Online-Appendix zu

„How Sustainable Is Private Equity? Unlocking the Impact of Private Equity on Asset-Level Sustainability: An Empirical Investigation“

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Appendix A

In the following the codes used for the matching are given. The appendix first gives the code used for the propensity score matching and then proceeds with the code that was developed for the blocking and matching method.

1. Propensity Score Matching

The code was adapted from Kline and Luo (2022). First the relevant libraries are imported:

```
from psmpy import PsmPy
from psmpy.functions import cohenD
from psmpy.plotting import *
import pandas as pd
```

Then the categorical variables location on the US state level (`8. ST`) and industry sector (`20. INDUSTRY SECTOR`) are converted to binary dummy variables via one-hot encoding. Subsequently erroneous values in the data of interest (the dependent variables; for the amount of total releases the dependent variable is labelled as `99. DIFF_TR` and for the amount of production waste the dependent variable is labelled as `99. DIFF_PW`) are removed from the data set and the data is split into two tables, one for the data on total releases (`df_tr`) and one for the data on production waste (`df_pw`).

```
# Get list of categorical columns
cat_cols = ['8. ST', '20. INDUSTRY SECTOR']

# Convert categorical columns to dummy variables
df_dummies = pd.get_dummies(df[cat_cols], prefix=cat_cols)

# Concatenate numeric and dummy variable dataframes
df_pr = pd.concat([df.select_dtypes(include='number'), df_dummies], axis=1)

# Drop rows with missing values in '99. DIFF_PW' and '99. DIFF_TR'
df_pw = df_pr[df_pr['99. DIFF_PW'].notna()].copy().reset_index(drop=True)
df_tr = df_pr[df_pr['99. DIFF_TR'].notna()].copy().reset_index(drop=True)
```

The control variables were defined as explained in chapter 3.3.1 and according to the code parameters set by Kline and Luo (2022), the respective datafields are deemed to be excluded from the set of matching variables.

```
columns_to_exclude = ['104. TOTAL RELEASES',
                      '116. PRODUCTION WSTE (8.1-8.7)corr', '119. 8.9 -
PRODUCTION RATIO_adj',
                      '99. DIFF_PW', '99. DIFF_TR']
```

Finally, the propensity score matching is executed for the total releases data and the production waste data individually. The cases were handled based on a unique ID number (`2. TRIFD_Numeric`). The dummy variable PE (`IN_DEAL`) was used to distinguish between observations involved in private equity transactions and those not involved in such

transactions. For convenience during writing the code print statements had been added to check for correct operation.

```
psm_pw = PsmPy(df_pw, treatment='IN_DEAL', indx='2. TRIFD_Numeric',
exclude=columns_to_exclude)
psm_tr = PsmPy(df_tr, treatment='IN_DEAL', indx='2. TRIFD_Numeric',
exclude=columns_to_exclude)
print("Initialized PSM Class")

psm_pw.logistic_ps(balance=True)
psm_tr.logistic_ps(balance=True)
print("Predicted Scores")

psm_pw.knn_matched(matcher='propensity_logit', replacement=False,
caliper=None, drop_unmatched=True)
psm_tr.knn_matched(matcher='propensity_logit', replacement=False,
caliper=None, drop_unmatched=True)
print("Performed matching")
```

Similar to the literature approach, plots were generated to check the result of the matching.

```
sns.set(rc={'figure.figsize': (10, 8)}, font_scale=1)
plt.figure()
psm_pw.plot_match(Title='Production Waste', Ylabel='Facility count',
Xlabel='Propensity logit', names=['treatment', 'control'],
colors=['#4B778D', '#A52A2A'], save=False)
plt.savefig('pw_match.png', bbox_inches='tight')

plt.figure()
psm_tr.plot_match(Title='Total Releases', Ylabel='Facility count',
Xlabel='Propensity logit', names=['treatment', 'control'],
colors=['#4B778D', '#A52A2A'], save=False)
plt.savefig('tr_match.png', bbox_inches='tight')

plt.figure()
psm_pw.effect_size_plot(title='Standardized Mean differences accross
covariates before and after matching: Production Waste',
before_color='#E0A471', after_color='#93B1B8', save=False)
plt.savefig('pw_effect.png', bbox_inches='tight')

plt.figure()
psm_tr.effect_size_plot(title='Standardized Mean differences accross
covariates before and after matching: Total Releases',
before_color='#E0A471', after_color='#93B1B8', save=False)
plt.savefig('tr_effect.png', bbox_inches='tight')
```

Finally, the one-hot encoding was reversed and the data was exported to excel.

```
# Drop the dummy columns from the matched dataframes
dummy_columns = [col for col in df_dummies.columns if col in
psm_pw.df_matched.columns]
psm_pw.df_matched.drop(columns=dummy_columns, inplace=True)
psm_tr.df_matched.drop(columns=dummy_columns, inplace=True)

psm_pw.df_matched.to_excel('PW_matched_data.xlsx', index=False)
psm_tr.df_matched.to_excel('TR_matched_data.xlsx', index=False)

# merge with original dataframes
df_pw_1 = pd.merge(df, psm_pw.df_matched[['2. TRIFD_Numeric',
'propensity_score', 'propensity_logit', 'matched_ID']], on='2.
TRIFD_Numeric')
```

```
df_tr_1 = pd.merge(df, psm_tr.df_matched[['2. TRIFD_Numeric',
'propensity_score', 'propensity_logit', 'matched_ID']], on='2.
TRIFD_Numeric')
df_pw_full = pd.merge(df, df_pw_1, left_on='2. TRIFD_Numeric',
right_on='matched_ID')
df_tr_full = pd.merge(df, df_tr_1, left_on='2. TRIFD_Numeric',
right_on='matched_ID')

# Save full dataframes to Excel
df_pw_full.to_excel('PW_full_data.xlsx', index=False)
df_tr_full.to_excel('TR_full_data.xlsx', index=False)
```

2. Blocking and Matching

The Blocking and Matching approach developed in this thesis relied on common knowledge and on the function given by Petrou (2017). First the relevant libraries are imported:

```
import os
from concurrent.futures import ThreadPoolExecutor
import pandas as pd
```

Then the function to create blocks based on control variables year (`1. YEAR`), hazard (`42. HAZARD`), industry sector (`20. INDUSTRY SECTOR`) and location on the US state level (`8. ST`) and to match within each block based on closest amount of production waste (`116. PRODUCTION WSTE (8.1-8.7)corr`) is defined. For the latter, the default "backward" search of the `pandas.merge_asof` is used which selects the last row in the right DataFrame whose 'on' key is less than or equal to the left's key.

```
# Matching process with identifier propagation
def process_data(year, hazard, state, industry, df):
    df_year = df[(df['1. YEAR'] == year) & (df['42. HAZARD'] == hazard) &
(df['8. ST'] == state) & (
                df['20. INDUSTRY SECTOR'] == industry)]
    df_treatment_year = df_year[df_year['IN_DEAL'] == 1]
    df_control_year = df_year[df_year['IN_DEAL'] == 0]

    # Sort both treatment and control dataframes based on the "116.
PRODUCTION WSTE (8.1-8.7)corr" column
    df_treatment_year = df_treatment_year.sort_values("116. PRODUCTION WSTE
(8.1-8.7)corr")
    df_control_year = df_control_year.sort_values("116. PRODUCTION WSTE
(8.1-8.7)corr")

    # Find the closest matches in the control group for each treatment
group row
    df_matched = pd.merge_asof(df_treatment_year, df_control_year, on="116.
PRODUCTION WSTE (8.1-8.7)corr", direction='nearest',
suffixes=('_treatment', '_control'))

    return df_matched
```

Then the function to process a single combination of parameters was defined. To enhance the code in terms of reduced computing time, the `ThreadPoolExecutor` subclass according to Python Software Foundation (2023) is implemented to execute calls asynchronously.

```
# Create a function to process a single combination of parameters
def process_single_combination(params):
    year, hazard, state, industry = params
    return process_data(year, hazard, state, industry, df)


with ThreadPoolExecutor() as executor:
    # Create a list of parameter combinations
    params = [(year, hazard, state, industry) for year in years for hazard
in hazards for state in states for industry
              in industries]

    # Call process_single_combination for each combination of parameters
using ThreadPoolExecutor
    results = list(executor.map(process_single_combination, params))

    for i, result in enumerate(results):
        result['index'] = i
```

The residual part of the code for cleaning the data, creating list of categories for categorical blocking control variables and for storing the results is executed as follows. The matched file is exported to excel for further analysis.

```
# Drop rows with missing values in '99. DIFF_PW' , '99. DIFF_TR'
df.dropna(subset=['99. DIFF_PW'], inplace=True)
# Replace all missing values or NaN values in the "99. DIFF_TR" column with
0
df['99. DIFF_TR'] = df['99. DIFF_TR'].fillna(0)

df_treatment = df[df['IN_DEAL'] == 1]
df_control = df[df['IN_DEAL'] == 0]

df_treatment = df_treatment.reset_index(drop=True)
df_control = df_control.reset_index(drop=True)

years = sorted(df['1. YEAR'].unique())
hazards = [1, 2, 3, 4]
states = sorted(df['8. ST'].unique())
industries = sorted(df['20. INDUSTRY SECTOR'].unique())

results = []
# Concatenate the results based on the 'index' column
df_balanced = pd.concat(results, axis=0, ignore_index=True, sort=False)

print("Balancing 1 completed")
df_balanced.to_excel('Df Balanced +PW corr.xlsx', index=False)
```

Appendix B

The following table contains a complete list of all the NAICS codes that are covered by the TRI program, by their corresponding SIC codes.

Taken from U.S.C. 40 § 372.23 SIC and NAICS codes to which this Part applies [71 FR 32474, June 6, 2006, as amended at 73 FR 32470, June 9, 2008; 78 FR 42882, July 18, 2013; 82 FR 60909, Dec. 26, 2017; 86 FR 66964, Nov. 24, 2021; 87 FR 72896, Nov. 28, 2022]

Major group or industry code	Exceptions and/or limitations
NAICS codes that correspond to SIC codes 20-39.	
311 - Food Manufacturing	Except 311119 - Exception is limited to facilities previously classified under SIC 0723, Crop Preparation Services for Market, Except Cotton Ginning. Except 311340 - Exception is limited to facilities previously classified under SIC 5441, Candy, Nut, and Confectionery Stores. Except 311352 - Exception is limited to facilities previously classified under SIC 5441, Candy, Nut, and Confectionery Stores. Except 311611 - Exception is limited to facilities previously classified under SIC 0751, Livestock Services, Except Veterinary. Except 311612 - Exception is limited to facilities previously classified under SIC 5147, Meats and Meat Products. Except 311811 - Exception is limited to facilities previously classified under SIC 5461, Retail Bakeries.
312 - Beverage and Tobacco Product Manufacturing	Except 312112 - Exception is limited to facilities previously classified under SIC 5149, Groceries and Related Products, Not Elsewhere Classified. Except 312230 - Exception is limited to facilities previously classified under SIC 7389, Business Services, Not Elsewhere Classified, except facilities primarily engaged in solvent recovery services on a contract or fee basis.
313 - Textile Mills	Except 313310 - Exception is limited to facilities previously classified under SIC 5131, Piece Goods, Notions, and Other Dry Goods; and facilities previously classified under SIC 7389, Business Services, Not Elsewhere Classified, except facilities primarily engaged in solvent recovery services on a contract or fee basis.
314 - Textile Product Mills	Except 314120 - Exception is limited to facilities previously classified under SIC 5714, Drapery, Curtain, and Upholstery Stores. Except 314999 - Exception is limited to facilities previously classified under SIC 7389, Business Services, Not Elsewhere Classified, except facilities primarily engaged in solvent recovery services on a contract or fee basis.
315 - Apparel Manufacturing	Except 315290 - Exception is limited to facilities previously classified under SIC 5699, Miscellaneous Apparel and Accessory Stores.
316 - Leather and Allied Product Manufacturing	
321 - Wood Product Manufacturing	
322 - Paper Manufacturing	
323 - Printing and Related Support Activities	Except 323111 - Exception is limited to facilities previously classified under SIC 7334, Photocopying and Duplicating Services.
324 - Petroleum and Coal Products Manufacturing	
325 - Chemical Manufacturing	Except 325998 - Exception is limited to facilities previously classified under SIC 7389, Business Services, Not Elsewhere Classified.
326 - Plastics and Rubber Products Manufacturing	Except 326212 - Exception is limited to facilities previously classified under SIC 7534, Tire Retreading and Repair Shops.
327 - Nonmetallic Mineral Product Manufacturing	Except 327110 - Exception is limited to facilities previously classified under SIC 5719, Miscellaneous Home Furnishings Stores.
331 - Primary Metal Manufacturing	
332 - Fabricated Metal Product Manufacturing	
333 - Machinery Manufacturing	

Major group or industry code	Exceptions and/or limitations
334 - Computer and Electronic Product Manufacturing	Except 334610 - Exception is limited to facilities previously classified under SIC 7372, Prepackaged Software; and to facilities previously classified under SIC 7819, Services Allied to Motion Picture Production.
335 - Electrical Equipment, Appliance, and Component Manufacturing	Except 335312 - Exception is limited to facilities previously classified under SIC 7694, Armature Rewinding Shops.
336 - Transportation Equipment Manufacturing	
337 - Furniture and Related Product Manufacturing	Except 337110 - Exception is limited to facilities previously classified under SIC 5712, Furniture Stores. Except 337121 - Exception is limited to facilities previously classified under SIC 5712, Furniture Stores. Except 337122 - Exception is limited to facilities previously classified under SIC 5712, Furniture Stores.
339 - Miscellaneous Manufacturing	Except 339113 - Exception is limited to facilities previously classified under SIC 5999, Miscellaneous Retail Stores, Not Elsewhere Classified. Except 339115 - Exception is limited to lens grinding facilities previously classified under SIC 5995, Optical Goods Stores. Except 339116 - Exception is limited to facilities previously classified under SIC 8072, Dental Laboratories.
111998 - All Other Miscellaneous Crop Farming	Limited to facilities previously classified under SIC 2099, Food Preparations, Not Elsewhere Classified.
113310 - Logging	
211130 - Natural Gas Extraction	Limited to facilities that recover sulfur from natural gas and previously classified under SIC 2819, Industrial Inorganic Chemicals, Not Elsewhere Classified.
212323 - Kaolin, Clay, and Ceramic and Refractory Minerals Mining	Limited to facilities operating without a mine or quarry and previously classified under SIC 3295, Minerals and Earths, Ground or Otherwise Treated.
212390 - Other Nonmetallic Mineral Mining and Quarrying	Limited to facilities previously classified under SIC 3295, Minerals and Earths, Ground or Otherwise Treated.
488390 - Other Support Activities for Water Transportation	Limited to facilities previously classified under SIC 3731, Shipbuilding and Repairing.
512230 - Music Publishers	Except facilities previously classified under SIC 8999, Services, Not Elsewhere Classified.
512250 - Record Production and Distribution	Limited to facilities previously classified under SIC 3652, Phonograph Records and Prerecorded Audio Tapes and Disks.
5131 - Newspaper, Periodical, Book, and Directory Publishers	Except for facilities primarily engaged in web search portals and except for facilities previously classified under SIC 7331, Direct Mail Advertising Services and SIC 8999, Services Not Elsewhere Classified.
516210 - Media Streaming Distribution Services, Social Networks, and Other Media Networks and Content Providers	Limited to Internet publishing facilities previously classified under SIC 2711, Newspapers: Publishing, or Publishing and Printing; facilities previously classified under SIC 2721, Periodicals: Publishing, or Publishing and Printing; facilities previously classified under SIC 2731, Books: Publishing, or Publishing and Printing; facilities previously classified under SIC 2741, Miscellaneous Publishing; facilities previously classified under SIC 2771, Greeting Cards; Except for facilities primarily engaged in web search portals.
519290 - Web Search Portals and All Other Information Services	Limited to Internet publishing facilities previously classified under SIC 2711, Newspapers: Publishing, or Publishing and Printing; facilities previously classified under SIC 2721, Periodicals: Publishing, or Publishing and Printing; facilities previously classified under SIC 2731, Books: Publishing, or Publishing and Printing; facilities previously classified under SIC 2741, Miscellaneous Publishing; facilities previously classified under SIC 2771, Greeting Cards; Except for facilities primarily engaged in web search portals.
541713 - Research and Development in Nanotechnology	Limited to facilities previously classified under SIC 3764, Guided Missile and Space Vehicle Propulsion Units and Propulsion Unit Parts; and facilities previously classified under SIC 3769, Guided Missile and Space Vehicle Parts and Auxiliary Equipment, Not Elsewhere Classified.

Major group or industry code	Exceptions and/or limitations
541715 - Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)	Limited to facilities previously classified under SIC 3764, Guided Missile and Space Vehicle Propulsion Units and Propulsion Unit Parts; and facilities previously classified under SIC 3769, Guided Missile and Space Vehicle Parts and Auxiliary Equipment, Not Elsewhere Classified.
811490 - Other Personal and Household Goods Repair and Maintenance	Limited to facilities previously classified under SIC 3732, Boat Building and Repairing.

NAICS codes that correspond to SIC codes other than SIC codes 20-39.

211130 - Natural Gas Extraction	Limited to facilities classified under SIC 1321, Natural Gas Liquids.
212114 - Surface Coal Mining	
212115 - Underground Coal Mining	
212220 - Gold Ore and Silver Ore Mining	
212230 - Copper, Nickel, Lead and Zinc Mining	
212290 - Other Metal Ore Mining	Limited to facilities previously classified under SIC 1061, Ferroalloy Ores, Except Vanadium (nickel); and facilities previously classified under SIC 1099, Miscellaneous Metal Ores, Not Elsewhere Classified.
221111 - Hydroelectric Power Generation	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221112 - Fossil Fuel Electric Power Generation	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221113 - Nuclear Electric Power Generation	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221114 - Solar Electric Power Generation	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221115 - Wind Electric Power Generation	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221116 - Geothermal Electric Power Generation	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221117 - Biomass Electric Power Generation	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221118 - Other Electric Power Generation	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221121 - Electric Bulk Power Transmission and Control	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221122 - Electric Power Distribution	Limited to facilities that combust coal and/or oil for the purpose of generating power for distribution in commerce.
221210 - Natural Gas Distribution	Limited to facilities previously classified under SIC 4931, Electric and Other Services Combined and facilities previously classified under SIC 4939, Combination Utilities, Not Elsewhere Classified.
221330 - Steam and Air Conditioning Supply	Limited to facilities previously classified under SIC 4939, Combination Utilities, Not Elsewhere Classified.
424690 - Other Chemical and Allied Products Merchant Wholesalers	
424710 - Petroleum Bulk Stations and Terminals	
425120 - Wholesale Trade Agents and Brokers	Limited to facilities previously classified in SIC 5169, Chemicals and Allied Products, Not Elsewhere Classified.
562112 - Hazardous Waste Collection	Limited to facilities primarily engaged in solvent recovery services on a contract or fee basis and previously classified under SIC 7389, Business Services, Not Elsewhere Classified;
562211 - Hazardous Waste Treatment and Disposal	Limited to facilities regulated under the Resource Conservation and Recovery Act, subtitle C, 42 U.S.C. 6921 et seq.
562212 - Solid Waste Landfill	Limited to facilities regulated under the Resource Conservation and Recovery Act, subtitle C, 42 U.S.C. 6921 et seq.

Major group or industry code	Exceptions and/or limitations
562213 - Solid Waste Combustors and Incinerators	Limited to facilities regulated under the Resource Conservation and Recovery Act, subtitle C, 42 U.S.C. 6921 et seq.
562219 - Other Nonhazardous Waste Treatment and Disposal	Limited to facilities regulated under the Resource Conservation and Recovery Act, subtitle C, 42 U.S.C. 6921 et seq.
562920 - Materials Recovery Facilities	Limited to facilities regulated under the Resource Conservation and Recovery Act, subtitle C, 42 U.S.C. 6921 et seq.

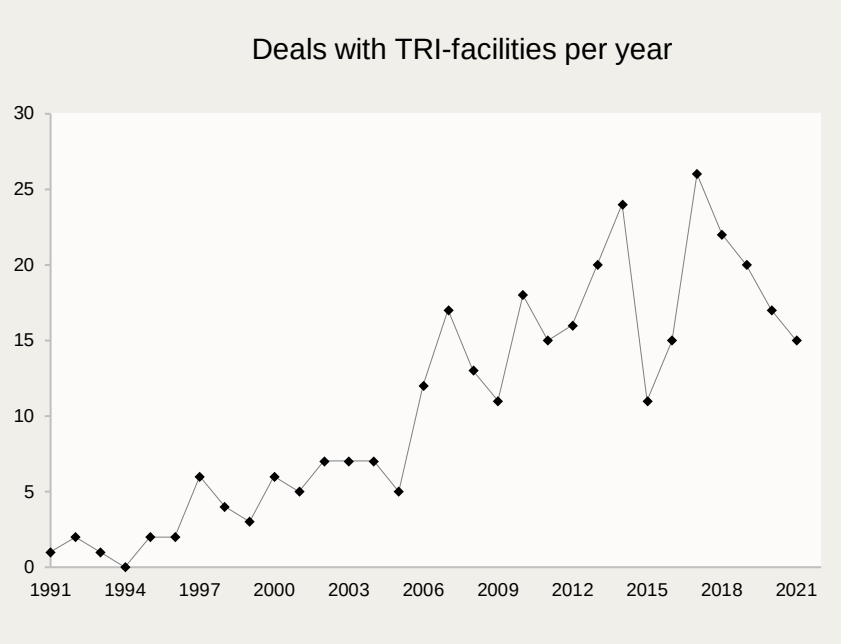
APPENDIX C

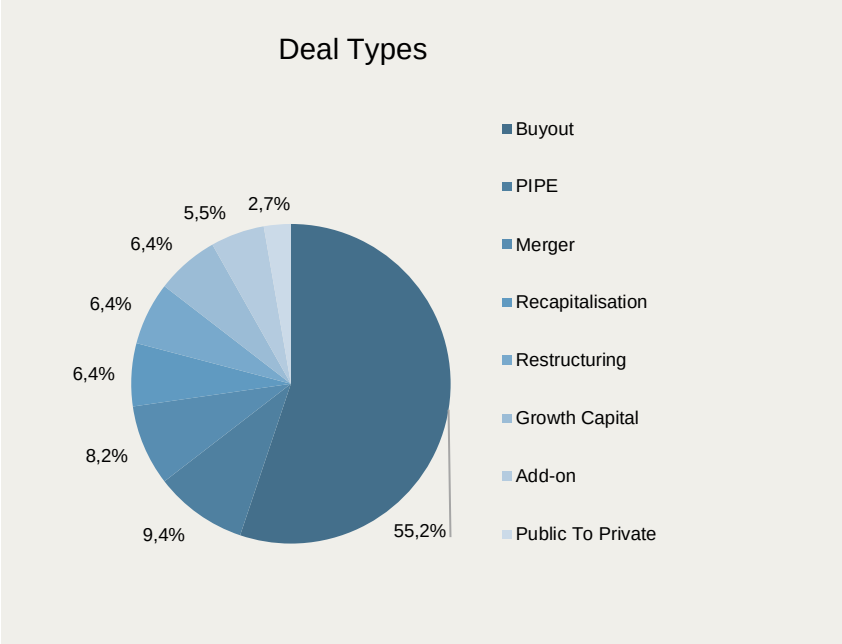
How sustainable is private equity?

Supporting information

DEAL STATISTICS

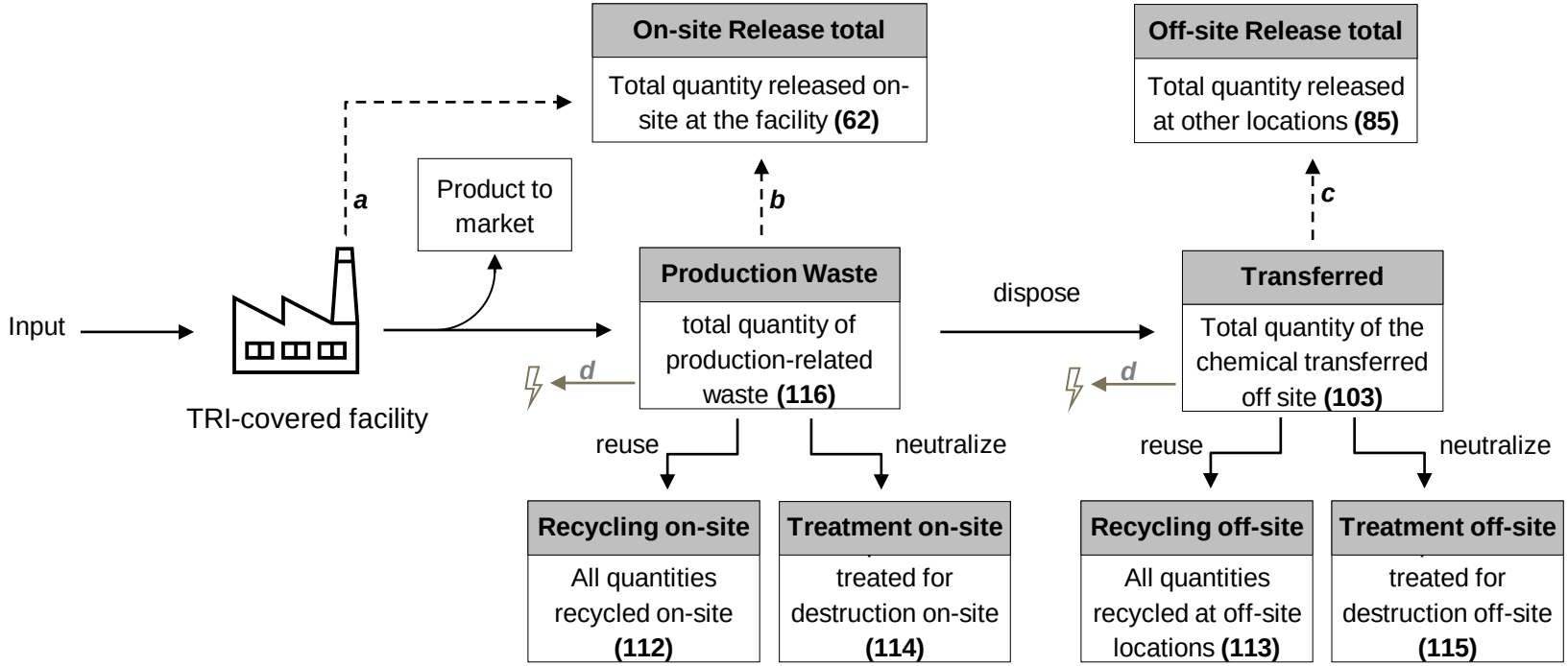
Preqin Data:





DATA ROOM

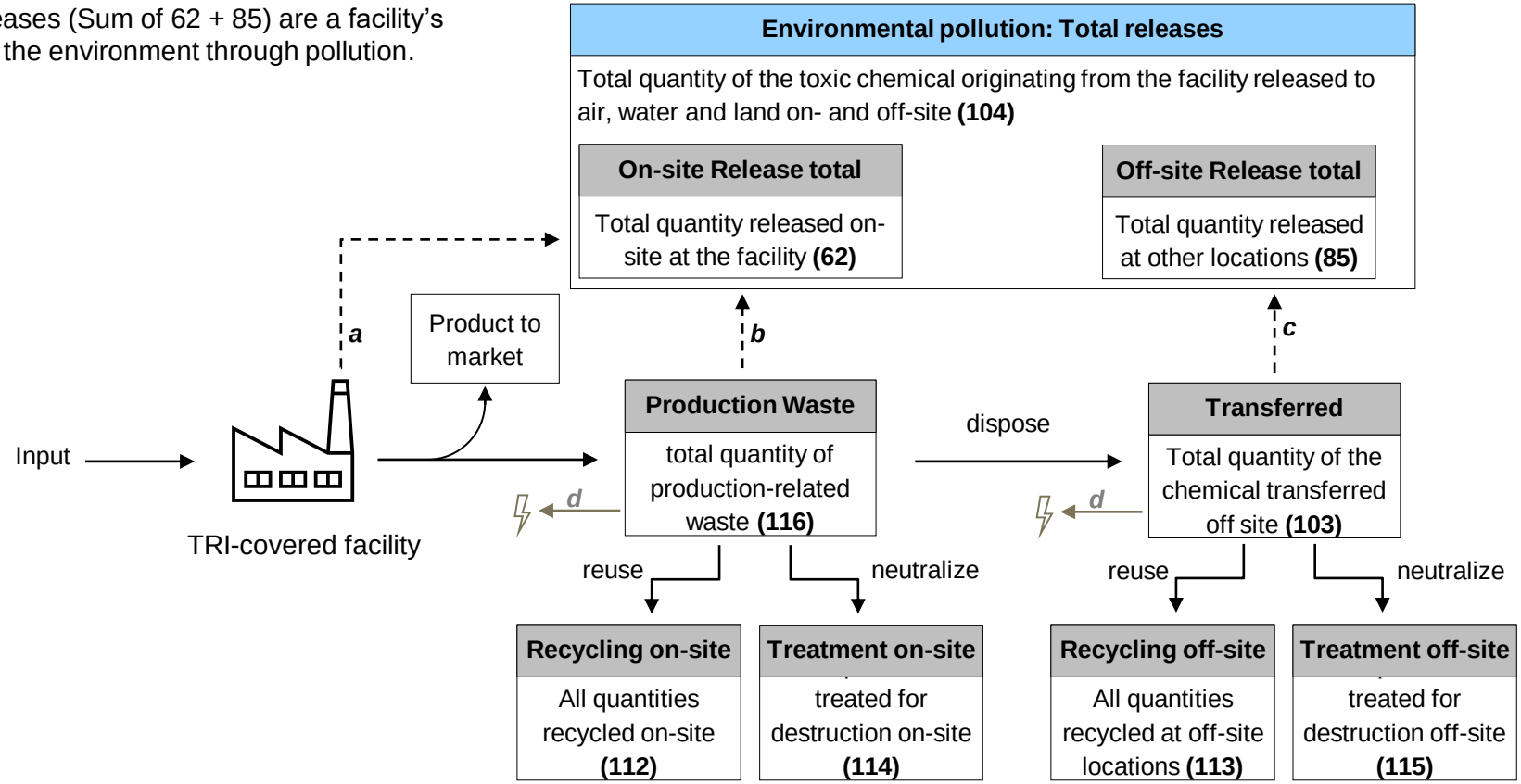
Summarized version of the TRI-data notation as the information a facility has to report for any section-313 EPCRA chemical. Numbers in brackets represent data field numbers in the TRI basic datafile. Dashed errors denote releases to the environment, solid arrows denote transport processes.



a; e.g., fugitive or stack air, *b*; e.g., dust or leaching to groundwater while storing; additionally for *c*; e.g., loss during transportation, *d*; utilization of substance for energy production (downcycling, thermal or other). Also, for *a, b, c*: loss of containment as one-time release also covered by the TRI under No. 117

DATA ROOM

Total Releases (Sum of 62 + 85) are a facility's impact on the environment through pollution.



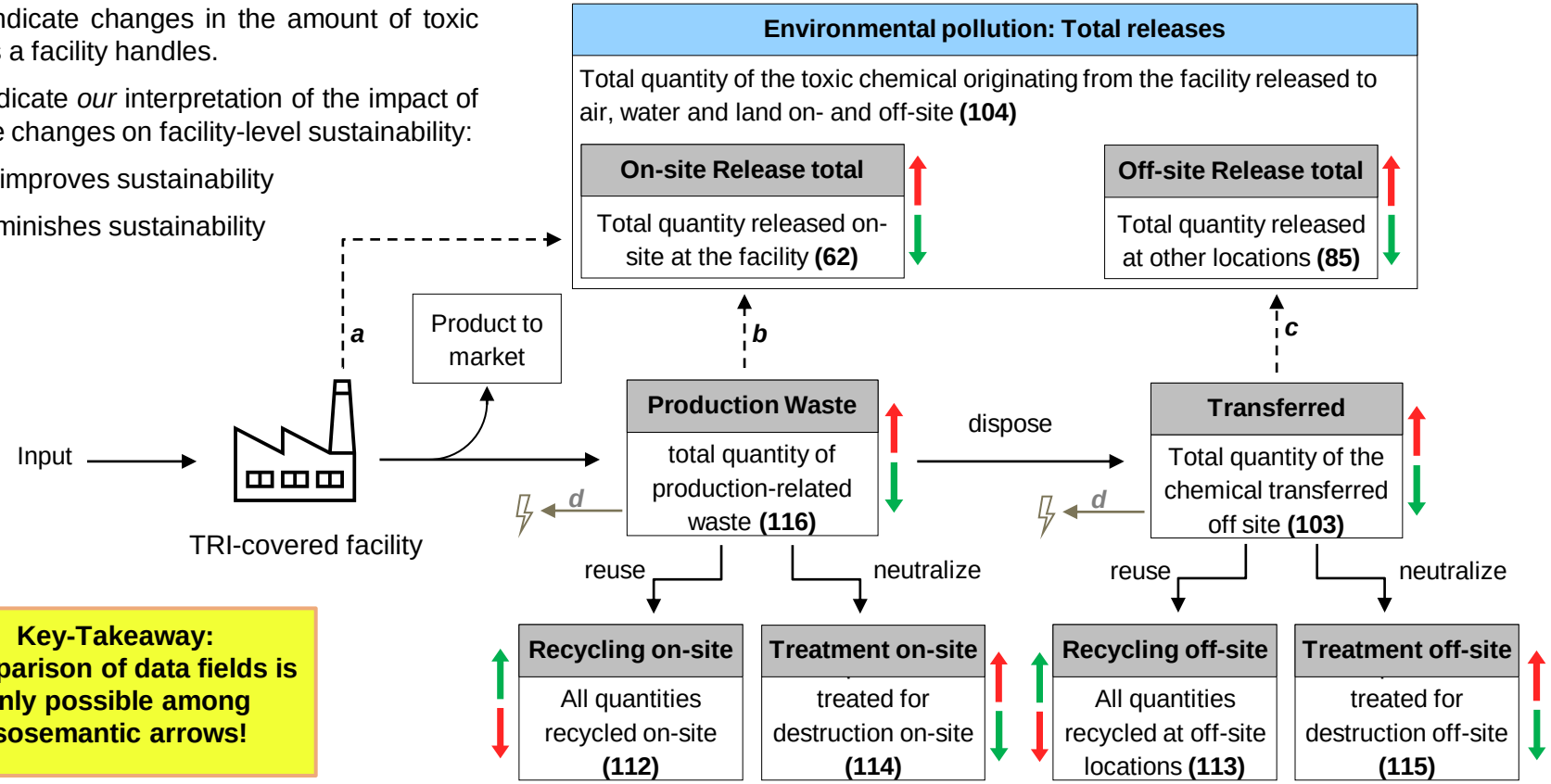
a; e.g., fugitive or stack air, *b*; e.g., dust or leaching to groundwater while storing; additionally for *c*; e.g., loss during transportation, *d*; utilization of substance for energy production (downcycling, thermal or other).
Also, for *a, b, c*: loss of containment as one-time release also covered by the TRI under No. 117

ESG-INDICATORS

Arrows indicate changes in the amount of toxic chemicals a facility handles.

Colors indicate *our* interpretation of the impact of respective changes on facility-level sustainability:

- **Green** improves sustainability
- **Red** diminishes sustainability

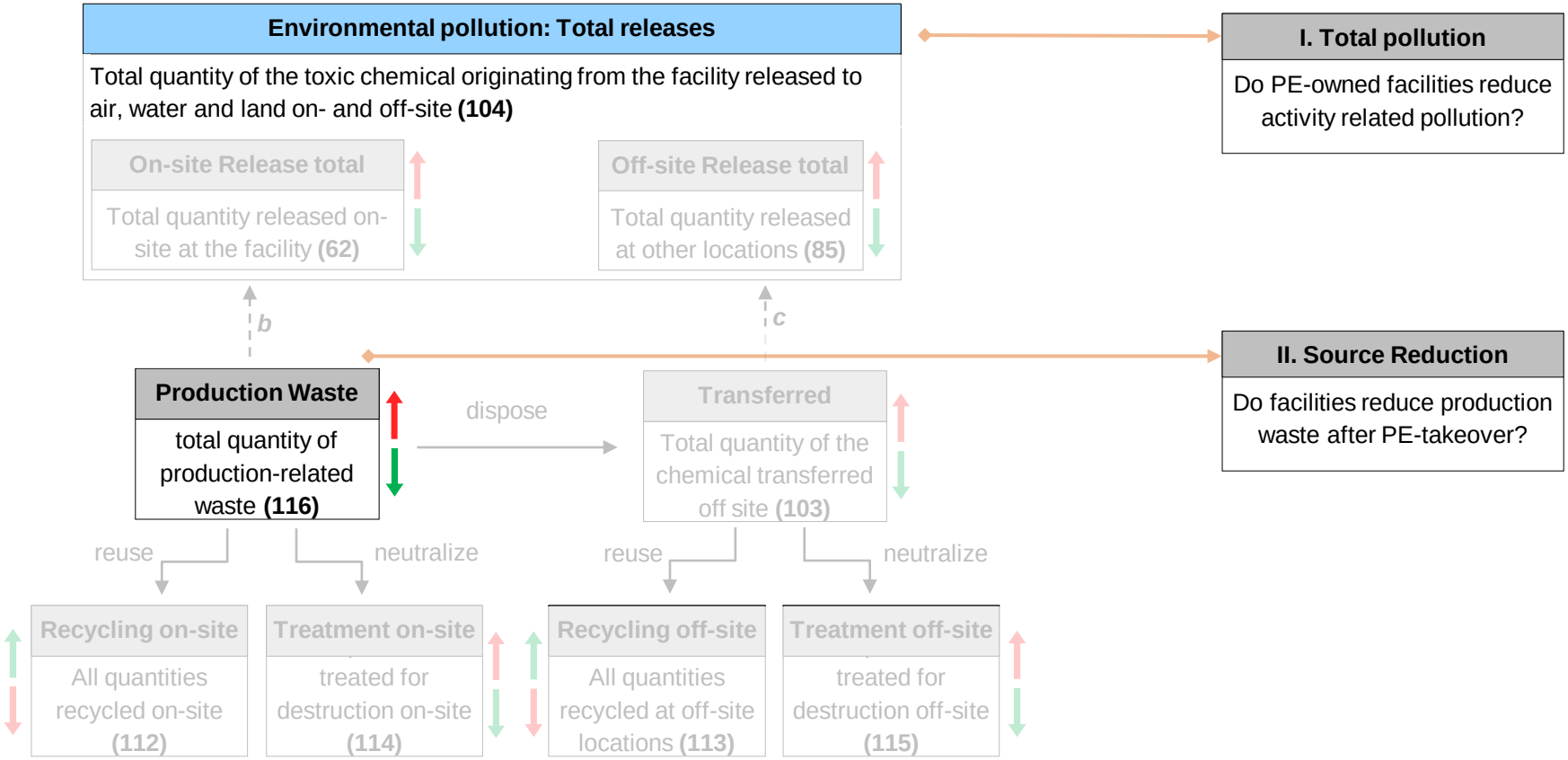


Key-Takeaway:
Comparison of data fields is only possible among isosemantic arrows!

a; e.g., fugitive or stack air, *b*; e.g., dust or leaching to groundwater while storing; additionally for *c*; e.g., loss during transportation, *d*; utilization of substance for energy production (downcycling, thermal or other).
Also, for *a, b, c*: loss of containment as one-time release also covered by the TRI under No. 117

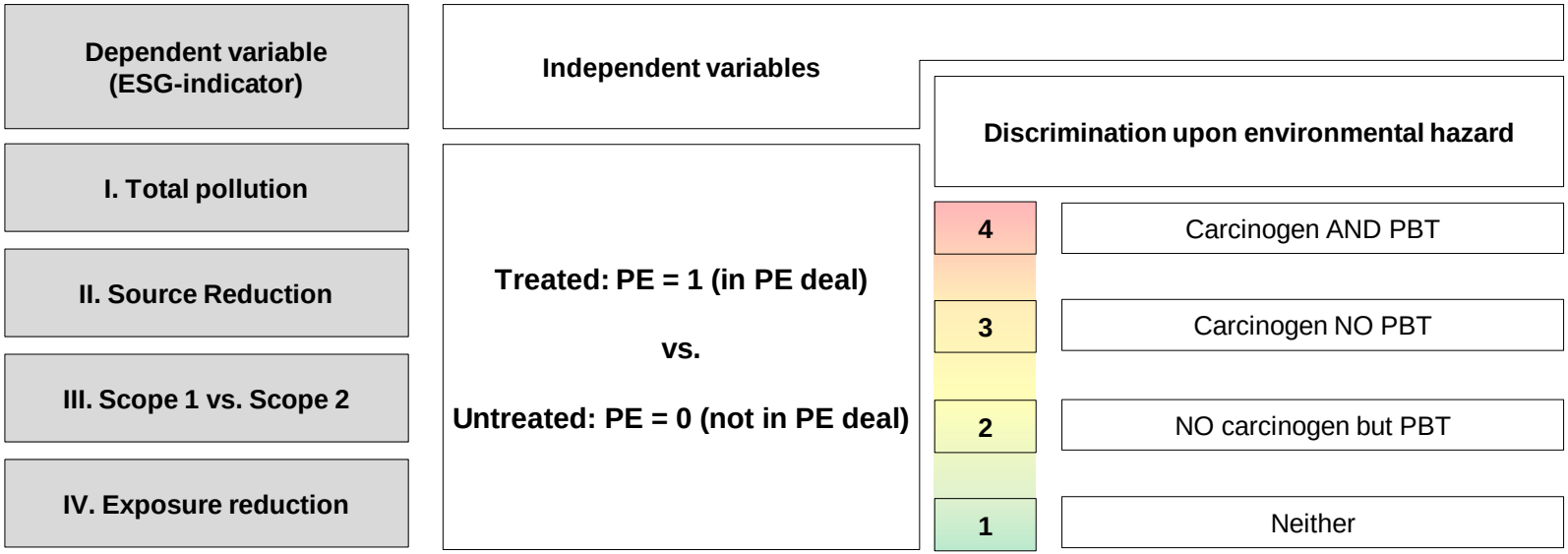
DEPENDENT VARIABLES

To calculate the dependent variables, the amount of chemicals from two data fields are taken for each observation.



DATA SCOPE

The **environmental hazard model (EHM)** is introduced as a pollution-specific control variable. The chemical information from the TRI database are used to model the ***environmental hazard of pollution.*** The EHM is a primitive **measure of the long-term severity** of the pollution. **It allows further dissection of the environmental impact of a facility** (i.e., a PE-owed asset) on an **ordinary scale** from 1 to 4.



This thesis aims to get a deep look into the matter of asset-level sustainability and for the first time in research* tries to assess whether private equity does or does not improve the impact on the environment from a toxicological point of view.

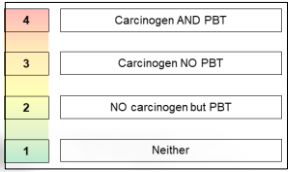
** To the best of the author's knowledge.*

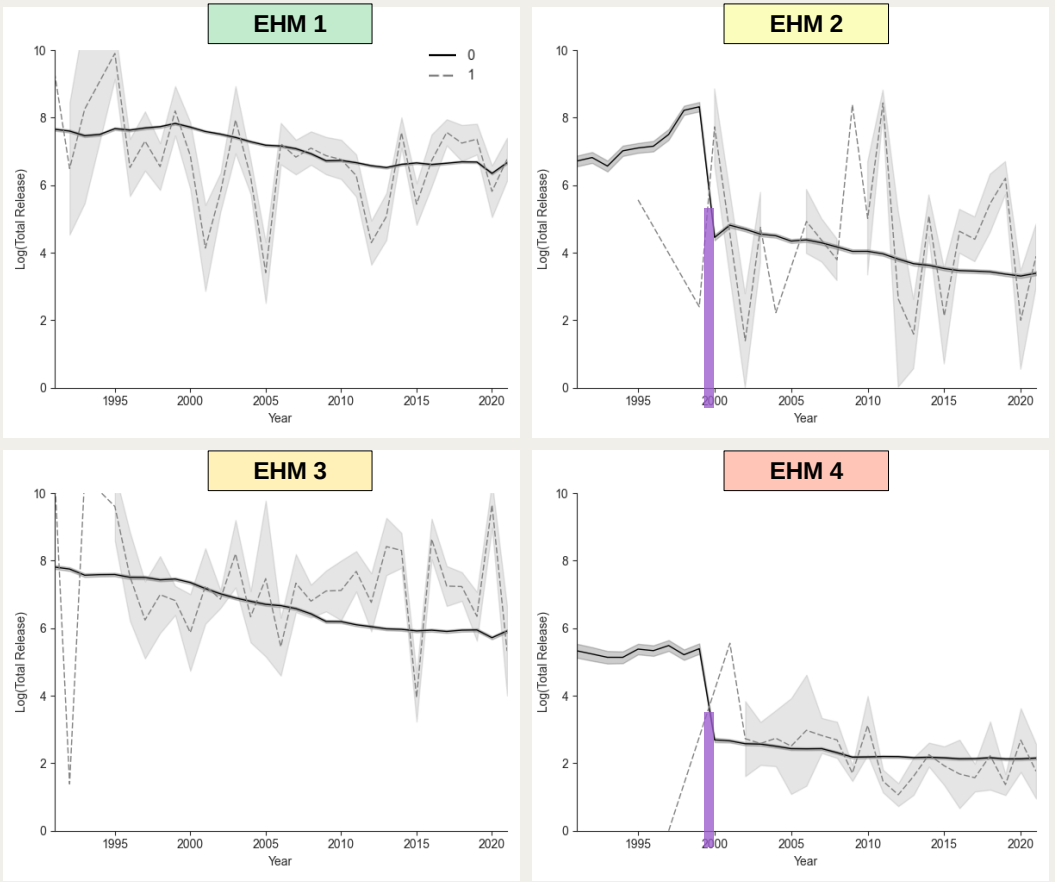
TOTAL RELEASE (1/2)

The yearly amounts of the quantity of chemicals emitted to the environment by the facility.

The reduction rates of toxic releases varied across different hazard levels of the chemicals.

It is worth noting the impact of EPA's 1999 lowering of reporting thresholds for PBT chemicals: With a greater number of facilities meeting the lower thresholds (the number quadrupled!), the average pollution levels were diluted, as evidenced by the observed gap (purple bar).





The shadings indicate the standard error of the mean pollution. Year-datapoints are connected via linear interpolation. .

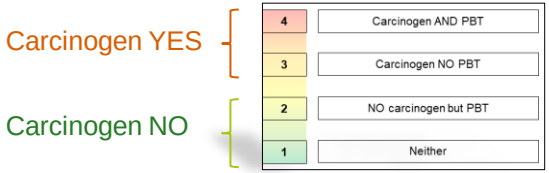
TOTAL RELEASE (2/2)

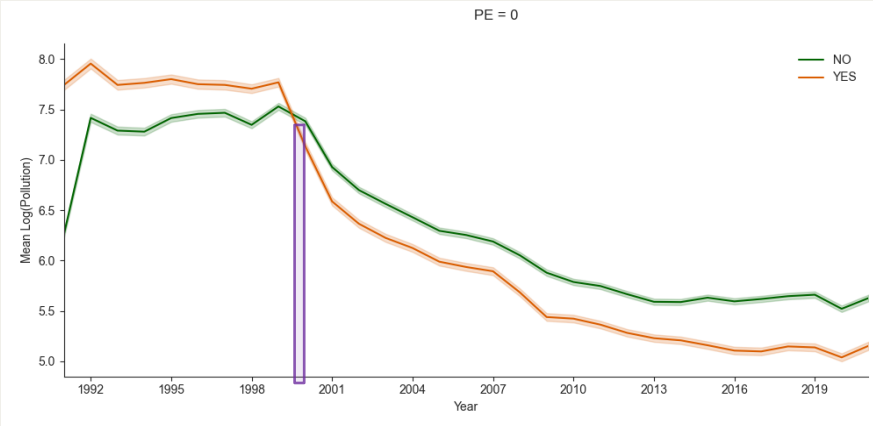
The smaller number of observations for the PE = 1 sample resulted in less uniform trends.

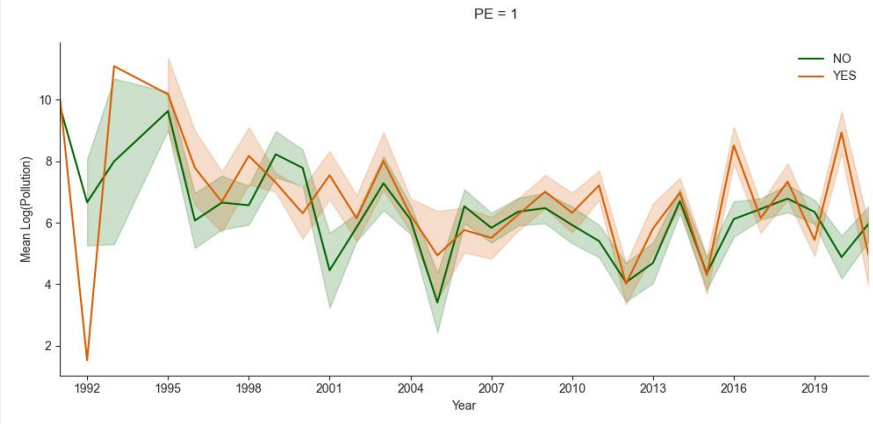
A general decrease in industry-agnostic average pollution per facility over the reporting period is found, consistent with literature reports.

This imposes a significant imbalance on comparing assets' inter-year absolute pollution levels.

An effective mitigation strategy in the thesis is the utilization of <u>intra-year matching</u> in the BaM method.







The shadings indicate the standard error of the mean pollution. Year-datapoints are connected via Linear interpolation. The graph depicts the rolling three-period average.

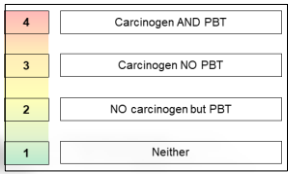
PRODUCTION WASTE (1/2)

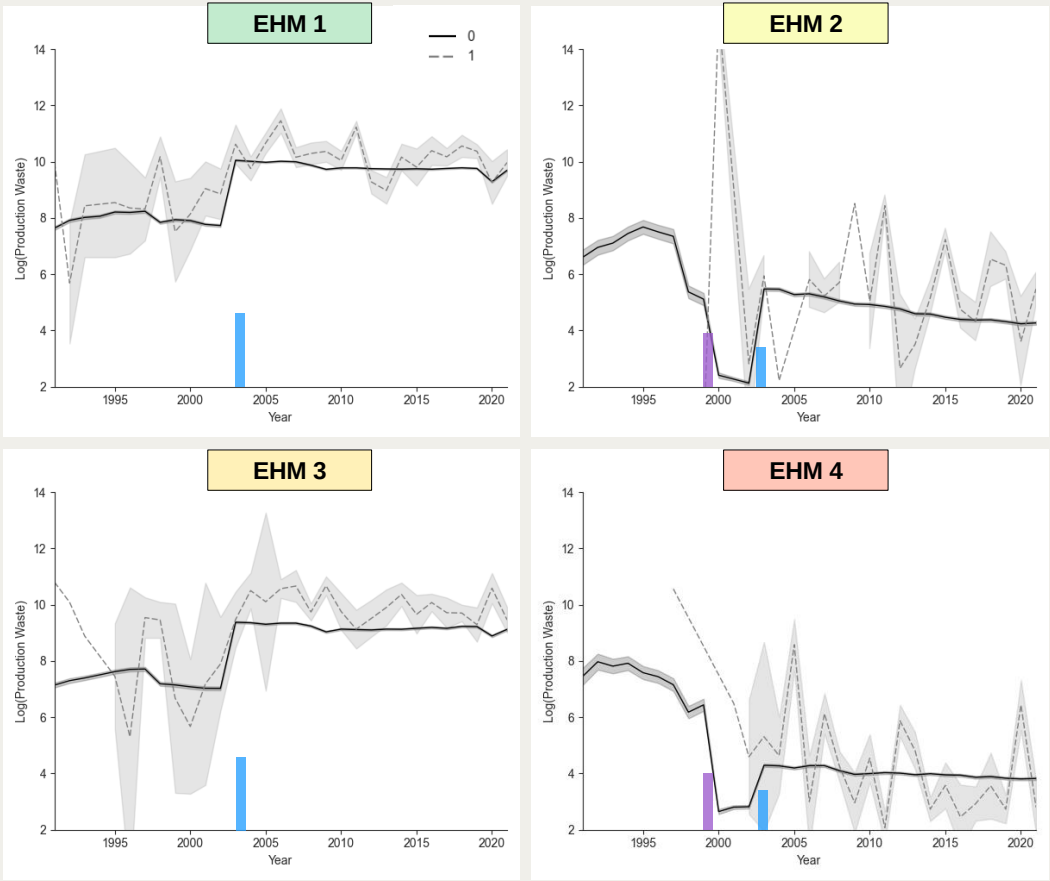
The change in the quantity of chemicals utilized in the form of production waste by the facility.

The reduction rates of toxic releases varied across different hazard levels of the chemicals.

The impact of EPA's 1999 lowering of reporting thresholds for PBTs is observable (purple bar).

In 2003, six additional categories of waste streams tracking quantities of toxic chemicals were introduced, resulting in an increase in the average production waste. The increase was comparatively lower for carcinogens, which were already subject to stricter controls (blue bar).





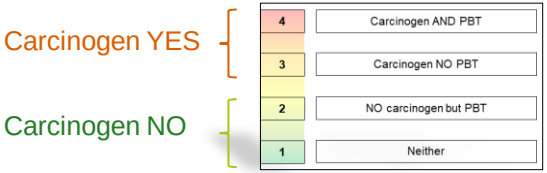
The shadings indicate the standard error of the mean pollution. Year-datapoints are connected via Linear interpolation. .

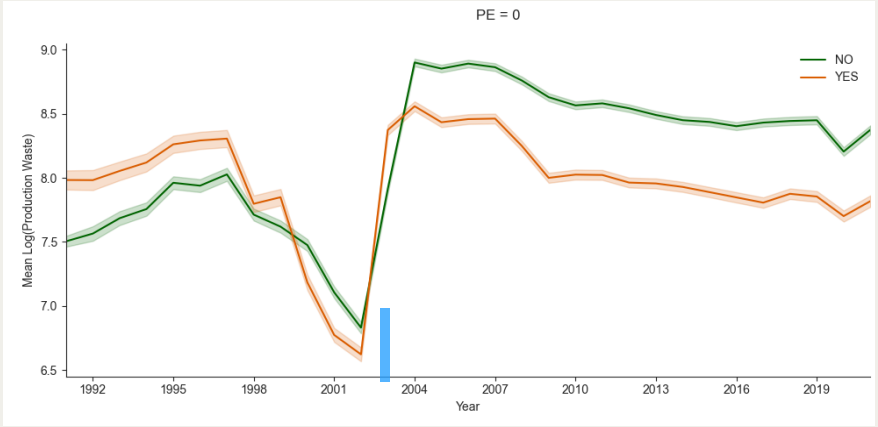
PRODUCTION WASTE (2/2)

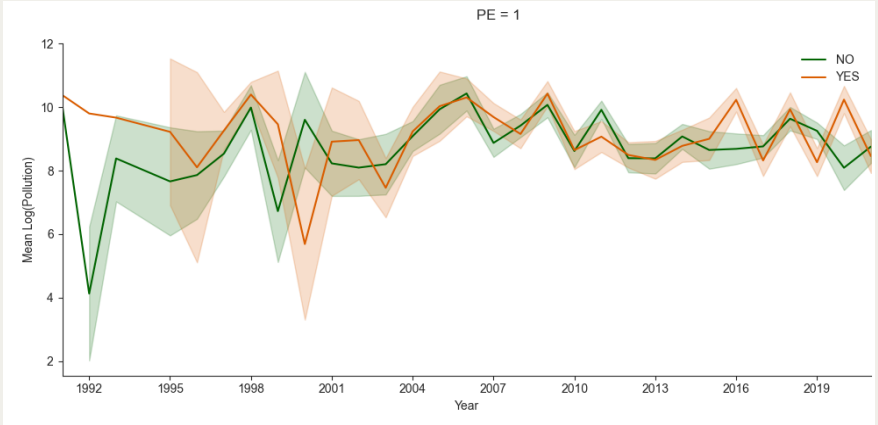
The smaller number of observations for the PE = 1 sample resulted in less uniform trends.

The quantities of toxic chemicals in production waste show a relatively consistent trend over time, although it is important to note that these amounts have not been normalized to account for changes in productivity.

Normalization of pollution levels can be done at the facility level because the TRI captures the production ratios individually for each utilized chemical, allowing for a more accurate interpretation of facility-level changes in pollution levels.



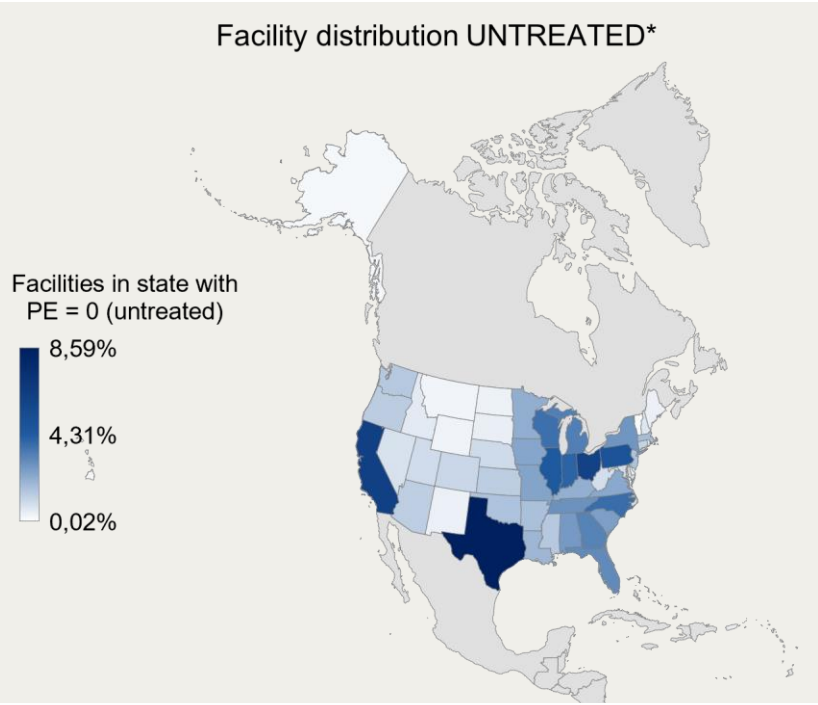


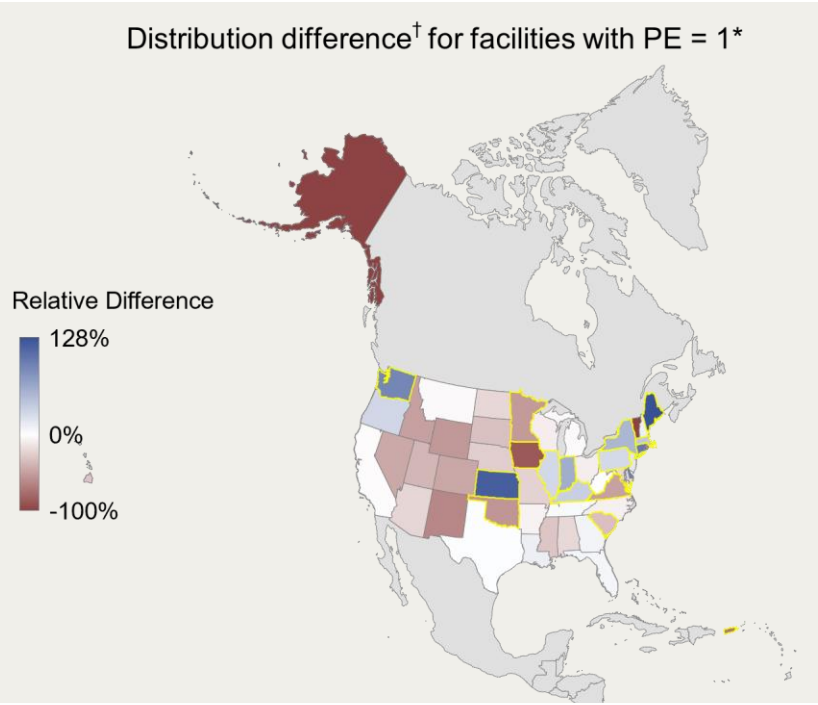


The shadings indicate the standard error of the mean pollution. Year-datapoints are connected via Linear interpolation. The graph depicts the rolling three-period average.

LOCATION

The **sample exhibits** significant **heterogeneity** in **geographic distribution** (left map). Location imposes regulatory differences for facilities, new regulations can effect changes only in certain locations.
Additionally, **geographic distribution differs for PE-owned assets**, which is significant for a few states at the p = 0.9 confidence level.

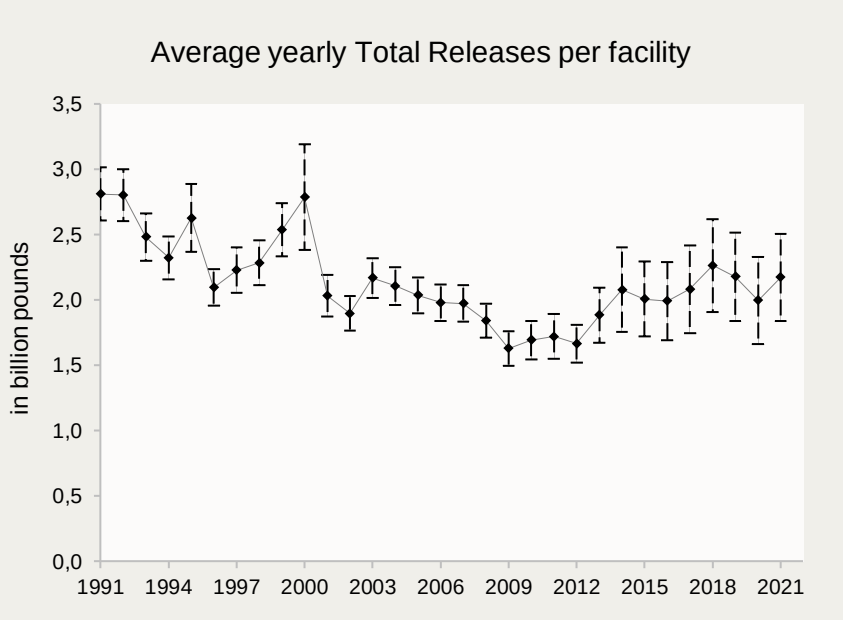


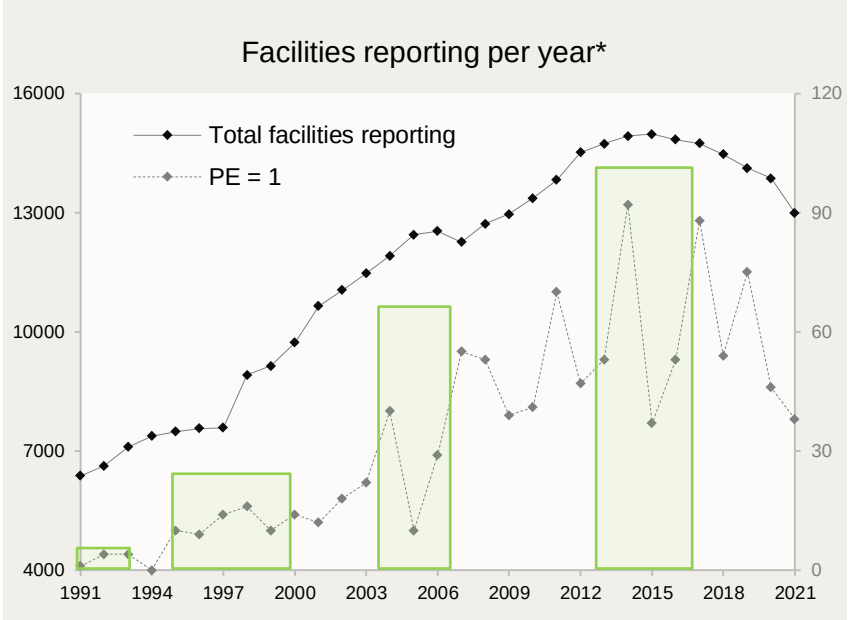


**Pacific overseas territories are not shown since not present in the PE = 1 sample. Facilities in American Samoa, Guam and Northern Mariana Islands are present in the PE = 0 sample.*
†States marked in yellow show significant differences in geographic distribution of facilities for the PE = 1 sample at the p = 0.9 confidence level (n = 709)

TIME

PE deals predominate in the last two decades, shifting the weight of pollution intensities to more recent years relative to the full sample. Additionally, the number of reporting facilities increases over the reporting period in both groups, with the PE = 1 group fluctuations roughly reflecting the private equity **boom** and **bust** cycles* (Brown, Harries, Jenkison, Kaplan, Robinson, 2020).



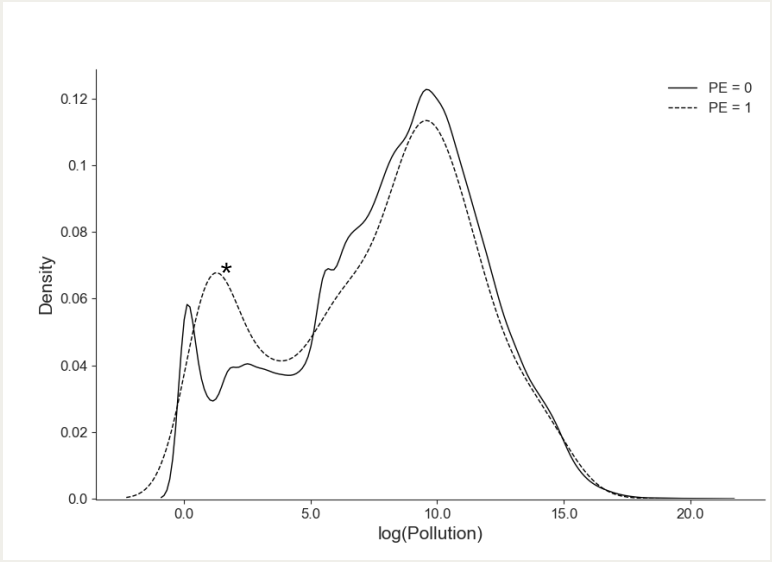


Assets involved in PE-deals (PE = 1) indicated by the dashed grey line as on the second y-axis; Green boxes mark suggested boom-phases of Private Equity according to Brown et al. (2020).

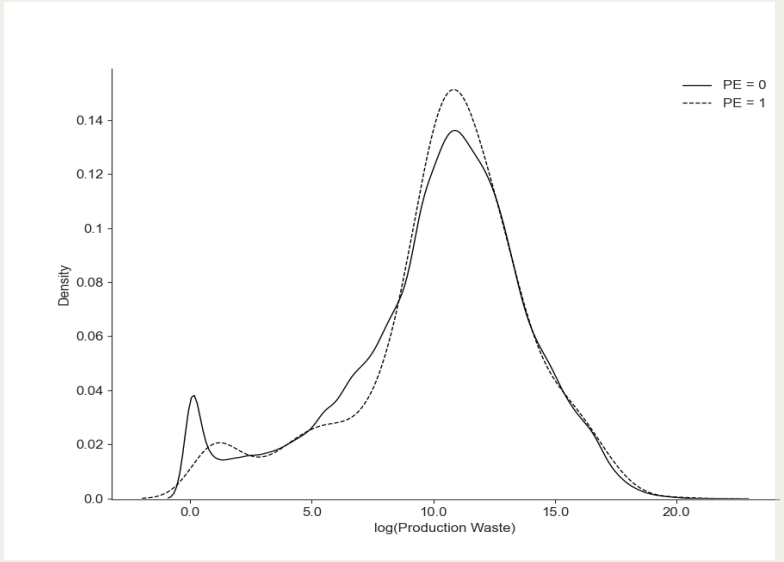
POLLUTION SIZE (1/2)

The presence of disproportionalities in pollution levels among facilities skews the comparison of facility level pollution. The gaussian kernel density estimation (bandwidth = 0.25) revealed **similar disproportionalities in both samples.** The slight difference in distribution* hints that PE-firms might exhibit pollution-dependent selection bias where PE-firms select firms that are already clean.

I. Total pollution



II. Production Waste

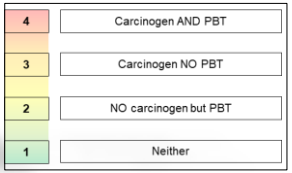


Note, the difference in distribution in light of the logarithmic scale of the x-axis.

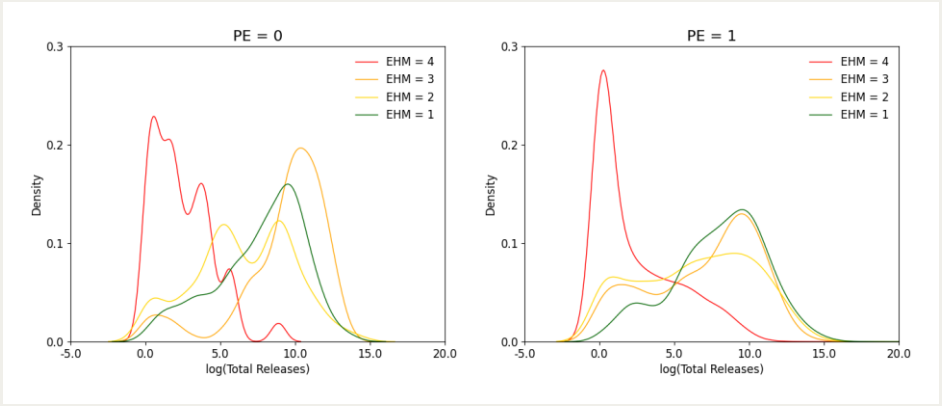
POLLUTION SIZE (2/2)

Employing the Environmental Hazard Model gives a more precise picture on the assets impact on the environment.

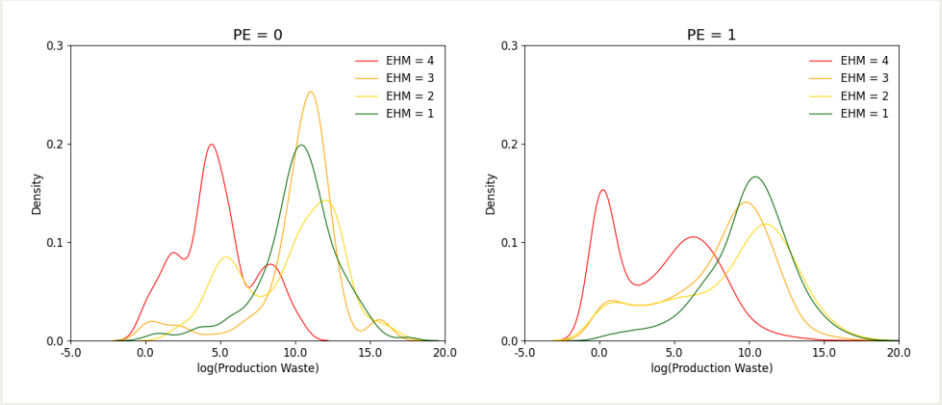
This implies, that PE-Firms *do* pick those Assets, that produce less severe pollution. PE-Firms are not shy, however, when assets handle hazardous waste. These are first hints on PE-firms controlling chemicals in their production processes and reducing potential for environmental harm.



I. Total pollution



II. Production Waste



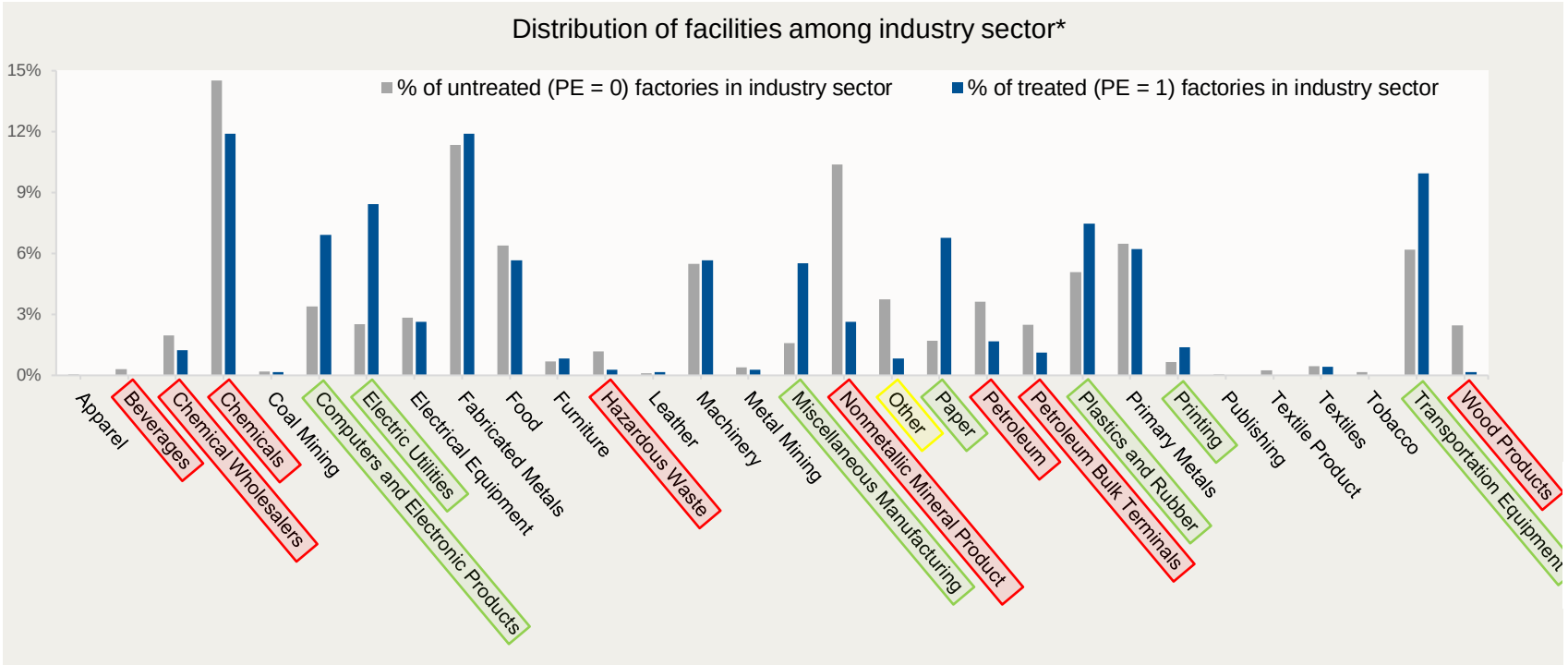
INDUSTRY (1/2)

The industrial sectors covered and the proportion of enterprises in each sector as defined by North American Industrial Classification System (NAICS) codes. The distribution presents the total sample as well as the PE=1 subset.

		Number of facilities			
Industry sector(s)	***NAICS-code(s)***	*Total*	*In percent*	*Thereof in deal*	*In percent*
Apparel	*315*	7	0,03%	0	0%
Beverages	*3121*	62	0,30%	0	0%
Chemical Wholesalers	*4246*	417	2,01%	9	1,24%
Chemicals	*325*	3102	14,94%	86	11,88%
Coal Mining	*2121*	41	0,20%	1	0,14%
Computers and Electronic Products	*334*	755	3,64%	50	6,91%
Electric Utilities	*2211*	583	2,81%	61	8,43%
Electrical Equipment	*335*	607	2,92%	19	2,62%
Fabricated Metals	*332*	2440	11,75%	86	11,88%
Food	*311*	1368	6,59%	41	5,66%
Furniture	*337*	149	0,72%	6	0,83%
Hazardous Waste	*562*	247	1,19%	2	0,28%
Leather	*316*	20	0,10%	1	0,14%
Machinery	*333*	1180	5,68%	41	5,66%
Metal Mining	*2122*	84	0,40%	2	0,28%
Miscellaneous Manufacturing	*339*	366	1,76%	40	5,52%
Nonmetallic Mineral Product	*327*	2174	10,47%	19	2,62%
Other	*999*	783	3,77%	6	0,83%
Paper	*322*	403	1,94%	49	6,77%
Petroleum	*324*	766	3,69%	12	1,66%
Petroleum Bulk Terminals	*4247*	524	2,52%	8	1,10%
Plastics and Rubber	*326*	1105	5,32%	54	7,46%
Primary Metals	*331*	1387	6,68%	45	6,22%
Printing	*323*	144	0,69%	10	1,38%
Publishing	*511*	5	0,02%	0	0,00%
Textile Product	*314*	47	0,23%	0	0,00%
Textiles	*313*	96	0,46%	3	0,41%
Tobacco	*3122*	34	0,16%	0	0%
Transportation Equipment	*336*	1358	6,54%	72	9,94%
Wood Products	*7389*	511	2,46%	1	0,14%

INDUSTRY (2/2)

Pollution levels and the potentials for mitigation have been shown to **vary** drastically **among industries** (Kube, et al., 2019). **Industry-specific** technological **characteristics manipulate** the potential for pollution management for **certain industries**. Additionally, PE-firms exhibit selection bias upon industries, which is significant for half of the industries at the p = 0.9 confidence level.*



Industry sectors marked show significant differences (green: PE-preferred industry, red: PE-demoted industry) in industry distribution of facilities for the PE = 1 sample in 16 out of 30 industries at the p = 0.9 confidence level (n = 709).

HYPOTHESES

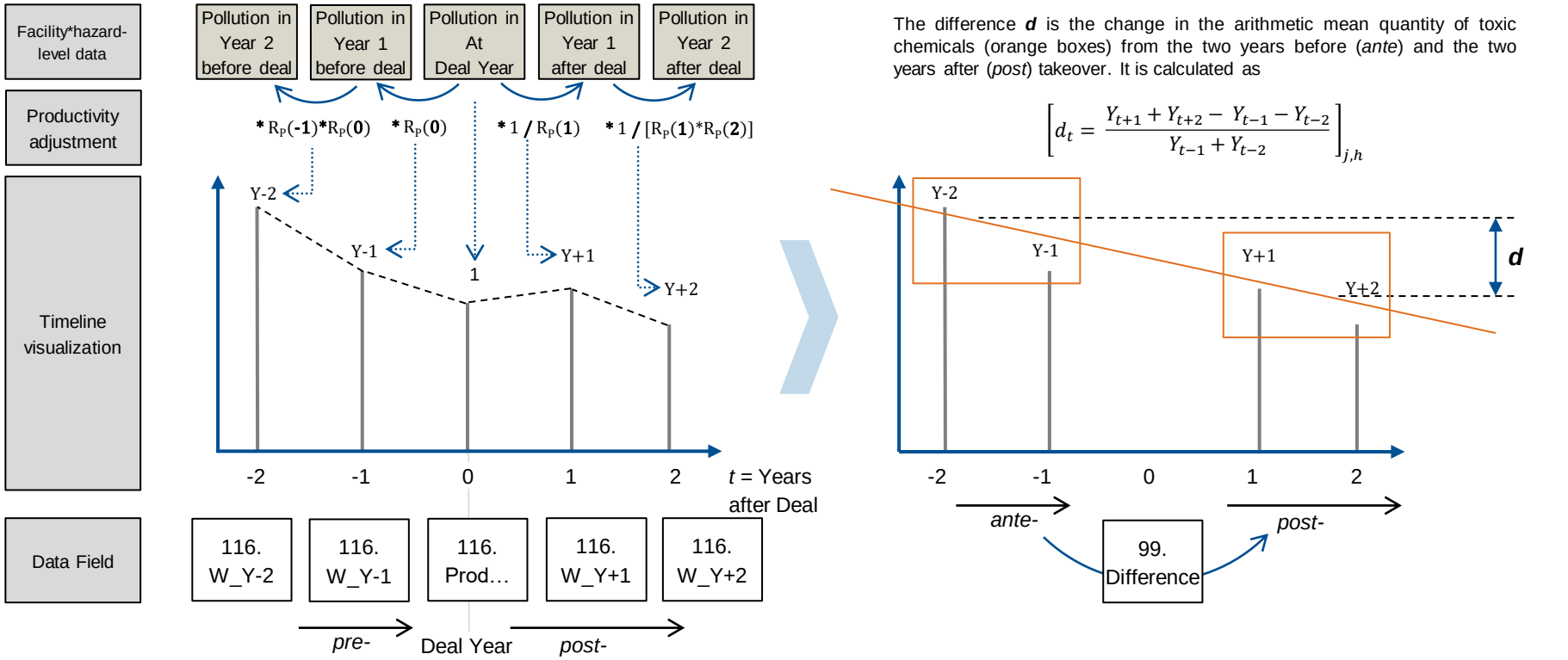
In light of the research question, the following Hypotheses are tested.

Research Question: Does PE-takeover lead to an improved level of environmental hazard management in targets' facilities?

	Hypothesis	Method
1a	Private equity takeover leads to a decrease in pollution post deal year	Change in quantity of toxic chemicals 2 years before and 2 years after
1b	Private equity takeover leads to a decrease in production waste post deal year	
2a	Private equity ownership results in a greater reduction of highly dangerous pollution compared to less dangerous pollution.	Change in hazard level 1 to 4 as quantity of toxic chemicals 2 years before and 2 years after
2b	Private equity ownership results in a greater reduction of highly dangerous production waste compared to less dangerous production waste.	

METHODS: FINDING THE CHANGE

Graphical representation of the Impact of PE-Ownership via measurement of the difference in quantity $Y(t)$ *ante*- and *post*- deal year for chemicals with hazard class h handled at a facility j in year t.

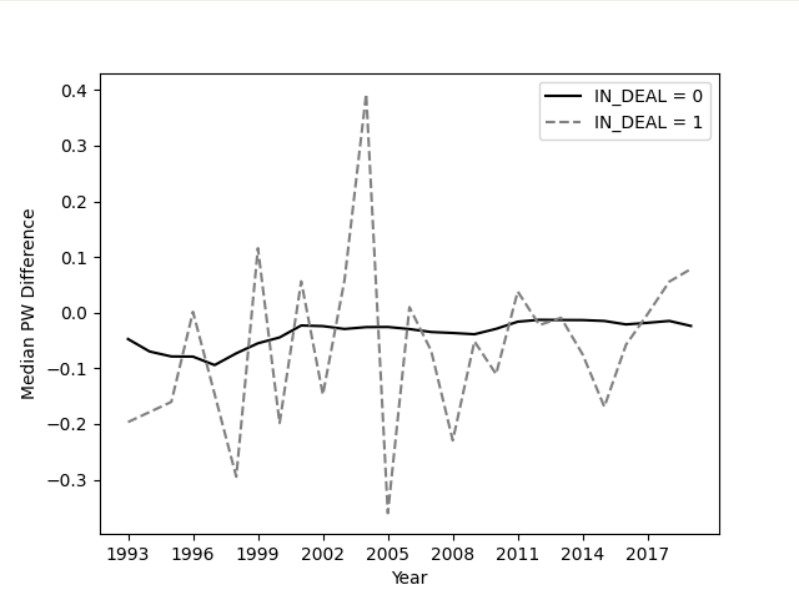


$R_P(t)$ is the change in productivity from the previous year to year t This way, the pollution in Year t is adjusted to productivity level in year t = 0.

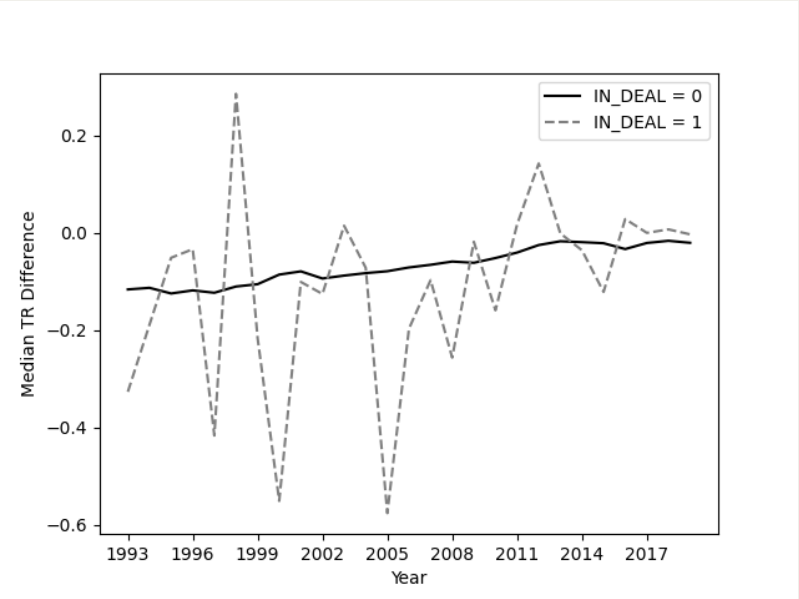
DESCRIPTIVE STATISTICS

The average difference in the year-over-year change in the amount of toxic chemicals in production waste, adjusted for the change in plant productivity between PE = 1 and PE = 0. Robust to outliers: **Cut-Off at 2.5 x median absolute deviation from median.**

***d* Production Waste**



***d* Total Releases**



Graphical representation showing the difference in the amount of toxic chemicals in each data field over time. The reduction in pollution was particularly pronounced in the early years of the TRI, reflecting the emerging awareness of pollution in the 1990s. The PE = 1 sample fluctuates around this benchmark mainly due to fewer observations.