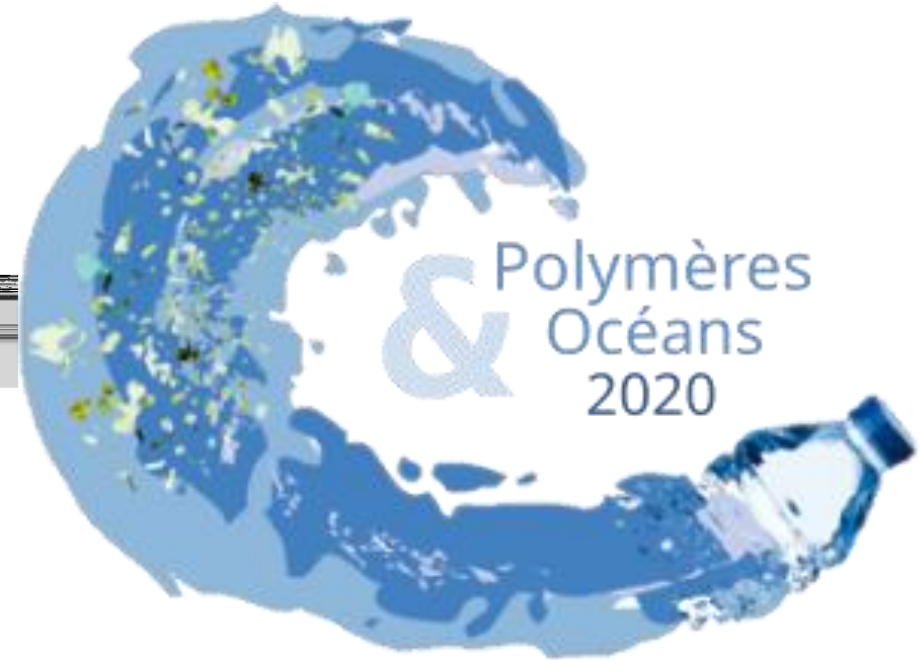




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## PLASTIC POLLUTION AND ECONOMIC GROWTH: INFLUENCE OF CORRUPTION AND LACK OF EDUCATION

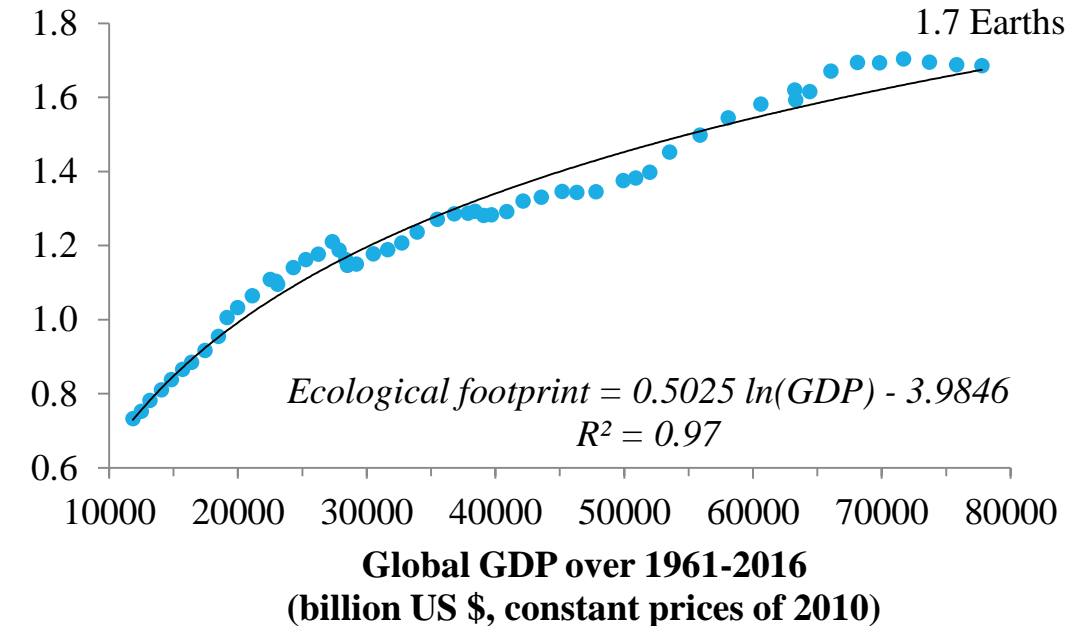
Mateo Cordier, Takuro Uehara, Juan Baztan, Bethany Jorgensen, Huijie Yan

# CONTEXT

- **Green economic growth** led by **technological solutions** is often mentioned as a solution for mitigating plastic pollution.
- However, economic growth (global GDP, *Gross Domestic Product*) appears to be in contradiction to **planetary boundaries** (*Global ecological footprint*).

To maintain our current appetite for natural resources, we would need the equivalent of 1.7 Earths

Global ecological footprint (Number of Earth)



Linear regression: Ecological footprint =  $f(\ln(GDP))$

Source	SS	df	MS	Number of obs =	56
Model	3.88352381	1	3.88352381	F( 1, 54) =	1901.57
Residual	.110282952	54	.002042277	Prob > F =	0.0000
				R-squared =	0.9724
				Adj R-squared =	0.9719
Total	3.99380676	55	.072614668	Root MSE =	.04519

Ecological footprint	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
LN (GDP)	.5025289	.0115241	43.61	0.000	.4794245 .5256332
_cons	-3.984623	.1204577	-33.08	0.000	-4.226126 -3.74312

Sources of data for the graph:

- Global Footprint Network (2020). Country Trends. <https://data.footprintnetwork.org/#/countryTrends?type=earth&cn=5001>
- World Bank (2020). PIB (\$ US constants de 2010). <https://donnees.banquemondiale.org/indicateur/NY.GDP.MKTP.KD>

# RESEARCH QUESTION

- Which **non-technological solutions** could reduce plastic contamination of the global ocean ?

# METHOD

- We answer that question by developing **two worldwide socio-economic models**, for forecasting inadequately managed plastic waste up to the year 2050 across **217 countries and territories**.

Plastic pollution and economic growth: the influence of corruption and the lack of education

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4 authors:



Mateo Cordier  
Université de Versailles Saint-Quentin



Takuro Uehara  
Ritsumeikan University



Juan Baztan  
Université de Versailles Saint-Quentin



Bethany Jorgensen  
Cornell University

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# METHOD: MODEL EQUATIONS

- **Equation 1** : general equation merging Eq. 2., Eq. 3 (or Eq. 3bis) and population size

*Inadequately managed plastic waste = plastic waste per capita x inadequately managed waste % x population*

- **Equation 2** : estimating plastic waste per capita

*$\ln(\text{Plastic waste per capita}) = \alpha + \beta \ln(Q_i) + \gamma \ln(Q_i)^2 + \delta X_i + \varepsilon_i$*

where the subscript  $i$  denotes countries,  $\alpha$  is an intercept,  $Q_i$  is income per capita,  $X_i$  is a vector of exogenous variables explaining *plastic waste per capita*, and  $\varepsilon_i$  are the disturbance terms.

- **Equation 3** : estimating inadequately managed waste percentage (includes [corruption control policy](#))

*$\text{Inadequately managed waste \%} = \frac{e^{\rho_1 + \sigma_1 \ln(Q_i) + \tau_1 C_i + \varphi_1 Z_{1i}}}{1 + e^{\rho_1 + \sigma_1 \ln(Q_i) + \tau_1 C_i + \varphi_1 Z_{1i}}}$*

where  $\rho_1$  is the constant term,  $C_i$  is the degree of corruption control, and  $Z_{1i}$  is a vector of the exogenous variable explaining *Inadequately managed waste %*.

- **Equation 3bis** : estimating inadequately managed waste percentage (includes [education](#))

*$\text{Inadequately managed waste \%} = \frac{e^{\rho_2 + \sigma_2 \ln(Q_i) + \tau_2 E_i + \varphi_2 Z_{2i}}}{1 + e^{\rho_2 + \sigma_2 \ln(Q_i) + \tau_2 E_i + \varphi_2 Z_{2i}}}$*

where  $\rho_2$  is the constant term,  $E_i$  is the educational level, and  $Z_{2i}$  is a vector of the exogenous variable explaining *Inadequately managed waste %*.

# METHOD: MODEL STRUCTURE

## In Equation 2 (plastic waste per capita)

- We included the influence of:
  - Income per capita (GDP per capita in \$/year)
  - Urbanisation (% of total population)
  - International tourism on small islands (dummy variable [0, 1])
  - Market regulatory quality (percentile rank)

**Table 2. Linear regression model estimate for Plastic waste per capita (natural logarithm) (Eq. 2).**

Variable	Coefficient	Std. Error	<i>p</i> -Value	
LN (GDP per capita)	1.573	0.708	0.028	**
(LN (GDP per capita)) <sup>2</sup>	-0.080	0.039	0.041	**
Small islands	0.562	0.139	0.000	***
Urban population	0.012	0.003	0.001	***
Market regulatory quality	0.008	0.004	0.065	*
Constant	-5.347	3.151	0.092	*
R <sup>2</sup>	0.4804			
AIC	326.3714			
BIC	344.3951			
<i>N</i>	149			

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ .

# METHOD: MODEL STRUCTURE

## In Equation 3 (inadequately managed waste %)

- We included **corruption control policies** (estimate from -2.5 to +2.5) following Biswas et al. (2012) who demonstrated controlling corruption reduces polluting emissions (Candau and Dienesch, 2017; Biswas et al., 2012; Milfont and Markowitz, 2016; Damania et al., 2003).
  - **Corruption** = when the public power is used for private gain, including petty and grand forms of corruption and the State is captured by elites and private interests (definition from **the World Bank**).

# METHOD: MODEL STRUCTURE

## In Equation 3<sub>bis</sub> (inadequately managed waste %)

- We included **education** (number of years spend at school per inhabitant) because:
  - making informed pro-environmental choices is difficult if one has no knowledge (Gifford and Nilsson, 2014; Vicente-Molina et al., 2013; Hidalgo-Ruz et al., 2018).
  - A minimum level of education is required to develop the ability to manage contrasting information, a skill that is central to ecological behaviors (Otto and Pensini, 2017).



# METHOD: MODEL STRUCTURE

## In Equation 3 and 3<sub>bis</sub>

- We also included other explanatory variables :
  - GDP per capita (natural logarithm)
  - International tourism on small islands (dummy variable [0, 1])
  - Geographical variables for Middle East and African countries, and Latin American countries (dummy variables [0, 1])

**Table 3. Logistic model estimate for inadequately managed waste percentage with a focus on corruption control policies (Eq. 3).**

Variable	Coefficient	Std. Error	<i>p</i> -Value	
LN (GDP per capita)	-1.159	0.410	0.005	***
Corruption control policies	-1.244	0.562	0.027	**
Middle East and African countries	2.215	0.926	0.017	**
Latin American countries	3.057	0.885	0.001	***
Small islands	-1.684	0.809	0.037	**
Constant	9.926	3.683	0.007	***
Pseudo R <sup>2</sup>	0.5411			
Log likelihood	-38.8019			
AIC	89.6037			
BIC	106.4278			
<i>N</i>	122			

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ .

**Table 4. Logistic model estimate for inadequately managed waste percentage with a focus on education policies (Eq. 3<sub>bis</sub>).**

Variable	Coefficient	Std. Error	<i>p</i> -Value	
Years of school	-0.437	0.174	0.012	**
LN (GDP per capita)	-1.385	0.387	0.000	***
Latin American countries	3.287	1.120	0.003	***
Constant	16.179	3.717	0.000	***
Pseudo R <sup>2</sup>	0.6140			
Log likelihood	-26.7485			
AIC	61.4971			
BIC	71.9177			
<i>N</i>	100			

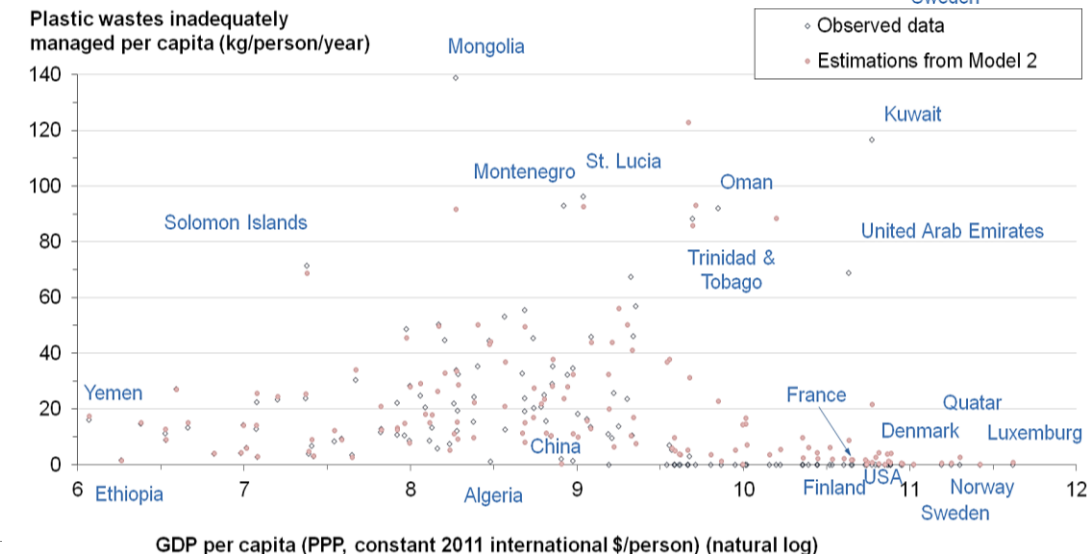
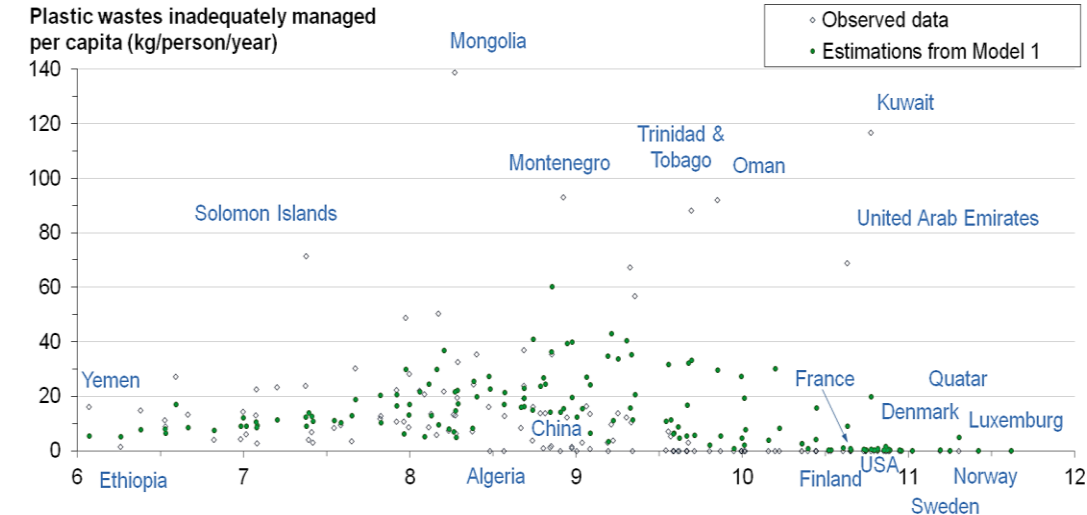
\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ .

# RESULTS BUSINESS-AS-USUAL SCENARIO (COUNTRY BY COUNTRY)

- The top 43 countries generating the highest amounts of inadequately managed plastic waste in 2017

- Estimations from Models 1 and 2 and comparison with observed data in 141 pays in 2011-2017.

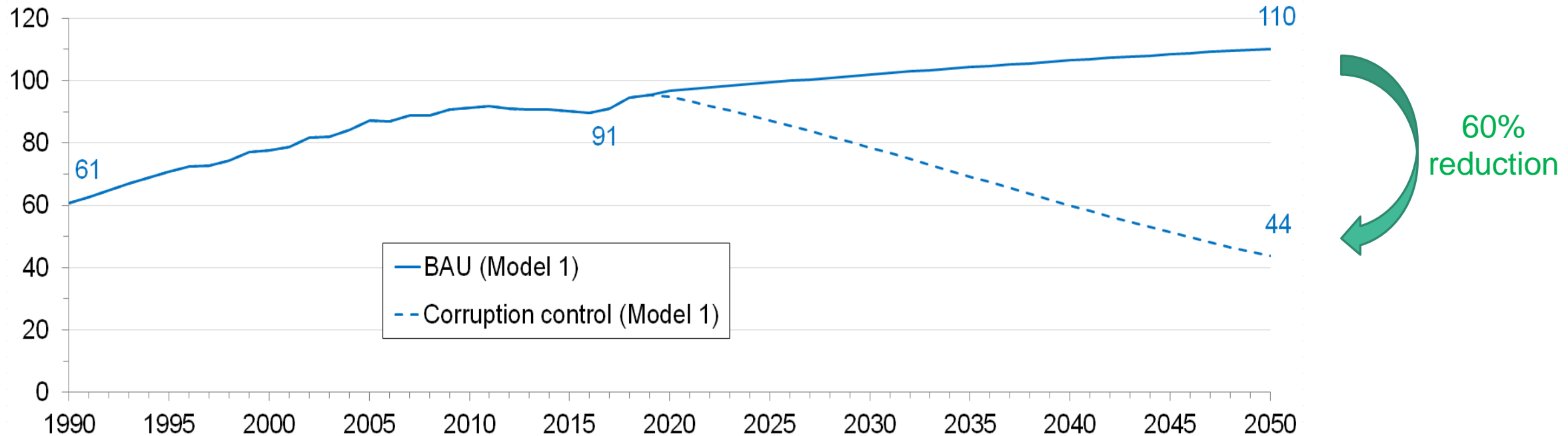
Observed data from World Bank (2018a, 2019)						BAU scenario (results from Model 2 except in the ranges where results from Models 1 and 2 are shown)				
Country	Income category	Corruption control policy estimate		Years of schooling		Population (million)	Plastic waste generation rate (kg/person/yr)	% Inadequately managed waste	Inadequately managed plastic waste (MMT/yr)	Inadequately managed plastic waste (MMT/yr)
(Years) →		1996	2017	1995	2010	2017	2017	2017	2017	2050
1 India	LMC	-0.38	-0.24 ↗	3.51	5.39 ↗	1338.7	20.2	79.6%	13.85 – 21.57	4.50 – 8.98
2 China	UMC	-0.27	-0.27 →	5.69	7.12 ↗	1386.4	31.0	32.2%	12.38 – 13.82	1.71 – 10.05
3 Brazil	UMC	-0.02	-0.53 ↘	4.84	7.66 ↗	207.8	44.8	94.0%	8.64 – 8.75	5.11 – 8.66
4 Mexico	UMC	-0.51	-0.93 ↘	6.48	8.33 ↗	124.8	45.0	85.1%	4.78 – 5.29	1.80 – 7.46
5 Indonesia	LMC	-0.86	-0.25 ↗	4.21	7.26 ↗	264.6	30.1	53.7%	2.89 – 4.28	0.78 – 0.80
6 Pakistan	LMC	-1.22	-0.78 ↗	2.77	4.45 ↗	207.9	17.8	90.8%	2.77 – 3.37	3.46 – 3.49
7 Nigeria	LMC	-1.19	-1.07 ↗	N.A.	N.A.	190.9	19.4	80.5%	2.91 – 2.98	7.76 – 7.99
8 Bangladesh	LMC	-0.97	-0.83 ↗	3.29	4.91 ↗	159.7	15.5	92.1%	2.01 – 2.29	1.57 – 1.69
9 Colombia	UMC	-0.51	-0.37 ↗	6.09	8.45 ↗	48.9	46.6	92.8%	2.10 – 2.12	1.98 – 3.20
10 Argentina	HIC	-0.10	-0.26 ↘	8.34	9.48 ↗	44.0	44.3	79.4%	1.70 – 1.55	0.56 – 1.57
11 Vietnam	LMC	-0.49	-0.58 ↘	4.60	7.45 ↗	94.6	19.6	69.9%	1.16 – 1.30	0.23 – 0.67
12 Philippines	LMC	-0.36	-0.48 ↘	7.12	8.18 ↗	105.2	27.0	44.3%	1.26 – 1.54	0.15 – 1.16
13 Peru	UMC	-0.40	-0.50 ↘	7.25	8.68 ↗	31.4	45.5	86.8%	1.24 – 1.34	0.32 – 1.75
14 Egypt	LMC	-0.47	-0.54 ↘	4.05	6.55 ↗	96.4	19.7	53.8%	1.02 – 1.68	0.13 – 2.29
15 Ethiopia	LIC	-0.93	-0.56 ↗	N.A.	N.A.	106.4	9.6	97.6%	0.90 – 1.00	0.92 – 1.20
16 Morocco	LMC	-0.11	-0.13 ↘	2.66	4.24 ↗	35.6	29.8	84.6%	0.90 – 0.93	0.53 – 1.45
17 Chile	HIC	1.45	1.04 ↘	8.40	9.71 ↗	18.5	61.2	72.3%	0.59 – 0.82	0.24 – 0.44
18 Venezuela	UMC	-0.86	-1.36 ↘	5.5	8.16 ↗	29.4	31.2	89.1%	0.82 – 0.88	0.38 – 1.09
19 Turkey	UMC	-0.15	-0.19 ↘	4.81	6.56 ↗	81.1	40.4	24.4%	0.56 – 0.80	0.08 – 0.17
20 Europe - 28	HIC	1.18	1.09 ↘	9.13	11.23 ↗	512.2	49.7	3.1%	0.80 – 1.01	0.07 – 1.13
[...]				[...]					[...]	
<b>Total 43 countries</b>									<b>77.3 – 86.9</b>	<b>49.6 – 90.9</b>
<b>Total world (217 countries)</b>									<b>91.0 – 95.4</b>	<b>61.2 – 110.2</b>



# RESULTS: CONTROLLING CORRUPTION SCENARIO

- In the top 43 countries discarding the highest amounts of inadequately managed plastic waste, corruption & lobby control policies are raised closer to the level of France and Estonia in 2017

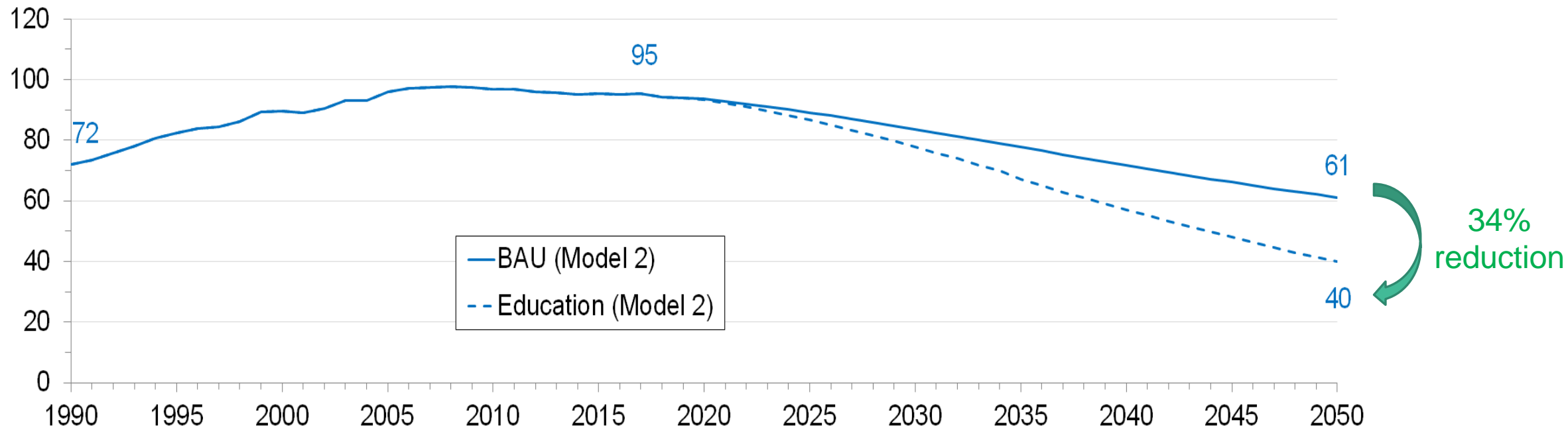
Annual plastic waste inadequately managed globally (MMT/year)



# RESULTS: EDUCATION SOLUTION SCENARIO

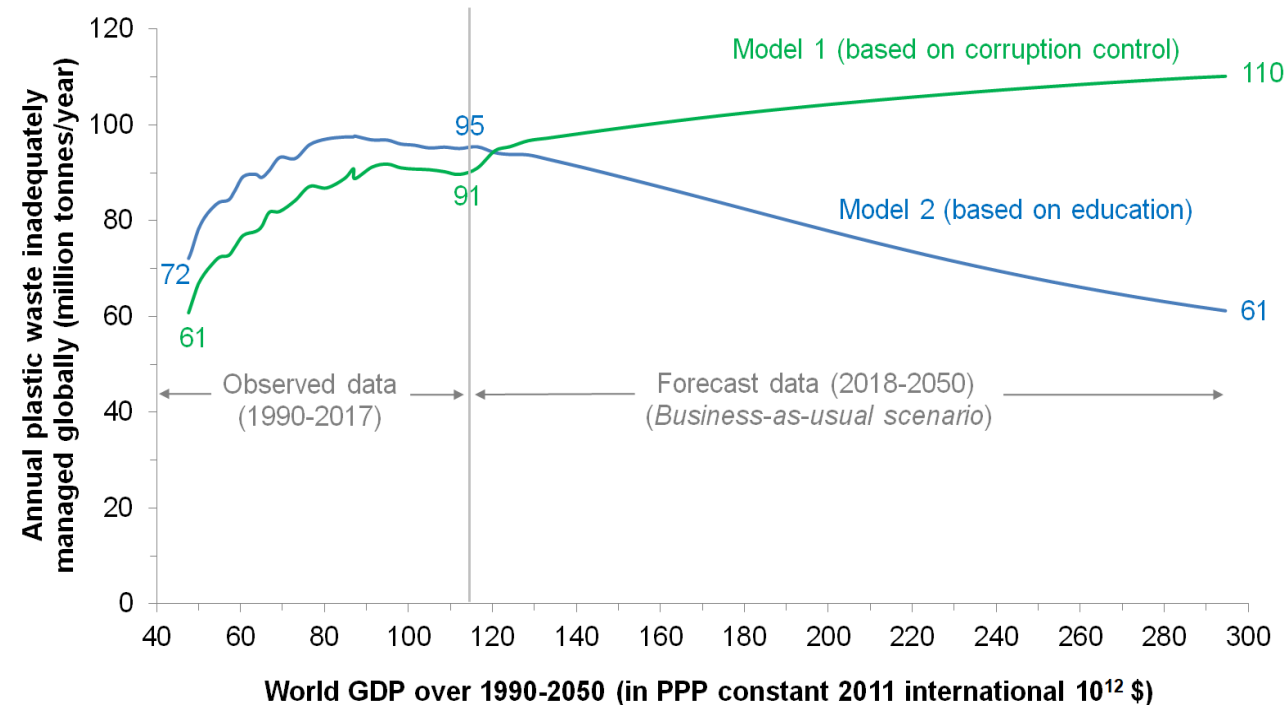
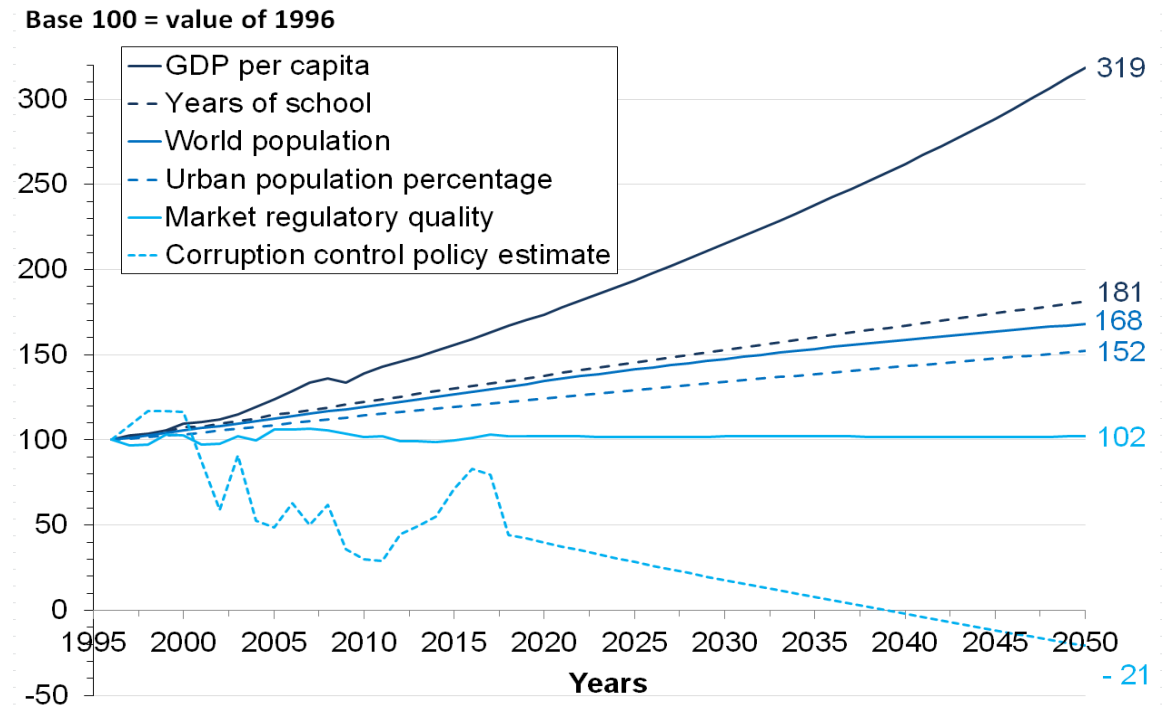
- In the top 43 countries, the number of schooling years for individuals  $\geq 25$  years old is increased to 12 years

Annual plastic waste inadequately managed globally (MMT/year)



# CONCLUSION

- Our model simulations show the **growth of GDP per capita** in the BAU scenario will not create sufficient investment capacity in waste treatment infrastructures to resolve plastic waste contamination of the ecosystems by 2050.
- Non-technological solutions such as **corruption & lobby control policies** as well as **education** are able to reduce inadequately managed plastic waste. They must be part of implemented interventions.



# FOR MORE INFORMATION...

Email: [mateo.cordier@uvsq.fr](mailto:mateo.cordier@uvsq.fr)

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Plastic pollution and economic growth: The influence of corruption and lack of education

Mateo Cordier<sup>a,b,c,\*</sup>, Takuro Uehara<sup>d</sup>, Juan Baztan<sup>a,c</sup>, Bethany Jorgensen<sup>c,e</sup>, Huijie Yan<sup>a</sup>

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Mateo Cordier  
Université de Versailles Saint-Quentin



Juan Baztan  
Université de Versailles Saint-Quentin



Takuro Uehara  
Ritsumeikan University



Bethany Jorgensen  
Cornell University

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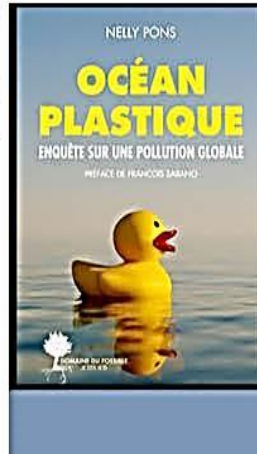
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