ENVIRONMENTAL RESEARCH
LETTERS

PERSPECTIVE • **OPEN ACCESS**

Recycling paradox: another piece of the plastic pollution problem

To cite this article: Richard York *et al* 2026 *Environ. Res. Lett.* **21** 061001

ENVIRONMENTAL RESEARCH
LETTERS

OPEN ACCESS

RECEIVED
8 January 2026

REVISED
2 March 2026

ACCEPTED FOR PUBLICATION
17 March 2026

PUBLISHED
24 March 2026

PERSPECTIVE

Recycling paradox: another piece of the plastic pollution problem

Richard York[1,2], **Stefano B Longo**[2,*] **and Borja Nogué Algueró**[2]

[1] Department of Sociology, University of Oregon, Eugene, OR, United States of America
[2] Department of Sociology and Work Science, University of Gothenburg, Gothenburg, Sweden
[*] Author to whom any correspondence should be addressed.

E-mail: stefano.longo@gu.se

Keywords: displacement paradox, waste disposal, social drivers, growth dynamics

1. Introduction

The growing problems around plastic pollution have been well-documented. Plastic pollution has become emblematic of a global environmental crisis whose scale is both recent and unprecedented. What began as limited production following the Second World War, about 2 Mt worldwide in 1950, has expanded into a system that in recent years generates close to 500 Mt annually, growing faster than almost any other industrial material and projected to increase susbtantially (OECD 2022). Because plastics do not meaningfully decompose, most of the billions of tonnes produced persist as waste, spreading across land, waterways, oceans, and the atmosphere.

Allen *et al* (2024) describe how the plastic industry has for decades promoted recycling as a solution to the plastic waste crisis, even though, as internal documents demonstrate, they were aware that most plastics cannot or will not be recycled. As Geyer *et al* (2017) explain, only 9% of all the plastic ever produced has been recycled. In documenting the industry's intentional misinformation campaign, Allen *et al* (2024) call into serious question whether widespread recycling of plastic is a genuine goal of industry or is even feasible under current conditions.

Here, we raise a distinct but related issue concerning the environmental consequences of plastic recycling: has the (limited) recycling of plastics helped to reduce the total amount of plastic waste that goes to landfills and incinerators or is otherwise mismanaged to some degree? Many people presume (at least implicitly) that each kilogram of recycled plastic can reduce the amount of plastic that is disposed of by other methods. This assumes a zero-sum relationship. However, there are theoretical reasons to question this assumption. Environmental social science theories emphasizing the structural growth imperative fundamental to modern economies suggest it is possible that plastics recycling may, paradoxically, be *positively* associated with the amount of plastic entering other waste streams (Schnaiberg 1980, Longo *et al* 2015, York 2017). One potential reason behind this, as some researchers have argued, is that industry promoted recycling strategies may function to deflect attention from the environmental impacts of plastic and forestall regulation, thereby allowing for the continuing expansion of plastics production and consumption (CIEL 2017, Geyer 2020, Mah 2022, Vandenberg 2024).

2. Exploring a recycling paradox

Insights relevant to the plastic waste crisis can be gleaned from research on energy and food production systems. Research focusing on energy systems has found that the growth in production of non-fossil fuel energy sources has done little to suppress fossil fuel use, with new energy sources (e.g. nuclear power), for the most part, added on to, rather than in place of, established sources (e.g. coal) (Apergis *et al* 2010, York 2012, Shafiei and Salim 2014, Liddle and Sadorsky 2017, York and Bell 2019, Greiner *et al* 2022, Fressoz 2024, Thombs 2025). Based on this body of research, the failure of a new resource or technology (e.g. renewable energy) to replace, or at least suppress, the use of a more established resource or technology (e.g. fossil fuels), when the newer one in principle clearly can substitute for the established one has been called the 'displacement paradox' (York 2017).

Research suggests that this is a common macro-phenomenon. Cross-national analyses have identified this paradox in various realms, including the failure of aquaculture to suppress wild captured fish (Longo *et al* 2019, Longo and York 2024) and the growth of poultry consumption to suppress other types of meat consumption (York 2021). Analysts have argued that

although there are likely numerous reasons the displacement paradox occurs, one of the main forces leading to it relates to the growth dynamics of modern economies, where technologies and innovation are typically deployed to expand production and consumption rather than conserve resources (Longo and York; York 2017, York and Bell 2019).

The research on the displacement paradox suggests that recycling of plastic may not suppress the total volume of plastic that ends up as non-recycled waste. There may in fact be a recycling paradox. While in an immediate sense, each piece of plastic that is recycled is one that does not become another form of waste, the overall effect of recycling in an economy may be tied to social processes that generate growth in the factors that produce so much plastic waste in the first place. As we noted above, analysts have discerned processes by which recycling can be part of a structured system that facilitates, rather than inhibits, plastics waste production (Mah 2022, Allen *et al* 2024). Emphasis on the benefits of recycling systems furthers the plastics industry assertions that plastic waste can be managed in an environmentally sensitive manner and may help reduce political and public pressure for strict regulations on plastics production and consumption. Thus, it is conceivable that plastics recycling may not only fail to reduce plastic in other waste streams; it may in fact help to spur growth in plastic waste in all forms.

To explore the argument we make here, that recycling may not necessarily have reduced non-recycled plastic waste, we can examine the patterns of waste production and recycling within nations. Although there are limitations in the cross-national data that are available on plastic waste, especially those broken down into end-of-life fate, the OECD (2024) provides useful data that allows for a preliminary assessment of the association between plastic recycling and the quantity of non-recycled plastic waste. These data are not available for most individual nations, but rather for regional aggregates (e.g., OECD Asia, Latin America). However, there are data for the three most populous nations in the world—China, India, and the United States—which combined are responsible for over 44% of the world's total amount of plastic waste. We therefore take a closer look at the plastic production and recycling dynamics in these nations to further reflect on the potential for displacement.

For each nation, we estimate a Prais–Winsten time-series regression model which corrects for first order autocorrelation. We use the amount of plastic (per capita) that is landfilled, incinerated, mismanaged, and littered ('non-recycled' plastic waste) for each nation as the dependent variable. The amount of waste that is recycled is our key independent variable. Importantly, we include factors that are associated with the scale of production and consumption in general. These are commonly used variables in the literature cited above on the displacement paradox: GDP per capita (including a quadratic to allow for a non-linear relationship), energy consumption per capita, urbanization, and the age dependency ratio of the population (since populations with higher ratios of dependents to working age people are less economically productive, all else equal).

Since we are focusing on per capita values, the structure of the model accounts for direct scaling consequences of population growth, although not necessarily controlling for changes in various structural and behavior factors that may be associated with that growth. If we did not control for these factors, it would be unsurprising to find a positive association between the amount of plastic that is recycled and the amount of plastic that is not recycled, since they are both part of the total amount of plastic waste that is generated. However, if the macro-level factors that we include in the model account appropriately for the forces behind the scale of resource use, the amount of plastic that is recycled should have a negative effect on the amount that is not recycled if recycled plastic is cutting down on the non-recycled waste stream. In fact, given the structure of the model, we would expect to find a regression coefficient of approximately -1 if each kg of plastic recycled removes one kg of plastic from other parts of the waste stream (proportional displacement), in an idealized, all else equal, scenario. Of course, since these are real-world data in non-experimental conditions, we are only getting a descriptive sense of the association between the amount of plastic that is recycled and the amount that is not, and there may be multiple potential explanations for such an association.

The data on plastic waste are from the OECD Data Explorer Archive (2024) and are for the years 1990–2019. They report the end-of-life fate of plastics by disposal method. We use the amount recycled and the amount not recycled (which includes landfilled, incinerated, mismanaged, and littered). We analyze per capita values in kilograms of waste. As noted above, most of the data on plastic waste are aggregated by global region. The data on all other variables are from the World Bank (2025). GDP per capita is measured in 1000s of inflation adjusted (constant year 2015) USD. The age dependency ratio is the number of young (under 15 years) and old (over 64) per 100 people of working age (15–64). Energy use per capita is measured in tonnes of oil equivalent. Urbanization is the percentage of the population living in urban areas. All data are first-differenced in our models, which addresses trending and non-stationarity.

The estimates presented in table 1 are consistent with the possibility that rather than necessarily reducing non-recycled plastic waste, recycling may be associated with rising overall plastic waste generation. For all three nations, the coefficient for recycled plastics is positive and substantial in size.

Table 1. The association between non-recycled plastic waste (dependent variable in all models) and recycled plastic waste, 1990–2019. Plastic wastes are in per capita terms (kg). All data are first-differenced. The estimates are from Prais–Winsten regression models correcting for first-order autocorrelation.

	China Coef. (S.E)	India Coef. (S.E)	USA Coef. (S.E)
Recycled	7.555***	5.623***	23.810***
	(.467)	(.526)	(2.094)
Energy use, p.c.	1.785**	−1.205	2.724*
	(.478)	(.821)	(1.192)
Age dep. ratio	−.290***	.009	−1.719*
	(.070)	(.064)	(.620)
Urbanization	−1.572***	−.522**	11.476***
	(.291)	(.179)	(2.631)
GDP p.c.	1.151*	3.527**	3.131
	(.460)	(.981)	(1.609)
$(\text{GDP p.c.})^2$	−.167***	−1.516**	−.037*
	(.017)	(.373)	(.016)
Intercept	1.588***	.214***	−6.043***
	(.017)	(.049)	(1.119)
N	29	29	29
R^2	.977	.977	.917

*** $p < .001$ ** $p < .01$ * $p < .05$ (two-tailed tests).

Although not indicative of a direct causal relationship, these associations point to a pattern that non-recycled plastics and recycling have risen together in these three nations in recent decades, even when accounting for factors related to overall production and consumption.

3. Conclusion

It has been well established that the plastics industry has promoted recycling as a solution to the plastic waste crisis while knowing that most plastic cannot or will not be recycled. In fact, research has argued that recycling, far from being an effective solution to the plastic waste crisis, is part of industry efforts to evade regulation and allow for continuing growth of plastic production (Mah 2022, Allen *et al* 2024). This suggests the possibility that plastic recycling in current political-economic contexts may not necessarily reduce the amount of non-recycled plastic waste overall, since recycling programs may help allow for overall growth in plastics production and consumption.

For example, in the three most populous nations in the world, India, China, and the United States, the amount of non-recycled plastic waste is positively correlated with the amount of plastic that is recycled, even controlling for numerous factors that may drive overall production and consumption. This aligns with displacement paradox arguments that plastic recycling is likely interconnected with plastic production and may not, when all things are considered, help to suppress plastic waste. Clearly, more research and more robust data are necessary to assess the forces leading to the expansion of plastics use and pollution, the specific dynamics of how these processes work, how recycling fits into these dynamics, the political-economic forces that empower the plastics industry, and how these processes operate in various nations around the world. Studying these processes in more detail, including the recycling paradox that we outlined here, will be a worthwhile effort for confronting plastic pollution concerns.

The body of research produced by numerous scholars (e.g. Center for International Environmental Law 2017, Geyer 2020, Mah 2022, Allen *et al* 2024, Vandenberg 2024) suggests that addressing global plastic pollution may require challenging the industry-promoted solution of plastic recycling and taking measures to directly suppress plastic production and consumption. An effective response to plastic pollution will likely involve binding policies at the national and international levels that directly limit aggregate plastic production through imposing hard caps on virgin polymer production, especially in affluent economies that account for a disproportionate share of global demand. These types of solutions have been strongly challenged by the petrochemical industry and state actors strongly influenced by fossil fuel producers (Mah 2023, Dauvergne *et al* 2025). Ultimately, this implies confronting an economic growth regime oriented toward perpetual capital growth, which systematically externalizes environmental costs and functions as a fundamental driver of plastic pollution and other forms of global environmental degradation.

Acknowledgment

This research is supported by the Swedish Research Council (Vetenskapsrådet) Grant #2023-00961. RY acknowledges additional support of the Ingeborg and Knut J:son Mark Foundation for the University of Gothenburg Guest Professorship.

Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: http://10.6084/m9.figshare.31026070.

Conflict of interest

The authors report no conflicts of interest.

Author contributions

Richard York
Conceptualization (equal), Formal analysis (lead), Methodology (lead), Writing – original draft (lead), Writing – review & editing (equal)

Stefano B Longo 0000-0002-6409-8399
Conceptualization (equal), Formal analysis (supporting), Funding acquisition (lead), Project administration (lead), Writing – original draft (supporting), Writing – review & editing (equal)

Borja Nogué Algueró 0000-0003-3376-9564
Conceptualization (supporting), Data curation (supporting), Formal analysis (supporting), Investigation (supporting), Writing – review & editing (supporting)

References

Allen D, Linsley C, Spoelman N and Johl A 2024 The fraud of plastic recycling. (Center for Climate Integrity) (available at: https://climateintegrity.org/projects/plastics-fraud)

Apergis N, Payne J E, Menyah K and Wolde-Rufael Y 2010 On the causal dynamics between emissions, nuclear energy, renewable energy and economic growth *Ecol. Econ.* **69** 2255–60

Center for International Environmental Law 2017 Plastic industry awareness of the ocean plastics problem fueling plastics (CIEL) (available at: www.ciel.org/wp-content/uploads/2017/09/Fueling-Plastics-Plastic-Industry-Awareness-of-the-Ocean-Plastics-Problem.pdf)

Dauvergne P, Xiao M, Wu X, Karimi H R, Xie X, Cao J and Zheng W X 2025 Competing axes of power in the global plastics treaty: understanding the politics of progress and setbacks in negotiating a high-ambition agreement *Mar. Policy* **181** 106820

Fressoz J 2024 *More and More and More: An All-consuming History of Energy* (Allen Lane)

Geyer R, Jambeck J E and Law K L 2017 Production, use, and fate of all plastics ever made *Sci. Adv.* **3** e1700782

Geyer R 2020 Production, use, and fate of synthetic polymers *Plastic Waste and Recycling* ed T M Letcher (Academic) (https://doi.org/10.1016/B978-0-12-817880-5.00002-5)

Greiner P T, York R and McGee J A 2022 When are fossil fuels displaced? An exploratory inquiry into the role of nuclear electricity production in the displacement of fossil fuels *Heliyon* **8** e08795

Liddle B and Sadorsky P 2017 How much does increasing non-fossil fuels in electricity generation reduce carbon dioxide emissions? *Appl. Energy* **197** 212–21

Longo S B, Clark B, York R and Jorgenson A K 2019 Aquaculture and the displacement of fisheries captures *Conserv. Biol.* **33** 832–41

Longo S B, Clausen R and Clark B 2015 *The Tragedy of the Commodity: Oceans, Fisheries and Aquaculture* (Rutgers University Press)

Longo S B and York R 2024 Why aquaculture may not conserve wild fish *Sci. Adv.* **10** eado3269

Mah A 2022 *Plastic Unlimited: How Corporations are Fuelling the Ecological Crisis and What We Can Do about It* (Wiley)

Mah A 2023 *Petrochemical Planet: Multiscalar Battles of Industrial Transformation* (Duke University Press)

OECD Data Explorer Archive 2024 Plastic waste by region and end-of-life fate (available at: https://data-explorer.oecd.org) (Accessed 7 November 2025)

OECD 2022 *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (OECD Publishing) (https://doi.org/10.1787/de747aef-en)

Schnaiberg A 1980 *The Environment: From Surplus to Scarcity* (Oxford University Press)

Shafiei S and Salim R A 2014 Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: a comparative analysis *Energy Policy* **66** 547–56

Thombs R P 2025 Does renewable energy production displace fossil fuel production in the U.S.: a panel data study of fossil fuel-producing U.S. states, 1997–2020 *J. Environ. Stud. Sci.* (https://doi.org/10.1007/s13412-025-01013-8)

Vandenberg J 2024 Plastic politics of delay: how political corporate social responsibility discourses produce and reinforce inequality in plastic waste governance *Glob. Environ. Pol.* **24** 122–45

World Bank 2025 World Development Indicators (available at: https://databank.worldbank.org/source/world-development-indicators) (Accessed 7 November 2025)

York R 2012 Do alternative energy sources displace fossil fuels? *Nat. Clim. Change* **2** 441–3

York R 2017 Why petroleum did not save the whales socius: sociological research for a dynamic world 3 (https://doi.org/10.1177/2378023117739217)

York R 2021 Poultry and fish and aquatic invertebrates have not displaced other meat sources *Nat. Sustain.* **4** 766–8

York R and Bell S E 2019 Energy transitions or additions?: why a transition from fossil fuels requires more than the growth of renewable energy *Energy Res. Soc. Sci.* **51** 40–43

York R, Noguè-Alguerò B and Longo S B 2025 Plastic recycling displacement data *Figshare* (available at: https://doi.org/10.6084/m9.figshare.31026070)