(0.032)	(0.028)	(0.030)	(0.030)
Education: College		-0.054	0.030	0.060*	-0.030
		(0.036)	(0.033)	(0.034)	(0.033)
Education: Graduate		-0.066	-0.005	0.103***	-0.037
		(0.041)	(0.042)	(0.037)	(0.038)
Region: Midwest		0.082***	0.066**	0.095***	0.090***
		(0.030)	(0.027)	(0.026)	(0.025)
Region: South		0.036	0.085***	0.114***	0.148***
		(0.029)	(0.025)	(0.025)	(0.023)
Region: West		0.10***	0.110***	0.036	0.137***
		(0.031)	(0.028)	(0.026)	(0.025)
Rural		0.131***	0.114***	0.130***	0.017
		(0.033)	(0.032)	(0.038)	(0.043)
Constant	3.789***	3.506***	3.501***	3.640***	3.485***
	(0.026)	(0.098)	(0.103)	(0.090)	(0.086)
F-test of income coefficients	8.45	9.85	11.25	4.01	10.76
Observations	2,571	2,571	3,714	3,703	3,624
R-squared	0.008	0.038	0.032	0.032	0.038

The dependent variable is Exposure to Foreign Environmental Taxes ($EFET_{it}$) described in expression (3). Robust standard errors in parentheses. Household exposure calculated by multiplying itemized household consumption with 2002 WIOD outscourcing index or foreign regulation index for each type of good and summing for each household. Ater-tax income measured in $10,000. Nominal incomes adjusted using the CPI for all items; nominal expenditures are adjusted using the corresponding core, food and beverage, gasoline, electricity, and fuel oil CPIs.

***** for 1%, ** for 5%, * for 10%*

Table 4: Movement Along Parametric Engel Curves for Outsourcing Indexes

	Exposure to Outsourcing	Exposure to Foreign Environmental Taxes
Dependent Variable:	(1)	(2)
after-tax income ($10,000 in 2002 dollars)	0.110***	0.026***
	(0.026)	(0.007)
After-tax income squared	-0.133***	-0.032***
	(0.029)	(0.009)
Household size	-0.018	0.003
	(0.013)	(0.002)
Household size squared	0.008	-0.001
	(0.008)	(0.002)
Age	0.111***	0.021**
	(0.038)	(0.009)
Age squared	-0.093***	-0.017
	(0.034)	(0.008)
Married	-0.009*	-0.0003
	(0.005)	(0.001)
Race dummies	0.005	-0.002
Education dummies	-0.022	-0.004
Regional dummies	-0.063	-0.008
Total change due to income (movement along EC)	-0.0230	-0.0061
Total change due to other demographics	-0.0804	-0.0063
Unexplained difference (shift in EC)	-0.6036	0.1044

Estimates based on Oaxaca-Blinder decompositions. Robust standard errors in parentheses. Movements along each Engel curves described in expression (6) Term 1. Total change due to other *demographics described in expression (6) Term 3. Shifts in Engel curves described in expression (6) Term 2. The value of index based on 2002 production technology for all years. Ater-tax income measured in $10,000.*
**** for 1%, ** for 5%, * for 10%*

Table 5: Outsourcing Offset Due to Composition Changes in Household Consumption

				Offset by Movement along Engel Curve		Offset by Demographic Changes		Offset by Shifts in Engel Curve	
	Total Change	Scale Increase	Total spread (2) - (1)	Value	Share of Spread	Value	Share of Spread	Pounds	Share of Spread
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Exposure to Outsourcing	-0.71	0.99	1.70	1.01	0.60	0.081	0.047	0.603	0.36
Exposure to Foreign Environmental Taxes	0.09	0.50	0.40	0.50	1.24	0.006	0.016	-0.105	-0.26

The total change in the value of index is predicted using CEX, WIOD data, and ERT data based on 2002 production technology and environmental taxation (Table 1). The scale increase (SC) in the value of index is calculated by multiplying index level in 1996 by the proportional increase in after-tax income between 1996 and 2011 (Expression (7)). The total spread is calculated as the difference between the predicted change from the coefficients and the predicted change due to the scale effect. Offset in column 4 (CC) are calculated by subtracting the predicted value of index including scale effects and movements along the Engel curve from the scale scale effect alone (expression (8)). Offsets due to demographic changes (expression (6) Term 3) are calculated in an analogous manner. Offsets due to shifts shifts in the Engel curve (expression 6 Term 2) are calculated as the residual, and the offsets in columns 4,6 and 8 sum to column 3 by construction. After-tax income measured in $10,000.

Table 6: Results of Income Redistribution

	Income Redistribution	EO	$\%\Delta EO$	$EFET$	$\%\Delta EFET$
Original Value		7.0390		3.973	
To poorest	0.25	7.0418	0.04	3.974	0.0291
	0.5	7.0443	0.0747	3.975	0.0514
To average	0.25	7.0408	0.0254	3.974	0.0229
	0.5	7.0440	0.0712	3.9745	0.0389
All households	Marginal Redistribution	7.082	0.605	3.986	0.332
	Full Redistribution	7.065	0.372	3.984	0.275

Ater-tax income measured in $10,000

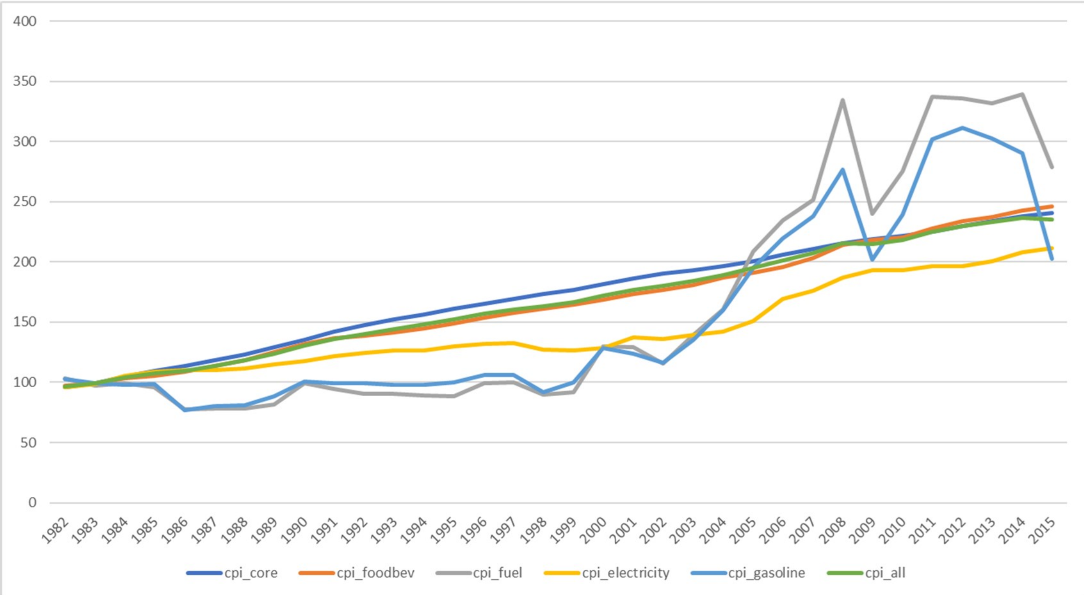
Table 7: Results of Income Redistribution with Technology Changes

	Income Redistribution	EO	$\%\Delta EO$	$EFET$	$\%\Delta EFET$
Original Value		10.9144		4.216	
To poorest	0.25	10.9181	0.0346	4.217	0.0202
	0.5	10.9215	0.0652	4.218	0.0411
To average	0.25	10.9172	0.0257	4.217	0.0161999
	0.5	10.9198	0.0495	4.217	0.03003
All households	Marginal Redistribution	10.973	0.537	4.230	0.332
	Full Redistribution	10.940	0.234	4.224	0.184

Ater-tax income measured in $10,000

A Appendix

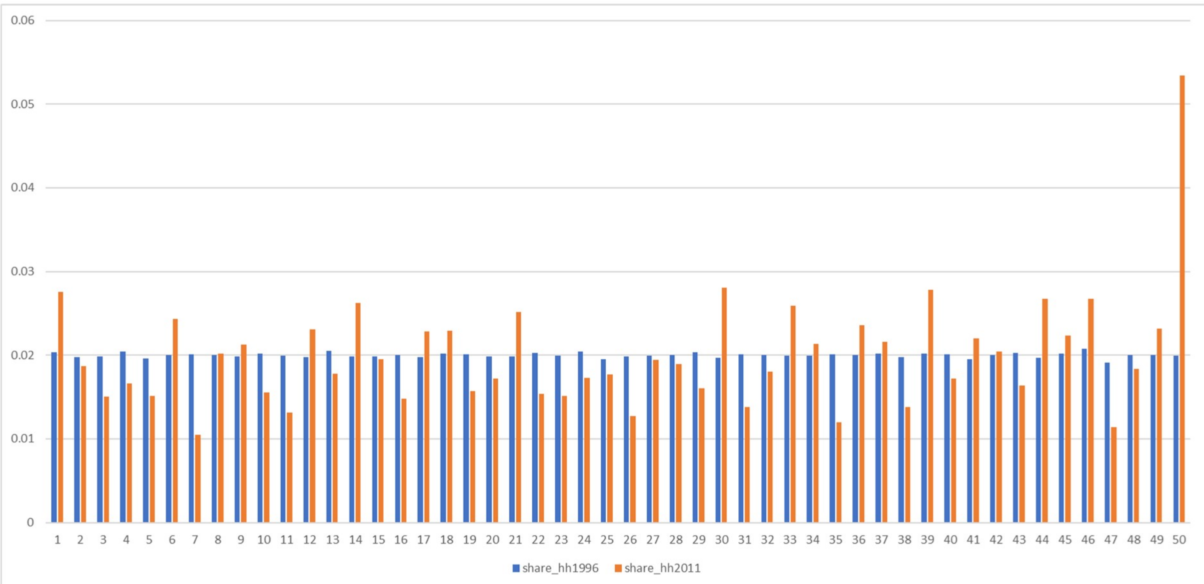
Figure A.1: Components of the Consumer Price Index, 1982-2014



Note: Core CPI includes all items, less food and energy.

Source: Bureau of Labor statistics, Consumer Price Index (available at http:// www.bls.gov/icpi/)

Figure A2: Share of Households in Each Income Bin from Figures 5 through 10

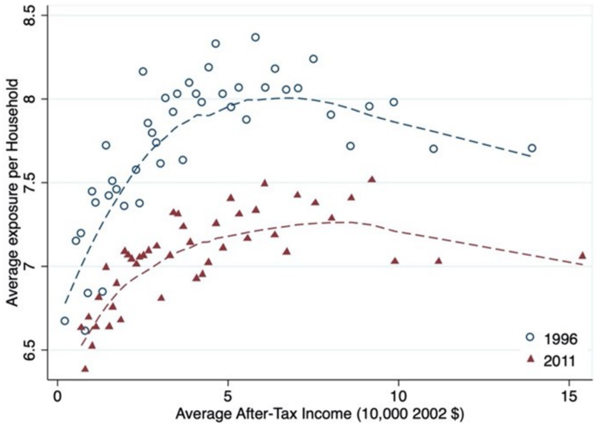


Note: The 1996 CEX is split into 50 groups based on after-tax income.

Source: Bureau of Labor statistics, Consumer Expenditure Surveys (available at https://www.bls.gov/cex/)

Figure A3a: Outsourcing Embodied in Household Consumption

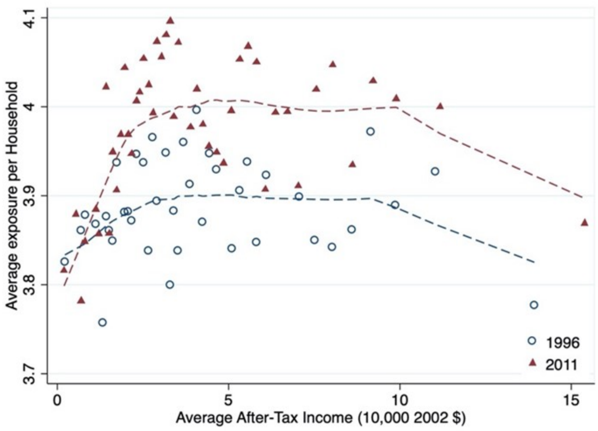
(Exposure to Outsourcing Index)



Income is adjusted for inflation using the all-items CPI. 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% of the 1996 CEX sample, with the highest and lowest 1% of households trimmed based on after-tax income.

Figure A3b: Foreign Environmental Taxes Embodied in Household Consumption

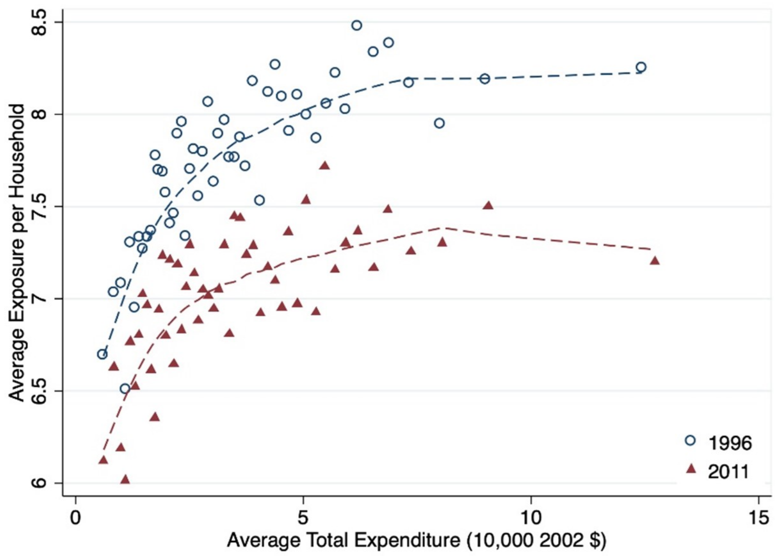
(Exposure to Foreign Environmental Taxes Index)



Income is adjusted for inflation using the all-items CPI. 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% of the 1996 CEX sample, with the highest and lowest 1% of households trimmed based on after-tax income.

Figure A4a: Engel Curves based on Total Expenditure

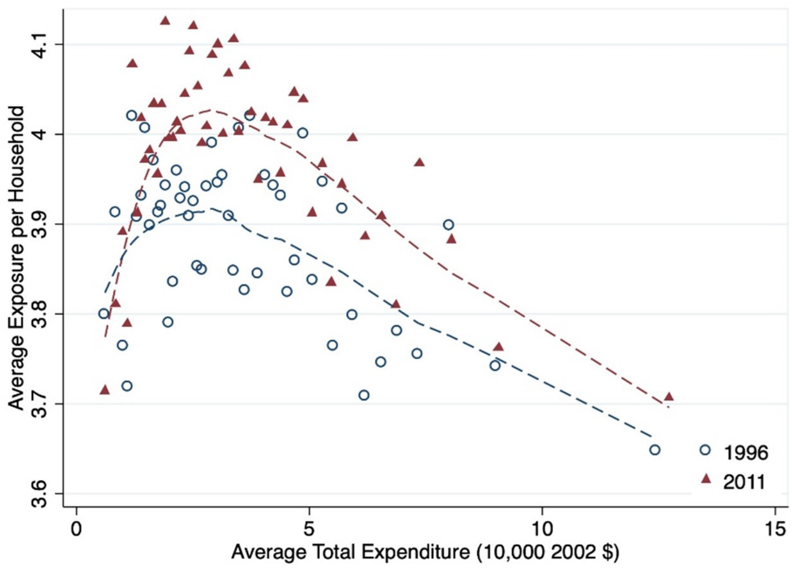
(Exposure to Outsourcing Index)



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% of the 1996 CEX example, with the highest and the lowest 1% of households trimmed based on after-tax income.

Figure A4b: Engel Curves based on Total Expenditure

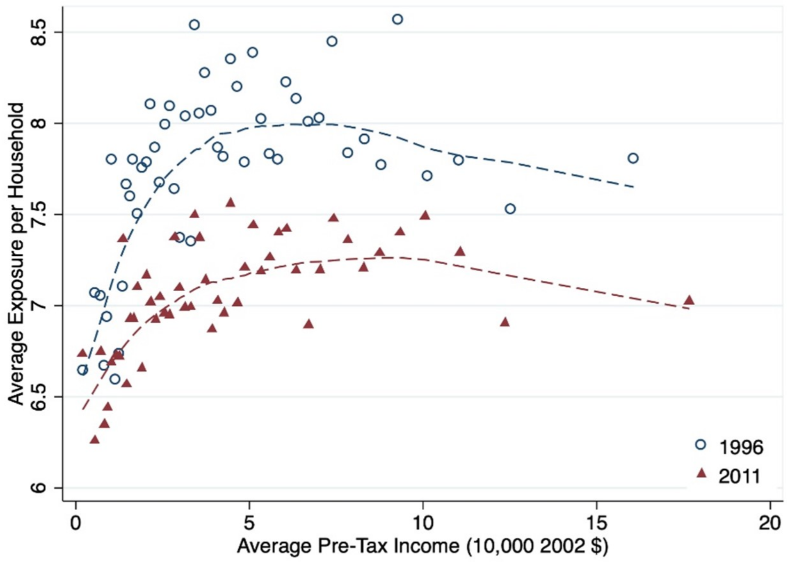
(Exposure to Foreign Environmental Taxes Index)



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% of the 1996 CEX example, with the highest and the lowest 1% of households trimmed based on after-tax income.

Figure A5a: Engel Curves based on Pre-Tax Income

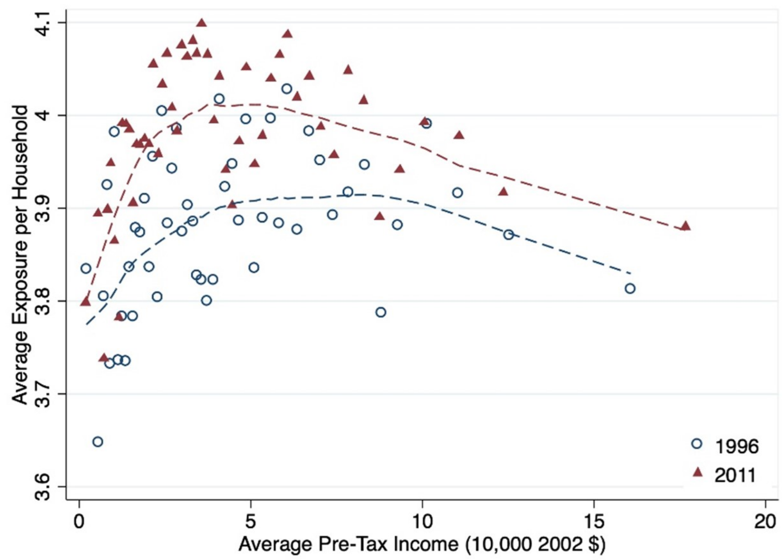
(Exposure to Outsourcing Index)



See notes in Figure 5.

Figure A5b: Engel Curves based on Pre-Tax Income

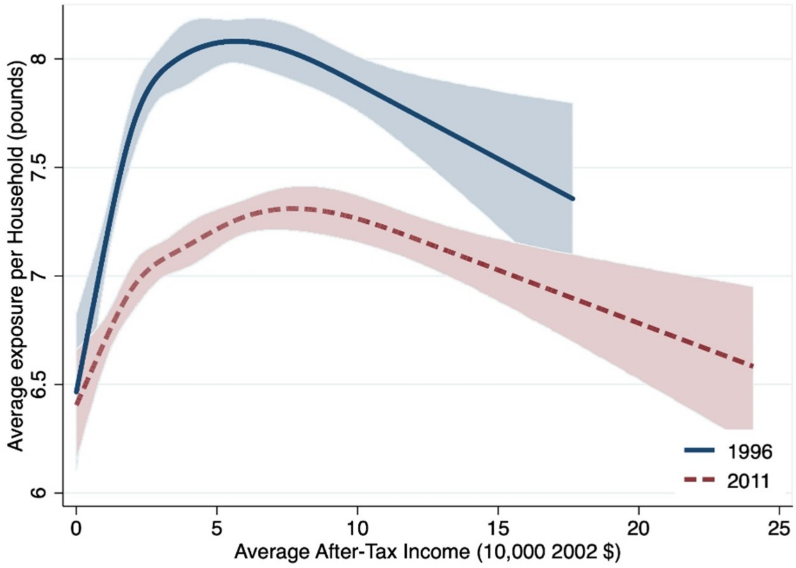
(Exposure to Foreign Environmental Taxes Index)



See notes in Figure 5.

Figure A6a: Engel Curves Using a Restricted Cubie Spline

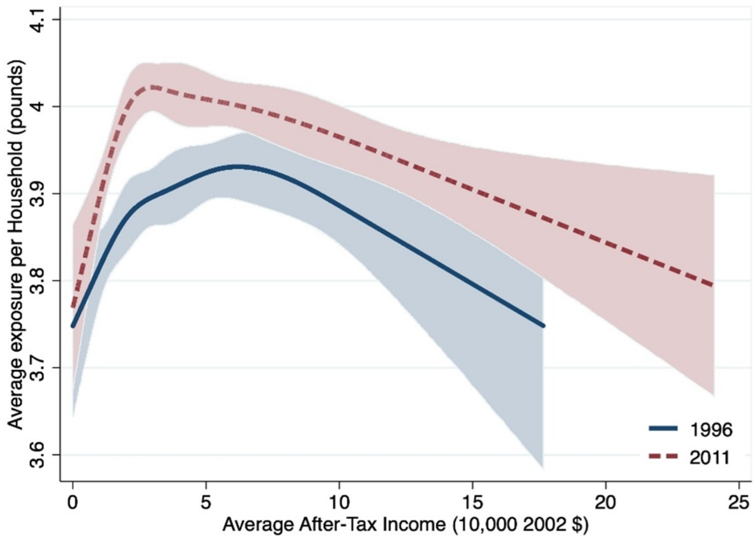
(Exposure to Outsourcing Index)



Inflation adjustments as in Figure 5. 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 index values are not estimated, so 95 percent confidence intervals (shaded) reflect variation in household spending.

Figure A6b: Engel Curves Using a Restricted Cubie Spline

(Exposure to Foreign Environmental Taxes Index)



Inflation adjustments as in Figure 5. 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 index values are not estimated, so 95 percent confidence intervals (shaded) reflect variation in household spending.

Table A1: Parametric Engel Cuves

	EO		EFET	
Dependent vairable:	1996	2011	1996	2011
Exposure per Household	(1)	(2)	(3)	(4)
After-tax income	0.215***	0.097***	0.046***	0.0280***
	(0.035)	(0.021)	(0.012)	(0.00722)
After-tax income squared	-0.014***	-0.005***	-0.003***	-0.00161***
	(0.002)	(0.001)	(0.001)	(0.000366)
Household size	0.259***	0.255***	-0.043	-0.0163
	(0.075)	(0.063)	(0.027)	(0.0227)
Household size squared	-0.021**	-0.018*	0.004	0.000284
	(0.008)	(0.007)	(0.003)	(0.00276)
Age	0.059***	0.059***	0.010**	0.0104***
	(0.013)	(0.009)	(0.004)	(0.00319)
Age squared	-0.0005***	-0.0005***	-0.0001**	-8.33e-05***
	(0.0001)	(0.00008)	(0.00004)	(2.95e-05)
Married	0.283***	0.149*	0.015	0.0422*
	(0.089)	(0.066)	(0.029)	(0.0231)
Race: Black	-0.563***	-0.327***	-0.002	0.0155
	(0.103)	(0.086)	(0.035)	(0.0326)
Race: Asian	-0.382*	-0.599***	0.055	0.0677
	(0.206)	(0.125)	(0.070)	(0.0428)
Race: Other	0.644	0.111	-0.008	-0.0147
	(0.485)	(0.237)	(0.195)	(0.0611)
Education: High school	0.182*	0.350***	-0.040	0.0703**
	(0.107)	(0.092)	(0.032)	(0.0313)
Education: Some college	0.102	0.342***	-0.077**	0.00591
	(0.112)	(0.092)	(0.032)	(0.0312)
Education: College	-0.166	0.007	-0.046	-0.0229
	(0.119)	(0.104)	(0.037)	(0.0347)
Education: Graduate	-0.436***	-0.084	-0.059	-0.0359
	(0.134)	(0.114)	(0.042)	(0.0395)
Region: Midwest	0.427***	0.344**	0.087***	0.106***
	(0.098)	(0.076)	(0.030)	(0.0259)
Region: South	0.720***	0.505***	0.032	0.161***
	(0.094)	(0.074)	(0.029)	(0.0237)
Region: West	-0.058	-0.159	0.101***	0.142***
	(0.101)	(0.079)	(0.032)	(0.0261)
Rural	0.820***	0.454***	0.138***	0.0254
	(0.093)	(0.110)	(0.035)	(0.0471)
Constant	4.630***	4.229	3.548***	3.497***
	(0.319)	(0.259)	(0.101)	(0.0899)
F-test of income coefficients	18.53	11.38	7.248	9.880
Observations	2,419	3,447	2,420	3,306
R-squared	0.209	0.139	0.035	0.038

See the note to Table 2