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Martin R. Goetz

Financing Conditions and Toxic Emissions

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House of Finance | Goethe University
Theodor-W.-Adorno-Platz 3 | 60323 Frankfurt am Main

Tel. +49 69 798 30080 | Fax +49 69 798 33910
info@safe-frankfurt.de | www.safe-frankfurt.de

Financing conditions and toxic emissions

Martin R. Goetz [*]

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Abstract

Exploiting heterogeneity in U.S. firms' exposure to an unconventional monetary policy shock that reduced debt financing costs, I identify the impact of financing conditions on firms' toxic emissions. I find robust evidence that lower financing costs reduce toxic emissions and boost investments in emission reduction activities, especially capital-intensive pollution control activities. The effect is stronger for firms in noncompliance with environmental regulation. Examining the ability of regaining regulatory compliance by implementing pollution control activities I find that only capital-intensive activities help firms regaining compliance. These findings underscore the impact of firms' financing conditions for emissions and the environment.

JEL Classification: G32, E52, Q52, Q53

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[*]Goethe University and SAFE, Goethe University Frankfurt, Theodor-W.-Adorno-Platz 3, 60323 Frankfurt am Main, Germany, goetz@safe.uni-frankfurt.de
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1 Introduction

A deteriorating environment has stark detrimental effects on the standard of living and economic outcomes. The harmful effect of pollution on economic outcomes is not limited to developing countries: Isen et al. (2017) find that a higher pollution level in the year of birth in the United States is followed by lower labor force participation and lower earnings 30 years later. Lower pollution in the U.S. not only improves health and reduces child mortality (Chay and Greenstone, 2003), but also contributes to higher house prices (Chay and Greenstone, 2005).

In this paper, I empirically examine the link between a firm's financing condition and its emission of toxic chemicals by identifying how lower financing costs impact the release of poisonous chemicals in the U.S. To pin down the impact of financing conditions on emissions I exploit heterogeneity in firms' exposure to a shock to long-term debt financing and further show that a reduction in financing costs (a) boosts investment in capital-intensive pollution abatement activities and (b) helps firms under greater regulatory scrutiny to regain compliance with environmental regulation.

Whether a reduction in financing costs affects toxic emissions is theoretically ambiguous. Cheaper financing may spur investments and increase production and without any changes in the production process also augment emissions (Fazzari et al., 1988). Investments to reduce pollution and save energy tend to be large and offer little cost-savings potential (Fowlie et al., 2015, 2018) rendering these investments suboptimal. Firms may also optimally choose to not change harmful behavior if they expect that the detection probability is low (Shapira and Zingales, 2017). Fines due to the violation of environmental regulation can be large and monetary penalties because of noncompliance with laws reduce firm value (Karpoff et al., 2005). This may encourage firm to invest in pollution control. Furthermore, investors may pressure firms to reduce toxic emissions due to their preference for a cleaner environment (Heinkel et al., 2001; Chava, 2014; Fernando et al., 2017).

Identifying a causal link running from a firm's financing conditions to their toxic emissions is empirically challenging. Particularly since unobservable heterogeneity across firms, such as the expansion of output (Fazzari et al., 1988), managers' focus on corporate social responsibility (Cheng et al., 2013) or regulators' ability to enforce and monitor regulation (Evans and Stafford, 2018) shape a firm's release of toxic chemicals and its financing condition (Kubik et al., 2011). Causality may even be reverse and heavy polluting firms become financially constrained in case of large monetary fines due to violations of environmental laws (Cohn and Deryugina, 2018).

To isolate the causal effect of a firm's financing conditions on toxic emissions, I exploit (1) the unexpected reduction in financing costs for long-term debt due to the unconventional monetary policy shock of the Federal Reserve's Maturity Extension Program, and (2) heterogeneity in firms' exposure to this shock due to their dependence on long-term debt financing. I further present novel evidence on the mechanism of emission reduction by studying differences between capital-intensive and other pollution control techniques and their ability to regain compliance with environmental regulation.

My identification strategy builds on theories and evidence that non-financial firms with a preference for long-term debt benefit more from a negative supply shock of long-term government debt (Greenwood et al., 2010; Badoer and James, 2016). In the presence of partial segmentation in bond markets and limits to arbitrage, firms and market participants have a preference for a specific maturity structure (Vayanos and Vila, 2009; Choi et al., 2018) and a reduction in the supply of government debt with a specific maturity shifts investors' focus on corporate bonds with a similar maturity (Baker et al., 2003). This reduces rates for long-term debt and firms that finance themselves with long-term debt experience a reduction in financing costs. Corporations may further respond by issuing securities with a corresponding maturity to fill the maturity gap in bond markets (Greenwood et al., 2010; Badoer and James, 2016).

The Federal Reserve's Maturity Extension Program (MEP), announced on September 21st 2011, was a surprise long-term debt markets as the MEP focused on buying

Treasury securities with a remaining maturity of more than six years.[1] With the aim of flattening the yield curve, the MEP specifically put pressure on rates for long-term debt and reduced financing costs for long-term bonds. Heterogeneity in firms' dependence on long-term debt financing then translates into differences in their exposure to this reduction in long-term financing costs.[2]

I start by assessing the impact of the MEP on debt markets and examine the impact of the MEP on (1) Treasury yields, (2) corporate bond yield spreads and (3) bond issuances. I find that the announcement of the MEP was followed by a flattening of the yield curve and significantly reduced long-term corporate spreads, i.e. spreads of bonds with a remaining maturity of more than six years. The pattern of corporate yield spreads shows that the MEP was a surprise event as long-term yield spreads only stated to decrease after the announcement of the MEP. Examining bond issuances, I find that the likelihood of issuing a bond with a maturity of more than six years increases following the announcement of the MEP, indicating that firms engage in gap-filling behavior.

Armed with the finding that the MEP reduced financing conditions for long-term debt, I use micro-level data from the Environmental Protection Agency (EPA) on the release of toxic emissions and pollution abatement investments to assess whether companies with a greater dependence on long-term debt reduce toxic emissions more after the announcement of the MEP. Exploiting granular data on the release of toxic chemicals in a difference-in-differences analysis allows me to further control for unobservable influences in my econometric analysis and I include different sets of fixed effects.

I find strong evidence that companies with a greater long-term debt dependence reduce toxic emissions more following the MEP. This result is robust to the inclusion of firm-level control variables and various fixed effects. Since the data provide granular

[1]As a response to the Financial Crisis, the Federal Reserve engaged in several large scale asset purchase programs (Kuttner, 2018).

[2]Foley-Fisher et al. (2016) presents evidence that the MEP was a shock to capital markets and firm financing and had real effects. Empirical evidence from Europe corroborates this and Grosse-Rueschkamp et al. (2018) shows that European firms, affected by the European Central Bank's Securities Purchase Program also benefited from a similar unconventional monetary policy shock.

information on the release of toxic chemicals at a the production plant level I can control for observable heterogeneity in the level of production.[3] My empirical specification rests on the assumption that firms with a greater long-term debt dependence are not different in their toxic emissions prior to the MEP. Examining the dynamic pattern of toxic emissions over the sample period, I find no evidence that firms with a greater dependence on long-term debt differ in their release of toxic emissions prior to the MEP. Following the MEP, however, firms with a greater long-term debt dependence reduce toxic emissions. This suggests that the reduction of financing costs for long-term debt benefitted firms with a greater dependence on long-term debt, enabling these firms to reduce toxic emissions.

My results are robust to a battery of additional tests examining other influences and exploring the sensitivity to alternative variable definitions. Specifically, I examine whether my findings remain if I account for (a) other influences of corporate financing condition, i.e. structure and interest contract of corporate debt, (b) changes in the sample composition, (c) alternative clustering of standard errors, (d) alternative definitions of long-term debt dependence and (e) other measures of toxic emissions. My results are robust to these potentially biasing influences.

To understand how firms reduce toxic emissions, I examine firms' investment behavior and study whether firms increase their investment in activities to reduce toxic emissions following the MEP. I use information on reported pollution abatement investments by firms and find that firms with a greater long-term debt dependence increase their investment in activities to reduce toxic emissions following the MEP.

I provide two further analyses to underscore the effect of cheaper financing in explaining the overall increase in emission reduction activities. First, I examine differences in the capital intensity of emission reduction activities and assess whether affected firms specifically increase capital-intensive emission reduction activities.[4] Second, I evaluate

[3]By specifically including time-varying fixed effects at the area- and industry-level, I account for unobservable (local) differences in the release of toxic chemical, such as, for instance, heterogeneity in the enforcement of environmental regulations across areas and industries over time.

[4]If a reduction in financing conditions due to the MEP is responsible for the overall finding, then I expect that affected firms particularly focus on capital-intensive emission reduction activities.

whether the effect of the MEP on the investment in pollution abatement is stronger for firms under higher regulatory scrutiny.[5]

Using aggregate information on the costs of emission reduction activities and differentiating emission reduction activities by their level of capital-intensity I examine whether the implementation of the MEP boosts investments in capital-intensive emission reduction activities. My results show that firms with a greater long-term debt dependence particularly increase investments in capital-intensive emission reduction activities. This is consistent with the idea that a reduction in financing costs due to the MEP allowed firms to invest in capital-intensive pollution abatement measures, contributing to lower toxic emissions.

As a further test, I examine whether a firm's focus on reducing toxic emissions is more pronounced if the firm violated environmental laws and hence needs to regain compliance with regulation.[6] My findings are more pronounced for firms under greater regulatory scrutiny and firms that were fined prior to the MEP and that depend more on long-term debt financing significantly invest more in capital-intensive emission reduction activities following the MEP. Since these firms need to regain compliance with environmental regulation this finding suggests that the reduction in financing conditions due to the MEP helped these firms to increase their emission reduction activities.

Finally, I examine the benefits of investing in emission reduction activities to regain compliance with environmental regulation and test whether investments in (capital-intensive) emission reduction activities help firms to achieve regulatory compliance. I find that the implementation of emission reduction activities decreases a firm's likelihood of regulatory intervention. Furthermore, my results show that the beneficial effect of pollution abatement investments is only significant for capital-intensive emission re-

[5]Since monetary penalties due to a violation of environmental laws tend to reduce firm value (Karpoff et al., 2005; Cohn and Deryugina, 2018), I expect that firms in noncompliance with environmental rules prior to the MEP focus more on reducing toxic emissions and implementing emission reduction activities following the MEP to regain compliance.

[6]Earlier work finds that monetary penalties by regulators due to environmental noncompliance decreases firm value (Badrinath and Bolster, 1996; Karpoff et al., 2005). Furthermore, regulatory enforcement actions are also followed by an increase in oversight and regulatory scrutiny (Evans and Stafford, 2018).

duction activities.[7] This pattern is consistent with the idea that the MEP reduced financing conditions for long-term debt, allowing affected firms to invest in capital-intensive emission reduction activities, helping them to ensure/regain compliance with environmental regulation.

My analysis contributes toward understanding the interlinkages between the financial sector and the environment (Popov and de Haas, 2018) and identifies one important feature, namely the role of a firm's financing conditions. Thus, my paper is related to recent empirical work, identifying how specific financial shocks impact the environment. Levine et al. (2018) find that positive bank credit supply shocks due to surprise discovery of shale gas (Gilje et al., 2016) reduces pollution. My results complement the findings of Levine et al. (2018) by identifying the impact of firm financing conditions on toxic emissions. Focusing on access to finance, Kim and Xu (2018) use different estimation strategies and find that lower financial constraints are associated with less pollution. My work differs from this paper along two dimensions: First, I focus on the intensive margin of changes in financing conditions by evaluating how a change in the cost of debt affects pollution. Second, I exploit a financial shock that directly affected firm's financing conditions to identify a causal relationship. Moreover, in addition to the findings of Levine et al. (2018) and Kim and Xu (2018), I provide further insights regarding the channels as I show that a reduction in financing costs boosts the implementation of capital-intensive emission reduction activities, helping firms to regain environmental compliance.

Furthermore, my findings contribute to research examining determinants of firm pollution. Harrison et al. (2015) finds that changes in environmental regulation reduce aggregate pollution in India as more establishments invest in pollution control when regulation tightens. Shapiro and Walker (2018) show that changes in environmental regulation contributed mostly to the reduction in overall emissions in the U.S. over the recent years. Examining the role of a firm's legal status, Shive and Forster (2018)

[7]While other emission reduction activities also increase the likelihood of regaining compliance with environmental laws, the effect is not statistically significant.

document that U.S. firm status (private ps. public) is an important determinant for firm pollution. Focusing on the legal environment, Akey and Appel (2017) find that an increase in liability protection for parent companies leads to an increase in toxic emissions by subsidiaries. I contribute to this literature by showing that, in addition to these factors, the cost of financing has a first order effect on firm emissions as financing conditions affect a firm's ability to implement (capital-intensive) emission reduction activities.

The remainder of this paper is organized as follows: Section 2 discusses the MEP, and examines its impact on government and corporate bond markets. Section 3 then examines the impact of the MEP on firms' emission of toxic chemicals due to heterogeneity in firms' dependence on long-term debt financing. Section 4 assess the impact of the MEP on the implementation of toxic emission reduction activities and evaluates differential effects on emission reduction activities depending on the level of capital-intensity. Section 5 analyzes (1) if the investment in pollution control differs whether firms are subject to greater regulatory scrutiny and (2) examines the link between emission reduction activities and the ability to regain compliance with environmental regulation. Section 6 concludes.

2 Unconventional monetary policy and corporate finance

2.1 The Maturity Extension Program

The Financial Crisis of 2007-09 led the Federal Reserve to engage in expansionary monetary policy by reducing its target for the federal funds rate since August 2007. This conventional monetary policy tool reached its limit by the end of 2008 as the target federal funds rate reached a lower bound. In November 2008, the Federal Reserve engaged in quantitative easing (QE) and started large scale asset purchase programs by purchasing direct obligations of housing related to government-sponsored enterprises.

This first QE program was extended in March 2009, increasing the amount of total purchases of mortgage-backed securities up to $1.25 trillion. Additionally, the Federal Reserve decided to purchase up to $300 billion of Treasury securities. About one and a half years later the Federal Reserve started a second QE program, focusing on purchasing about $600 billion of Treasury securities by the middle of 2011 (Kuttner, 2018).

On September 21, 2011 the Maturity Extension program (MEP) - the third and final QE program - was announced. The goal of the MEP was to change the slope of the yield curve and the Federal Reserve announced its intention (a) to purchase $400 billion of Treasury securities with remaining maturities of 6 to 30 years and (b) to sell, over the same period, a value of Treasury securities with remaining maturities of 3 years or less. With the aim of extending the average maturity of the Federal Reserve's holding of securities the MEP's goal was to "put downward pressure on longer-term interest rates and help make broader financial conditions more accommodative" (Federal Reserve System, 2011). This program was continued through the end of 2012 and the Federal Reserve announced in June 2012 that it would purchase an additional $267 billion in Treasury securities.

Table 1 represents the allocation of the MEP's initial amount ($ 400 billion) across Treasury securities with different remaining maturities: the majority of the MEP (about 65 percent of the total amount) was centered on Treasury securities with a remaining maturity between 6 and 10 years. The total amount of outstanding Treasury securities as of September 2011 in that maturity sector was about $ 1,455 billion and the MEP intended to purchase a sizeable amount (about 18 percent) of that market segment.

2.2 The effect of the MEP on government bond yields

Empirical evidence regarding the impact of the Federal Reserve's QE policies in general, and the role of the MEP in particular, on government bond yields finds weak effects. Abrahams et al. (2016), for instance argue that a reduction of real term premia contributed to lower yields when QE programs were announced. Examining supply effects, D'Amico and King (2013) document that the Federal Reserve's asset purchase programs particularly affected the targeted maturity sector of Treasury securities. Similarly, Weale and Wieladek (2016) conclude that the large scale asset purchase programs in the U.S. reduced long-term interest rates and household uncertainty, contributing positively to economic activity.[8] Focusing on the MEP, Meaning and Zhu (2012) argue that the MEP reduced long-term Treasury bond rates. Examining the effect of the Federal Reserve's purchase of long-term Treasury bonds, Krishnamurthy and Vissing-jorgensen (2011) find that yields of high grade corporate debt decreased, indicating spillover effects of this unconventional monetary policy.

I also examine the effects of the MEP on U.S. Treasury securities and collect information on the daily yields of U.S. Treasuries for different maturity sectors around the date of the MEP. In particular, I collect yield information for seven different maturity sectors: Treasury securities with a remaining maturity of 1 year, 2 years, 3 years, 7 years, 10 years, 20 years and 30 years.[9] The MEP focused on buying long-term Treasury securities, i.e. securities with an outstanding maturity of more than 6 years. Based on the aforementioned seven maturity sectors I consider U.S. Treasury securities with a remaining maturity of at least 7 years long-term. I then average daily yields for long-term and short-term (maturity less than 5 years) Treasuries on every trading day and construct the term spread between long-term and short-term Treasury securities by subtracting the short-term yield from long-term yield.

Figure 1 plots the average term spread between long- and short-term Treasury securities around the announcement date of the MEP. The figure shows that the average difference in yields between long-term and short-term Treasury securities prior to the

[8]Empirical work finds that the Federal Reserve's QE policies had an effect on bank lending and spurred local economic development (Kurtzman et al., 2018; Luck and Zimmermann, 2019).

[9]Information on the yield of Treasury securities with an outstanding maturity of 5 years are also reported. The MEP planned on acquiring outstanding Treasury securities with a maturity above 6 years. D'Amico and King (2013) find that QE had spillover to neighboring maturities and hence I do not use information on the daily yield of Treasuries with a maturity of 5 years here.

MEP was around 2.2 percentage points. Following the announcement of the MEP the spread between long-term and short-term Treasury securities decreased by about 40 basis points and the announcement of the MEP was followed by a flattening of the yield curve. While the term spread increased again after the MEP announcement date, it was still below the pre-MEP level.

2.3 The effect of the MEP on the corporate bond market

Figure 1 indicates that yields on U.S. Treasury securities for long-term government debt decreased following the MEP. If (a) debt markets for different maturities are partially segmented and (b) the MEP presents a (sufficiently large) shock to the supply of long-term government bonds, then bond yields for long-term corporate bonds should also decrease following the announcement of the MEP (Baker et al., 2003; Vayanos and Vila, 2009). Evaluating the Federal Reserve's first program to flatten the yield curve in 1961, Swanson (2011) finds that this program reduced aggregate corporate bond yields. I now analyze whether the MEP affected corporate bond yields and firm's bond issuance behavior. Specifically, I examine (1) if long-term corporate yield spreads, i.e. the difference between corporate bond yields and the risk-free rate, also decline following the announcement of the MEP and (2) whether firms increase their issuance of long-term corporate bonds to fill the gap in debt markets (Greenwood et al., 2010).

2.3.1 Data, variables and sample

Corporate yield spreads I collect data on daily bond yields for publicly traded corporate debt from Thomson Reuters. To construct a sample of comparable public corporate debt I focus on plain-vanilla fixed coupon rate bonds, denoted in US dollars, issued by non-financial corporations, headquartered in the U.S. and exclude callable bonds and bonds guaranteed by a third party. Since I explore differences in the price of corporate debt around the MEP I only consider securities issued prior to the announcement of the MEP with a maturity date after the MEP and exclude bonds with a remaining maturity of more than 25 years. My sample consists of 778 bonds with information on yields six trading days before and after the announcement of the MEP. To construct the spread between the bond yield and the risk-free rate, I subtract the daily corporate bond yield from the daily U.S. Treasury yield for the maturity sector, based on the information provided on daily Treasury yields for by the earlier mentioned seven maturity sectors. To limit the influence of outliers I exclude observations in the top and bottom 2 percent of yield spreads.

Corporate bond issuances I collect information on the new issuance of publicly traded corporate bonds from Thomson Reuters. To examine comparable corporate debt issuances I focus on the issuance of plain-vanilla (fixed coupon), non-callable US-Dollar denominated corporate bonds, issued by non-financial corporations, headquartered in the U.S. To examine the issuing behavior around the MEP, I further restrict attention to bonds, issued in a time period of 5 quarters around the announcement date of the MEP. My sample consists of 149 bond issuances between August 2010 and January 2013.

2.3.2 Econometric specification and results

Corporate yield spreads If the MEP indeed presents a large shock to financial markets, then spreads for long-term corporate bonds should not change prior to the MEP, but only change following the announcement of the MEP. To examine this I analyze bond spreads and estimate:

$$y_{b,t} = \sum_{j=-6}^{+6} \alpha_j \left(D_j \cdot (\text{Maturity} > 6 \text{ years})_b \right) + \alpha_b + \alpha_t + \epsilon_{b,t}, \tag{1}$$

where $y_{b,t}$ is the yield spread of bond b on date t; D_j is a dummy variable, taking on the value of one j days before (negative) or after (positive) the announcement of the MEP, and zero otherwise; $(\text{Maturity} > 6 \text{ years})_b$ is an indicator variable, taking on the value of one whether bond b has a remaining maturity of more than six years at the time of the MEP, or zero otherwise; α_b is a bond fixed effects and α_t are time fixed effects. The coefficients α_j represent the average difference in the yield spread among long-term and short-term bonds j days before/after the announcement of the MEP. The effect on the announcement day is dropped due to collinearity from the analysis and thus the coefficients α_j are relative to the announcement date. To account for possible noise at the maturity cut-off of six years due to spillovers, I drop bonds with a remaining maturity between five and seven years at the announcement date of the MEP.

Panel A of Figure 2 plots the estimated coefficients α_j as well as the 95 percent confidence interval for the coefficients obtained from estimating regression model (1). Standard errors are robust and clustered at the bond level, allowing for autocorrelation of yield spreads within a bond over time. The pattern in Panel A of Figure 2 shows that spreads for long-term bonds do not behave differently to short-term bonds prior to the announcement of the MEP. The announcement of the MEP, however, was followed by a decrease in the term spread. This is consistent with the idea that capital markets are (partially) segmented, leading to a spillover of the MEP to corporate debt markets triggered a reduction in the relative cost of long-term corporate debt.

Corporate bond issuances Earlier work finds that corporations respond to a reduction in the supply of government bonds and issue corporate debt to fill the resulting gap in debt markets (Greenwood et al., 2010; Badoer and James, 2016). Since the MEP is a negative shock to the supply of long-term Treasury securities, I expect that non-financial corporations will react and issue more long-term bonds after the MEP. To examine this, I use information on new bond issuances and estimate a logit regression model, where the dependent variable is a dummy variable, taking on the value of one, whether the newly issued bond has a maturity of more than six years, or zero otherwise.

To account for underlying economic conditions I include the term structure (difference between the 10 year and 1 year constant maturity U.S. Treasury yield) and

Moody's Baa Coporate yield spread (Badoer and James, 2016).[10] I further capture heterogeneity across issuances by including the natural logarithm of the issuance's face value.

To investigate the dynamic pattern of the likelihood of issuing a long-term bond around the announcement of the MEP, I split the time period into quarters, i.e. windows of 90 days, around the MEP announcement date and estimate:[11]

$$\text{Maturity} > 6 \text{ years}_b = \sum_{j=-6}^{+6} \alpha_j \cdot D_j + X'_{b,t}\gamma + \epsilon_b, \tag{2}$$

where Maturity > 6 years$_b$ is a dummy variable, taking on the value of one whether bond b has a maturity of more than six years at the date of the issuance, or zero otherwise; D_j is a dummy variable, taking on the value of one if the issuance takes place in the jth quarter before (negative) or after (positive) the announcement of the MEP, and zero otherwise; X_b is a set of bond characteristics. The coefficients α_j represent the average likelihood of issuing a long-term bond in a certain quarter before/after the announcement of the MEP. The effect in the window around the announcement date is dropped due to collinearity from the analysis and thus the coefficients α_j are relative to the window of the announcement date of the MEP.

Panel B of Figure 2 plots the estimated coefficients α_j as well as the 95 percent confidence interval for the coefficients obtained from estimating regression model (2) where standard errors are heteroskedasticity-robust. The pattern in Panel B of Figure 2 shows that the likelihood of issuing a bond with a maturity of more than 6 years is not significantly different from zero prior to the MEP. Following the announcement of the MEP, however, the probability of issuing a long-term bond increases significantly and remains significantly positive after the announcement of the MEP. This shows that firms react the negative supply shock of long-term Treasury securities due to the MEP

[10]Information on these variables is provided by the Federal Reserve Bank of St. Louis.

[11]The MEP announcement date (09/21/2011) is the midpoint of the reference quarter to assess changes in the likelihood of issuing bonds in relation to the MEP announcement date. For example the first time window in my analysis ranges from 05/14/2010 until 08/12/2010 (between 495 and 405 days before 09/21/2011), etc.

and respond by issuing long-term bonds to fill the gap in debt markets.

3 Maturity Extension program, long-term debt dependence and toxic emissions

The earlier findings show that the MEP had an effect on corporate debt markets and the Federal Reserve's decision to buy long-term government debt reduced financing costs for long-term corporate debt. If investors and firms have a preferred habitat with respect to their debt structure, then the reduction in long-term corporate debt spreads should particularly benefit firms that are more dependent on long-term debt financing. Thus, I now examine if the reduction in financing costs also has an effect on firm's pollution behavior.

3.1 Data, variable definitions and sample

3.1.1 Toxic emissions and pollution abatement

Toxic emissions The Toxic Release Inventory (TRI), compiled by the U.S. Environmental Protection Agency (EPA) reports detailed information regarding the release of toxic chemicals by industrial and federal facilities for the U.S.[12] The collection of this information was mandated by the U.S. Emergency Planning and Community Right-to-Know Act of 1986 with the aim of helping communities plan for chemical emergencies. Federal facilities and industrial plants that (1) belong to a specific industry (manufacturing, mining, electric power generation and hazardous waste treatment), (2) employ more than 10 full-time equivalent employees and (3) use a TRI-listed chemical exceeding a certain threshold need to file TRI reports on the release of individual chemicals with the EPA on an annual basis.[13] I focus on chemicals, commonly reported and

[12]Due to the granularity of the data, the TRI is used extensively when examining determinants and impact of firm pollution (see among others: Greenstone (2003); Currie et al. (2015); Akey and Appel (2017); Konar and Cohen (2001)).

[13]The chemicals that need to be reported are considered to cause (a) cancer or other chronic human health effects, (b) significant adverse acute human health effects, or (c) significant adverse

listed in Section 313 of the Emergency Planning and Community Right-to-know Act (EPCRA) and restrict attention to chemicals designated by the EPA as high production volume chemicals, i.e. chemicals with an aggregate volume greater than than one million pounds per year. The TRI reports the emission of toxic chemicals at the facility level. Based on these chemical specific data at the facility level I construct the total amount of toxic emissions at the firm-chemical level to account for differences in the emission of individual chemicals across firms. Hence, I examine a firm's total release of a certain chemical in my main analysis. To mitigate the effect of outliers, I take the natural logarithm of the total release of a firm's chemical in a year.

Emission reduction activities In 1990 U.S. Congress passed the Pollution Prevention Act which focused attention on reducing the level of pollution, especially reducing pollution "at the source" by decreasing emissions of toxic chemicals at the generation of these toxic emissions.[14] In addition to information regarding the quantity of toxic emissions, facilities need to report activities to reduce toxic emissions and provide details regarding the methods they implement to prevent pollution. In particular, facilities report whether they engage in activities and reduce emissions belonging to one of the following seven EPA categories: (1) good operating practice, (2) process modification, (3) inventory control, (4) spill and leak prevention, (5) cleaning and degreasing, (6) surface preparation and finishing or (7) product modification.[15] An example of how a facility reduces toxic emissions at the source is the change in the production process of the aircraft manufacturer Boeing: Boeing reports in 2016 that it added valves to allow separation of contaminated trichloroethylene (TCE) from clean TCE, allowing longer

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environmental effects. Facilities need to self-report storage and release of more than 650 TRI-listed chemicals.

[14]As part of the Pollution Prevention Act of 1990 the EPA collects data and establishes disseminating information to reduce toxic emissions with the aim that "...pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and that disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner."

[15]A list of reported emission reduction activities for the two most common categories (process modification and good operating practices) is provided in Table A1 in the appendix.

use of the remaining TCE and reducing emissions.

3.1.2 Firm's long-term debt dependence

The TRI provides information on a facility's parent company and I use that information to identify publicly traded parent corporations. Publicly traded firms separately report their outstanding debt with remaining maturities of up to five years. Based on theories and empirical evidence that firms have a preference for a specific debt maturity profile (Greenwood et al., 2010; Choi et al., 2018) I use balance sheet information on the maturity structure of debt to measure a firm's long-term debt dependence. Specifically, I use information on the longest maturity provided and define a firm's long-term debt dependence by scaling its stock of debt due in more than six years by total assets:[16]

$$\text{Long-term debt dependence} = \frac{\text{Debt with a maturity of at least six years}}{\text{Total assets}} \tag{3}$$

I calculate the historical average of this ratio prior to 2011 and consider firms with a relative share of long-term corporate debt above the sample median to depend more on long-term debt financing.[17] In robustness checks I examine the sensitivity of my findings to different definitions of long-term debt dependence (see section 3.3).

3.1.3 Control variables

I account for differences across firms in their level of production by including the log of a firm's total sales as well as the sales growth (Levine et al., 2018). Moreover, I account for heterogeneity in a firm's debt structure and control for a firm's book-debt-ratio, i.e. its share of debt in total assets (Badoer and James, 2016). When examining the robustness of my findings at the more granular facility-chemical level I use the

[16] Scaling a firm's long-term debt by assets instead of liabilities accounts for the overall debt structure of a firm. I hypothesize that firms with a greater long-term debt dependence are more affected by the MEP, but this only applies if firms also use a considerable amount of debt financing.

[17] Foley-Fisher et al. (2016) find that balance sheet information on debt with remaining maturities above three years is prone to measurement error. By defining a dummy variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median partly mitigates the potential influence due to measurement error.

natural logarithm of a facility's total sales as well as the growth of sales, provided by the University of Wisconsin's Business Research Dynamic Research Consortium. Colla et al. (2013) find that firms use different forms of debt financing and I use information from the Capital IQ Capital Structure database to account for heterogeneity in a firm's debt structure. To capture a firm's overall exposure to capital debt markets, I control for a firm's share of total senior notes and bond debt in its debt in the current year. Moreover, I control for heterogeneity in a firm's exposure to interest rate risk due to shocks to capital markets and include a firm's share of fixed rate debt (as a percentage of total debt) in the current year. The micro-level TRI data allow me further to account for a chemical's relative use in the production process. Specifically, the TRI reports a production/activity ratio, which provides the change in output associated with the release of a chemical in a given year.[18] The TRI reports the *level* of total toxic emission while the production/activity ratio reports a *change* in the relative use of a chemical. To control for changes in the level of production, I use the information and construct an index representing the output/activity in year t. In particular, I consider a chemical's production/output in the year of the MEP (2011) to represent 100 percent. Using information on the reported production/activity ratio I construct an index of production/activity, where this index represents the level of production/activity associated with total releases of a chemical relative to the level of production in 2011.[19]

[18]The production/activity ratio gives for each chemical and year the change in the production output as it reports the number of goods manufactured in the reporting year in relation to goods manufactured in the previous year. Consider for instance the production of refrigerators: the production ratio for a chemical used in the manufacturing of refrigerators in year t is then given as $\frac{\text{Number of refrigerators produced}_t}{\text{Number of refrigerators produced}_{t-1}}$. If a chemical is used as part of an activity instead of the production of goods, facilities report an activity ratio, which provides the chemical's use in this year's activity in relation to the previous year's activity. Suppose a chemical is used to clean molds in a facility: the activity ratio for that chemical in year t is then $\frac{\text{Molds cleaned}_t}{\text{Molds cleaned}_{t-1}}$.

[19]I have also explored alternative ways to base this index, e.g. use the first year a chemical is reported as the base year. Chemicals for firms enter the sample period at different points in time and hence, the base year for the resulting index would be different for each firm-chemical pair. While the firm-chemical fixed effects would account for this heterogeneity, I decided to use a common base year (2011) when constructing this index as it is (a) easily comparable across firms and chemicals and (b) is 100 for all chemicals in 2011.

3.1.4 Sample construction and descriptive statistics

Sample construction The TRI provides information on the parent company's name and I use that information to hand-match facilities to their parent companies using information on the name of the parent company. Following Akey and Appel (2017) I exclude chemical-years with production ratios greater than 3 to limit the influence of errors in the data. Furthermore, consistent with earlier work examining firm's gap-filling behavior, I exclude financial firms (SIC Code 6000 - 6999) (Greenwood et al., 2010; Badoer and James, 2016; Foley-Fisher et al., 2016) from my analysis.

Descriptive statistics The final sample consists of 561 firms and 4,151 unique facilities. On average a firm reports the emission of 8 different chemicals every year. Table 2 reports descriptive statistics. The average firms' share of outstanding long-term debt amounts to about 12 percent of its assets, average annual sales are about 5 bn $ and about 29 percent of a firm's assets are debt-financed. Moreover, Table 3 shows that the majority of firm debt (about 70 percent) comes from bonds and senior notes. I also examine differences with respect to the observable characteristics between firms by their dependence on long-term debt financing in the appendix. Table A2 in the appendix presents differences in observable characteristics between firms, considered not dependent on long-term debt (left) and firms dependent on long-term debt financing (right). Table A2 shows that firms that rely more on long-term debt financing tend to use more debt financing overall and are also larger. Table A3 further shows the distribution of firms according to their long-term debt dependence by industry groups. Aside from firms involved in the Utilities sector, Table A3 suggests that a greater dependence on long-term debt financing is not specific to certain industries and every industry group has a similar share of firms more/less dependent on long-term debt financing.

3.1.5 Empirical model

I examine whether the MEP is followed by a reduction in toxic emissions at firms with a greater dependence on long-term debt financing and estimate the following regression model:

$$ln(y_{c,f,i,m,t}) = \beta LTD_f \cdot (\text{Post MEP})_t + \mathbf{X'}_{f,t}\gamma + \alpha_{c,f} + \alpha_t/\alpha_{c,t}/\alpha_{i,t}/\alpha_{m,t} + \epsilon_{c,f,i,m,t}, \quad (4)$$

where $ln(y_{c,f,i,m,t})$ is the natural logarithm of total releases of chemical c by firm f, involved in industry i, located in an Economic Area (EA) m in year t;[20] LTD_f is a dummy variable, taking on the value of one whether firm f depends more on long-term debt financing, and zero otherwise; Post MEP$_t$ is a dummy variable taking on the value of one after the MEP, i.e. 2011; $\mathbf{X'}_{f,t}$ are a set of firm control variables, $\alpha_{c,f}$ is a chemical-firm fixed effect and $\alpha_t/\alpha_{c,t}/\alpha_{i,t}/\alpha_{m,t}$ are year/chemical-year/industry-year/EA-year fixed effects.

The coefficient of interest is β, which captures the average relative difference in toxic emissions after the MEP for firms more dependent on long-term debt financing. Since the MEP particularly reduced financing costs for long-term debt, a negative estimate of β indicates that firms more exposed to the MEP reduce toxic emissions following the MEP.

3.2 The impact of the MEP on firms' toxic emissions

3.2.1 Average effect

Table 3 reports regression results from estimating regression model (4) where standard errors are robust and clustered at the firm-chemical level.[21] The negative and statistically significant coefficient in column (1) of Table 3 indicates that firms with a greater long-term debt dependence reduce toxic emissions more following the MEP. This also

[20] EAs are defined by the Bureau of Economic Analysis as relevant regional markets surrounding metropolitan areas, encompassing several counties and sometimes even spanning across state lines. These geographic units are considered to share social coherence and comprise a common regional market for labor and information (Dougal et al., 2015).

[21] Clustering standard errors at the firm-chemical level allows for correlation of toxic emissions of the same chemical at the same firm over time. My results are robust to clustering standard errors at the firm level (allowing correlation over time across chemicals within the same firm) or the chemical level (allowing correlation over time at the chemical level). Section 3.3 provides further information on this.

holds after accounting for differences across firms by including the natural logarithm of sales, the growth rate of sales and a firm's book-debt ratio (column 2). To account for differences in a firm's debt composition and interest rate sensitivity, I further include the share of bond debt as well as the share of fixed rate debt as control variables in column (3).[22] I continue to find that greater long-term debt dependence is followed by a reduction in toxic emissions.

Toxic emissions are reported for different chemicals and the unit of observation is a firm-chemical pair. Regression model (4) accounts for time-invariant differences at this level by including firm-chemical fixed effects and the coefficient β thus represents the average change in the release of a chemical within a firm. To evaluate the robustness of my finding, I augment the regression specification with further fixed effects. Specifically, I allow for variation in the emissions of chemicals over time by including chemical-year fixed effects in column (4). The earlier finding remains. Moreover, I include EA-year fixed effects to capture unobservable time-varying differences at the EA-level (column 5). Again, I find that the MEP is followed by fewer emissions for firms more dependent on long-term debt financing. In column (6) I further include industry-year fixed effects to allow for heterogeneity in the time-varying fixed effects at the industry-level. I continue to find that firms with a greater long-term debt dependence reduce toxic emissions more after the MEP.

Economic magnitudes from the reported coefficients displayed in Table 5 are also sizable. Using the coefficient from column 6 of Table 4, I calculate that firms with a greater long-term debt dependence reduce a chemical's total emissions by about 1.35 pounds. Since half of all firms (280) are considered to be affected by the MEP, the total reduction in toxic emissions per chemical over the post-MEP period accrues to about 378 pounds. The median annual release prior to the MEP was about 17,106 pounds and my results suggest that the MEP reduced median annual toxic emissions by about 2.2 percent per year.

[22]Information on these variables comes from the Capital IQ Capital structure database and is not available for all firm-years in my sample.

3.2.2 Toxic emissions over time

My earlier findings and evidence by Foley-Fisher et al. (2016) suggests that the MEP was a surprise to capital markets. The underlying assumption for the identification of the effect of the MEP on toxic emissions, is that there are no differences in the level (or change) of toxic emissions between firms more/less exposed to the MEP due to their long-term debt dependence.

To examine whether emissions for firms in these two groups developed differently over the sample period, I compute the average level of toxic emissions for each group and year and examine the evolution of aggregate toxic emissions for each set of firms over the sample period. If the MEP is a shock for firms with a greater dependence on long-term debt, then toxic emissions prior to the MEP should be similar between the two groups and differences in toxic emissions between these two groups should only emerge after 2011. Figure 4 plots the average annual toxic emissions for all firm-chemicals in the two groups where the solid line represents emissions for firms dependent on long-term debt financing. The pattern in Figure 3 shows that firms with a greater dependence on long-term debt on average release more toxic emissions than firms with less dependence on long-term debt financing. Focusing on the period prior to 2011, the pattern in Figure 3 shows that both set of firms reduce toxic emissions over the sample period and firms in the two groups follow similar paths regarding the release of toxic emissions up until 2011. Following 2011, however, firms with a greater dependence on long-term debt start reducing their toxic emissions for the following 4 years, while firms less dependent on long-term debt do not change their toxic emission behavior. This pattern suggests that 2011 marked a difference for firms with greater long-term debt dependence as toxic emissions of firms with a greater dependence on long-term debt decrease markedly following 2011.

3.2.3 Facility-level analysis

I use aggregate toxic emissions for a specific chemical at a firm to examine how the MEP affects firm-wide toxic emissions. The TRI provides the information at a more granular-level as it reports information on a chemical's release at the facility level. On average firms in my sample have about 6 different facilities and aggregating the information at the firm-chemical level does not capture heterogeneity in a firm's exposure, for instance, to geographical differences as facilities may be located at different parts of the country and are hence subject to different local unobservable effects.

To account for this, I re-examine the earlier relationship using the micro-level data and re-estimate regression model (4) at the facility-chemical level. The advantage of exploiting micro-level data at the facility-chemical level is that I can account for time-varying changes in the organizational structure of firms due to changes in the composition of facilities over time and capture differences in the level of production using information on the production/activity index. Since facilities are subject to state-regulators it is further important to account for differences in the geographic distribution of a firm's facilities. Moreover, since the TRI reports the production/activity ratio and thus provides information on the use of a certain chemical at a facility in the production process, I can control for a chemical's level of production/activity at the facility level by including the constructed production/activity index.

Table 4 reports regression results from estimating equation (4) at the facility-chemical level where standard errors are clustered at the facility-chemical level. Similar to before, I find that the coefficient on a firm's long-term debt dependence dummy and the MEP dummy is negative and statistically significant, showing that firms with a greater long-term debt dependence reduce toxic emissions more following the MEP. Furthermore, this result is robust to the inclusion of EA-year (column 2) and industry-year (column 3) fixed effects. Note, that the analysis is at the facility-chemical level and this set of fixed effects thus compares the differential effect of toxic emissions of the same chemical across facilities, located in the same area and involved in the same industry. Since I include the production/activity ratio index in the analysis, I also directly control for heterogeneity in the relative use of chemicals in a facility's production process. In columns (4) to (6) I examine the sensitivity of this result and replace the firm-level control variables with facility level control variables.[23] As before, I find that the MEP is followed by a reduction in toxic emissions for facilities, belonging to firms with a greater dependence on long-term debt financing. This indicates that my results are not due to the aggregation of toxic emissions at the firm-chemical level, but indicate an overall reduction of toxic emissions across a firm's facilities.

3.3 Robustness and sensitivity analyses

The results indicate that firms with a greater dependence on long-term debt reduce toxic emissions more. In the following I examine the robustness of this finding to different subsamples, econometric specifications and variable definitions.[24]

3.3.1 Heterogeneous debt structure

In the analysis I control for heterogeneity in a firm's debt structure by including the share of a firm's debt based on bonds and senior notes. My main measure of long-term debt dependence is based on a firm's total long-term debt and thus also includes other debt types. While on average about 70 percent of a firm's debt financing comes from bonds and senior notes, a specialization on other debt types (Colla et al., 2013) may still bias my estimate. Moreover, the MEP should primarily affect fixed rate long-term debt. While I control for a firm's share of fixed rate debt, a relationship between long-term debt dependence and the share of fixed rate debt may negatively bias my results. To examine the robustness of my findings to differences in a firm's debt structure, I interact my main measure of long-term debt dependence with (a) a dummy variable, taking on the value of one if more than half of a firm's debt financing in 2011 consists

[23]Unfortunately data for several facilites is missing and the sample size drops once I use these facility-level control variables.

[24]The regression model used in these robustness analyses employs all control variables and fixed effects as indicated.

of bonds and senior notes, and zero otherwise and (b) a dummy variable, taking on the value of one if more than half of a firm's debt in 2011 was fixed rate. If the structure of debt affects my results then the interaction of my main measure of long-term debt and these two dummy variables should be significantly different from zero. Table A4 in the appendix reports the results and I do not find that the coefficient on the interaction term is statistically significant, indicating that the effect of long-term debt on toxic emissions does not differ by a firm's debt type. This suggests that my findings are not driven by differences in a firm's exposure to the MEP due to its debt type or interest rate contract.

3.3.2 Survivorship bias: Firm-chemical exits

Some firm-chemical pairs drop from the sample due to, for instance, changes in the organizational structure of firms or changes in the reporting. While the firm-chemical fixed effects account for this selection, a systematic exiting of firms or firm-chemicals after the MEP may still bias the results. To examine whether a possible survivorship bias can explain the findings, I restrict attention to firm-chemical pairs that are always reported over the sample period. Using this subsample, I re-estimate the earlier regression model and report results in Panel A of Table A5. Similar to before I find that the MEP is followed by a reduction in toxic emissions for firms with a greater dependence on long-term debt. Moreover, the estimated coefficients in Table A5 are similar in magnitude to the coefficients obtained from the full sample (Table 3). Since I account for a possible survivorship bias due to the exiting of firm-chemicals from my sample here, this suggests that my findings are not due to a systematic exit of firm-chemicals from my analysis.

3.3.3 Common chemicals

The TRI reports information on the release of several hundred different toxic chemicals. Some chemicals are, however, not often emitted as part of the production process and hence not often reported. While the firm-chemical fixed effects account for heterogeneity in the prevalence of chemicals across firms, changes in the production after the MEP across firms, regions or time affects my results. To examine the robustness of my findings, I restrict attention to chemicals that are widely used over the sample period and focus on the 25 most commonly reported chemicals, i.e. the 25 most often reported chemicals in my sample. Panel B of Table A5 reports regression results obtained from using this subsample and similar to before I find that firms with a greater long-term debt dependence reduce toxic emissions more following the MEP. This suggests that my findings are not driven by changes in the emission of some (uncommon) chemicals.

3.3.4 Clustering of standard errors

In my main analysis I cluster standard errors at the firm-chemical level, assuming that toxic emissions for a chemical are correlated at the firm-level. To examine the robustness of my findings to different choices of clustering standard errors, I re-estimate regression model (4) and cluster standard errors at the (1) firm level and (2) chemical level.[25] Table A6 reports regression results from this analysis. Across the different choices of clustering standard errors, I find that the coefficient on the interaction between the MEP dummy and a firm's long-term debt dependence indicator is negative and significantly different from zero. This suggests that my significant finding is not a result of the choice of clustering standard errors in my main analysis.

3.3.5 Alternative independent variable

The main independent variable is an indicator whether a firm uses more long-term debt financing and the difference-in-differences estimation allows me to identify the effect of the MEP on toxic emissions due a firm's greater exposure to the MEP. To examine if my results are due to the definition of a firm's long-term debt dependence, I change the main variable in this analysis. Specifically, I first replace this indicator variable with

[25]Clustering standard errors at the firm-level assumes that toxic emissions across *all* chemicals are correlated over time within a firm. Clustering standard errors at the chemical level assumes autocorrelation of toxic emissions across all firms.

a continuous measure of a firm's long-term debt financing. Results from re-estimating regression model (4) with this continuous measure of long-term debt dependence are presented in columns (1) to (3) of Table A7 and similar to before, I find that firms with a greater dependence on long-term debt reduce toxic emissions more after the MEP.

To address the potential impact the financial crisis had on the structure of debt financing, I further use information up until 2007 when computing a firm's average long-term debt dependence (Foley-Fisher et al., 2016). Hence, I compute a firm's average share of debt with a maturity greater than 6 years, scaled by firm assets up until 2007 and consider firms above the sample median of this variable to depend more on long-term debt financing. Columns (4) to (6) of Table A6 reports regression results using this variable as the main independent variable and I continue to find that firms more dependent on long-term debt financing reduce toxic emissions more. This suggests that my findings are not due to the defintion of firms' long-term debt dependence.

3.3.6 Alternative dependent variable: Emissions per production

When examining toxic emissions at the facility-chemical level I account for differences in the use of chemicals in the production process by including the production/activity index. Regression results in Table 4 show that even conditioning on differences in production, I find that the MEP is followed by a reduction in toxic emissions for firms with a greater long-term debt dependence. In the following I modify the main dependent variable at the firm-chemical level and compute a measure of aggregate toxic emissions per unit produced/activity employed to directly incorporate changes in the level of production at the firm-chemical level. Specifically, I first compute the annual change of total toxic emissions at the facility-chemical level and scale it such that the value in the year of the MEP, ie. 2011, is equal to 100 percent. This "onsite-release index" in year t thus represents the amount of emissions in year t relative to the chemical's use in the year of the MEP. To construct a measure of toxic emissions per unit produced/activity employed, I scale this index then by the constructed production/activity index. The resulting "release-production/activity" index represents the relationship between toxic emissions to output/activity for a chemical relative to the year 2011. I then aggregate the "release-production/activity" index at the firm-chemical level and re-estimate regression model (4) and report regression results in Table A8. Similar to before I find that firms with a greater dependence on long-term debt reduce toxic emissions more. Since the dependent variable now directly accounts for changes in production, the negative and statistically significant coefficient in Table A8 implies that firms with a greater exposure to the MEP reduce their productivity-adjusted emission of toxic chemicals more. Thus, my earlier finding that aggregate toxic emissions fall is not due to the fact that firms with a greater long-term debt dependence reduce output following the MEP.

4 MEP and emission reduction activities

4.1 Firm's focus on reducing toxic emissions

I find that firms with a greater dependence on long-term debt financing reduce toxic emissions more following the MEP. Since the MEP reduced financing costs and spurred the issuing of long-term corporate debt (see Section 2.3) this pattern is consistent with the idea that the MEP reduced financing costs for long-term debt, allowing firms to increase their focus on reducing toxic emission. To study this, I use information on firms' reported emissions reduction activities and examine if firms with a greater dependence on long-term debt indeed increase their investments in emission reduction activities.

4.1.1 The impact of the MEP on firms' emission reduction activities

Using information from the TRI on the implementation of pollution control measures, I construct a dummy variable, taking on the value of one if a firm reports emission reduction activities for a chemical and year and estimate:

$$R_{c,f,i,m,t} = \beta LTD_f \cdot (\text{Post MEP})_t + \mathbf{X'}_{f,t}\gamma + \alpha_{c,f} + \alpha_{c,t}/\alpha_{i,t}/\alpha_{m,t} + \epsilon_{c,f,i,t}, \tag{5}$$

where $R_{c,f,i,m,t}$ is a dummy variable, taking on the value of one whether firm f, involved in industry i, located in EA m reports emission reduction activities for chemical c, or zero otherwise.

4.1.2 Results

Table 5 presents regression results from estimating regression model (5). The positive and statistically significant coefficient on the interaction of a firm's long-term debt dependence dummy variable and the MEP dummy shows that firms with a greater dependence on long-term debt financing are more likely to invest in emission reduction activities following the MEP. This finding is robust to the inclusion of firm level control variables (columns 2 and 3) as well as additional fixed effects and I continue to find a positive and statistically significant effect of the MEP once I include EA-year (column 4), industry-year (column 5) or both fixed effects simultaneously (column 6).

Since the dependent variable in Table 5 is a dummy variable, the coefficients represent changes in the likelihood to enact emission reduction activities. Considering the coefficient from column (5), for instance, I compute that firms with a greater dependence on long-term debt financing increase their likelihood of investing in emission reduction activities by about 2.5 percentage points more. The unconditional average probability of emission reduction activities is 14.6 percent and thus, firms with a greater dependence on long-term debt financing are almost 20 percent more likely to invest in emission reduction activities following the MEP.

4.2 Capital intensity of emission reduction activities

As mentioned earlier, firms can choose between different emission reduction activities.[26] Since the MEP reduced financing conditions for long-term debt, firms that benefit more from this reduction in financing costs may also be more likely to implement capital-intensive emission reduction activities.

4.2.1 Cost of emission reduction activities

While the TRI reports specific information about the type of emission reduction activities, detailed information regarding the capital intensity of individual emission reduction activities is not readily available. To gather information on industries' costs regarding the protection of the environment, the U.S. Census Bureau conducts the Pollution Abatement Costs and Expenditures (PACE) survey. This survey is based on facility-level data regarding capital expenditures and operating costs of pollution abatement investments for industries belonging to the manufacturing sector.[27] The EPA then publishes aggregate information at the industry-level on the costs of pollution prevention measures.

To rank the reported seven emission reduction categories with respect to capital intensity, I start by using the 2005 TRI data and gather information on facilities' implementation of emission reduction activities. Based on the seven emission reduction categories, I compute for each industry the average share of reported emission reduction activities within that category.[28] The PACE survey reports total capital expenditures for different pollution prevention and treatment methods of toxic chemicals for 20 industries based on three digit NAICS-codes. I use the reported information on capital expenditures for pollution prevention and divide this by the total of all emission reduction activities at the industry level. This serves as an estimate for the average

[26]See Section 3.1.1 for a discussion regarding firms' choices between different measures to reduce toxic emissions at the source.

[27]While the survey was envisioned to be conducted regularly, the most recent survey was conducted in 2005.

[28]I compute the total number of emission reduction activities for each three digit NACIS-code and then calculate the relative share of each category.

capital expenditure per emission reduction activity category at the industry level. I then compute the rank correlation between the average capital expenditure per emission reduction activity and the prevalence of different emission reduction categories at the industry level to establish a ranking of emission reduction activities by capital intensity.[29]

Table 6 reports pairwise spearman rank correlation coefficients between the aforementioned seven emission reduction categories and the average capital expenditures at the industry level. The correlation coefficients indicate that industries with a higher share of emission reduction activities based on (1) processes modification, (2) good operating practices and (3) spill and leak prevention tend to exhibit higher average capital expenditures. This suggests that these three emission reduction activities are more capital intensive.[30] Since the MEP reduced debt financing costs I expect that firms that benefit more from this are also more likely to implement capital-intensive emission reduction activities.

4.2.2 Empirical analysis and results

To distinguish between emission reduction activities I construct two dummy variables, depending on whether a reported emission reduction activity is capital-intensive or not. Thus, I construct a dummy variable, taking on the value of one whether the reported emission reduction activity belongs to one of the aforementioned three activities, considered to be capital intensive ("Emission reduction activity (capital-intensive)"). Similarly, I define a dummy variable, taking on the value of one, whether the reported emission reduction activity is not considered to be capital-intensive according to Table 6 ("Emission reduction activity (other)"). Using these two dummy variables as dependent variables, I then re-estimate regression model (5) separately to assess if the effect of a firm's greater dependence on long-term debt differs by anemission reduction

[29]To limit the influence of outliers, I calculate rank correlations and examine whether a specific emission reduction activity is associated with a higher per unit cost of emission reduction.

[30]Especially, process modification investments and spill and leak prevention measures display a high and statistically significant rank correlation with per unit capital expenditures across industries.

activity's capital-intensity.

4.2.3 Capital intensity of emission reduction activities

Table 7 reports regression results from this analysis. I find that firms with a greater dependence on long-term debt financing only increase the likelihood of implementing capital intensive emission reduction activities (columns 1 - 3). The negative (and mostly) statistically significant coefficient when examining other emission reduction activities (columns 4 - 6) shows that firms that are more affected by the MEP reduce their focus on emission reduction activities that are not capital intensive. Since I find that overall firms affected by the MEP increase their emission reduction activity (Table 6), the pattern in Table 7 suggests that the increase in capital intensive emission reduction activities is responsible for this overall finding. This is consistent with the idea that the reduction in financing costs due to the MEP allows firms to increase their investment of capital intensive emission reduction activities, triggering a reduction in toxic emissions.

5 Incentives to implement emission reduction activities: regulatory intervention

5.1 Regulatory scrutiny and emission reduction

The findings in Table 5 and 7 show that firms that are more exposed to the MEP invest more in emission reduction activities and particularly shift attention to capital-intensive emission reduction activities. To examine this further, I now focus on firms, subject to greater regulatory scrutiny and hence a higher incentive to implement emission reduction activities.

5.1.1 Enforcement actions

The EPA enforces environmental laws and typically works with state regulators to ensure that firms and facilities comply with environmental regulation (the Clean Air Act, the Resource Conservation and Recovery Act and the Safe Drinking Water Act). As part of their enforcement tools, the EPA and state regulators can take criminal or civil enforcement actions against facilities that violate environmental laws.[31] The EPA provides information regarding their enforcement actions and facilities' compliance with regulatory standards in their Integrated Compliance Information System (ICIS), which tracks formal administrative and judicial enforcement actions. These data report for every enforcement case detailed information regarding the date and type of violation as well as whether the case was enforced using administrative or judicial activities. Via an online-tool the EPA also provides detailed information regarding the specific violation of environmental regulations.[32]

Earlier work finds that enforcement actions and monetary penalties due to environmental noncompliance decrease firm value: using a sample of publicy traded firms in the U.S. Karpoff et al. (2005) and Badrinath and Bolster (1996) find that legal penalties due to the violation of environmental laws significantly reduce firm value. Examining the link between environmental performance and firm value, Konar and Cohen (2001) finds that a firm's bad environmental performance is associated with a lower value of intangibles, indicating that the stock market values a firm's environmental performance. In addition to monetary penalties, the enactment of enforcement actions against firms may also trigger reactions by communities, that motivate firms

[31] Civil enforcement actions can be distinguished into non-judicial enforcement actions and judicial actions. Non-judicial enforcement actions are administrative actions taken by the EPA or a state regulator under its own authority. These actions take the form of a notice of violation or an order directing an individual, a business, or other entity to take action to come into compliance. Civil judicial actions are formal lawsuits, filed by the U.S. Department of Justice on behalf of the EPA or by a state's attorney general on behalf of the state. Criminal enforcement actions are imposed by a judge at the sentencing and are usually reserved for the most serious violations. The EPA provides detailed information regarding ongoing enforcement actions, guidelines and legal background on its website (http://www.epa.gov/enforcement).

[32] This is made available via the EPA's Enforcement and Compliance History Online System (http://echo.epa.gov).

to implement pollution abatement investments (Pargal and Wheeler, 1996). Furthermore, enforcement actions are also followed by an increase in oversight and regulatory scrutiny (Evans and Stafford, 2018).

Regulatory fines thus represent a shock to firms as they reduce value or hurt a firm's reputation. Thus, I hypothesize that firms that were subject to an enforcement action before the MEP are focusing more on implementing emission reduction activities to come into compliance with environmental regulation.[33]

I collect information from the ICIS and identify whether a firm was fined prior to the MEP.[34] I then re-estimate the earlier regression model (5) and examine whether a firm's emission and its implementation in emission reduction following the MEP differ depending on whether the firm was fined prior to the MEP.

5.1.2 Results

Regression results from estimating regression model (5) for the two subset of firms are reported in Table 8. I separately examine the differential impact of a firm's long-term debt dependence following the MEP on capital-intensive (Panel A) and other (Panel B) emission reduction activities. The sample in columns (1) to (3) comprises firms that were not fined prior to the MEP, while the sample in columns (4) to (6) examines firms subject to a regulatory fine prior to the MEP.

The pattern in Table 8 shows that particularly firms under greater regulatory scrutiny are more likely to invest in capital-intensive emission reduction activities following the MEP. The positive and statistically significant coefficient shows that greater regulatory scrutiny shifts firms' focus on implementing pollution abatement measures when financing costs decrease (due to the MEP). Since these firms have a greater incentive to implement emission reduction activities to come into compliance, the pattern

[33]Moreover, reporting the implementation of measures to reduce toxic emissions may be an optimal response due to a communities' heightened interest in a firm's emission behavior (Pargal and Wheeler, 1996) or due to (state) regulators' increased oversight activity (Evans and Stafford, 2018).

[34]In particular I focus on regulatory intervention in 2010, i.e. the year before the MEP. About 35 percent of all firms in my sample were fined in 2010.

in Table 8 suggests that the reduction in financing costs allows firms to implement capital-intensive emission reduction measures and reduce toxic emissions.

5.2 Emission reduction activities and regulatory compliance

5.2.1 Persistence of regulatory intervention and emission reduction activities

The findings are consistent with the idea that a reduction in financing costs allows firms to invest in capital-intensive activities to reduce toxic emissions to address deficiencies that may have triggered fines. Investments in emission reduction activities are especially worthwhile if they indeed help firms to come into compliance with environmental regulation again. To examine this, I use information on reported fines and examine if a firm's investment in emission reduction activities helps the firm to regain regulatory compliance as it reduces the likelihood of being fined:

$$\begin{aligned} F_{f,i,m,t} = {} & \beta_1 F_{f,i,m,t-1} + \beta_2 R_{f,i,m,t} + \beta_3 F_{f,i,m,t-1} \cdot R_{f,i,m,t} + \\ & + \mathbf{X'}_{f,t}\gamma + \alpha_f + \alpha_t/\alpha_{i,t}/\alpha_{m,t} + \epsilon_{f,i,m,t}, \end{aligned} \tag{6}$$

where $F_{f,i,m,t}$ is a dummy variable taking on the value of one whether firm f was fined in year t, and zero otherwise, $R_{f,i,m,t}$ is a dummy variable if firm f reports emission reduction investments in year t, and zero otherwise. The coefficient of interest is β_3 which represents whether the implementation of emission reduction activities in year t affects a firm's likelihood of coming into compliance with environmental regulation and hence are not fined.

5.2.2 Results

Table 9 reports regression results from estimating model (6) where standard errors are clustered at the firm-level. All regressions use firm control variables and fixed effects as indicated. The positive and statistically significant coefficient on the lagged fine dummy variable shows that fines are persistent and it takes time for firms to regain compliance.

The negative and statistically significant estimate of β_3 further shows that firms will improve their ability to come into compliance after being fined if they invest in emission reduction activities. This finding is robust to the inclusion of additional fixed effects (columns 1 - 3). Examine this further and analyzing whether capital-intensive or other emission reduction activities have a different impact on the persistence of noncompliance with environmental regulation yields interesting results. Specifically, I re-estimate regression model (6) where I distinguish whether an emission reduction activity is considered to be capital intensive or not. The negative and statistically significant of β_3 when examining the role on capital-intensive emission reduction activities in columns (4) to (6) shows that these capital-intensive emission reduction activities have a positive and significant impact on a firm's chance of reducing the likelihood of being fined again. The insignificant coefficient on β_3 when investigating the ability of other emission reduction activities, however, shows that other emission control measures do not significantly affect a firm's likelihood of coming into compliance (columns 7 - 9).

This finding is consistent with the idea that the implementation of emission reduction activities helps firms to address issues that result in noncompliance with environmental regulation. Since regulatory fines reduce firm value (Karpoff et al., 2005) firms have an incentive to mitigate the non-compliance with environmental regulation as soon as possible. The pattern in able 9 suggests that capital-intensive emission reduction activities seem to be better at helping firms to become compliant with regulation. Thus firms may prefer to implement capital-intensive emission reduction activities once financing costs decrease.

6 Conclusion

In this paper, I examine how the Federal Reserve's Maturity Extension Program (MEP) affects a corporation's financing conditions and its emission of toxic chemicals. The MEP decreased the supply of long-term U.S. Treasury securities and I find that the MEP was followed by a reduction in the U.S. Treasury yield spread, a reduction in financing costs for long-term corporate debt and gap-filling behavior of firms.

Exploiting micro-level data regarding the emission of toxic chemicals for U.S. firms that the facility level, I find that firms with a greater dependence on long-term debt reduce toxic emissions more following the MEP. This effect is robust to the inclusion of several control variables as well as fixed effects to account for unobservable heterogeneity across firms, industries and time. Examining the dynamic pattern, I find that firms with a greater dependence on long-term debt did not behave differently in their release of toxic emissions prior to the MEP, but start reducing the release of poisonous chemicals after the announcement of the MEP. Further robustness tests confirm my finding and show that the result is not due to other influences, such as changes in the composition of firms or variable definitions.

Since firms also report whether they invest in pollution prevention procedures to reduce toxic emissions at the source I examine if the MEP is followed by a boost in pollution prevention activities. Moreover, since the MEP improved financing conditions I expect that affected firms specifically focus their efforts on capital intensive emission reduction activities. To examine this, I first use information on the capital-intensity of emission reduction activities at the industry level and classify reported emission reduction activities by their capital-intensity. I find that firms indeed are more likely to invest in capital intensive activities to reduce toxic emissions. This is consistent with the idea that the reduction in long-term financing costs allows firms to reduce toxic emissions as it allows them to implement (capital-intensive) emission reduction activities.

Finally, I explore whether the effect differs whether the firm is under greater regulatory scrutiny. Using information on whether a firm was fined due to noncompliance with environmental regulation, I find that particularly firms that were fined prior to the MEP implement capital-intensive emission reduction activities. Exploring the link between emission reduction activities and the likelihood of regaining compliance with environmental regulation, I find that the implementation of capital-intensive pollution prevention methods significantly increases a firm's likelihood of becoming compliant with environmental regulation. Overall the findings are consistent with the idea that the MEP reduced financing conditions for long-term corporate debt, boosting firms' investment in capital-intensive emission reduction activities which was followed by a reduction in toxic emissions.

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Tables

Table 1: Maturity Extension Program

This table presents information on the volume of the Maturity Extension Proram (MEP) by different maturity sectors as well as the amount of outstanding Treasury securities as of September 2011. The total volume of the MEP is set at 400 bn $. Data regarding the allocation of this amount across different maturity sectors is provided by the Federal Reserve Bank of New York.

	Remaining Maturity			
	6 – 8 Years	8 – 10 Years	10 – 20 Years	20 – 30 Years
Percentage of total MEP amount on maturity bucket	32%	32%	4%	29%
Amount of MEP [$ bn]	128	128	16	116
Amount oustanding [$ bn]	837	617	238	596

Table 2: Summary statistics

This table presents descriptive statistics of variables, used in the analysis. 'Total release' is the aggreagte total release of toxic chemicals at the firm-level; 'Long-term debt dependence' is the average of total debt with a maturity of more than six years, scaled by total assets using information up until 2011; 'Share of bond debt (%)' is the percentage of a firm's senior bond and notes debt in its total debt; 'Share of fixed rate debt (%)' is the percentage of a firm's fixed rate debt in its total debt' 'Book-debt-ratio' is a firm's share of total debt, scaled by assets, 'ln(Sales)' is the natural logarithm of total sales, 'Sales Growth' is the annual growth rate of sales, 'Production ratio index' is the level of output in that year in terms of output in 2011, 'Emission reduction activity' is a dummy variable, taking on the value of one whether the facility/firm reports activities to reduce emissions for a chemical and year, 'Emission reduction activity (capital intensive)/'Emission reduction activity (other)' is an indicator taking on the value of one whether the emission reduction activity is capital-intensive or not.

	N	Mean	St.Dev.	Min	Max
Firm Level					
Long-term debt dependence	561	0.12	0.11	0.00	0.64
Share of bond debt (%)	3,810	68.98	29.95	0	100
Share of fixed rate debt (%)	4,059	69.19	30.33	0	100
Book-debt-ratio	5,082	0.285	0.182	0	1
ln(Sales)	5,080	7.891	1.613	-3.381	12.98
Sales Growth	5,027	0.039	0.214	-1.646	2.003
Firm-Chemical Level					
Total release (thousand pounds)	40,782	126.28	1220.94	0	77,070
Emission reduction activity	40,782	0.15	0.35	0	1
Emission reduction activity (Capital intensive)	40,782	0.11	0.32	0	1
Emission reduction activity (Other)	40,782	0.03	0.18	0	1
Facility Level					
Total release (thousand pounds)	101,414	48.97	328.32	0	18,002
Production ratio index	101,414	0.99	0.36	0	3.11
ln(Sales)	53,680	10.69	2.14	2.64	16.46
Sales Growth	50,096	0.13	0.75	-0.82	8.81

Table 3: Maturity Extension Program, long-term debt dependence and toxic emissions

This table reports results from an OLS regression at the firm-chemical-level. The dependent variable is the natural logarithm of total emissions for a chemical at the firm. The sample period ranges from 2006 to 2016. '=1 if firm dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011.All regressions include controls and fixed effects as indicated. Standard errors are clustered at the firm-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
(=1 if firm dependent on long-term debt financing) * MEP	-0.152***	-0.155***	-0.202***	-0.202***	-0.159**	-0.319***
	(0.052)	(0.053)	(0.059)	(0.061)	(0.067)	(0.081)
ln(Sales)		0.054	-0.019	-0.024	-0.060	-0.153*
		(0.055)	(0.074)	(0.075)	(0.076)	(0.091)
Growth of sales		-0.012	0.072	0.050	0.130*	0.282***
		(0.059)	(0.071)	(0.073)	(0.079)	(0.093)
Book-debt-ratio		-0.101	-0.212	-0.230	-0.166	-0.027
		(0.144)	(0.187)	(0.187)	(0.192)	(0.240)
Share of bond debt			-0.196**	-0.208**	-0.245***	-0.094
			(0.097)	(0.092)	(0.093)	(0.113)
Share of fixed term debt			0.130	0.140*	0.227***	0.070
			(0.083)	(0.081)	(0.083)	(0.100)
Year fixed effect	x	x	x			
Firm-chemical fixed effect	x	x	x	x	x	x
Chemical-year fixed effect				x	x	x
EA-year fixed effect					x	x
Industry-year fixed effect						x
Observations	40,782	40,232	34,002	33,676	33,672	33,614
R-squared	0.892	0.892	0.894	0.902	0.904	0.909

Table 4: Maturity Extension Program, long-term debt dependence and toxic emissions - facility-level

This table reports results from an OLS regression at the facility-chemical-level. The dependent variable is the natural logarithm of total emissions for a chemical at the facility. The sample period ranges from 2006 to 2016. '=1 if parent company dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a facility's parent company's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011. 'Parent control variables' are control variables measured at the parent company;'Facility controls' are control variables, measured at the facility level. All regressions include controls and fixed effects as indicated. Standard errors are clustered at the facility-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
(=1 if parent company dependent on long-term debt financing) * MEP	-0.144***	-0.157***	-0.117***	-0.207***	-0.190***	-0.175***
	(0.026)	(0.028)	(0.030)	(0.035)	(0.039)	(0.040)
Production ratio index	0.511***	0.517***	0.521***	0.583***	0.621***	0.619***
	(0.024)	(0.025)	(0.025)	(0.033)	(0.034)	(0.034)
Parent control variables						
ln(Sales)	-0.059*	-0.068*	-0.061			
	(0.031)	(0.037)	(0.039)			
Growth of sales	-0.057	-0.070*	-0.083**			
	(0.037)	(0.039)	(0.042)			
Book-debt-ratio	-0.208**	-0.217**	-0.228**			
	(0.095)	(0.103)	(0.110)			
Share of bond debt	0.088**	0.090*	0.018			
	(0.044)	(0.050)	(0.052)			
Share of fixed rate debt	0.000	0.000	0.001			
	(0.000)	(0.000)	(0.000)			
Facility controls						
ln(Sales)				0.026*	0.019	0.022
				(0.013)	(0.016)	(0.016)
Growth of sales				0.004	0.007	0.008
				(0.006)	(0.007)	(0.007)
Facility-chemical fixed effect	x	x	x	x	x	x
Chemical-year fixed effect	x	x	x	x	x	x
EA-year fixed effect		x	x		x	x
Industry-year fixed effect			x			x
Observations	90,197	87,580	87,576	49,924	48,978	48,974
R-squared	0.933	0.936	0.937	0.935	0.940	0.940

Table 5: Maturity Extension Program, long-term debt dependence and emission reduction activities

This table reports results from an OLS regression at the firm-chemical-level. The dependent variable is a dummy variable taking on the value of one whether a firm reports emission reduction activities for a certain chemical and year, or zero otherwise. The sample period ranges from 2006 to 2016. '=1 if firm dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011.All regressions include controls and fixed effects as indicated. Standard errors are clustered at the firm-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
(=1 if firm dependent on long-term debt financing) * MEP	1.487	1.162	2.261**	2.442**	3.183**	2.896**
	(0.933)	(0.948)	(1.048)	(1.078)	(1.349)	(1.429)
ln(Sales)		3.545***	2.969***	2.718***	3.133***	2.100*
		(0.726)	(0.864)	(0.901)	(1.192)	(1.188)
Growth of sales		-0.840	-0.840	-0.841	-3.091**	-2.003
		(0.882)	(1.032)	(1.073)	(1.418)	(1.433)
Book-debt-ratio		-7.022***	-3.621	-3.426	-5.634	-9.582**
		(2.417)	(2.909)	(3.048)	(4.092)	(4.139)
Share of bond debt			-2.245	-2.598	-3.923**	-3.654*
			(1.519)	(1.598)	(1.990)	(2.059)
Share of fixed rate debt			3.117**	3.048**	4.646***	3.269*
			(1.401)	(1.475)	(1.797)	(1.860)
Year fixed effect	x	x	x			
Firm-chemical fixed effect	x	x	x	x	x	x
Chemical-year fixed effect				x	x	x
EA-year fixed effect					x	x
Industry-year fixed effect						x
Observations	40,782	40,232	34,002	33,676	33,618	33,614
R-squared	0.555	0.556	0.570	0.591	0.617	0.623

Table 6: Capital intensity of emission reduction activities - Correlation

This table reports the pairwise Spearman rank correlation at the industry (3digit NAICS) level. Capital expenditure per emission reduction is the total reported emission reduction capital expenditure at the industry level, scaled by an industry's total emission reduction activities. Emission share of process modification/good operating practices/raw material modification/cleaning and decreasing/surface preparation/product modification/spill and leak prevention is the relative share of each of the aforementioned emission reduction categories in overall emission reduction activities. *, **, *** mean significance at ten, five, and one percent, respectively.

			Emission reduction share of ...						
		Capital expenditure per emission reduction	... process modification	... good operating practices	... spill and leak prevention	... raw material modification	... cleaning and degreasing	... surface preparation	... product mofidifcation
	Capital expenditure per emission reduction	1.00							
Emission reduction share of ...	... process modification	0.44**	1.00						
	... good operating practices	0.30	0.02	1.00					
	... spill and leak prevention	0.63***	0.44*	0.18	1.00				
	... raw material modification	-0.73***	-0.37	-0.58***	-0.53	1.00			
	... cleaning and degreasing	-0.22	-0.03	0.16	0.04	-0.09	1.00		
	... surface preparation	-0.39*	-0.48**	-0.08	-0.53**	0.21	0.34	1.00	
	... product mofidifcation	-0.03	-0.25	0.07	-0.13	0.18	-0.02	0.26	1.00

Table 7: Maturity Extension Program, long-term debt dependence and emission reduction activities - Capital intensive and other emission reduction activities

This table reports results from an OLS regression at the firm-chemical-level. The dependent variable in columns (1) to (3) is a dummy variable taking on the value of one whether a firm reports capital-intensive emission reduction activities for a chemical in a year; the dependent variable in columns (4) to (6) is a dummy variable taking on the value of one whether the emission reduction activity is not capital intensive. The sample period ranges from 2006 to 2016.' =1 if firm dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011. All regressions include controls and fixed effects as indicated. Standard errors are clustered at the firm-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Emission reduction activities (Capital intensive)			Emission reduction activities (Other)		
(=1 if firm dependent on long-term debt financing) * MEP	3.773***	4.035***	4.677***	-1.331**	-0.852	-1.781**
	(0.977)	(1.225)	(1.323)	(0.568)	(0.713)	(0.746)
Control variables	x	x	x	x	x	x
Firm-chemical fixed effect	x	x	x	x	x	x
Chemical-year fixed effect	x	x	x	x	x	x
EA-year fixed effect		x	x		x	x
Industry-year fixed effect			x			x
Observations	33,676	33,618	33,614	33,676	33,618	33,614
R-squared	0.562	0.591	0.597	0.402	0.437	0.449

Table 8: Maturity Extension Program, long-term debt dependence and pollution abatement - Regulatory intervention

This table reports results from an OLS regression at the firm-chemical-level. The sample in columns (1) - (3) consists of firms without fines in 2010, while the sample in columns (4) to (6) consists of firms subject to a regulatory fine in 2010. The dependent variable in Panel A is a dummy variable taking on the value of one whether the emission reduction activity is capital intensive, or zero otherwise; the dependent variable in Panel C is a dummy variable taking on the value of one whether the emission reduction activity is not capital intensive, or zero otherwise. The sample period ranges from 2006 to 2016. '=1 if firm dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011. All regressions include controls and fixed effects as indicated. Standard errors are clustered at the firm-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Subsamples:		Not fined in 2010			Fined in 2010	
			Panel A: Emission reduction activity (capital intensive)			
(=1 if firm dependent on long-term debt financing) * MEP	3.580*	3.350	3.620	3.333***	3.749**	4.130**
	(2.026)	(2.593)	(2.562)	(1.110)	(1.494)	(1.618)
			Panel B: Emission reduction activity (other)			
(=1 if firm dependent on long-term debt financing) * MEP	-0.570	-1.441	-1.107	-1.406**	-1.274	-3.684***
	(0.998)	(1.299)	(1.377)	(0.695)	(1.025)	(0.987)
Control variables	x	x	x	x	x	x
Facility-chemical fixed effect	x	x	x	x	x	x
Chemical-year fixed effect	x	x	x	x	x	x
EA-year fixed effect		x	x		x	x
Industry-year fixed effect			x			x
Observations	10,520	10,459	10,459	22,428	22,403	22,399

Table 9: Emission reduction activities and compliance with regulation

This table reports results from an OLS regression at the firm-level. The dependent variable is a dummy variable, taking on the value of one whether the firm is subject to a fine in that year. 'Fine(lag)' is a dummy variable, taking on the value of one whether the firm was fined in the previous year, or zero otherwise. 'Emission reduction activity' is a dummy variable taking on the value of one whether the firm invest in emission reduction in year t, or zero otherwise. The employed emission reduction dummy in Panel A considers all emission reduction activities, the emission reduction activity variable in Panel B only considers capital intensive emission reduction activities, the emission reduction activity variable in Panel C considers all other emission reduction activities. The sample period ranges from 2006 to 2016. All regressions include controls and fixed effects as indicated. Standard errors are clustered at the firm level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Panel A: Emission reduction activity			Panel B: Emission reduction activity (capital intensive)			Panel C: Emission reduction activity (other)		
Fine (lag)	0.555***	0.549***	0.544***	0.548***	0.541***	0.536***	0.516***	0.503***	0.504***
	(0.018)	(0.021)	(0.022)	(0.017)	(0.020)	(0.021)	(0.016)	(0.019)	(0.019)
Emission reduction activity * Fine(lag)	-0.099***	-0.106***	-0.096***	-0.097***	-0.104***	-0.092***	-0.030	-0.025	-0.032
	(0.022)	(0.026)	(0.027)	(0.023)	(0.027)	(0.028)	(0.029)	(0.039)	(0.039)
Emission reduction activity	0.038**	0.040**	0.041**	0.036**	0.034*	0.033*	0.015	0.024	0.027
	(0.016)	(0.017)	(0.017)	(0.018)	(0.019)	(0.019)	(0.026)	(0.028)	(0.028)
Controls	x	x	x	x	x	x	x	x	x
Firm fixed effect	x	x	x	x	x	x	x	x	x
Year fixed effect	x	x	x	x	x	x	x	x	x
EA-year fixed effect		x	x		x	x		x	x
Industry-year fixed effect			x			x			x
Observations	5,244	4,907	4,898	5,244	4,907	4,898	5,244	4,907	4,898
R-squared	0.598	0.652	0.661	0.598	0.652	0.661	0.597	0.651	0.660

Figures

Figure 1: Long-term and short-term Treasury yields around MEP announcement

This figure plots the dynamic pattern of the average yield spread between long and short-term U.S. Treasuryv securities around the 21st September 2011. The average yield spread for is the difference between the daily yield of Treasury securities with a remaining maturity of at least 7 years (long-term) and Treasury securities with a remaining maturity of less than 5 years.

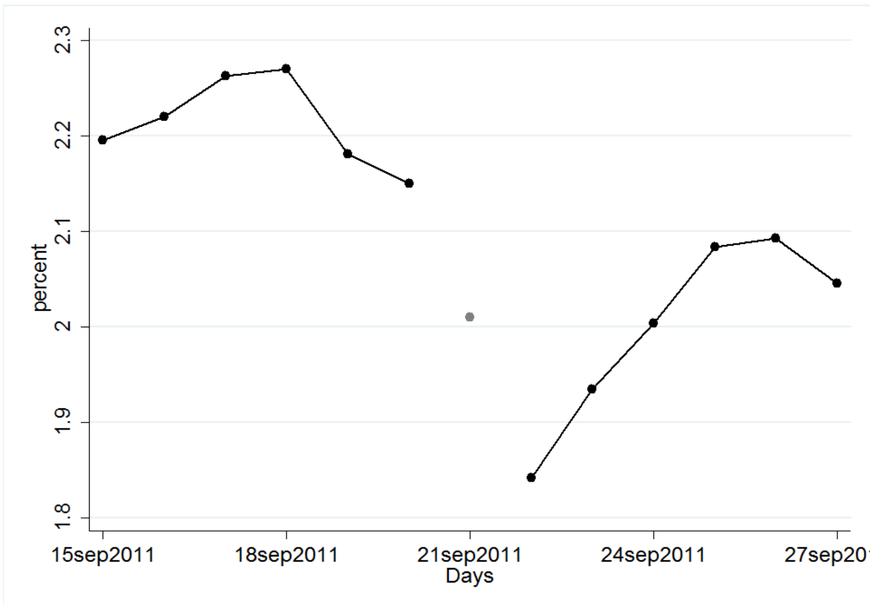
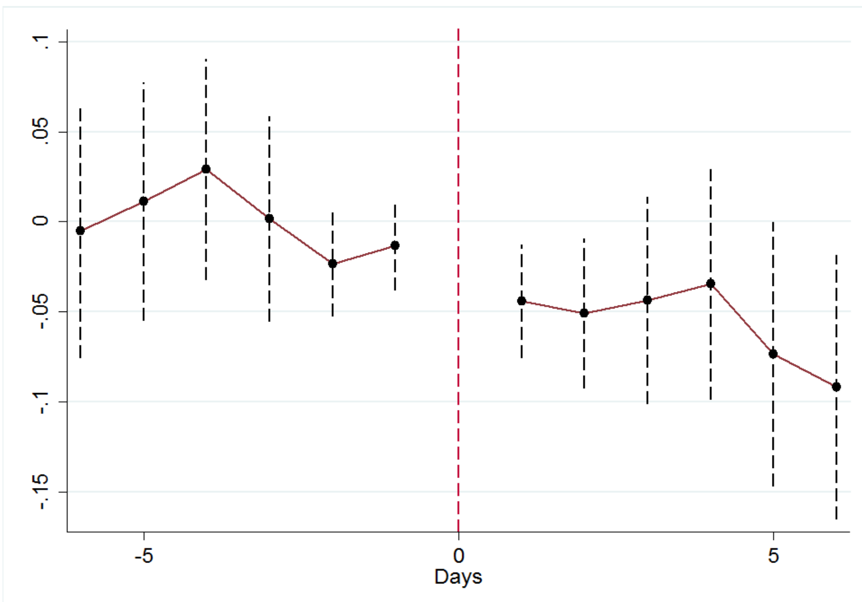


Figure 2: MEP announcement and corporate debt markets

This figure plots changes in U.S. corporate debt markets around the MEP announcement.bond yields around the MEP announcement date. Panel A reports estimated coefficients from an OLS regression using information on daily bond yield spread for 6 trading days before and after the MEP anouncement date (September 21, 2011). The coefficients are obtained from a regression of daily bond yields on a dummy variable, taking on the value of one whether the day is t days before/after the announcement of the MEP. The regression includes bond and year fixed effects. The announcement day is dropped due to collinearity and the coefficients are relative to the announcement date. The dotted bars represent the 95 percent confidence interval. Panel B plots estimated marginal effects from a logit regression using information on bond issuances for 5 quarters, cnetered on the MEP anouncement date (September 21, 2011). The coefficients are obtained from a logit regression of a dummy variable, taking on the value of one whether bond b issued in a time window has a maturity of more than six years, or zero otherwise. The regression includes the term structure, the average BAA spread, the log of face value. The quarters are centered around the announcement day is dropped due to collinearity and the coefficients are relative to the time period around the announcement date. The dotted bars represent the 95 percent confidence interval.

Panel A: Daily yield spread (long-term - short term corporate bonds)



Panel B: Long-term bond issuances

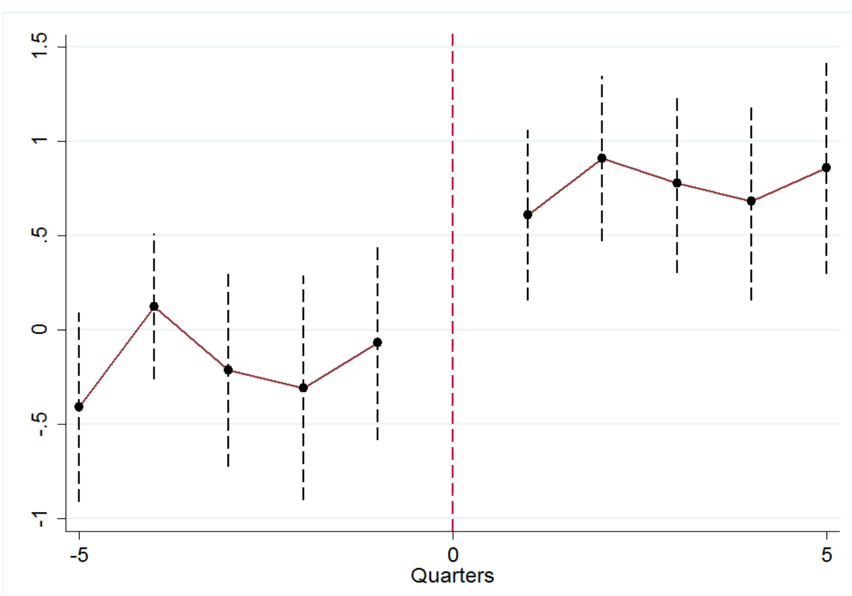
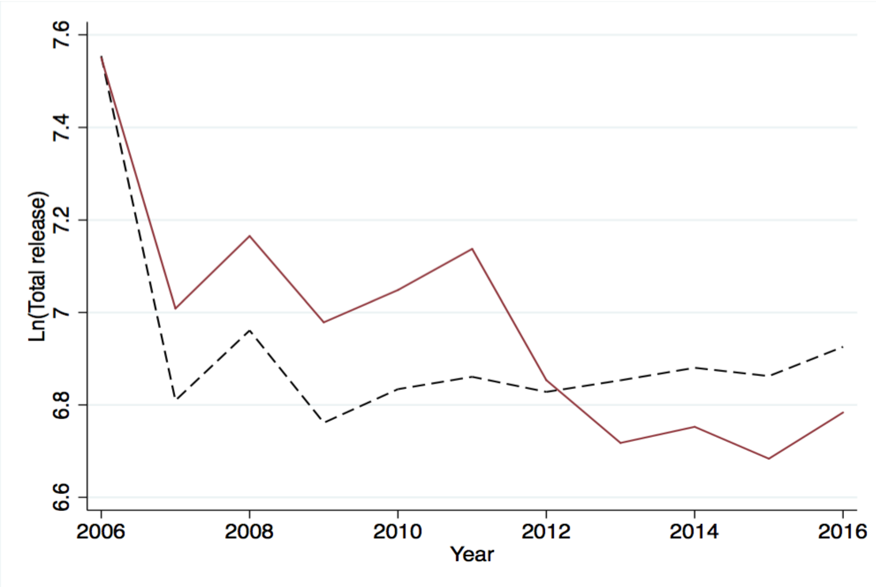


Figure 3: Average annual toxic emissions by firm type

This figure plots the average level of toxic emissions for firms dependent on long-term debt financing (solid line) and firms not dependent on long-term debt financing (dashed line) over the sample period 2006 - 2016.



Appendix

Table A1: Emission reduction activities

This table reports detailed descriptions for two emissions reduction categories (Process modification and Good operating practices).

Process Modifications	
	Optimized reaction conditions or otherwise increased efficiency of synthesis
	Instituted re-circulation within a process
	Modified equipment, layout, or piping
	Used a different process catalyst
	Instituted better controls on operating bulk containers to minimize discarding of empty containers
	Changed from small volume containers to bulk containers to minimize discarding of empty containers
	Reduced or eliminated use of an organic solvent
	Used biotechnology in manufacturing process
	Other process modifications made
Good Operating Practices	
	Improved maintenance scheduling, record keeping, or procedures
	Changed production schedule to minimize equipment and feedstock changeovers
	Introduced in-line product quality monitoring or other process analysis system
	Other changes made in operating practices

Table A2: Differences between firms

This table reports average values of variables at the firm level in 2010. The sample is split between firms with a below median level of long-term debt dependence (left panel) and firms with an above median level of long-term debt dependence.

	Average Long-term debt dependence below median					Average Long-term debt dependence above median						
	N	**Mean**	**St.Dev.**	**Min**	**Max**	**N**	**Mean**	**St.Dev.**	**Min**	**Max**	**Abs(Diff)**	**T-Stat**
Total release	265	351.720	0	12,226	12,226	284	1,844	0	55,320	55,320	-1,492***	(-3.67)
Long-term debt dependence	265	0.04	0.04	0.00	0.105	284	0.204	0.092	0.105	0.644	0.164***	(-27.24)
Book-debt ratio	264	0.186	0.161	0	1	284	0.368	0.157	0.077	1	0.182***	(-13.40)
ln(Sales)	264	7.13	1.83	-1.26	12.75	284	8.160	1.316	3.148	12.061	1.035***	(-7.64)
Growth of sales	264	0.07	0.17	-0.55	1.601	281	0.042	0.119	-0.281	1.212	0.0247*	(1.96)
Share of bond debt (%)	191	56.324	31.722	0	100	263	65.633	28.316	0	100	9.309***	(-3.29)
Share of fixed rate debt (%)	208	62.071	31.183	0	100	273	68.832	25.885	0.209	100	6.762***	(-2.60)

Table A3: Firms by long-term debt dependence and industry

This table reports the distribution of firms across the 12 Fama-French industry groups in 2010.

	Long-term debt dependence...	
	...below median	... above median
Consumer NonDurables -- Food, Tobacco, Textiles, Apparel, Leather, Toys	17	23
Consumer Durables -- Cars, TV's, Furniture, Household Appliances	21	20
Manufacturing -- Machinery, Trucks, Planes, Off Furn, Paper, Com Printing	101	90
Energy Oil, Gas, and Coal Extraction and Products	32	35
Chems Chemicals and Allied Products	10	17
Business Equipment -- Computers, Software, and Electronic Equipment	37	18
Telephone and Television Transmission	0	1
Utilities	0	46
Wholesale, Retail, and Some Services (Laundries, Repair Shops)	17	7
Healthcare, Medical Equipment, and Drugs	17	10
Other -- Mines, Constr, BldMt, Trans, Hotels, Bus Serv, Entertainment	13	17

Table A4: Maturity Extension Program, long-term debt dependence and toxic emissions
Differential effects

This table reports results from an OLS regression at the firm-chemical-level. The dependent variable is the natural logarithm of total on-site emissions for a chemical at the firm. The sample period ranges from 2006 to 2016. '=1 if firm dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011. 'Bond financing share (2011)>50%' is a dummy variable, taking on the value of one whether a firm's share of bond financing in 2011 was above 50%; 'Fixed rate debt financing share (2011) > 50%' is a dummy variable, whether a firm's share of fixed rate debt is above 50% in 2011. All regressions include controls and fixed effects as indicated. Standard errors are clustered at the firm-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(=1 if firm dependent on long-term debt financing) * MEP	-0.281**	-0.478***	-0.536***	-0.357**	-0.518***	-0.521***	-0.326**	-0.519***	-0.569***
	(0.128)	(0.164)	(0.162)	(0.140)	(0.172)	(0.169)	(0.148)	(0.185)	(0.182)
(=1 if firm dependent on long-term debt financing) * MEP *	0.094	0.161	0.253				-0.104	0.012	0.177
(Bond financing share (2011) > 50%)	(0.144)	(0.187)	(0.183)				(0.177)	(0.227)	(0.231)
(=1 if firm dependent on long-term debt financing) * MEP *				0.189	0.214	0.236	0.259	0.202	0.116
(Fixed rate debt financing share (2011) > 50%)				(0.155)	(0.196)	(0.193)	(0.191)	(0.239)	(0.244)
Controls	x	x	x	x	x	x	x	x	x
Firm-chemical fixed effect	x	x	x	x	x	x	x	x	x
Chemical-year fixed effect	x	x	x	x	x	x	x	x	x
EA-year fixed effect		x	x		x	x		x	x
Industry-year fixed effect			x			x			x
Observations	33,676	33,618	33,614	33,676	33,618	33,614	33,676	33,618	33,614
R-squared	0.902	0.908	0.909	0.902	0.908	0.909	0.902	0.908	0.909

Table A5: Maturity Extension Program, long-term debt dependence and toxic emissions Subsamples

This table reports results from an OLS regression at the firm-chemical-level. The dependent variable is the natural logarithm of total emissions for a chemical at the firm. The sample period ranges from 2006 to 2016. '=1 if firm dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011. The sample in columns (1) to (3) only consides firm-chemical observations that are constantly reported over the sample period, the sample in columns (4) to (6) comprises the 25 most common chemicals. All regressions include controls and fixed effects as indicated. Standard errors are clustered at the firm-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Subsample:	Panel A: Balanced Panel			Panel B: 25 most common chemicals		
(=1 if firm dependent on long-term debt financing) * MEP	-0.164**	-0.294***	-0.285***	-0.145*	-0.248***	-0.227**
	(0.065)	(0.084)	(0.088)	(0.076)	(0.093)	(0.099)
Controls	x	x	x	x	x	x
Firm-chemical fixed effect	x	x	x	x	x	x
Chemical-year fixed effect	x	x	x	x	x	x
EA-year fixed effect		x	x		x	x
Industry-year fixed effect			x			x
Observations	19,158	19,105	19,105	20,343	20,292	20,288
R-squared	0.899	0.905	0.907	0.906	0.913	0.914

Table A6: Maturity Extension Program, long-term debt dependence and toxic emissions
Clustering

This table reports results from an OLS regression at the firm-chemical-level. The dependent variable is the natural logarithm of total emissions for a chemical at the firm. The sample period ranges from 2006 to 2016. '=1 if firm dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011. Standard errors in regressions, reported in columns (1) to (3) are clustered at the firm-level; results reported in columns (4) to (6) are based on a clustering of standard errors at the chemical level. All regressions include controls and fixed effects as indicated. Standard errors are reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Clustering:		Panel A: Firm			Panel B: Chemical	
(=1 if firm dependent on long-term debt financing) * MEP	-0.202**	-0.335***	-0.319***	-0.202***	-0.335***	-0.319***
	(0.102)	(0.088)	(0.085)	(0.050)	(0.072)	(0.088)
Controls	x	x	x	x	x	x
Firm-chemical fixed effect	x	x	x	x	x	x
Chemical-year fixed effect	x	x	x	x	x	x
EA-year fixed effect		x	x		x	x
Industry-year fixed effect			x			x
Observations	33,676	33,618	33,614	33,676	33,618	33,614
R-squared	0.902	0.908	0.909	0.902	0.908	0.909

Table A7: Maturity Extension Program, long-term debt dependence and toxic emissions
Alternative independent variables

This table reports results from an OLS regression at the firm-chemical-level. The dependent variable is the natural logarithm of total emissions for a chemical at the firm. The sample period ranges from 2006 to 2016. 'Long-term debt dependence' is a firm's average level of long-term debt in total assets. '=1 if firm dependent on long-term debt financing (2007)' is an indicator variable, taking on the value of one whether a firm's long-term debt dependencse up until 2007 is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011. Standard errors are clustered at the firm-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
(Long-term debt dependence) * MEP	-0.924***	-2.162***	-1.928***			
	(0.349)	(0.513)	(0.541)			
(=1 if firm dependent on long-term debt financing (2007) * MEP				-0.113*	-0.249***	-0.270***
				(0.063)	(0.092)	(0.097)
Controls	x	x	x	x	x	x
Firm-chemical fixed effect	x	x	x	x	x	x
Chemical-year fixed effect	x	x	x	x	x	x
EA-year fixed effect		x	x		x	x
Industry-year fixed effect			x			x
Observations	33,676	33,618	33,614	32,404	32,350	32,346
R-squared	0.902	0.908	0.909	0.901	0.907	0.908

Table A8: Maturity Extension Program, long-term debt dependence and toxic emissions Alternative dependent variable

This table reports results from an OLS regression at the firm-chemical-level. The dependent variable is the 'Release-production' index and represents the ratio of toxic emissions to production/activity. The sample period ranges from 2006 to 2016. '=1 if firm dependent on long-term debt financing' is an indicator variable, taking on the value of one whether a firm's long-term debt dependence is above the sample median, or zero otherwise. 'MEP' is a dummy variable taking on the value of one in the year after the MEP, i.e. 2011.All regressions include controls and fixed effects as indicated. Standard errors are clustered at the firm-chemical level, and reported in parentheses. *, **, *** mean significance at ten, five, and one percent, respectively.

	(1)	(2)	(3)
(=1 if firm dependent on long-term debt financing) * MEP	-0.891***	-1.376***	-1.253**
	(0.324)	(0.487)	(0.518)
Controls	x	x	x
Firm-chemical fixed effect	x	x	x
Chemical-year fixed effect	x	x	x
EA-year fixed effect		x	x
Industry-year fixed effect			x
Observations	23,665	23,595	23,586
R-squared	0.380	0.410	0.415

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