Sustainability
2026
Webinars

2026 Best Paper Award Ceremony

28 April 2026, 02:00 pm (CEST)

Future Projections of Global Plastic Pollution: Scenario Analyses and Policy Implications

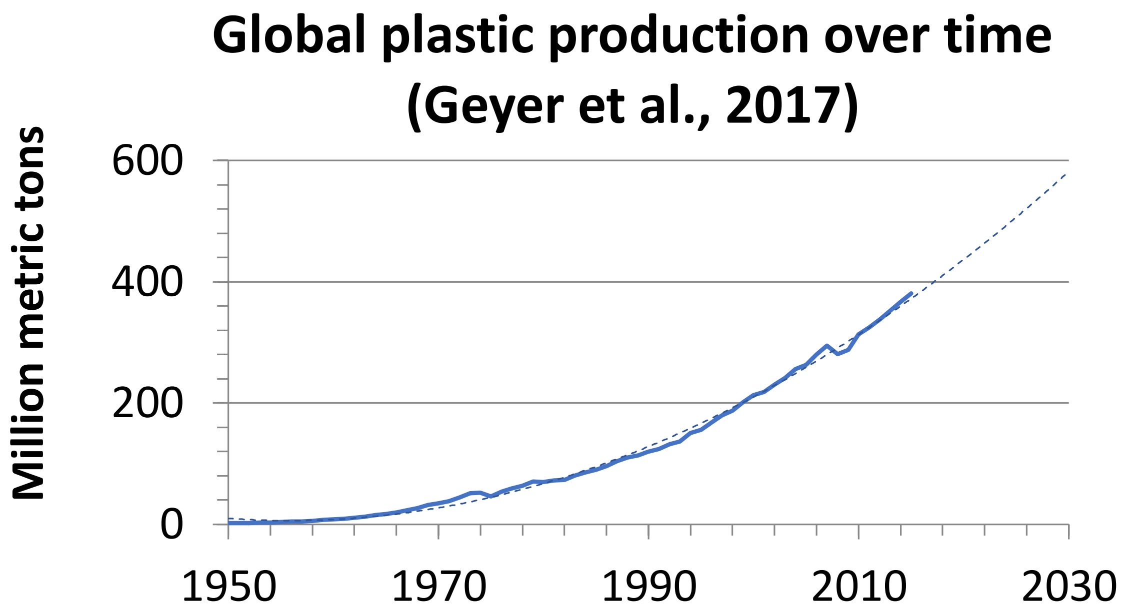
Huijie Yan [1], Mateo Cordier [1,2] and Takuro Uehara [3,*]

sustainability MDPI

UVSQ université PARIS-SACLAY
Observatoire de Versailles Saint-Quentin-en-Yvelines
CAMPUS DE SAINT-QUENTIN-EN-YVELINES
cnrs
RITSUMEIKAN UNIVERSITY
CEARC
Cultures • Environnements
Arctique • Représentations • Climat
UNIVERSITÉ DE VERSAILLES ST-QUENTIN-EN-YVELINES

Why plastic pollution matters?

- Plastic production increased from 2 to 380 million metric tons between 1950 and 2015.



- Marine plastic pollution harms ecosystems, biodiversity, and human health.
- Chemicals used in plastics (endocrine disruptors) generate diseases (intellectual disabilities, diabetes, cancers, obesity, endometriosis, cardiovascular mortality, etc.): 5.1 million people affected in the United States (in 2018) and 1.7 million people in the European Union (in 2010).

Sources:
- Graph: based on Geyer et al. (2017)
- Diseases: Duquesne et al., 2025 (read pages 1217, 1219-1220), based on :
  - Trasande *et al.* (2024b), available here: http://dx.doi.org/10.1210/jendso/bvad163
  - The Endocrine Society (2023)

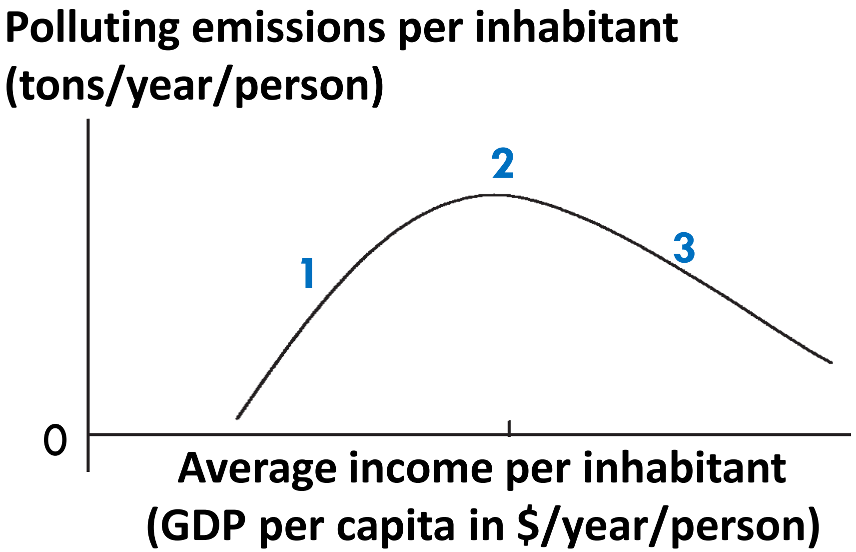
Research objectives

- Empirically test the **Environmental Kuznets Curve (EKC) relationship** between GDP per capita and plastic pollution.
- Analyze **sociodemographic drivers** of plastic pollution (based on a dataset of observations in 128 countries over 1993–2017)
- Project global and country-level trends to **2050**.
- Provide **policy insights** for sustainable development

Method : EKC and STIRPAT

Environmental Kuznets Curve (EKC) logic

- Plastic pollution per inhabitant rises with income **(1)**, then declines **(3)** after a turning point **(2)**.
- But evidence is mixed.



STIRPAT model :

(Stochastic Impacts by Regression on Population, Affluence and Technology)

- Plastic pollution is a function of Population size, Affluence, Technology, and Demographic factors.
- Panel data approach (vs. cross-sectional in earlier studies: Barnes (2019) and Cordier et al. (2021).

Method: data & variables

STIRPAT equation

$$lnPP_{it} = \beta_0 + \beta_1 lnGDPPC_{it} + \beta_2[lnGDPPC_{it}]^2 + \beta_3 lnPOP_{it} + \sum_{h=4}^{8} \beta_h lnDF_{ith} + \beta_9 lnMAN_{it} + \beta_{10} lnSER_{it} + \beta_{11} lnCOR_{it} + \varepsilon_{it} \quad (3)$$

where *PP* represents plastic pollution; *GDPPC* is the gross domestic product (GDP) per capita; *POP* denotes population size; *DF* represents the set of demographic factors, including population age (AGE1564 and AGE65), population density (PDEN), urbanization level (URB), and urban primacy (UPRI); *MAN* and SER denote the proportions of the manufacturing and service sectors in the economy, respectively; *COR* is the control of corruption; ε is the error term; i and t represent the units of analysis and time, respectively; and β_j ($j = 1, 2, \ldots, 11$) is the coefficient to be estimated. The symbol "*ln*" denotes a natural logarithm.

- **Dependent variable:** PP (plastic pollution), measured as inadequately managed plastic waste, defined as the annual amount of plastic waste that is openly dumped or discarded in waterways and marine environments (World Bank, 2018).
- **Independent variables (key drivers):** GDP per capita, population size, age structure, urbanization, urban primacy, population density, percentage of services and manufacturing sectors, control of corruption
- **Estimation method for the STIRPAT equation:** Random Effects model (based on robustness tests)

EKC Results over 1993-2017

- **EKC** confirmed statistically based on empirical data from the World Bank (2012 and 2018).
- **Turning point:** it ranges from US$ 3213 to US$ 6458 per capita (US$ at constant prices of the year 2010).
- **But:** GDP per capita explains only **15%** of variation in plastic pollution ($R^2 = 0.15$)

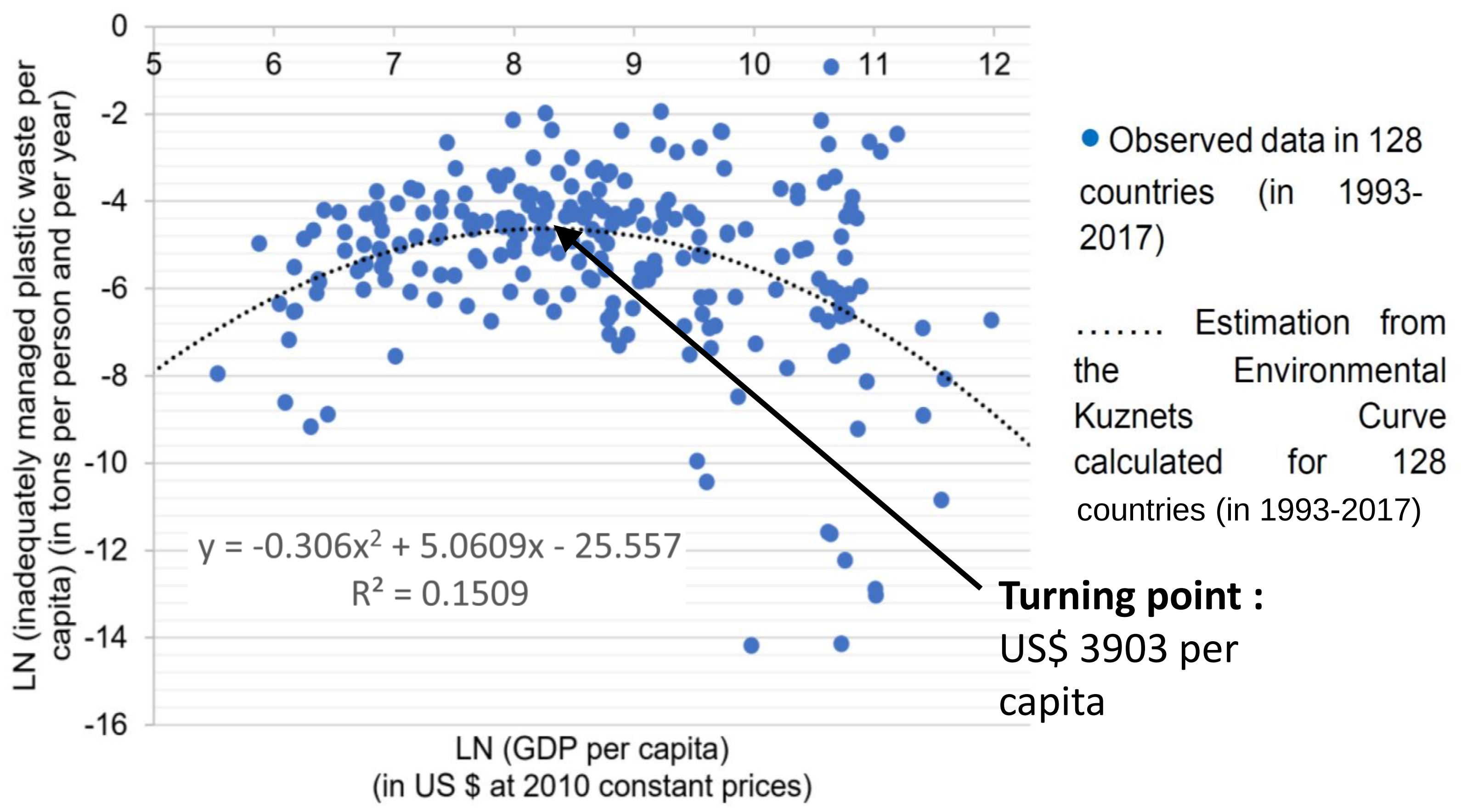


Figure V.2-23. Environmental Kuznets curve estimations compared to observed data of inadequately managed plastic waste generated per capita in 128 countries in 1993-2017 (own computation based on supplemental data provided in Yan *et al.* (2024a)). Note: inadequately managed plastic waste = municipal solid waste whose treatment consists in disposing of it in open dumps or discarding it in waterways or marine areas and including waste treatment categorised as "unaccounted for" (waste for which the treatment category is not specified), and "others" (a treatment type that does not fall into any of the categories defined by the World Bank) as recommended by Kaza Silpa (2018), page 12). In the EKC (black dashed curve), GDP per capita only explains 15% ($R^2 = 0.15$, p-value < 0.01) of variation in inadequately managed plastic waste per capita.

Sources of the graph:
Duquesne et al., 2025 (available here: https://dx.doi.org/10.17180/57kw-9f45, page 1308)
→ Based on Yan et al. (2024a, available here: https://doi.org/10.3390/su16020643

Results: key determinants beyond GDP

- Population size: population growth increases pollution
- Age structure: 15–64 years → increases pollution

  ≥65 years → decreases pollution
- Urbanization & urban primacy → increase pollution
- Corruption control → reduces pollution
- GDP per capita: increases pollution but after an economic growth threshold (turning point), pollution declines

Results: key determinants beyond GDP

Table 2. Determinants of plastic pollution in the random effects (RE) regression (entire sample).

Variable	Model Specification					
	(1) RE	**(2) RE**	**(3) RE**	**(4) RE**	**(5) RE**	**(6) RE**
lnGDPPC	6.508 *** (1.398)	6.512 *** (1.406)	5.755 *** (1.551)	5.2 *** (1.478)	7.73 *** (1.523)	5.063 ** (1.983)
$(lnGDPPC)^2$	−0.375 *** (0.079)	−0.375 *** (0.079)	−0.328 *** (0.084)	−0.322 *** (0.081)	−0.444 *** (0.087)	−0.3 *** (0.105)
lnPOP	0.948 *** (0.104)	0.948 *** (0.105)	0.945 *** (0.098)	0.931 *** (0.104)	1.15 *** (0.186)	1.052 *** (0.173)
lnPDEN		0.007 (0.131)				0.06 (0.149)
lnAGE1564			5.072 ** (2.224)			5.578 ** (2.458)
lnAGE65			−1.486 *** (0.328)			−1.387 *** (0.354)
lnURB				1.444 *** (0.553)		0.824 (0.671)
lnUPRI					0.986 ** (0.425)	0.657 * (0.392)

Table 2. *Cont.*

Variable	Model Specification					
	(1) RE	(2) RE	(3) RE	(4) RE	(5) RE	(6) RE
lnMAN	−0.237 (0.316)	−0.238 (0.318)	0.283 (0.311)	−0.424 (0.321)	−0.252 (0.374)	−0.069 (0.379)
lnSER	−0.114 (0.886)	−0.129 (0.94)	1.084 (0.882)	−0.252 (0.874)	−0.571 (1.031)	0.557 (1.093)
lnCOR	−0.657 ** (0.288)	−0.657 ** (0.289)	−0.52 * (0.272)	−0.581 ** (0.285)	−0.515 * (0.29)	−0.41 (0.275)
Constant	−28.58 *** (6.818)	−28.56 *** (6.845)	−50.33 *** (8.48)	−26.04 *** (6.811)	−39.03 *** (8.307)	−53.65 *** (9.994)
Turning point	5866	5902	6458	3213	6033	4619
Coefficient of determination (R^2)	0.5491	0.5493	0.6266	0.5637	0.4605	0.5657
Akaike's information criterion (AIC)	1.412	1.423	1.233	1.396	1.429	1.266
Bayesian information criterion (BIC)	1.539	1.569	1.399	1.542	1.591	1.509
Mean absolute error (MAE)	1.343	1.344	1.262	1.339	1.309	1.201
Root mean squared forecast error (RMSFE)	3.787	3.786	3.088	3.681	3.746	3.015
Observed	174	174	170	173	148	148
Test statistics:						
F-test (POLS vs. FE)	4.89 ***	4.83 ***	3.88 ***	5.11 ***	5.19 ***	4.19 ***
LM test (POLS vs. RE)	45.28 ***	44.16 ***	40.25 ***	48.12 ***	43.95 ***	39.3 ***
Hausman test (FE vs. RE)	4.49	4.9	3.4	7.9	2.97	8.76

Note: Standard errors are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. LM: Lagrange multiplier, POLS: pooled ordinary least squares, and FE: fixed effects.

Why EKC does not guarantee global decline of pollution

- **Displacement effects:** part of the EKC pattern reflects the relocation of pollution-intensive industries from high-income to low- and middle-income countries (Roca et al., 2001).
- **Waste export bias:** plastic waste exported (often illegally) from high-income countries is counted as “recycled” but often mismanaged in practice.
- **Limited explanatory power of GDP:** GDP per capita explains only a small share of variation in mismanaged plastic waste ($R^2 = 0.15$).
- **Other drivers dominate:** sociodemographic and institutional factors (corruption, population growth, urbanization, age structure).
    - Including these in STIRPAT changes the result: no inverted U-shape in plastic pollution (1996–2050).

Global projections with STIRPAT model (BAU scenario)

- Global inadequately managed plastic waste keeps rising to 2050.
- No inverted-U at global scale. "Global plastic pollution does not follow the inverted U-shape predicted by the EKC."

Global plastic pollution per capita

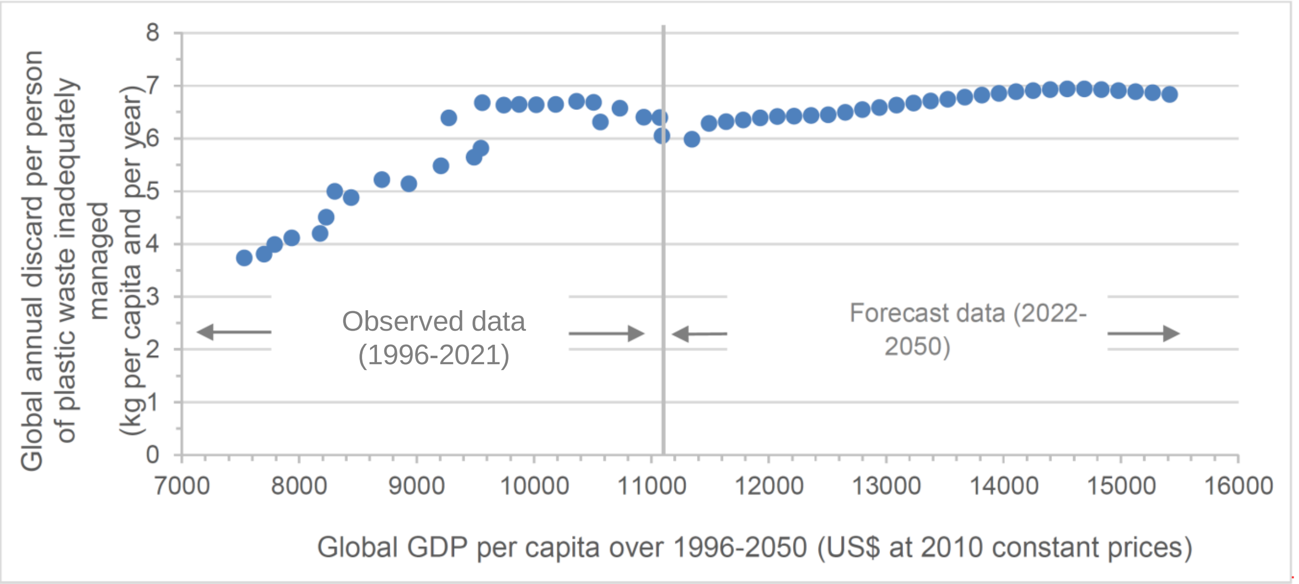


Figure V.2-24. World: simulation of the evolution of global annual discard per capita of inadequately managed plastic waste (already in the ecosystems or likely to reach it) and global GDP over the period 1996-2050 (business as usual scenario). Source : computed using the supplemental data provided by Yan *et al.* (2024a) – relying on their Model (6)'s equations,

Global plastic pollution (total)

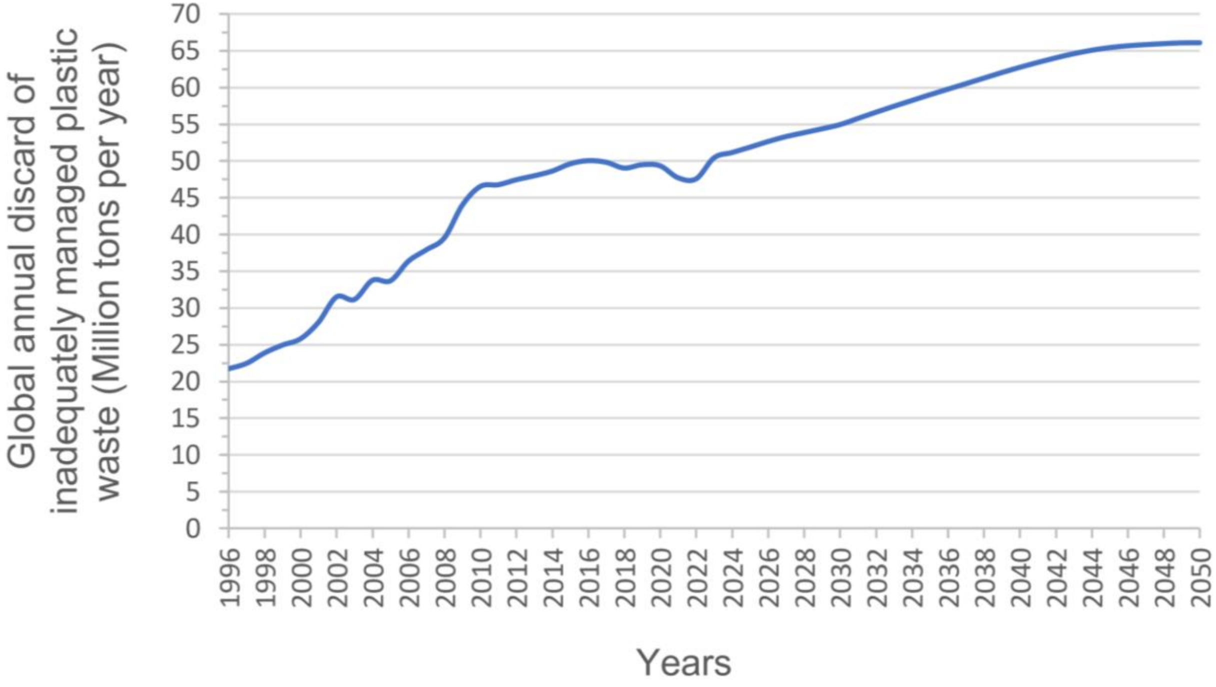


Figure V.2-26. World: simulation of the evolution of global annual discard of inadequately managed plastic waste (already in the ecosystems or likely to reach it) over the period 1996-2050 (business as usual scenario). Source : computed using the supplemental data provided by Yan *et al.* (2024a) – relying on their Model (6)'s equations, which includes several

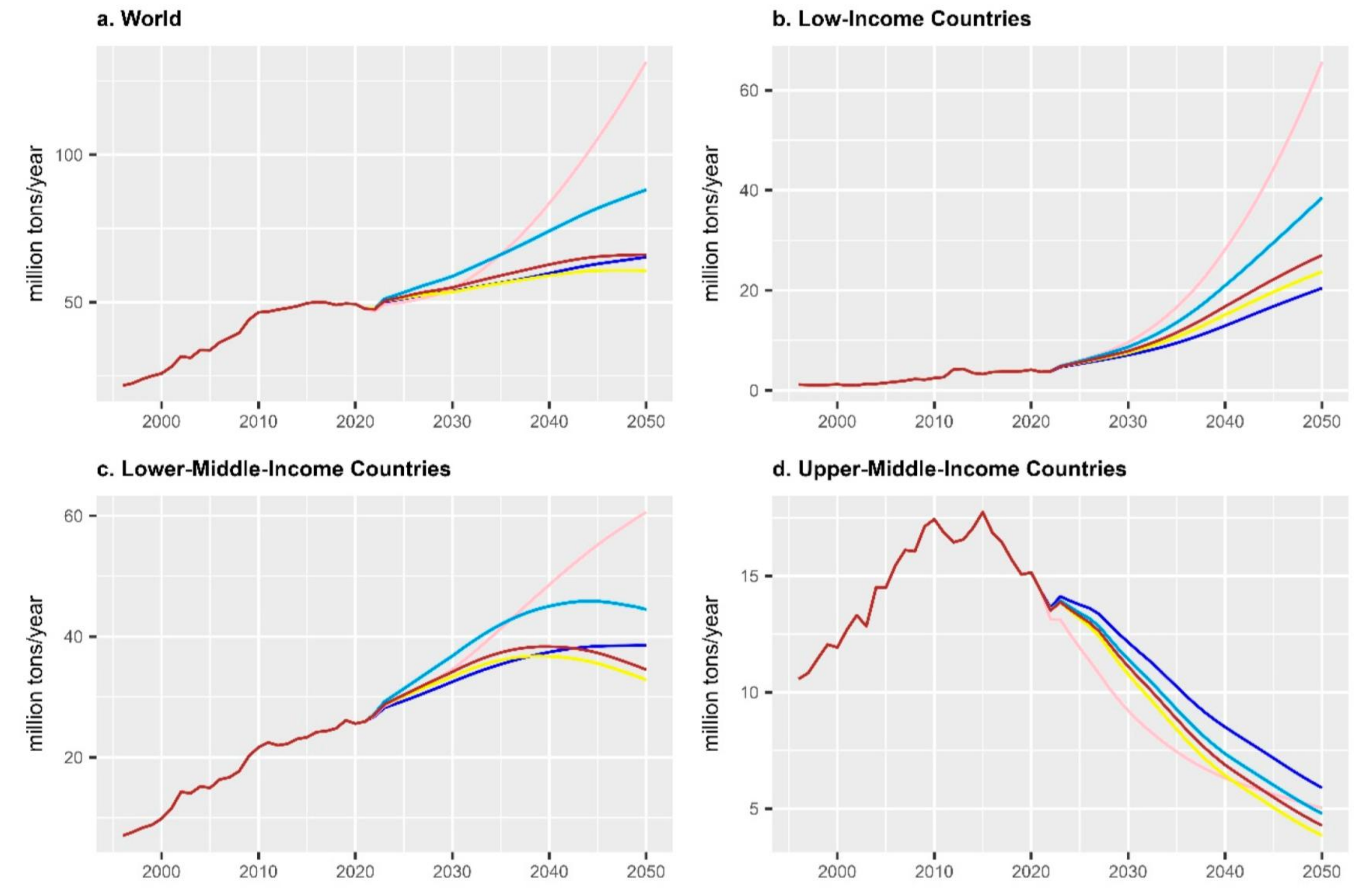
Sources:

- Duquesne et al., 2025 (available here: https://dx.doi.org/10.17180/57kw-9f45, pages 1310-1311)
- Yan, H., Cordier, M., & Uehara, T. (2024a). Future projections of global plastic pollution: Scenario analyses and policy implications. *Sustainability*, 16(2), 643. https://doi.org/10.3390/su16020643

Scenario Analysis : world and income groups

Scenario simulated with STIRPAT model specification 6(RE) :

- **BAU scenario:** all dependent variables increase with the same linear trend from 1996 to 2021 (if their projections are unavailable).
- **Scenario A (slow GDP):** GDP per capita grows at half the average annual rate of the BAU scenario for 2022–2050.
- **Scenario B (change in population structure):** The 15–64 age group grows twice as quickly compared to the average annual rate of the BAU scenario for 2022–2050.
- **Scenario C (high-speed urbanization):** the percentage of the population residing in urban areas doubles compared to the average annual rate of the BAU scenario for 2022–2050.
- **Scenario D (high-speed urban primacy):** the percentage of the urban population residing in the largest city of the country doubles compared to the average annual rate of the BAU scenario for 2022–2050.



Low- and lower-middle income countries may account for 66.8% of global plastic pollution by 2050.

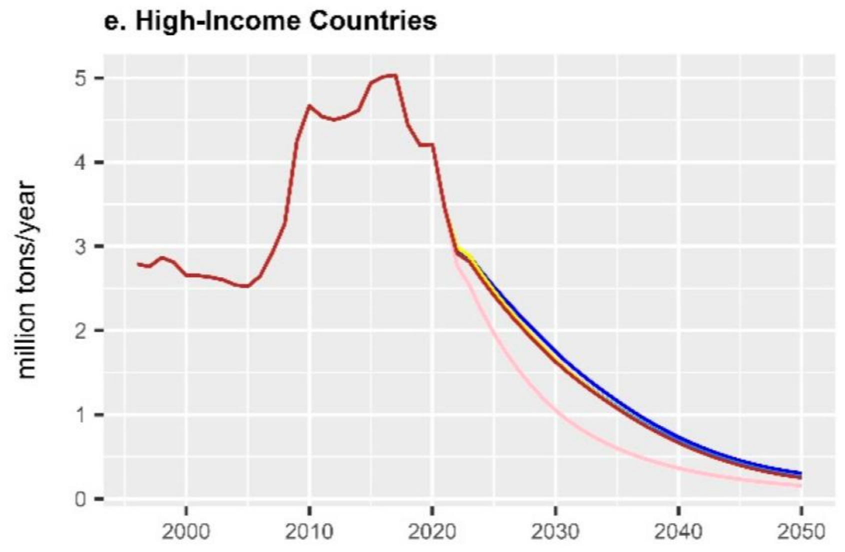
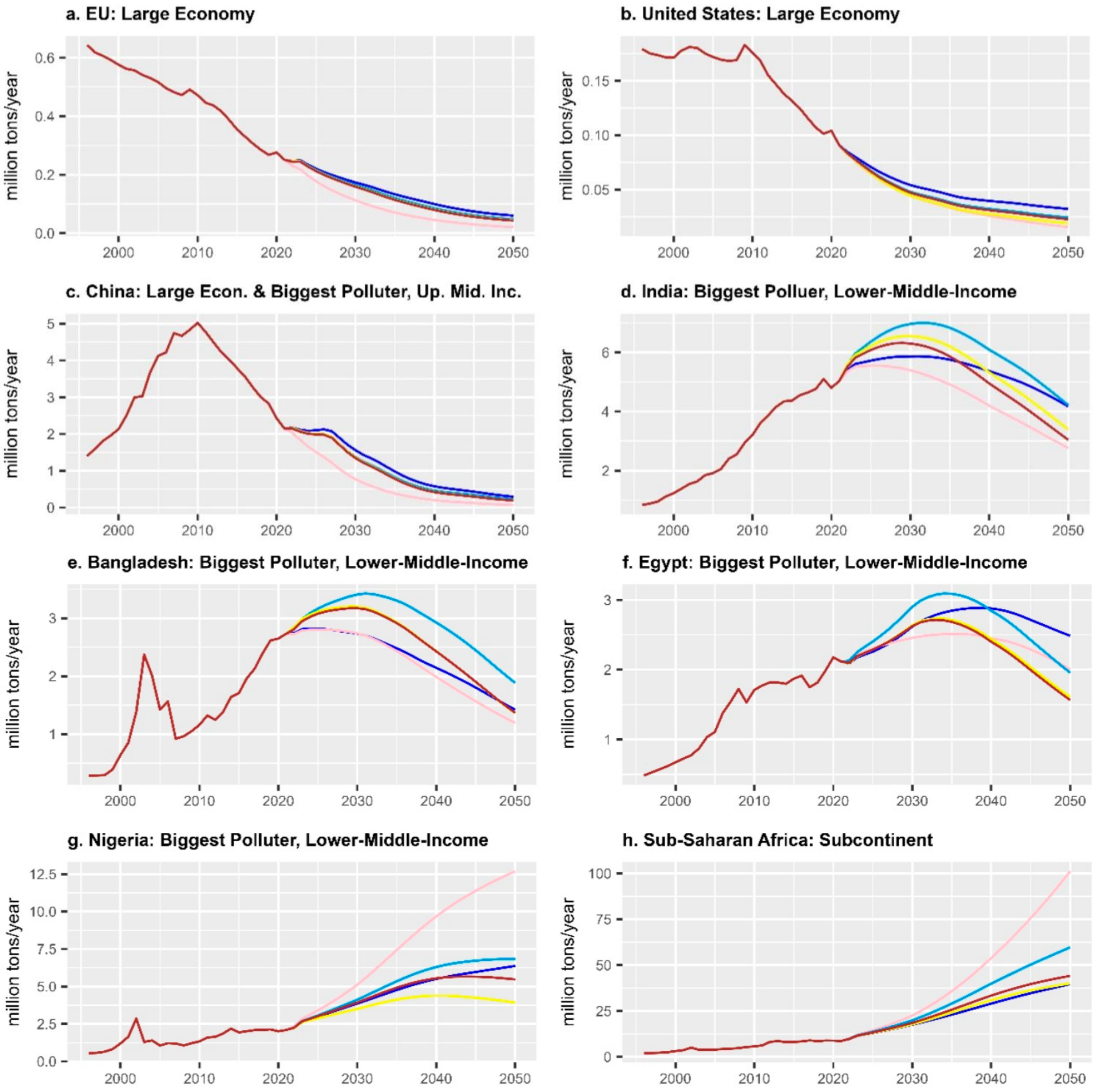


Figure 1. Projections of plastic pollution worldwide based on income levels of the countries. Brown: BAU (business-as-usual), blue: Scenario A (slow GDP), pink: Scenario B (change in population structure), light blue: Scenario C (urbanization), and yellow: Scenario D (urban primacy).

Figure 2. Projections of plastic pollution for large economies, biggest polluters, and a subcontinent region.

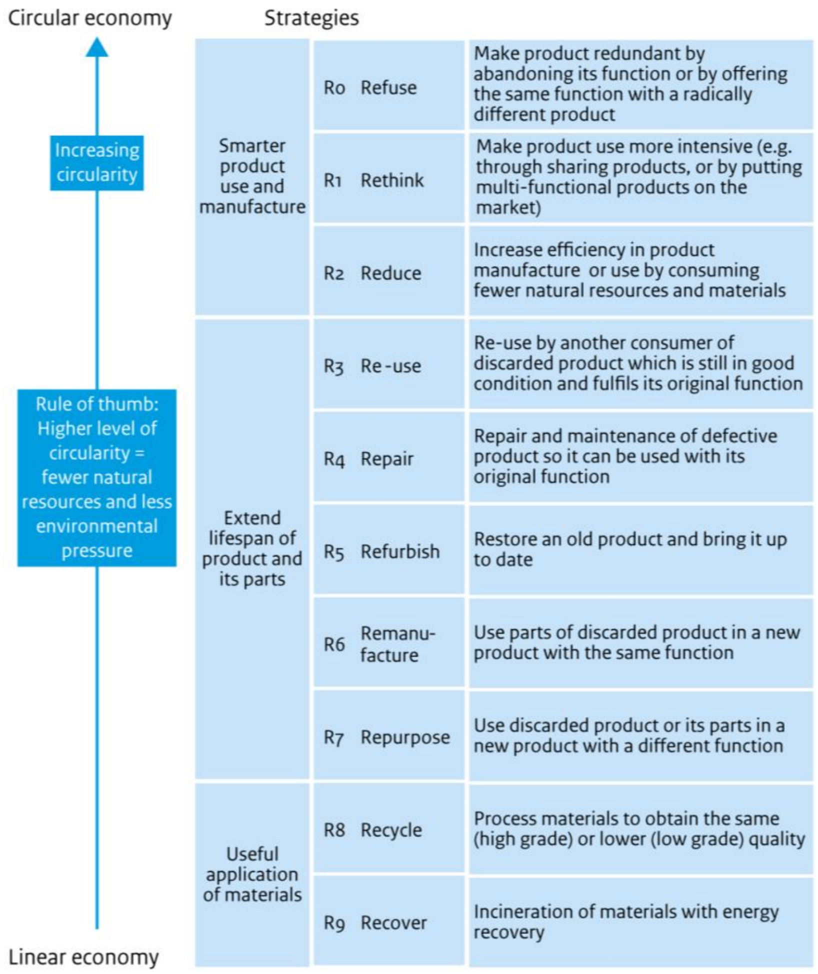
- Brown: BAU (business-as-usual)
- Blue: Scenario A (slow GDP),
- Pink: Scenario B (change in population structure),
- Light blue: Scenario C (urbanization),
- Yellow: Scenario D (urban primacy).

Econ.: economy, Up. Mid. Inc.: Upper-middle-income.



Policy implications

1. **Prioritize support to low- and lower-middle income regions:** especially Sub-Saharan Africa
2. **Ban plastic waste exports for so-called “recycling” from high-income to low income countries :** a significant share is openly burned or otherwise mismanaged.
3. **Consider microplastitc waste :** plastic pollutants (macroplastics) emitted by high-income countries will be nearly zero in any scenario by 2050. But what about microplastics emissions (not considered in this study)?
4. **Integrate plastic waste into circular economy :** applying the 9Rs and respect the hierarchy: 1-Refuse, 2-Rethink, 3-Reduce the use of plastic materials, 4-Reuse and 5-Repair already processed plastic products, … (Potting et al., 2017; Duquesne et al., 2025).



Source of the Figure: Potting J., Hekkert M., Worrell E., Hanemaaijer A., 2017. *Circular economy: measuring innovation in the product chain. Policy report. Planbureau voor de Leefomgeving (publiation number 2544* The Hague. https://www.pbl.nl/en/publications/circular-economy-measuring-innovation-in-product-chains

Conclusions

- The Environmental Kuznets Curve (EKC) exists statistically but does not solve global plastic pollution.
- Demographics, corruption, and urbanization are decisive.
- Without strong policies, global pollution rises until 2050.
- Circular economy strategies are essential.
- Future investigations should include rural–urban migration and monocentric/polycentric urban forms to reveal more detailed information on the effects of urbanization on plastic pollution.

***Thank you** for attending this conference.*

***Contact:** mateo.cordier@uvsq.fr*

Thank you !

Contacts:

mateo.cordier@uvsq.fr

UVSQ
université PARIS-SACLAY
Observatoire de Versailles Saint-Quentin-en-Yvelines
CAMPUS DE SAINT-QUENTIN-EN-YVELINES
cnrs
立命館大学
RITSUMEIKAN UNIVERSITY
CEARC
Cultures • Environnements
Arctique • Représentations • Climat
UNIVERSITÉ DE VERSAILLES ST-QUENTIN-EN-YVELINES