Journal of Benefit-Cost Analysis (2025), 1–15
doi:10.1017/bca.2025.7

CAMBRIDGE UNIVERSITY PRESS

ARTICLE

What Are the Effects of Early Childhood Exposure to Environmental Lead on Personality?

Arthur Fraas[1], Randall Lutter[2], Joshua Murphy[3], Qinrui Xiahou[4], Jeff Potter[5] and Samuel D. Gosling[6]

[1]Resources for the Future, Washington, DC, USA
[2]Enveritas Inc, Old Greenwich, CT, USA
[3]Ontario, Canada
[4]Faculty of Business and Economics, The University of Hong Kong, Hong Kong
[5]Psychology, The University of Texas at Austin College of Liberal Arts, Austin, TX, USA
[6]Manhattan Institute for Policy Research Inc, New York, NY, USA
Corresponding author: Randall Lutter; Email: rwlutter@gmail.com

Keywords: atmospheric lead; early childhood; personality traits

JEL Codes: D91E71J24Q53

Abstract
In the first analysis purporting to causally link environmental pollution to personality, Schwaba and colleagues leveraged a natural experiment driven by the United States. They used the Clean Air Act to assess the impact of decreased atmospheric lead on the "big five" personality traits. Using data from an online personality test taken by more than 1.2 million U.S. residents, Schwaba *et al.* reported that people born after lead levels had peaked in their county of birth had more mature, psychologically healthy personalities in adulthood (higher agreeableness and conscientiousness, and lower neuroticism) than cohorts born earlier and exposed to higher levels of atmospheric lead. One concern with their findings is that personality differences among people born in different periods could come from factors unrelated to lead, for example, access to abortion and birth control, or demographic, cultural, or technological changes. Schwaba *et al.* recognized this possibility but did not fully explore it. When we account for cohort-wide changes by introducing birth year fixed effects into Schwaba *et al.*'s models, the estimated effects of the lead phaseout on personality largely disappear, becoming indistinguishable from zero while remaining precise. Meanwhile, the estimated birth year fixed effects are jointly significant, suggesting differences in personality traits across cohorts. These results indicate that any effects of the lead phaseout on more mature, psychologically healthy adult personalities are not consistently observable in the data used by Schwaba

Fraas is a visiting fellow at Resources for the Future. Lutter is a senior fellow at the Manhattan Institute. Murphy is an economist at Finance Canada. Xiahou is a PhD candidate at the University of Hong Kong. Potter is Chief Technology Officer at Enveritas. Gosling is a professor at the University of Texas, Austin. The authors are entirely responsible for the views expressed in this article, and their views should not be attributed to any institution with which any author may be affiliated.

et al. More broadly, they caution against making causal inferences without controlling for time period effects.

1. Introduction

Personality is important for labor market performance (e.g., Borghans *et al.*, 2016; Heckman *et al.*, 2006) and other outcomes related to love, creativity, curiosity, and intellect (Schwaba *et al.*, 2021). Belfield *et al.* (2015) sought to develop economic analysis of interventions to improve social and emotional skills, following Karoly (2012), but economists and other analysts have rarely sought to link personality or social and emotional skills to in utero or early childhood environments. In the first large-scale analysis (that we are aware of) regarding the effects of early life exposure to air pollution on subclinical adult personality traits, Schwaba *et al.* (2021) report that childhood exposure to atmospheric lead concentrations common in the early 1970s predicts adulthood levels of several of the "big five" personality traits – extraversion, agreeableness, conscientiousness, neuroticism, and openness to new experiences. Exploiting a natural experiment driven by the Clean Air Act (CAA), study participants "born after atmospheric lead levels began to decline in their county had more mature, psychologically healthy adult personalities (higher agreeableness and conscientiousness and lower neuroticism), but these findings were not discriminable from pure cohort effects" (Schwaba *et al.*, 2021).[1]

This work has attracted significant attention. In 2023, USA Today published a news article titled "Lead can alter personalities," which relied on Schwaba *et al.* (Rodriguez, 2023). McFarland *et al.* (2024) modeled a collection of effects of lead, including mental health symptoms and changes in personality traits. Regarding the latter, they concluded "Population-level neuroticism increased by 0.14 standard deviations and conscientiousness decreased by 0.20 standard deviations," from exposure to lead, based on nationwide modeling of lead effects on personality reported by Schwaba *et al.* (2021). Amplifying this research, *Popular Science* recently published a story about lead and mental health stating, "Due to childhood lead poisoning, the research of McFarland *et al.* suggests that Americans, overall, are less conscientious and more neurotic" (Leffer, 2024). In this article, we reconsider the effects of early childhood lead exposures on adult personalities and examine county and birth cohort effects.

Lead is of special interest because childhood lead exposure is linked to a variety of neurological and behavioral concerns. Examples of this include aggression and destructive behavior, delinquency, attention deficit hyperactivity disorder, and criminal conduct (Centers for Disease Control and Prevention (CDC), 2019; Gibson et al 2022; Landrigan *et al.* 2018; Reyes, 2007; Reyes, 2015; and Grönqvist *et al.* 2014). It is also associated with a loss of self-control and shortened attention span, dullness, irritability, loss of memory (CDC, 2019). Using data on 849 children, and geolocation data for the children's residences for the first 36 months of life, Gatze-Kopp *et al.* (2021) employed an instrumental variable strategy to show that lead exposure had small negative effects for both child IQ and executive function. Using data on 1476 children younger than 8 years, Gatze-Kopp *et al.* (2024) found a nonlinear association between lead and executive function, with lead lowering mean inhibitory control, but not cognitive flexibility. Banzhaf and Banzhaf (2023), using

[1] The authors add: "Because shifts in personality were tied both to chronological year and to the county-specific date of lead phase out, both cohort effects and lead reduction remain plausible causal drivers of observed personality shifts in each county."

https://doi.org/10.1017/bca.2025.7 Published online by Cambridge University Press

confidential Social Security data on date of birth, find that greater in utero exposure to lead is associated with worsening disabilities in adulthood, greater reliance on public assistance, and more limited opportunities for adult employment. Environmental Protection Agency (EPA) has discussed effects of lead on personality qualitatively and has acknowledged that "some studies found that noncognitive personality traits are at least as predictive of life outcomes as IQ," (EPA 2020), citing Borghans *et al.* (2016) and Heckman *et al.* (2006). The EPA's estimates of the gains in lifetime income that may result from reductions in childhood exposure to lead dominate its benefits analysis (EPA, 2020; EPA, 2024b).

Because of these effects, lead exposure is of ongoing interest to policymakers. In a reconsideration of its 2021 hazard standards and clearance levels for dust-lead, the EPA recently issued significantly more stringent dust-lead action levels and dust-lead reportable levels that affect 31 million pre-1978 residences and day care facilities (EPA, 2024a). Supported by new benefit–cost analysis (e.g., Levin & Schwartz, 2023), it recently set new requirements to replace lead and certain galvanized service lines, reduce the lead action level to 0.01 mg/L, and tighten tap sampling procedures (EPA, 2024b). EPA is also taking steps to limit lead in civil aviation fuel (EPA, 2023). An outbreak of elevated blood lead levels in young children in 2023 led the Food and Drug Administration to issue a consumer advisory and announce a recall of applesauce products contaminated with lead (FDA, 2023a; FDA, 2023b).

EPA regulates lead based on its causal effect on cognitive function (reduced IQ, decreased academic function), although lead-related conditions include diminished attention, increased impulsivity, hyperactivity, and developmental effects (e.g., delayed pubertal onset).[2]

Nedellec and Rabl (2016) show lead controls offer reduced mortality benefits that are likely larger than benefits related to cognitive function, and note that there is apparently no exposure level with no effects.

We explore relationships among the big five personality traits and measures of exposure to airborne lead. Using data on airborne lead and personality and other data described by Schwaba *et al.* and courteously provided to us by Schwaba, we find that introducing birth year fixed effects (FE) significantly changes the associations between atmospheric lead and the big five personality traits that Schwaba *et al.* reported. Effects common to all infants born in a given year may occur because of changes unrelated to airborne lead – for example, federal law (e.g., pertaining to abortion), or demographic, cultural, or technological changes (e.g., regarding contraception or child rearing), or new employment or educational opportunities for women of childbearing age.

Including such effects also changes the estimated causal effects of changes in atmospheric lead levels on personalities. When we introduce birth year FE into Schwaba *et al.*'s models, the estimated effects of the lead phaseout on personality traits largely disappear, becoming indistinguishable from zero while remaining precise. More broadly, these results serve as a reminder of the risks associated with estimating causal effects without controlling for period or cohort effects. They do not imply an overstatement in the EPA's estimates of the quantifiable benefits of reducing childhood exposure to lead, which are based on the economic value of gains to IQ.

[2] See EPA (2024a). In addition, the EPA concluded (EPA, 2023) that the evidence supports a conclusion that there is "likely to be causal relationship" between lead exposure and conduct disorders in children and young adults, encompassing symptoms such as depression, anxiety, and withdrawn behavior, as well as impairments in auditory function and fine and gross motor skills. 88 *FR* 72395

https://doi.org/10.1017/bca.2025.7 Published online by Cambridge University Press

The rest of this article is organized as follows. First, we show how the use of birth year FE in the preregistered model presented by Schwaba *et al.* changes the sign and statistical significance for three of the personality traits (agreeableness, conscientiousness, and neuroticism) and alters the estimated associations for the other two traits. Second, we modify the model that Schwaba *et al.* used to identify the casual effects of lead and show that introducing birth year FE again upends the estimated effects of lead on personality. We conclude with a discussion of our results and conclusions.

2. Analysis

Building on Reuben *et al.* (2019), Schwaba *et al.* report associations between atmospheric concentrations of lead during the first 18 years of life and self-reported personality traits during adulthood collected through a web-based survey. Schwaba *et al.* used EPA's data on atmospheric lead concentrations, and modified it via interpolations and extrapolations to address missing observations. They also used a big data convenience sample of personality traits and parent's years of schooling from the Gosling–Potter Internet Personality Project (GPIPP; https://www.thebigfiveproject.com/). The GPIPP data used by Schwaba *et al.* were collected from 2003 to 2015 through an online survey using the "Big Five Inventory, a widely used 44-item index of the Big Five personality domains," according to Schwaba *et al.* They explain that for each of the 44 items, "participants reported the degree to which they agreed with a short phrase (e.g., "I am someone who tends to be lazy"), using a 5-point rating scale." Schwaba *et al.* provide descriptive statistics for the big five personality traits and related data in their Table S1.[3] Using preregistered covariates controlling for the respondent's age, parental college schooling, and median county income, Schwaba *et al.* find that both extraversion and openness to new ideas increase with increased lead exposure, while agreeableness and conscientiousness decline with increased lead exposure. These relationships are all significantly different from zero at the 99.9 % level while a fifth trait, neuroticism, has no statistically significant relationship with lead.

While Schwaba *et al.* explore these associations in a variety of models, they do not estimate models with FE for the year of birth. Birth year and age correlate imperfectly because the data were collected over 12 years, ending in 2015. Some of those born in 1970 (say) completed the survey in 2004 at age 34, while others born in the same year may have completed it as late as 2015 at age 45. Indeed, respondents of various ages completed the survey at quite different times. The sum of birth year and age, a proxy for the year a respondent completed the survey, accounted for 10.7% of the responses for 2003, 2004, and 2005 and for 31.5% of the responses for 2003, 2004, and 2005. Thus, roughly a decade separates the time of completion for about 42% of responses.[4] Reviewers of an earlier draft of this article recommended we use cohort effects by birth year.[5] In principle, it should be possible to separate the effects of the regulation-induced lead phaseout from pure cohort

[3] Schwaba et al. report that prior research has demonstrated that US GPIPP participants are broadly representative of the racial composition of the US general population. Our analysis, like that of Schwaba et al., focuses on the county of residence because EPA's data on atmospheric lead concentrations is organized by county. Early empirical research using factor analysis showed that English adjectives to describe personality were clustered in five different groups – the big five traits (McCrae & John, 1992).

[4] Note that this proxy is less than the year of survey completion for respondents who complete the survey earlier than their birthday.

https://doi.org/10.1017/bca.2025.7 Published online by Cambridge University Press

effects as lead declined in some counties much more than in others and the timing of the lead phaseout varied across counties.

2.1. Associations

Although the causal analysis by Schwaba *et al.* of the effects of the lead phasedown provides their most convincing results, their work first focuses on evidence of associations following a preregistered analysis plan. Here, we show that introduction of birth year FE into their models, which include only age, parental education, and median county income, reverses the estimated relationships between lead and four of the big five personality traits, confirming the importance of cohort effects in a wider range of models.

Schwaba *et al.* report that reduced lead exposure is associated with healthier and more mature personalities (more agreeableness, conscientiousness, and less neuroticism), but with the addition of birth year FE, we find different results – lead is associated with more agreeable and more conscientious and less neurotic personalities. Table 1a and 1b shows the contents of Table S6 of Schwaba *et al.* and the results of modifications to include birth year FE.[6] With the introduction of birth year FE, the associations involving

- lead and extraversion drops by half
- lead and agreeableness changes from negative (and statistically significant at the 99.9% level), to positive (and statistically significant at the 95% level),
- lead and conscientiousness changes from negative (and statistically significant at the 99.9% level) to positive (but is only significant at the 90% level),
- lead and neuroticism becomes negative and significant at the 99% level rather than insignificant (but positive).

While the association between lead and the fifth trait – openness to new ideas – is qualitatively unaffected by the introduction of birth year FE, the estimated coefficient nearly doubles, jumping from 0.009 to 0.017. F-statistics for each of these five models indicate the joint significance of birth year FE exceeds the 99.9% level.

2.2. Effects of early life exposure to airborne lead

Schwaba *et al.* also examine the causal effects of lead reductions on the big five personality traits by using a differences-in-differences identification strategy. For each county, they select the year with the greatest atmospheric lead concentration as the beginning of (local) lead emissions controls, noting that this peak year varies among the counties in their sample, with a mean of 1973 and a standard deviation of 4.27 years. Schwaba *et al.* then compare the personality traits of people born after the peak years with those born earlier, attributing the difference to the shift caused by the lead phasedown.

---

[5] Schwaba et al. conducted supplementary analyses (Tables S17–S21) that used the year of birth as a linear explanatory variable and categorical variables for age and for regions in the United States.

Table 1a. Associations between atmospheric lead concentrations during childhood and big five personality traits

	Extraversion		Agreeableness		Conscientiousness	
	1	2	3	4	5	6
Lead	0.022***	.012***	−0.030***	.005**	−.079***	.003*
	(.018, .025)	(.007, .016)	(−.034, −.026)	(−.0002, .009)	(−.083, −.076)	(−.002, .008)
Age	−0.002*	−.006***	0.012***	.029***	.034***	.049***
	(−.002, −.001)	(−.007, −.005)	(.011, .012)	(.028, .030)	(.034, .034)	(.048, .049)
Parent college	0.049***	.046***	−0.01***	−.012***	−.002	−.009***
	(.043, .054)	(.041, .052)	(−.015, −.005)	(−.018, −.007)	(−.006, .003)	(−.014, −.004)
County median income	−0.004***	−.005***	−.012***	−.013***	−.017***	−.017***
	(−.006, −.002)	(−.007, −.003)	(−.014, −.010)	(−.015, −.011)	(−.019, −.015)	(−.019, −.015)
Constant	0.034***	.305***	-.208***	1.151***	–730***	−1.891***
	(.018, .050)	(.225, .385)	(-.224, -.192)	(−1.231, −1.072)	(-.745, -.714)	(−1.969, −1.814)
Birth year FE	No	Yes	No	Yes	No	Yes
Observations	1,104,455	1,104,455	1,104,455	1,104,455	1,104,455	1,104,455
R^2	0.001	0.002	0.007	0.013	0.058	0.066

Parentheses denote 99% confidence intervals. We use * for estimates with p < 0.1, while ** and *** denote p < 0.05 and p<0.01, respectively. Data represent 1,104,455 respondents nested in 269 U.S. counties.

Table 1b. *Associations between atmospheric lead concentrations during childhood and big five personality traits*

	Neuroticism		Openness	
	7	8	9	10
Lead	.002	−.012***	.009***	.017***
	(−.002, .005)	(−.016, −.007)	(.005, .013)	(.012, .022)
Age	−.008***	−.017***	.007***	−.004***
	(−.008, −.008)	(−.018, −.017)	(.006, .007)	(−.005, −.003)
Parent college	−.061***	−.059***	.157***	.153***
	(−.066, −.056)	(−.065, −.054)	(.152, .163)	(.147, .158)
County median income	.003***	.004***	.003***	.004***
	(.001, .005)	(.002, .006)	(.001, .005)	(.002, .006)
Constant	.219***	.719***	-.296***	.177***
	(.203, .235)	(.639, .799)	(-.312, -.280)	(.098, .257)
Birth year FE	No	Yes	No	Yes
Observations	1,104,455	1,104,455	1,104,455	1,104,455
R^2	0.005	0.008	0.009	0.012

Parentheses denote 99% confidence intervals. We use * for estimates with p < 0.1, while ** and *** denote p < 0.05 and denotes p<0.01. Data represent 1,104,455 respondents nested in 269 U.S. counties.

Table 2a. *Shifts in personality traits after each county's lead phaseout: estimates and 99% confidence intervals in ()*

	Extraversion		Agreeableness		Conscientiousness	
Model	Schwaba *et al.*	With birth year FE	Schwaba *et al.*	With birth year FE	Schwaba *et al.*	With birth year FE
Shift in traits	−.018***	0.003	.088***	0.008	.217***	0.002
	(−.032, −.004)	(−.011, .017)	(.075, .101)	(−.006, .022)	(.201, .233)	(−.012, .015)
Age	−.001***	−0.005***	.011***	0.027***	.026***	0.044***
	(−.001, −.001)	(−.005,−.004)	(.010, .011)	(.026,.028)	(.026, .026)	(.043,.045)
Constant	.038***	−0.542	−.360***	−2.215**	−.872***	−6.747***
	(.018, .057)	(−3.117, 2.032)	(−.380, -.340)	(−4.769, 0.339)	(−.892, −.851)	(−9.223, –4.271)
R^2	–	0.003	–	0.019	–	0.077

Source for the Schwaba columns: Table S25. Shifts in traits are interpretable as a standardized Z score. We use *** for p<0.01. The sample represents 1,219,290 participants from 269 counties.

Table 2b. *Shifts in personality traits after each county's lead phaseout: estimates and 99% confidence intervals in ()*

	Neuroticism		Openness	
Model	Schwaba *et al.*	With birth year FE	Schwaba *et al.*	With birth year FE
Shift in traits	−.049***	−0.014**	.042***	0.007
	(−.062, −.036)	(−0.028, 0.001)	(.026, .057)	(−0.008, 0.021)
Age	−.009***	−0.018***	.008***	−0.004***
	(−.010, −.009	(−0.019, −0.017)	(.008, .008)	(−0.005, −0.004)
Constant	.307***	1.841*	−.279***	−0.194
	(.287, .327)	(−0.718, 4.401)	(−.300, −.257)	(−2.752, 2.365)
R^2	–	0.014	–	0.015

Source for the Schwaba columns: Table S25. Shifts in traits are interpretable as a standardized Z score. We use *** for p<0.01. The sample represents 1,219,290 participants from 269 counties.

We reproduce their results from Table S25 in Tables 2a and 2b.[7] They show statistically significant (p<0.001) effects of lead phaseout on reducing extraversion and neuroticism and increasing agreeableness, conscientiousness, and openness. While these models include age (which is correlated with birth year), entered linearly, they do not include birth year as an explanatory variable.

After replicating these results using the code courteously provided by Schwaba, we test robustness in two ways. First, we modify the random effects model used by Schwaba et al. so that the randomness is exclusively county-specific, and not both by county and for the emission controls. Then, we switch from random county effects to FE by county. We find that for each of the five personality traits, these changes have no material effect on the estimated coefficients, suggesting substantial robustness.[8]

Adding FE for birth years, however, yields quite different estimates of the effects of atmospheric lead on personality traits. As shown in Tables 2a and 2b, the introduction of birth year FE renders statistically insignificant the estimates of the effects of lead exposure on all traits except neuroticism. The lead phaseout still reduces neuroticism, but the estimated effect is less than one-third the magnitude reported by Schwaba et al. and is now statistically significant at (only) the 95% level. These new results are not the result of less precise estimates; the standard errors are essentially unchanged with the introduction of birth year FE, as shown in Figure 1.[9]

For all personality traits, the 99% confidence intervals for the effects of lead phaseout using birth year FE shown in Tables 2a and 2b exclude the point estimates of Schwaba *et al.* For all traits but extraversion, the 99% confidence intervals do not overlap those of Schwaba

[7] The increase in sample size relative to Tables 1a and 1b is attributable to Schwaba et al., who included in the analysis underlying Table 2 respondents who were born before atmospheric lead data collection began.

[8] For the four traits, the change in the coefficient is less than 10% and the significance level remains at p<0.01, while for extraversion the coefficient changes from −0.018 to −0.032 and remains significant at p<0.01.

[9] The 99% confidence intervals rise by 0.002 for agreeableness and by 0.003 for neuroticism, while falling or remaining constant for the other traits.

https://doi.org/10.1017/bca.2025.7 Published online by Cambridge University Press

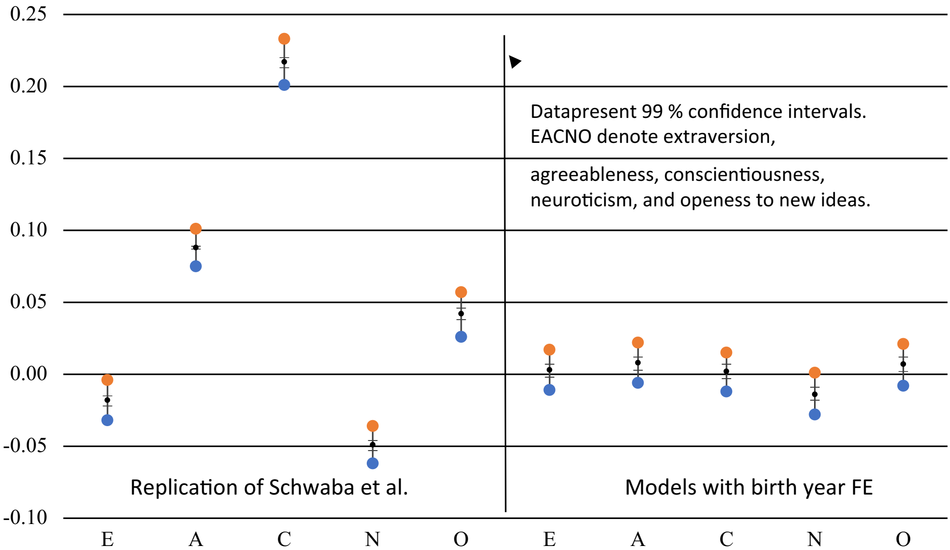

Figure 1. *Effects of lead phaseout on big five personality traits*

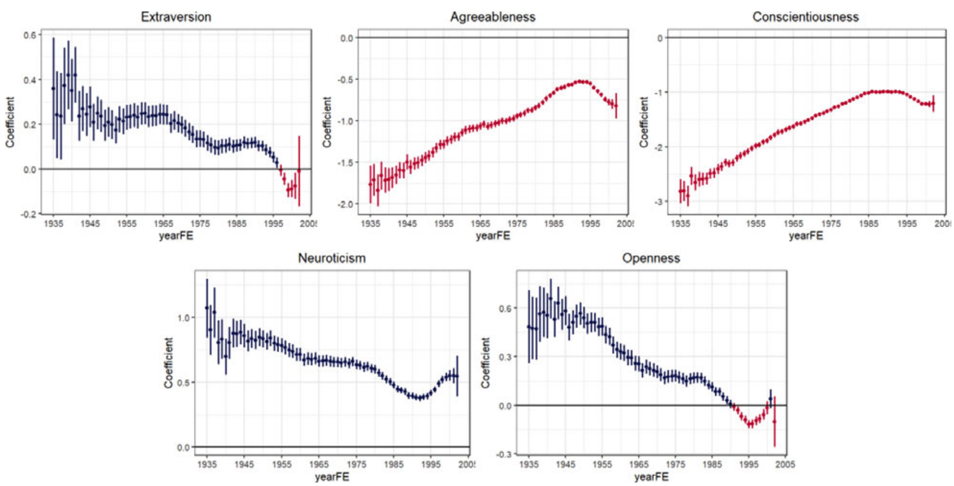

Figure 2. *Birth year coefficients and standard errors in models of personality traits and the phaseout of airborne lead, with county random effects*[10]

et al. Importantly, for each trait, the birth year FEs were jointly statistically significant at much better than the 99.9% level.

These results are insensitive to treating counties as having random effects – as in Tables 2a and 2b – or FE. With the latter assumption, the confidence intervals for lead phaseout effects on the personality traits are identical to two significant digits.

Importantly, as shown in Figure 2, coefficients for the birth year effects for each personality trait are nonlinear, with changes in slope around 1980 for extraversion and neuroticism and around 1983 for openness.[11] These patterns indicate that an assumption that birth year affects the big five personality traits linearly, as in Schwaba et al. is not warranted.

Following Banzhaf and Banzhaf's use of county FE, we also explore models with both county FE and the birth year FE described in Tables 1a and 1b, but no variable for the lead phaseout. These models represent an alternative approach to generating estimates of the effect of lead phaseout on the big five personality traits; they reflect entirely within-county variations in lead and personality and control for cohort-wide effects unrelated to atmospheric lead.

In models with both county FE and birth year FE, the estimated associations of lead exposure with extraversion, agreeableness, conscientiousness, and neuroticism all have the same sign as compared with the models in Table 1 with only birth year FE (see Appendix[12]). Focusing on the (even numbered) models with both county and birth year FE, the estimated associations of lead exposure with agreeableness, conscientiousness, and neuroticism are inconsistent with the preregistered hypotheses of Schwaba *et al.*

3. Discussion and conclusions

Our results suggest that Schwaba *et al.*'s findings on the relationships between atmospheric lead and personality traits are sensitive to their modeling decisions. In particular, as discussed above, the introduction of birth year FE changes the signs of associations between lead and more mature, psychologically healthy personality traits.[13] Lead, instead of being associated with less agreeableness, conscientiousness, and more neuroticism, is associated with more extraversion, agreeableness, conscientiousness, and less neuroticism after birth year FE are introduced. These same results hold in models with both birth year and county FE. For the fifth trait, openness to new ideas, the association with lead is positive with birth year FE but becomes negative when county FE are also included.

We introduce FE for birth years while retaining random effects for counties in the model of the effects of lead air pollution controls on personality traits and find the lead phaseout of lead has no effect on four of the big five personality traits. Neuroticism, the exception, declines with the lead phaseout (as in the Schwaba *et al.* results), but the magnitude of the effect becomes smaller and less significant in models with birth year FE. These results indicate that the data used by Schwaba *et al.* do not clearly support unambiguous causal relationships from childhood exposure to atmospheric lead to more mature, psychologically healthy adult personality traits.

The pioneering work by Almond and Currie (2011) showed that the early life environment may affect a variety of adulthood outcomes. More recent work – for example, Isen *et al.* (2017) studying total suspended particulates, and Banzhaf and Banzhaf (2023) studying

[10] We estimated these models after excluding the respondents with birth years before 1935. Plots without these exclusions show very wide confidence intervals for the years before 1935 but are qualitatively the same.

[11] Some evidence exists for nonmonotonicities around 1995, or perhaps earlier for agreeableness, conscientiousness, neuroticism, and openness, but it is hard to interpret. It may arise largely because as the birth year increases to 1995, the range of ages of respondents approaches 20 years, given that the last possible year for survey completion is 2015.

[12] For agreeableness and conscientiousness, adding county FE raises the level of statistical significance from 95% to 99% and from 90% to 99%, respectively.

[13] Schwaba et al also analyze adult personality traits and childhood lead exposure in Europe, but those analyses do not consider birth year cohort effects.

https://doi.org/10.1017/bca.2025.7 Published online by Cambridge University Press

airborne lead – report in utero and early life exposure to air pollutants adversely affects adulthood outcomes like labor market performance, although efforts to disentangle effects of different air pollutants on child cognitive development are ongoing (Wodtke *et al.*, 2022). Our results do not mean that EPA's estimates of the benefits of reducing lead exposure are too high and do not imply that early childhood atmospheric lead exposures experienced immediately prior to the CAA implementation had no effect on big five personality traits in adulthood. However, they do mean that any such effects are not consistently observable in the data used by Schwaba *et al.* More broadly, these results caution against making causal inferences without controlling for cohort or time period effects.

Acknowledgments. The authors gratefully acknowledge help from Ted Schwaba, who graciously answered questions about his data and code and from Dick Morgenstern. Fraas, Lutter, and Xiahou acknowledge financial support from the Smith Richardson Foundation which had no role in the design or execution of the study.

References

Almond, Douglas, and Janet Currie. 2011. "Killing Me Softly: The Fetal Origins Hypothesis." *Journal of Economic Perspectives*, *25* (3): 153–172.

Banzhaf, H.S., and M.R. Banzhaf. 2023. "Impact of in utero Airborne Lead Exposure on Long-run Adult Socio-economic Outcomes: A Population Analysis Using U.S. Survey and Administrative Data." *PLOS ONE*, *18*(11): e0293443. doi:10.1371/journal.pone.0293443

Belfield, C., A.B. Bowden, A. Klapp, H. Levin, R. Shand, and S. Zander. 2015. "The Economic Value of Social and Emotional Learning." *Journal of Benefit-Cost Analysis*, *6*(3):508–544. doi:10.1017/bca.2015.55

Borghans, L., B. H. Golsteyn, *et al.* 2016. "What Grades and Achievement Tests Measure." *Proceedings of the National Academy of Sciences*, *113*(47): 13354–13359.

Centers for Disease Control and Prevention, Agency for Toxic Substances and Disease Registry. 2019. "Case Studies in Environmental Medicine: Lead Toxicity." https://www.atsdr.cdc.gov/csem/lead/docs/CSEM-Lead_toxicity_508.pdf

Environmental Protection Agency. 2023. "Finding that Lead Emissions from Aircraft Engines That Operate on Leaded Fuel Cause or Contribute to Air Pollution that may Reasonably be Anticipated to Endanger Public Health and Welfare." *Federal Register*, *88*(202): 72372. https://www.govinfo.gov/content/pkg/FR-2023-10-20/pdf/2023-23247.pdf

Environmental Protection Agency. 2024a. "Reconsideration of the Dust-Lead Hazard Standards and Dust-Lead Post Abatement Clearance Levels, Final Rule." 89 *FR 89416*, https://www.federalregister.gov/documents/2024/11/12/2024-25070/reconsideration-of-the-dust-lead-hazard-standards-and-dust-lead-post-abatement-clearance-levels

Environmental Protection Agency. 2024b. "National Primary Drinking Water Standards for Lead and Copper: Improvements (LCRI)." 89 *FR* 86418, https://www.federalregister.gov/documents/2024/10/30/2024-23549/national-primary-drinking-water-regulations-for-lead-and-copper-improvements-lcri

Food and Drug Administration. 2023a. "FDA Advises Parents and Caregivers Not to Buy or Feed WanaBana Apple Cinnamon Fruit Puree Pouches to Toddlers and Young Children Because of Elevated Lead Levels." https://www.fda.gov/food/alerts-advisories-safety-information/fda-advises-parents-and-caregivers-not-buy-or-feed-wanabana-apple-cinnamon-fruit-puree-pouches

Food and Drug Administration. 2023b. "WanaBana Recalls WanaBana, Weis, and Schnucks Apple Cinnamon Fruit Purée Pouches & Cinnamon Apple Sauce Due to Elevated Lead Levels." https://www.fda.gov/safety/recalls-market-withdrawals-safety-alerts/wanabana-recalls-wanabana-weis-and-schnucks-apple-cinnamon-fruit-puree-pouches-cinnamon-apple-sauce

Gatzke-Kopp, L.M., S. Warkentien, M. Willoughby, C Fowler, D.C. Folch, and C. Blair . 2021. "Proximity to Sources of Airborne Lead is Associated with Reductions in Children's Executive Function in the First Four Years of Life." *Health Place*, *68*: 102517. doi: 10.1016/j.healthplace.2021.102517.

Gatzke-Kopp, L.M., M. Willoughby, A.M. Kress, K. McArthur, C. Wychgram, D.C. Folch, S. Brunswasser, D. Dabelea, A.J. Elliott, T. Hartert, M. Karagas, C.T. McEvoy, J.A. VanDerslice, R.O. Wright, and R.J. Wright . 2024. "Airborne Lead Exposure and Childhood Cognition: The Environmental Influences on Child Health

Outcomes (ECHO) Cohort (2003–2022).” *American Journal of Public Health*, *114*(3): 309–318. doi: 10.2105/AJPH.2023.307519. Erratum in: *Am J Public Health.* 2024 Mar 28;:e1.

Gibson, Jacqueline MacDonald, John M. MacDonald, Michael Fisher, Xiwei Chen, Aralia Pawlick, and Philip H. Cook. 2022. “Early Life Lead Exposure From Private Well Water Increases Juvenile Delinquency From Exposure to Well Water Increases Juvenile Deliquency Risk Among U.S. Teens.” *PNAS*, *119* (6): e2110694119. doi: 10.1073/pnas.2110694119

Grönqvist, Hans, Peter Nilsson, and Per-Olof Robling. 2014. “Early-Childhood Lead Exposure and Criminal Behavior: Lessons from the Swedish Phase-out of Leaded Gasoline.” *SOFI Working* Paper 2014/9 (October), Stockholm University.

Heckman, J., and J. Stixrud, *et al.* 2006. “The Effects of Cognitive and Noncognitive Abilities on Labor Market Outcomes and Social Behavior.” *Journal of Labor Economics*, *24*(3): 411–482.

Isen, Adam, Maya Rossin-Slater, and W. Reed Walker. 2017. “Every Breath You Take, Every Dollar You Make: The Long-Term Consequences of the Clean Air Act of 1970.” *Journal of Political Economy*, *125*(3). doi:10.1086/691465

Karoly, Lynn A. 2012. “Toward Standardization of Benefit-Cost Analysis of Early Childhood Interventions.” *Journal of Benefit-Cost Analysis*, *3*: 1 Article 4.

Landrigan, Philip J., Richard Fuller, Nereus J.R. Acosta, Olusoi Adeyi, Robert Arnold, Abdoulaye Bibi Balde, and Roberto Bertolini, *et al.* 2018. “The Lancet Commission on Pollution and Health.” *The Lancet 391*(10119): 462–512, p. 17

Leffer, Lauren. 2024. “Childhood Leaded Gasoline Exposure Damaged Americans’ Mental Health: A New Study Links 151 Million Instances of Psychiatric Illness to Leaded Gasoline.” *Popular Science*, Posted Dec 4, 2024, https://www.popsci.com/health/lead-exposure-mental-illness/

Levin, R., and J. Schwartz. 2023. “A Better Cost:Benefit Analysis Yields Better and Fairer Results: EPA’s Lead and Copper Rule Revision.” *Environmental Research*, *229*: 115738 . doi: 10.1016/j.envres.2023.115738.

McCrae, R.R., and O.P. John. 1992. “An Introduction to the Five-factor Model and its Applications.” *Journal of Personality*, June *60* (2): 175–215. doi:10.1111/j.1467-6494.1992.tb00970.x.

McFarland, M.J., A. Reuben, and M. Hauer. 2024. “Contribution of Childhood Lead Exposure to Psychopathology in the US Population over the Past 75 Years.” *Journal of Child Psychology and Psychiatry*. doi:10.1111/jcpp.14072

Nedellec, V., and A. Rable. 2016. “Costs of Health Damage from Atmospheric Emissions of Toxic Metals: Part 2-Analysis for Mercury and Lead.” *Risk Analysis*, *36*(11): 2096–2104. doi:10.1111/risa.12599

Reuben, A., J. D. Schaefer, T. E. Moffitt, J. Broadbent, H. Harrington, R. M. Houts, … A. Caspi. 2019. “Association of Childhood Lead Exposure with Adult Personality Traits and Lifelong Mental Health.” *JAMA Psychiatry*, *76*: 418–425

Reyes, J. 2007. “Environmental Policy as Social Policy? The Impact of Childhood Lead Exposure on Crime.” *B.E. Journal of Economic Analysis and Policy: Contributions to Economic Analysis and Policy*, *7*(1). https://jwreyes.people.amherst.edu/papers/LeadCrimeBEJEAP.pdf

Reyes, J. 2015. “Lead Exposure and Behavior: Effects on Antisocial and Risky Behavior among Children and Adolescents.” *Economic Inquiry*, *53*(3). doi:10.1111/ecin.12202

Schwaba, Ted, Wiebke Bleidor, Christopher J. Hopwood, Jochen E. Gebauer, P. Jason Rentfrow, Jeff Potter, and Samuel D. Gosling. 2021. “The Impact of Childhood Lead Exposure on Adult Personality: Evidence from the United States, Europe, and a Large-Scale Natural Experiment.” *PNAS*, *118*(29): e2020104118 doi:10.1073/pnas.2020104118 .

Wodtke, Geoffrey T., Kerry Ard, Clair Bullock, Kailey White, and Betsy Priem. 2022. “Concentrated Poverty, Ambient Air Pollution, and Child Cognitive Development.” *Science Advances*, *8*: eadd0285.DOI:10.1126/sciadv.add0285

Rodriguez Adrianna. 2023. Lead can alter personalities, pose lifelong risks. It’s still in America’s water pipes. USA Today. Dec 2. 2023.

Environmental Protection Agency. 2020. Data and Analysis of Piston-Engine Aircraft Emissions of Lead at US Airports. https://www.epa.gov/regulations-emissions-vehi-cles-and-engines/epas-data-and-analysis-piston-engine-aircraft-emissions.

Appendix

Exposure to Atmospheric Lead During Childhood and Adult Personality Traits with County Fixed Effects: Without and With Birth Year Fixed Effects.

Table A1. *Associations between atmospheric lead during childhood and adult personality in the United States: county and birth year fixed effects*

	Extraversion		Agreeableness		Conscientiousness	
	(1)	(2)	(3)	(4)	(5)	(6)
Lead exposure	0.029***	0.023***	−0.039***	0.008***	−0.094***	0.020***
	(0.025, 0.033)	(0.017, 0.029)	(−0.043, −0.035)	(0.002, 0.014)	(−0.098, −0.090)	(0.014, 0.026)
Age	−0.002***	−0.006***	0.012***	0.029***	0.035***	0.049***
	(−0.003, −0.002)	(−0.007, −0.005)	(0.012, 0.013)	(0.028, 0.030)	(0.035, 0.036)	(0.048, 0.050)
Parent college	0.048***	0.046***	−0.010***	−0.014***	−0.003	−0.012***
	(0.043, 0.054)	(0.040, 0.051)	(−0.016, −0.005)	(−0.019, −0.008)	(−0.008, 0.002)	(−0.017, −0.007)
Median county income	−0.064**	−0.062**	−0.077***	−0.077***	−0.009	−0.012
	(−0.132, 0.004)	(−0.130, 0.006)	(−0.145, −0.009)	(−0.145, −0.009)	(−0.075, 0.057)	(−0.077, 0.054)
Constant	0.352**	0.543***	0.085	−0.833***	−0.832***	−1.991***
	(−0.003, 0.706)	(0.180, 0.906)	(−0.268, 0.438)	(−1.194, −0.472)	(−1.176, −0.488)	(–2.342, −1.640)
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth year FE	No	Yes	No	Yes	No	Yes
R^2	0.002	0.004	0.009	0.015	0.060	0.068

Note: We use * to mean p<0.1, ** to denote p<0.05, and *** for p<0.01. The data have 1,104,455 observations from 269 counties.

https://doi.org/10.1017/bca.2025.7 Published online by Cambridge University Press

Table A2. *Associations between atmospheric lead during childhood and adult personality in the United States with county fixed effects: without and with birth year fixed effects*

	Neuroticism		Openness	
	(7)	(8)	(9)	(10)
Lead exposure	0.006***	−0.010***	−0.005***	−0.009***
	(0.002, 0.010)	(−0.016, −0.004)	(−0.011, −0.001)	(−0.015, −0.003)
Age	−0.008***	−0.017***	0.008***	−0.005***
	(−0.009, −0.008)	(−0.018, −0.017)	(0.007, 0.008)	(−0.005, −0.004)
Parent college	−0.060***	−0.058***	0.161***	0.157***
	(−0.066, −0.055)	(−0.064, −0.053)	(0.156, 0.167)	(0.152, 0.163)
Median county income	0.020	0.019	0.018	0.017
	−0.048, 0.087)	(−0.049, 0.087)	(−0.049, 0.086)	(−0.051, 0.084)
Constant	0.151	0.621***	−0.404***	0.247*
	(−0.202, 0.505)	(0.259, 0.983)	(−0.756, −0.051)	(−0.114, 0.607)
County FE	Yes	Yes	Yes	Yes
Birth year FE	No	Yes	No	Yes
R^2	0.007	0.010	0.013	0.016

Note: We use * to mean p<0.1, ** to denote p<0.05, and *** for p<0.01. The data have 1,104,455 observations from 269 counties.

Cite this article: Fraas, Arthur, Randall Lutter, Joshua Murphy, Qinrui Xiahou, Jeff Potter, and Samuel D. Gosling. 2025. "What Are the Effects of Early Childhood Exposure to Environmental Lead on Personality?." *Journal of Benefit-Cost Analysis*, doi:10.1017/bca.2025.7