



Universiteit
Leiden
The Netherlands

Environmental impacts of the global plastic waste trade: assessment and mitigation

Li, K.

Citation

Li, K. (2025, March 27). *Environmental impacts of the global plastic waste trade: assessment and mitigation*. Retrieved from <https://hdl.handle.net/1887/4209464>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/4209464>

Note: To cite this publication please use the final published version (if applicable).

References

- Ammendolia, J., & Walker, T. R. (2022). Global plastics treaty must be strict and binding. *Nature*, 611, 236. <https://doi.org/10.1038/d41586-022-03581-z>
- Australian Government. (2024). *Exports of waste plastic*. <https://www.dcceew.gov.au/environment/protection/waste/exports/plastic>
- Bachmann, M., Zibunas, C., Hartmann, J., Tulus, V., Suh, S., Guillén-Gosálbez, G., & Bardow, A. (2023). Towards circular plastics within planetary boundaries. *Nature Sustainability*, 6(5), 599-610. <https://doi.org/10.1038/s41893-022-01054-9>
- Basel Convention. (1989). *Text of the Convention*. <https://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx>
- Basel Convention. (2019). *Basel Convention Plastic Waste Amendments*. <https://www.basel.int/Implementation/Plasticwaste/Amendments/Overview/tabid/8426/Default.aspx>
- Bertoli, S., Goujon, M., & Santoni, O. (2016). *The CERDI-SeaDistance database*. <https://shs.hal.science/halshs-01288748v1/preview/2016.07.pdf>
- Bez, C., Bosetti, V., Colantone, I., & Zanardi, M. (2023). Exposure to international trade lowers green voting and worsens environmental attitudes. *Nature Climate Change*, 13(10), 1131-1135. <https://doi.org/10.1038/s41558-023-01789-z>
- Bianchi, F., Ludvigson, S. C., & Ma, S. (2022). Belief Distortions and Macroeconomic Fluctuations. *American Economic Review*, 112(7), 2269–2315. <https://doi.org/10.1257/aer.20201713>
- Bishop, G., Styles, D., & Lens, P. N. L. (2020). Recycling of European plastic is a pathway for plastic debris in the ocean. *Environment International*, 142, 105893. <https://doi.org/10.1016/j.envint.2020.105893>
- Bourtsalas, A. C., Yepes, I. M., & Tian, Y. (2023). U.S. plastic waste exports: A state-by-state analysis pre- and post-China import ban. *Journal of environmental management*, 344, 118604. <https://doi.org/10.1016/j.jenvman.2023.118604>
- Brandon, A., Vanapalli, K. R., Martin, O. V., Dijkstra, H., De la Torre, G. E., Hartmann, N. B., Meier, M. A. R., Pathak, G., Busch, P.-O., Ma, D., Iacovidou, E., Deere Birkbeck, C., & Pacini, H. (2023). Charting success for the Plastics Treaty. *One Earth*, 6(6), 575-581. <https://doi.org/10.1016/j.oneear.2023.05.022>
- Brewer, T., Andrew, N., Sharp, M., Thow, A., Kottage, H., & Jones, S. (2020). *A method for cleaning trade data for regional analysis: The Pacific Food Trade Database (version 2, 1995-2018)*. <https://purl.org/spc/digilib/doc/d52nm>
- Brooks Amy, L., Wang, S., & Jambeck Jenna, R. (2018). The Chinese import ban and its impact on global plastic waste trade. *Science Advances*, 4(6), eaat0131. <https://doi.org/10.1126/sciadv.aat0131>
- Brown, A., Laubinger, F., & Börkey, P. (2022). Monitoring trade in plastic waste and scrap. <https://doi.org/doi:https://doi.org/10.1787/8f3e9c56-en>

- Brown, E., MacDonald, A., Allen, S., & Allen, D. (2023). The potential for a plastic recycling facility to release microplastic pollution and possible filtration remediation effectiveness. *Journal of Hazardous Materials Advances*, 10, 100309. <https://doi.org/10.1016/j.hazadv.2023.100309>
- Chatham House. (2024). 'resourcetrade.earth'. <https://resourcetrade.earth/>
- Chen, C.-L., Hsu, T.-P., & Chang, J.-R. (2004). A novel approach to great circle sailings: the great circle equation. *The Journal of Navigation*, 57(2), 311-320.
- Chen, C., Jiang, Z., Li, N., Wang, H., Wang, P., Zhang, Z., Zhang, C., Ma, F., Huang, Y., & Lu, X. (2022). Advancing UN Comtrade for physical trade flow analysis: review of data quality issues and solutions. *Resources, Conservation and Recycling*, 186, 106526.
- Chen, C., Jiang, Z., Li, N., Wang, H., Wang, P., Zhang, Z., Zhang, C., Ma, F., Huang, Y., Lu, X., Wei, J., Qi, J., & Chen, W.-Q. (2022). Advancing UN Comtrade for Physical Trade Flow Analysis: Review of Data Quality Issues and Solutions. *Resources, Conservation and Recycling*, 186, 106526. <https://doi.org/https://doi.org/10.1016/j.resconrec.2022.106526>
- Chesson, A., Marilyn, T., & Haynes, J. (2018). *Asymmetries in trade data—diving deeper into UK bilateral trade data* (Office for National Statistics, Issue. <https://backup.ons.gov.uk/wp-content/uploads/sites/3/2018/01/Asymmetries-in-trade-data-diving-deeper-into-UK-bilateral-trade-data.pdf>
- Cortés Arbués, I., Chatzivasileiadis, T., Ivanova, O., Storm, S., Bosello, F., & Filatova, T. (2024). Distribution of economic damages due to climate-driven sea-level rise across European regions and sectors. *Scientific Reports*, 14(1), 126. <https://doi.org/10.1038/s41598-023-48136-y>
- Cuñat, A., & Zymek, R. (2023). Bilateral Trade Imbalances. *The Review of Economic Studies*, 91(3), 1537-1583. <https://doi.org/10.1093/restud/rdad052>
- Di, J., Reck, B. K., Miatto, A., & Graedel, T. E. (2021). United States plastics: Large flows, short lifetimes, and negligible recycling. *Resources, Conservation and Recycling*, 167, 105440. <https://doi.org/10.1016/j.resconrec.2021.105440>
- Doka, G. (2018). *Inventory parameters for regionalised mixes of municipal waste disposal in ecoinvent v3.5*. <https://www.doka.ch/WasteDisposalMixDoka2018.pdf>
- Doka LCA. (2018). *Inventory parameters for regionalised mixes of municipal waste disposal in ecoinvent v3.5*. <https://www.doka.ch/WasteDisposalMixDoka2018.pdf>
- Dong, K., Dong, X., & Jiang, Q. (2020). How renewable energy consumption lower global CO2 emissions? Evidence from countries with different income levels. *The World Economy*, 43(6), 1665-1698. <https://doi.org/https://doi.org/10.1111/twec.12898>
- Douglass, K., & Cooper, J. (2020). Archaeology, environmental justice, and climate change on islands of the Caribbean and southwestern Indian Ocean. *Proceedings of the National Academy of Sciences*, 117(15), 8254-8262. <https://doi.org/doi:10.1073/pnas.1914211117>
- Environment Investigation Agency. (2023). *Plastic Waste Power Play*. https://eia-international.org/wp-content/uploads/EIA_UK_Plastic_Waste_Trade_Report_0123_FINAL_SPREADS.pdf

- Environmental Investigation Agency. (2021). *The Truth Behind Trash: The scale and impact of the international trade in plastic waste*. <https://eia-international.org/wp-content/uploads/EIA-The-Truth-Behind-Trash-FINAL.pdf>
- ESCAP. (2016). *Asymmetries in International Merchandise Trade Statistics: A case study of selected countries in Asia-Pacific*. https://ec.europa.eu/eurostat/documents/7828051/8076585/Asymmetries__trade_goods.pdf
- European Commission. (2022). *Developer Environmental Footprint (EF)*. <https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html>
- European Commission. (2024). *Waste shipments*. https://environment.ec.europa.eu/topics/waste-and-recycling/waste-shipments_en
- European Environment Agency. (2023). *The plastic waste trade in the circular economy*. <https://www.eea.europa.eu/publications/the-plastic-waste-trade-in>
- European Union. (2020). *Commission Delegated Regulation (EU) 2020/2174 of 19 October 2020 amending Annexes IC, III, IIIA, IV, V, VII and VIII to Regulation (EC) No 1013/2006 of the European Parliament and of the Council on shipments of waste (Text with EEA relevance)*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2020.433.01.0011.01.ENG&toc=OJ%3AL%3A2020%3A433%3ATOC
- European Union. (2024). *Regulation (EU) 2024/1157 of the European Parliament and of the Council of 11 April 2024 on shipments of waste, amending Regulations (EU) No 1257/2013 and (EU) 2020/1056 and repealing Regulation (EC) No 1013/2006 Text with EEA relevance*. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1157>
- Eurostat. *Electricity prices for non-household consumers - bi-annual data*. Retrieved 2023-11-11 from https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_205/default/table?lang=en
- Fagnani, D. E., Kim, D., Camarero, S. I., Alfaro, J. F., & McNeil, A. J. (2023). Using waste poly(vinyl chloride) to synthesize chloroarenes by plasticizer-mediated electro(de)chlorination. *Nature Chemistry*, 15(2), 222-229. <https://doi.org/10.1038/s41557-022-01078-w>
- Faraca, G., Martinez-Sanchez, V., & Astrup, T. F. (2019). Environmental life cycle cost assessment: Recycling of hard plastic waste collected at Danish recycling centres. *Resources, Conservation and Recycling*, 143, 299-309. <https://doi.org/https://doi.org/10.1016/j.resconrec.2019.01.014>
- Feenstra, R. C., Lipsey, R. E., Deng, H., Ma, A. C., & Mo, H. (2005). World Trade Flows: 1962-2000. *National Bureau of Economic Research Working Paper Series, No. 11040*. <https://doi.org/10.3386/w11040>
- Gaulier, G., & Zignago, S. (2010). Baci: international trade database at the product-level (the 1994-2007 version).
- Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, 3(7), e1700782. <https://doi.org/10.1126/sciadv.1700782>

- Google Maps Platform. (2022). *Distance Matrix API request and response*. Retrieved 19th October 2022 from <https://developers.google.com/maps/documentation/distance-matrix/distance-matrix>
- Government of Canada. (2023). *Canada-US agreement on waste*. <https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/international-commitments/canada-united-states-agreement.html>
- Government of the United Kingdom. (2023). *Guidance on reasons for trade in goods asymmetries*. <https://www.gov.uk/government/publications/uk-trade-in-goods-statistics-reasons-for-trade-in-goods-asymmetries/reasons-for-trade-in-goods-asymmetries>
- Greenpeace Research Laboratories. (2022). *Hazardous chemical contaminants in samples of surface water, soil, ash, sediment and waste plastic from waste dumpsites in Turkey*. https://www.greenpeace.to/greenpeace/wp-content/uploads/2022/02/Plastic_waste_dumpsites_Turkey_GRL-AR-2022-01.pdf
- Guardian. (2019). *Where does your plastic go? Global investigation reveals America's dirty secret*. <https://www.theguardian.com/us-news/2019/jun/17/recycled-plastic-america-global-crisis>
- Hallak, J. C. (2006). Product quality and the direction of trade. *Journal of International Economics*, 68(1), 238-265. <https://doi.org/https://doi.org/10.1016/j.jinteco.2005.04.001>
- Helveston, J. P., He, G., & Davidson, M. R. (2022). Quantifying the cost savings of global solar photovoltaic supply chains. *Nature*, 612(7938), 83-87. <https://doi.org/10.1038/s41586-022-05316-6>
- Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1526), 2115-2126. <https://doi.org/doi:10.1098/rstb.2008.0311>
- Hudgins, E. J., Cuthbert, R. N., Haubrock, P. J., Taylor, N. G., Kourantidou, M., Nguyen, D., Bang, A., Turbelin, A. J., Moodley, D., Briski, E., Kotronaki, S. G., & Courchamp, F. (2023). Unevenly distributed biological invasion costs among origin and recipient regions. *Nature Sustainability*, 6(9), 1113-1124. <https://doi.org/10.1038/s41893-023-01124-6>
- Huijbregts, M. A. J., Steinmann, Z. J. N., Elshout, P. M. F., Stam, G., Verones, F., Vieira, M., Zijp, M., Hollander, A., & van Zelm, R. (2017). ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. *The International Journal of Life Cycle Assessment*, 22(2), 138-147. <https://doi.org/10.1007/s11367-016-1246-y>
- Hull, E. V. (2010). Poisoning the poor for profit: The injustice of exporting electronic waste to developing countries. *Duke Envtl. L. & Pol'y F.*, 21, 1.
- International Labour Organization. *Average monthly earnings of employees by sex and economic activity*. Retrieved 2023-11-12 from <https://ilostat.ilo.org/topics/wages/>
- International Labour Organization. (2023). *Hazardous exposures to plastics in the world of work*. https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@ed_dialogue/@lab_admin/documents/publication/wcms_894387.pdf
- International Labour Organization. (2024). *Beyond the bin: Decent work deficits in the waste management and recycling industry*. <https://ilostat.ilo.org/blog/beyond-the-bin-decent-work-deficits-in-the-waste-management-and-recycling-industry/>

- Istrate, I.-R., Galvez-Martos, J.-L., Vázquez, D., Guillén-Gosálbez, G., & Dufour, J. (2023). Prospective analysis of the optimal capacity, economics and carbon footprint of energy recovery from municipal solid waste incineration. *Resources, Conservation and Recycling*, 193, 106943. <https://doi.org/10.1016/j.resconrec.2023.106943>
- IUCN-EA-QUANTIS. (2020). *National Guidance for plastic pollution hotspotting and shaping action for Vietnam*. https://www.iucn.org/sites/default/files/content/documents/2021/vietnam_-_national_guidance_for_plastic_pollution_hotspotting_and_shaping_action.pdf
- Jakob, M., Kübler, D., Steckel, J. C., & van Veldhuizen, R. (2017). Clean up your own mess: An experimental study of moral responsibility and efficiency. *Journal of Public Economics*, 155, 138-146. <https://doi.org/https://doi.org/10.1016/j.jpubeco.2017.09.010>
- Jakob, M., Ward, H., & Steckel, J. C. (2021). Sharing responsibility for trade-related emissions based on economic benefits. *Global Environmental Change*, 66, 102207. <https://doi.org/https://doi.org/10.1016/j.gloenvcha.2020.102207>
- Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*, 347(6223), 768-771. <https://doi.org/doi:10.1126/science.1260352>
- Janssens, C., Havlík, P., Boere, E., Palazzo, A., Mosnier, A., Leclère, D., Balkovič, J., & Maertens, M. (2022). A sustainable future for Africa through continental free trade and agricultural development. *Nature Food*, 3(8), 608-618. <https://doi.org/10.1038/s43016-022-00572-1>
- Janssens, C., Havlík, P., Krisztin, T., Baker, J., Frank, S., Hasegawa, T., Leclère, D., Ohrel, S., Ragnauth, S., Schmid, E., Valin, H., Van Lipzig, N., & Maertens, M. (2020). Global hunger and climate change adaptation through international trade. *Nature Climate Change*, 10(9), 829-835. <https://doi.org/10.1038/s41558-020-0847-4>
- Kanemoto, K., Lenzen, M., Peters, G. P., Moran, D. D., & Geschke, A. (2012). Frameworks for Comparing Emissions Associated with Production, Consumption, And International Trade. *Environmental Science & Technology*, 46(1), 172-179. <https://doi.org/10.1021/es202239t>
- Kee, H. L., & Nicita, A. (2022). Trade fraud and non-tariff measures. *Journal of International Economics*, 139, 103682. <https://doi.org/https://doi.org/10.1016/j.jinteco.2022.103682>
- Keefer, D. L., & Verdini, W. A. (1993). Better estimation of PERT activity time parameters. *Management science*, 39(9), 1086-1091.
- Larrain, M., Van Passel, S., Thomassen, G., Van Gorp, B., Nhu, T. T., Huysveld, S., Van Geem, K. M., De Meester, S., & Billen, P. (2021). Techno-economic assessment of mechanical recycling of challenging post-consumer plastic packaging waste. *Resources, Conservation and Recycling*, 170, 105607. <https://doi.org/https://doi.org/10.1016/j.resconrec.2021.105607>
- Lau, W. W. Y., Shiran, Y., Bailey, R. M., Cook, E., Stuchtey, M. R., Koskella, J., Velis, C. A., Godfrey, L., Boucher, J., Murphy, M. B., Thompson, R. C., Jankowska, E., Castillo Castillo, A., Pilditch, T. D., Dixon, B., Koerselman, L., Kosior, E., Favoino, E., Gutberlet, J., . . . Palardy, J. E. (2020). Evaluating scenarios toward zero plastic pollution. *Science*, 369(6510), 1455-1461. <https://doi.org/10.1126/science.aba9475>

- Le, T.-H., Le, A. T., & Le, H.-C. (2021). The historic oil price fluctuation during the Covid-19 pandemic: What are the causes? *Research in International Business and Finance*, 58, 101489. <https://doi.org/https://doi.org/10.1016/j.ribaf.2021.101489>
- Letcher, T. M. (2020). *Plastic Waste and Recycling: Environmental Impact, Societal issues, Prevention, and Solutions*. Academic Press.
- Li, K., Ward, H., Lin, H. X., & Tukker, A. Structural differences in recycling rates for imported and domestic plastic waste revealed. *Nature Communications*, in review.
- Li, K., Ward, H., Lin, H. X., & Tukker, A. (2024a). Economic viability requires higher recycling rates for imported plastic waste than expected. *Nature Communications*, 15(1), 7578. <https://doi.org/10.1038/s41467-024-51923-4>
- Li, K., Ward, H., Lin, H. X., & Tukker, A. (2024b). Traded Plastic, Traded Impacts? Designing Counterfactual Scenarios to Assess Environmental Impacts of Global Plastic Waste Trade. *Environmental Science & Technology*, 58(20), 8631-8642. <https://doi.org/10.1021/acs.est.4c02149>
- Lim, X. (2021). Microplastics are everywhere—but are they harmful. *Nature*, 593(7857), 22-25.
- Locke, R. M., Rissing, B. A., & Pal, T. (2013). Complements or Substitutes? Private Codes, State Regulation and the Enforcement of Labour Standards in Global Supply Chains. *British Journal of Industrial Relations*, 51(3), 519-552. <https://doi.org/https://doi.org/10.1111/bjir.12003>
- Lombardi, L., Carnevale, E., & Corti, A. (2015). A review of technologies and performances of thermal treatment systems for energy recovery from waste. *Waste Management*, 37, 26-44. <https://doi.org/https://doi.org/10.1016/j.wasman.2014.11.010>
- Mangold, H., & von Vacano, B. (2022). The frontier of plastics recycling: Rethinking waste as a resource for high-value applications. *Macromolecular Chemistry and Physics*, 223(13), 2100488. <https://doi.org/https://doi.org/10.1002/macp.202100488>
- Meijer, L. J. J., van Emmerik, T., van der Ent, R., Schmidt, C., & Lebreton, L. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. *Science Advances*, 7(18), eaaz5803. <https://doi.org/10.1126/sciadv.aaz5803>
- Ministry of the Environment (Japan). (2003). *The Asian Network for Prevention of Illegal Transboundary Movement of Hazardous Wastes*. https://www.env.go.jp/en/recycle/asian_net/#:~:text=%E2%80%9CThe%20Asian%20Network%20for%20Prevention,wastes%20and%20assisting%20countries%20in
- Mutel, C. (2017). Brightway: An open source framework for Life Cycle Assessment. *Journal of Open Source Software*, 2(12), 236. <https://doi.org/10.21105/joss.00236>
- Nava, V., Chandra, S., Aherne, J., Alfonso, M. B., Antão-Geraldes, A. M., Attermeyer, K., Bao, R., Bartrons, M., Berger, S. A., Biernaczyk, M., Bissen, R., Brookes, J. D., Brown, D., Cañedo-Argüelles, M., Canle, M., Capelli, C., Carballeira, R., Cereijo, J. L., Chawchai, S., . . . Leoni, B. (2023). Plastic debris in lakes and reservoirs. *Nature*, 619(7969), 317-322. <https://doi.org/10.1038/s41586-023-06168-4>
- Navarre, N., Barbarossa, V., Tukker, A., & Mogollón, J. (2023). The consequences of trade on global plastic pollution. *Research Square*. <https://doi.org/10.21203/rs.3.rs-3275353/v1>

- Navarre, N., Mogollón, J. M., Tukker, A., & Barbarossa, V. (2022). Recycled plastic packaging from the Dutch food sector pollutes Asian oceans. *Resources, Conservation and Recycling*, 185, 106508. <https://doi.org/10.1016/j.resconrec.2022.106508>
- Ng, C. H., Mistoh, M. A., Teo, S. H., Galassi, A., Ibrahim, A., Sipaut, C. S., Foo, J., Seay, J., Taufiq-Yap, Y. H., & Janaun, J. (2023). Plastic waste and microplastic issues in Southeast Asia [Review]. *Frontiers in Environmental Science*, 11. <https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2023.1142071>
- Nikiema, J., & Asiedu, Z. (2022). A review of the cost and effectiveness of solutions to address plastic pollution. *Environmental Science and Pollution Research*, 29(17), 24547-24573. <https://doi.org/10.1007/s11356-021-18038-5>
- OECD. (2021). *Decision of the Council on the Control of Transboundary Movements of Wastes Destined for Recovery Operations*. <https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0266>
- OECD. (2022a). *Global Plastics Outlook*. <https://read.oecd.org/10.1787/aa1edf33-en?format=pdf>
- OECD. (2022b). *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*. Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/environment/global-plastics-outlook_de747aef-en
- OECD. (2022c). *Global plastics outlook: economic drivers, environmental impacts and policy options*. O. Publishing. <https://www.oecd-ilibrary.org/deliver/de747aef-en.pdf?itemId=%2Fcontent%2Fpublication%2Fde747aef-en&mimeType=pdf>
- Our World in Data. (2022). *Ocean plastics: How much do rich countries contribute by shipping their waste overseas?* <https://ourworldindata.org/plastic-waste-trade>
- Pathak, G., Nichter, M., Hardon, A., Moyer, E., Latkar, A., Simbaya, J., Pakasi, D., Taqeban, E., & Love, J. (2023). Plastic pollution and the open burning of plastic wastes. *Global Environmental Change*, 80, 102648. <https://doi.org/10.1016/j.gloenvcha.2023.102648>
- Peng, Y., Wu, P., Schartrup, A. T., & Zhang, Y. (2021). Plastic waste release caused by COVID-19 and its fate in the global ocean. *Proceedings of the National Academy of Sciences*, 118(47), e2111530118. <https://doi.org/10.1073/pnas.2111530118>
- Peryman, M., Cumming, R., Ngata, T., Farrelly, T. A., Fuller, S., & Borrelle, S. B. (2024). Plastic pollution as waste colonialism in Aotearoa (New Zealand). *Marine Policy*, 163, 106078. <https://doi.org/10.1016/j.marpol.2024.106078>
- Plastic Europe. (2019). *The circular economy for plastics – a European overview*. <https://plasticseurope.org/fr/knowledge-hub/the-circular-economy-for-plastics-a-european-overview/>
- Plastics Europe. (2023). *Plastics – the Fast Facts 2023*. <https://plasticseurope.org/wp-content/uploads/2023/10/Plasticsthefastfacts2023-1.pdf>
- Ragaert, K., Delva, L., & Van Geem, K. (2017). Mechanical and chemical recycling of solid plastic waste. *Waste Management*, 69, 24-58. <https://doi.org/10.1016/j.wasman.2017.07.044>

- Rahimi, A., & García, J. M. (2017). Chemical recycling of waste plastics for new materials production. *Nature Reviews Chemistry*, 1(6), 0046. <https://doi.org/10.1038/s41570-017-0046>
- Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., Schmidt, W. P., Suh, S., Weidema, B. P., & Pennington, D. W. (2004). Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications. *Environment International*, 30(5), 701-720. <https://doi.org/https://doi.org/10.1016/j.envint.2003.11.005>
- Ren, Y., Shi, L., Bardow, A., Geyer, R., & Suh, S. (2020). Life-cycle environmental implications of China's ban on post-consumer plastics import. *Resources, Conservation and Recycling*, 156, 104699. <https://doi.org/10.1016/j.resconrec.2020.104699>
- Rosenboom, J.-G., Langer, R., & Traverso, G. (2022). Bioplastics for a circular economy. *Nature Reviews Materials*, 7(2), 117-137. <https://doi.org/10.1038/s41578-021-00407-8>
- Saltelli, A., Ratto, M., Tarantola, S., & Campolongo, F. (2005). Sensitivity Analysis for Chemical Models. *Chemical Reviews*, 105(7), 2811-2828. <https://doi.org/10.1021/cr040659d>
- Sarira, T. V., Zeng, Y., Neugarten, R., Chaplin-Kramer, R., & Koh, L. P. (2022). Co-benefits of forest carbon projects in Southeast Asia. *Nature Sustainability*, 5(5), 393-396. <https://doi.org/10.1038/s41893-022-00849-0>
- Schwarz, A. E., Ligthart, T. N., Godoi Bizarro, D., De Wild, P., Vreugdenhil, B., & van Harmelen, T. (2021). Plastic recycling in a circular economy; determining environmental performance through an LCA matrix model approach. *Waste Management*, 121, 331-342. <https://doi.org/https://doi.org/10.1016/j.wasman.2020.12.020>
- Sciarra, C., Chiarotti, G., Ridolfi, L., & Laio, F. (2020). Reconciling contrasting views on economic complexity. *Nature Communications*, 11(1), 3352. <https://doi.org/10.1038/s41467-020-16992-1>
- Shaar, K. (2019). *Reconciling international trade data*.
- Skelton, A. (2013). EU corporate action as a driver for global emissions abatement: A structural analysis of EU international supply chain carbon dioxide emissions. *Global Environmental Change*, 23(6), 1795-1806. <https://doi.org/https://doi.org/10.1016/j.gloenvcha.2013.07.024>
- Smith, E., Bilec, M. M., & Khanna, V. (2023). Evaluating the Global Plastic Waste Management System with Markov Chain Material Flow Analysis. *ACS Sustainable Chemistry & Engineering*, 11(6), 2055-2065. <https://doi.org/10.1021/acssuschemeng.2c04270>
- Stahel, W. R. (2019). *The Circular Economy: A User's Guide*. Routledge.
- Steubing, B., de Koning, D., Haas, A., & Mutel, C. L. (2020). The Activity Browser — An open source LCA software building on top of the brightway framework. *Software Impacts*, 3, 100012. <https://doi.org/10.1016/j.simpa.2019.100012>
- Stoett, P., Schrich, V. M., Elliff, C. I., Andrade, M. M., de M. Grilli, N., & Turra, A. (2024). Global plastic pollution, sustainable development, and plastic justice. *World Development*, 184, 106756. <https://doi.org/https://doi.org/10.1016/j.worlddev.2024.106756>
- Subramanian, M. (2022). Plastics tsunami: Can a landmark treaty stop waste from choking the oceans? *Nature*, 611(7937), 650-653.

- Sun, N., & Tabata, T. (2021). Environmental impact assessment of China's waste import ban policies: An empirical analysis of waste plastics importation from Japan. *Journal of Cleaner Production*, 329, 129606. <https://doi.org/10.1016/j.jclepro.2021.129606>
- Szkutnik, T. (2020). Identification of outliers in high density areas with the use of a quantile regression model. *Folia Oeconomica Stetinensia*, 20(2), 375-391.
- Tacconi, L., & Williams, D. A. (2020). Corruption and Anti-Corruption in Environmental and Resource Management. *Annual Review of Environment and Resources*, 45(Volume 45, 2020), 305-329. <https://doi.org/https://doi.org/10.1146/annurev-environ-012320-083949>
- The Global Initiative. (2021). *Plastic for profit: Tracing illicit plastic waste flows, supply chains and actors*. <https://globalinitiative.net/wp-content/uploads/2021/10/GITOC-Plastic-for-Profit.pdf>
- Tickler, D., Meeuwig, J. J., Bryant, K., David, F., Forrest, J. A. H., Gordon, E., Larsen, J. J., Oh, B., Pauly, D., Sumaila, U. R., & Zeller, D. (2018). Modern slavery and the race to fish. *Nature Communications*, 9(1), 4643. <https://doi.org/10.1038/s41467-018-07118-9>
- Timmer, M. P., Erumban, A. A., Los, B., Stehrer, R., & de Vries, G. J. (2014). Slicing up global value chains. *Journal of Economic Perspectives*, 28(2), 99-118. <https://doi.org/10.1257/jep.28.2.99>
- Tukker, A., de Koning, A., Wood, R., Moll, S., & Bouwmeester, M. C. (2013). Price Corrected Domestic Technology Assumption—A Method To Assess Pollution Embodied in Trade Using Primary Official Statistics Only. With a Case on CO2 Emissions Embodied in Imports to Europe. *Environmental Science & Technology*, 47(4), 1775-1783. <https://doi.org/10.1021/es303217f>
- Uekert, T., Singh, A., DesVeaux, J. S., Ghosh, T., Bhatt, A., Yadav, G., Afzal, S., Walzberg, J., Knauer, K. M., Nicholson, S. R., Beckham, G. T., & Carpenter, A. C. (2023). Technical, economic, and environmental comparison of closed-loop recycling technologies for common plastics. *ACS Sustainable Chemistry & Engineering*, 11(3), 965-978. <https://doi.org/10.1021/acssuschemeng.2c05497>
- UN Comtrade. (2019). *Methodology guide for UN Comtrade user on UN Comtrade upgrade 2019*. <https://uncomtrade.org/docs/home-page/>
- UN Comtrade. (2024). *UN Comtrade Database*. Retrieved 2023-11-12 from <https://comtradeplus.un.org/>
- United Nations Office on Drugs and Crime. (2024). *Turning the tide: A look into the European Union-to-Southeast Asia waste trafficking wave*. https://www.unodc.org/documents/bmb/environmental-crime/FINAL_for_printing_-_Turning_the_tide.pdf
- United Nations Statistics Division. (2023). *GUIDANCE NOTE v.3 Bilateral trade asymmetry (goods and services)*. https://unstats.un.org/wiki/download/attachments/201752670/GNV.3%20Bilateral%20asymmetries_SITS_IMTS_for_information_only.pdf?version=2&modificationDate=1707941904590&api=v2
- United States Environmental Protection Agency. (2020). *Advancing Sustainable Materials Management: 2018 Tables and Figures* (Advancing Sustainable Materials Management:

- Facts and Figures Report, Issue. https://www.epa.gov/sites/default/files/2021-01/documents/2018_tables_and_figures_dec_2020_fnl_508.pdf
- United States Environmental Protection Agency. (2021). *New International Requirements for the Export and Import of Plastic Recyclables and Waste*. <https://www.epa.gov/hwgenerators/new-international-requirements-export-and-import-plastic-recyclables-and-waste>
- United States Environmental Protection Agency. (2024). *Plastics: Material-Specific Data*. Retrieved 1st May 2024 from <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data>
- UNODC. (2022). *Combating Waste Trafficking: A Guide to Good Legislative Practices*. https://sherloc.unodc.org/cld/uploads/pdf/Combating_Waste_Trafficking_-_Guide_on_Good_Legislative_Practices_-_EN.pdf
- USDA National Agricultural Library. (2015). *LCA Commons*. <https://doi.org/10.15482/USDA.ADC/1173236>
- Verschuur, J., Koks, E. E., & Hall, J. W. (2022). Ports' criticality in international trade and global supply-chains. *Nature Communications*, 13(1), 4351. <https://doi.org/10.1038/s41467-022-32070-0>
- Vining, D. R., & Elwertowski, T. C. (1976). The Relationship between Relative Prices and the General Price Level. *The American Economic Review*, 66(4), 699-708. <http://www.jstor.org/stable/1806715>
- Wand, M. P., & Jones, M. C. (1994). *Kernel Smoothing*. CRC Press.
- Wang, C., Zhao, L., Lim, M. K., Chen, W.-Q., & Sutherland, J. W. (2020). Structure of the global plastic waste trade network and the impact of China's import Ban. *Resources, Conservation and Recycling*, 153, 104591. <https://doi.org/10.1016/j.resconrec.2019.104591>
- Wang, X.-T., Liu, H., Lv, Z.-F., Deng, F.-Y., Xu, H.-L., Qi, L.-J., Shi, M.-S., Zhao, J.-C., Zheng, S.-X., Man, H.-Y., & He, K.-B. (2021). Trade-linked shipping CO₂ emissions. *Nature Climate Change*, 11(11), 945-951. <https://doi.org/10.1038/s41558-021-01176-6>
- Wen, Z., Xie, Y., Chen, M., & Dinga, C. D. (2021). China's plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide. *Nature Communications*, 12(1), 425. <https://doi.org/10.1038/s41467-020-20741-9>
- Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, B. (2016). The ecoinvent database version 3 (part I): overview and methodology. *The International Journal of Life Cycle Assessment*, 21(9), 1218-1230. <https://doi.org/10.1007/s11367-016-1087-8>
- World Bank Group. (2021a). *Market Study for Malaysia: Plastics Circularity Opportunities and Barriers* (Marine Plastics Series, East Asia and Pacific Region, Issue. <https://documents1.worldbank.org/curated/en/272471616512761862/pdf/Market-Study-for-Malaysia-Plastics-Circularity-Opportunities-and-Barriers.pdf>
- World Bank Group. (2021b). *Market Study for Thailand: Plastics Circularity Opportunities and Barriers* (Marine Plastics Series, East Asia and Pacific Region, Issue.

- <https://documents1.worldbank.org/curated/en/973801612513854507/pdf/Market-Study-for-Thailand-Plastics-Circularity-Opportunities-and-Barriers.pdf>
- World Bank Group. (2022). *Plastic Waste Material Flow Analysis for Thailand – Summary Report* (Marine Plastics Series, East Asia and Pacific Region, Issue. <http://hdl.handle.net/10986/37182>
- World Customs Organization. (2002). *Chapter 39 Plastics and articles thereof*. <https://www.wcoomd.org/-/media/wco/public/global/pdf/topics/nomenclature/instruments-and-tools/hs-nomenclature-older-edition/2002/hs-2002/0739e.pdf>
- World Economic Forum. (2020). *Radically reducing plastic pollution in Indonesia: A multistakeholder action plan national plastic action partnership*. https://pacecircular.org/sites/default/files/2021-03/NPAP-Indonesia-Multistakeholder-Action-Plan_April-2020_compressed%20%281%29.pdf
- World Economic Forum. (2022). *Waste pickers risk their lives to stop plastic pollution—now they could help shape global recycling policies*. https://www.weforum.org/agenda/2022/12/waste-pickers-plastic-pollution-recycling-policies/?itid=lk_inline_enhanced-template
- Zhang, C., Zhao, X., Sacchi, R., & You, F. (2023). Trade-off between critical metal requirement and transportation decarbonization in automotive electrification. *Nature Communications*, 14(1), 1616. <https://doi.org/10.1038/s41467-023-37373-4>
- Zhang, Z., Jiang, Z., Chen, C., Zhang, X., Wang, H., Li, N., Wang, P., Zhang, C., Ma, F., Huang, Y., Qi, J., & Chen, W.-Q. (2022). Advancing UN Comtrade for physical trade flow analysis: Addressing the issue of missing values. *Resources, Conservation and Recycling*, 186, 106525. <https://doi.org/https://doi.org/10.1016/j.resconrec.2022.106525>
- Zhao, H., Chang, J., Havlík, P., van Dijk, M., Valin, H., Janssens, C., Ma, L., Bai, Z., Herrero, M., Smith, P., & Obersteiner, M. (2021). China's future food demand and its implications for trade and environment. *Nature Sustainability*, 4(12), 1042-1051. <https://doi.org/10.1038/s41893-021-00784-6>
- Zou, H., Wang, T., Wang, Z.-L., & Wang, Z. (2023). Continuing large-scale global trade and illegal trade of highly hazardous chemicals. *Nature Sustainability*, 6(11), 1394-1405. <https://doi.org/10.1038/s41893-023-01158-w>

Curriculum vitae

Kai Li was born on November 29th, 1994, in Handan, Hebei, China. He attended Handan No. 1 High School and later transferred to Tianjin No. 47 High School, where he graduated in 2013. That same year, he was admitted to Wuhan University of Technology and majored in Construction Management, inspired by China's promising real estate markets.

In 2017, he earned an opportunity to pursue a master's degree in Management Science and Engineering at Chongqing University. During the summer of that year, he completed a two-month internship as an on-site construction engineer at Country Garden. This practical but tough experience made him realise that his true passion lay in academia. He became motivated after publishing work on urban economics and sustainability in collaboration with Prof. Zhili Ma and Dr. Minda Ma.

At the end of 2019, while seeking PhD opportunities overseas with an initial focus on urban economics, Dr. Mingming Hu, who was working part-time with Chongqing University, introduced him to Prof. Arnold Tukker during his visit to the university. In an informal discussion, Kai brought up Dr. Hauke Ward, whose research combines economic analysis with broad environmental science. This talk paved the way for Kai to begin his PhD journey on February 15, 2021, under the supervision of Dr. Hauke Ward, Prof. Haixiang Lin, and Prof. Arnold Tukker. His research later shifted its focus to the global trade of plastic waste, a topic he found both nice and intriguing.

List of publications

Li, K.; Ward, H.; Lin, H. X.; Tukker, A. Economic viability requires higher recycling rates for imported plastic waste than expected. *Nature Communications* **2024**, *15* (1), 7578. DOI: 10.1038/s41467-024-51923-4.

Li, K.; Ward, H.; Lin, H. X.; Tukker, A. Traded Plastic, Traded Impacts? Designing Counterfactual Scenarios to Assess Environmental Impacts of Global Plastic Waste Trade. *Environmental Science & Technology* **2024**, *58* (20), 8631-8642. DOI: 10.1021/acs.est.4c02149.

Li, K.; Ma, M.; Xiang, X.; Feng, W.; Ma, Z.; Cai, W.; Ma, X. Carbon reduction in commercial building operations: A provincial retrospection in China. *Applied Energy* **2022**, *306*, 118098. DOI: 10.1016/j.apenergy.2021.118098.

Acknowledgments

I sincerely thank the reading committee members: Prof. dr. ing. M.G. Vijver, Prof. dr. ir. J.B. Guinée, Prof. dr. ing. K.J.P. Ragaert, Prof. dr. E. Worrell, and Dr. J.M. Mogollón for their valuable time in reviewing this thesis.

I owe my deepest gratitude to Prof. Arnold Tukker, whose visit to Chongqing University in 2019 unexpectedly paved my way to Leiden University in 2021. I will never forget how you decisively opposed the idea of using a country's average recycling rate, which sparked our journey to develop a new method for measuring the recycling rate of traded plastic waste. Your leadership brought our team of four together.

Dr. Hauke Ward, you have been a wise, thoughtful, and inspiring mentor throughout this journey. Our discussions were often filled with creative ideas, and your support encouraged me to explore a new research area. Beyond academics, you have also shown me what it means to be a great husband and father, teaching me valuable life lessons.

I sincerely thank Prof. Haixiang Lin (林海翔) for guiding me through the mathematical challenges. Your clear explanations of probability and statistics, along with the carefully derived formulas you shared, were incredibly helpful. From your revisions, I learned the importance of being precise and thorough in mathematical work.

To my parents, Lifeng Jia (贾立峰) and Chunxi Li (李春喜), thank you for always listening to my endless research stories, starting from my master's in Chongqing. You have earned honorary 'PhDs' in our family for your lasting support and patience. I look forward to listening to your "tedious" stories for the rest of my life.

A special thanks to Yanan Liang (梁亚楠). Your support has helped me navigate all the ups and downs over the years. You have always been eager to discuss scientific problems with me, and your insights have inspired me greatly.

I am also deeply grateful to my mentors and friends at CML. Thank you, Mingming (胡鸣明) and Sammy, for introducing me to this institute. My appreciation goes to Ranran (王冉冉) and Arjan for generously offering learning opportunities in their environmentally input-output courses. I greatly appreciate the chance to present my research at conferences generously supported by René Kleijn. To Suiting Ding (丁穗庭), Shijie Wei (魏世杰), and Pengxuan Xie (谢朋轩), your friendship has brought me so much joy. To Sander, Brenda, and Maarten,

it has been a pleasure to work with you at CML. To Nicolas Navarre, both your work and thesis set good examples for me. To my fellow alumni from Chongqing University: Chunbo Zhang (张纯博), Xining Yang (杨希宁), and Xiaoyang Zhong (钟晓阳), I am fortunate to have met and learned from you. To Keyong Deng (邓克勇) and Shuaiqun Pan (潘帅群), thank you for the memorable tennis moments. Xiao Li (李骁), our unbelievable reunion at CML as fellow Handan citizens was a true delight.

Finally, I would like to thank all my colleagues in CML. I am grateful for the four years working with you and look forward to seeing how the institute will continue to thrive in the future.