STRANDED ASSETS

PROGRAMME

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

Making climate policy more like monetary policy: calibrating climate policy through corporate solvency

Working Paper

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About the Stranded Assets Programme

The Stranded Assets Programme at the University of Oxford's Smith School of Enterprise and the Environment was established in 2012 to understand environment-related risks driving asset stranding in different sectors and systemically. We research how environment-related risks might emerge and strand assets; how different risks might be interrelated; assess their materiality (in terms of scale, impact, timing, and likelihood); identify who will be affected; and what impacted groups can do to pre-emptively manage and monitor risk.

We recognise that the production of high-quality research on environment-related risk factors is a necessary, though insufficient, condition for these factors to be successfully integrated into decision-making. Consequently we also research the barriers that might prevent integration, whether in financial institutions, companies, governments, or regulators, and develop responses to address them. We also develop the data, analytics, frameworks, and models required to enable integration for these different stakeholders.

The Programme is currently supported by grants from: Craigmore Sustainables, European Climate Foundation, Foreign & Commonwealth Office, Generation Foundation, Growald Family Fund, HSBC Holdings plc, KR Foundation, Lloyd's of London, Norges Bank Investment Management, Tellus Mater Foundation, The Luc Hoffmann Institute, The Rothschild Foundation, The Woodchester Trust, and WWF-UK. Past grant-makers include: Ashden Trust, Aviva Investors, and Bunge Ltd. Our research partners include: Standard & Poor's, Carbon Disclosure Project, TruCost, Ceres, Carbon Tracker Initiative, Asset Owners Disclosure Project, 2° Investing Initiative, Global Footprint Network, RISKERGY, and Corporate Knights.

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Table of Contents

Executive summary

Rapid carbon abatement improves the chances that dangerous anthropogenic climate change will be averted. But if the rate of curtailment is unnecessarily fast, it could cause excessive corporate failures – which would add to the social cost of abatement. At present, policymakers do not have a consistent way to quickly and accurately gauge what impact climate policies are having on corporate solvency. If they did and if these measures were applied correctly, the efficacy and cost-efficiency of climate policy could be improved.

The idea of using objective economic statistics to calibrate the optimal strictness of policy measures is not new. It is perhaps most prevalent in the views that fiscal and monetary policy can be used to smooth the business cycle. With regard to monetary policy, central banks may use measures of economic output, unemployment, inflation, and other economic statistics to determine lending strategies and money supply.

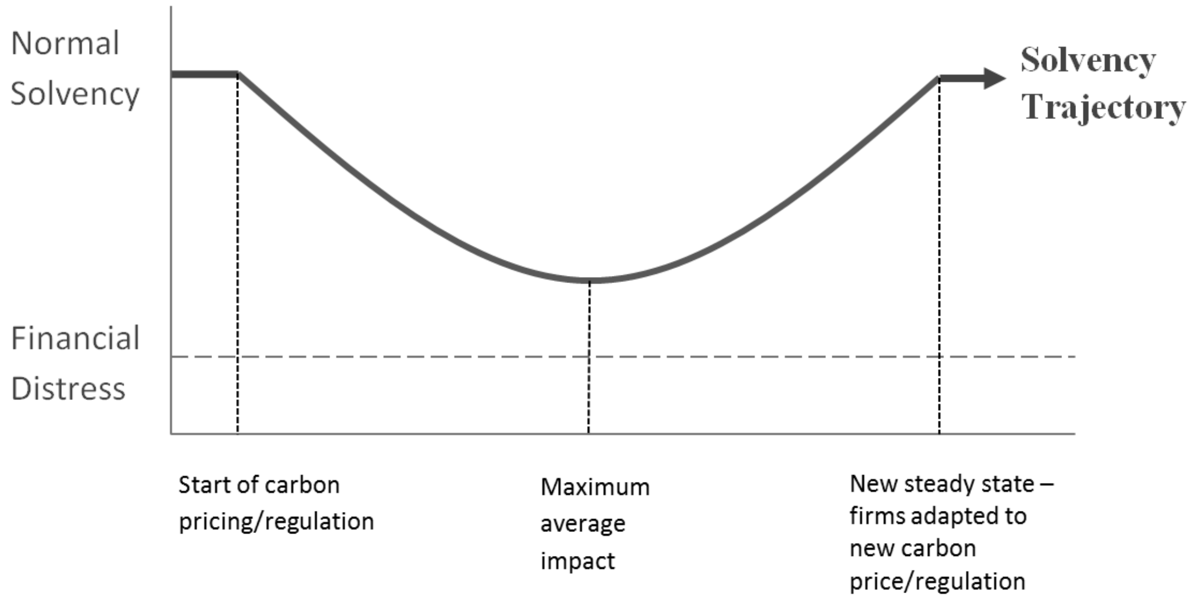
In this paper we propose that metrics of corporate solvency be used as an objective tool for policymakers to calibrate the optimal magnitude of climate policies, and thereby achieve greater emissions abatement at lower social cost. In particular, solvency metrics could calibrate the optimal severity of climate policies and/or the generosity of industrial compensation. Policymakers currently monitor and regulate certain aspects of corporate solvency for financial firms (such as capital reserve requirements) in order to reduce the risk of bankruptcy while simultaneously maintaining profitability. In a similar vein, policymakers could do likewise with respect to climate change policies which target carbon-intensive firms.

The most fundamental goal of climate policy is to incentivise industry to reduce carbon emissions and transition to lower carbon processes and technologies. When firms face carbon-related taxes, prices or regulation, and restructure their businesses accordingly,[1] it is expected that during this transition they will suffer some loss of solvency. However, if the firm goes bankrupt as a result of this regulation, not only will this restructuring not occur – possibly causing emitting industries to expand in less constrained jurisdictions (so-called carbon leakage), but social value will also be destroyed in the form of deadweight losses paid to liquidators and the dissolution of organisational capital. For example, in a meta-analysis of past studies on the cost to investors of corporate bankruptcy, Branch[2] estimates 12-20% of the firm's value to be lost in the liquidation process. Adding on the social costs arising from unemployment and new job search would magnify this figure further still. Finally, there is also the danger that a sudden industry-wide loss of solvency could incite a wider financial panic.

On the other hand an excessively lenient climate policy with low future carbon price expectations could fail to restrain industry from investments in long-lived carbon-intensive infrastructure[3] that could become stranded, and therefore potentially induce the need for a more rapid and expensive transition in future in order to meet fixed climate change goals. An ideal solvency trajectory for firms affected by climate change policy would therefore cause corporate solvency to initially decline – approaching but not exceeding 'distressed' levels – and then gradually improve to a new 'steady state' once the climate change transition had been achieved, at which point the regulation would continue but any compensation provided to industry could end. This sequence is depicted by the U-shaped solvency curve in the figure below. Although obviously idealised, if the solvency curve was adopted as a climate policy target, it could potentially improve the social efficiency of carbon reduction across affected industries.

[1] See for example Requate and Unold (2003).
[2] Branch, B. (2002) The costs of bankruptcy: A review. International Review of Financial Analysis, 11: 39-57.
[3] An example of this may be the 19 highly-carbon intensive coal plants currently at various stages of planning in the EU (Mathiesen, 2014).

Idealised Solvency Trajectory for Industries Affected by Climate Policy



An additional advantage of using corporate solvency to calibrate climate change policy is the fact that this process would be comparatively objective. At present there is considerable potential for industrial outcry and political lobbying to bias how climate change policies are adjusted, with potentially negative social outcomes. Climate change policy based on corporate solvency could be adjusted relatively mechanically at each financial reporting period, and would automatically be sensitive to variations in the business cycle.[4]

In this paper we have applied our framework to one of the most recent and significant additions to climate change regulations in Europe: the United Kingdom's Carbon Price Support (CPS). The CPS is a surcharge to the Climate Change Levy (CCL): a pre-existing tax on the use of energy delivered to non-domestic users in the United Kingdom. It is a unilateral tax that the UK applied without the participation of any other EU member states in response to the chronic failure of the EU ETS to produce a consistent and meaningful price signal for industry to invest in low carbon technology; and a desire by the UK to meet its commitments to both generate 15% of energy from renewable sources by 2020 and reduce greenhouse gas emissions by 80% of 1990 levels by 2050. The CPS is calculated based on a top-up payment to the price level of EU ETS permits. When the CPS is combined with the price of EU ETS permits it is known as the Carbon Price Floor (CPF). Our analysis of changes to corporate solvency due to the CPS finds that that energy-intensive firms in the UK were not under undue financial pressure as a result of the new policy. Therefore, we argue that the industrial outcry against the CPS and UK policymakers' decision to freeze it in response were unwarranted.

The question of where the optimal solvency threshold should lie is important for the practical application of corporate solvency measures to climate change policy. For instance, it could be argued that either (i) an average solvency level; (ii) a minimum solvency level for the most financially distressed firm; or (iii) a maximum solvency loss should be the relevant benchmark. The universal availability and timeliness of financial data will also influence the optimal threshold level. Since the financial position of firms may deteriorate between financial reports, it may be prudent to adjust thresholds upwards to add a margin of safety against rapid solvency losses.

It may also be the case that within a given emissions target, it may not be possible to maintain the solvency of all affected firms. In such cases the emissions target may need to take precedence over solvency concerns, but nevertheless the use of policy calibration via solvency could still be an efficient way to minimise whatever bankruptcies may be necessary to achieve the desired emission reduction goal.

[4] Depending on the timeliness of financial reporting.

Future research may look to refining the solvency measures (Altman Z-Scores) produced in our analysis, or compare other methods for producing metrics of corporate solvency, such as conditional probability models. Such research could also quantify and operationalise the 'optimal' trajectory of corporate solvency according to specific industries, macroeconomic conditions, financial reporting regimes, and climate change targets. Historical instances of other significant environmental regulation such as the sulfur dioxide cap and trade programme in the US or automobile emissions standards could also be evaluated from the standpoint of optimal corporate solvency trajectories for affected firms, improving our understanding of the efficiency of these interventions, and potentially suggesting implications for the improvement of current and future environmental policies.

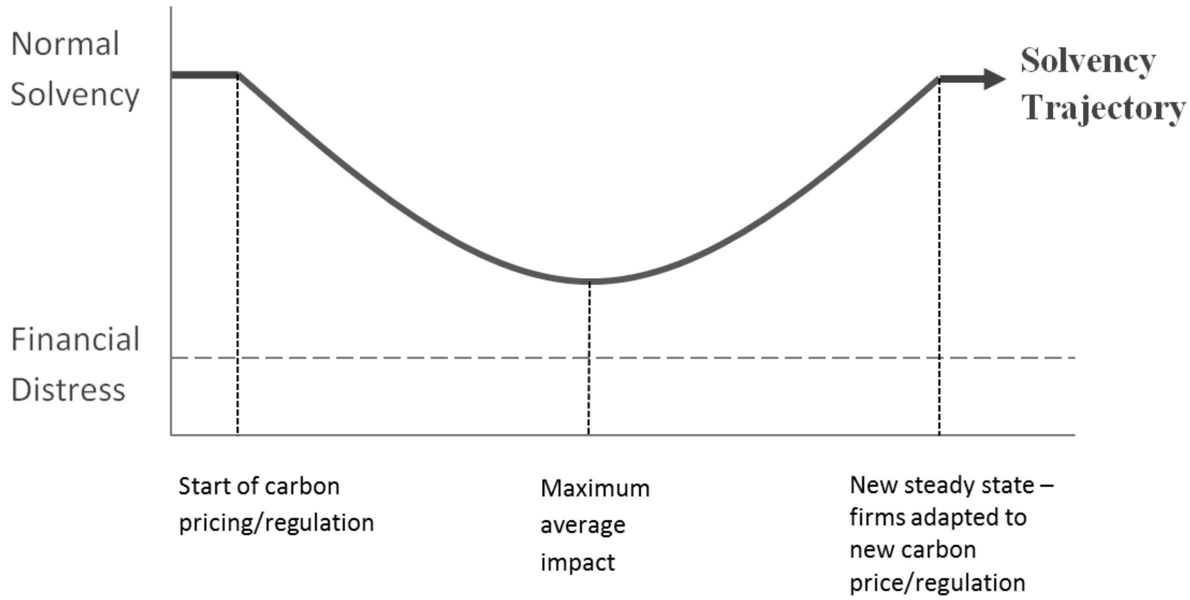
1. Introduction

Rapid carbon abatement improves the chances that dangerous anthropogenic climate change will be averted. But if the rate of curtailment is unnecessarily fast, it could cause excessive corporate failures – which would add to the social cost of abatement. At present, policymakers do not have a consistent way to quickly and accurately gauge what impact climate policies are having on corporate solvency. If they did and if these measures were applied correctly, the efficacy and cost-efficiency of climate policy could be improved.

In response to this shortcoming, we propose that metrics of corporate solvency be used as an objective tool for policymakers to calibrate the optimal magnitude of climate policies, and thereby achieve greater emissions abatement at lower social cost. In particular, solvency metrics could calibrate the optimal severity of climate policies and/or the generosity of industrial compensation. Policymakers currently monitor and regulate certain aspects of corporate solvency for financial firms (such as capital reserve requirements) in order to reduce the risk of bankruptcy while simultaneously maintaining profitability. In a similar vein, policymakers could do likewise with respect to climate change policies which target carbon-intensive firms.

The most fundamental goal of climate policy is to incentivise industry to reduce carbon emissions and transition to lower carbon processes and technologies. When firms face carbon-related taxes, prices or regulation, and restructure their businesses accordingly,[5] it is expected that during this transition they will suffer some loss of solvency. However, if the firm goes bankrupt as a result of this regulation, not only will this restructuring not occur – possibly causing emitting industries to expand in less constrained jurisdictions (so-called carbon leakage), but social value will also be destroyed in the form of deadweight losses paid to liquidators and the dissolution of organisational capital. For example, in a meta-analysis of past studies on the cost to investors of corporate bankruptcy, Branch[6] estimates 12-20% of the firm's value to be lost in the liquidation process. Adding on the social costs arising from unemployment and new job search would magnify this figure further still. Finally, there is also the danger that a sudden industry-wide loss of solvency could incite a wider financial panic.

Figure 1: Idealised Solvency Trajectory for Industries Affected by Climate Policy



[5] See for example Requate and Unold (2003).
[6] Branch, B. (2002) The costs of bankruptcy: A review. International Review of Financial Analysis, 11: 39-57.

On the other hand an excessively lenient climate policy with low future carbon price expectations could fail to restrain industry from investments in long-lived carbon-intensive infrastructure[7] that could become stranded, and therefore potentially induce the need for a more rapid and expensive transition in future in order to meet fixed climate change goals. An ideal solvency trajectory for firms affected by climate change policy would therefore cause corporate solvency to initially decline – approaching but not exceeding 'distressed' levels – and then gradually improve to a new 'steady state' once the climate change transition had been achieved, at which point the regulation would continue but any compensation provided to industry could end. This sequence is depicted by the U-shaped solvency curve in Figure 1 above. Although obviously idealised, if Figure 1 was adopted as a climate policy target, it could potentially improve the social efficiency of carbon reduction across affected industries.

An additional advantage of using corporate solvency to calibrate climate change policy is the fact that this process would be comparatively objective. At present there is considerable potential for industrial outcry and political lobbying to bias how climate change policies are adjusted, with potentially negative social outcomes. Even when the need for regulatory change is obvious, many policymakers struggle to enact needed reforms, and even if successful often fail to do so in a timely manner. For instance, it is widely acknowledged that the EU Emissions Trading Scheme (EU ETS) has failed to deliver a price signal consistent with intentions since at least the beginning of 2012, when price levels stabilised below 5€/ton CO_2.[8] However, a plan to redress this situation was not approved by the EU Commission until 2014, and this plan is not due to be implemented until 2021. By contrast, a climate change policy based on corporate solvency could be adjusted relatively mechanically at each financial reporting period, and would automatically be sensitive to variations in the business cycle.[9]

The remainder of this paper applies this policy calibration framework to one of the most recent and significant additions to climate change regulations in Europe: the United Kingdom's Carbon Price Support (CPS). The CPS is a surcharge to the Climate Change Levy (CCL): a pre-existing tax on the use of energy delivered to non-domestic users in the United Kingdom. It is a unilateral tax that the UK applied without the participation of any other EU member states in response to the chronic failure of the EU ETS to produce a consistent and meaningful price signal for industry to invest in low carbon technology; and a desire by the UK to meet its commitments to both generate 15% of energy from renewable sources by 2020 and reduce greenhouse gas emissions by 80% of 1990 levels by 2050. The CPS is calculated based on a top-up payment to the price level of EU ETS permits. When the CPS is combined with the price of EU ETS permits it is known as the Carbon Price Floor (CPF).

Table I: UK Carbon Price Support History

	Ratified	Start	End	Effect
Carbon Price Support (CPS) Tax on fossil fuels used to generate electricity (Northern Ireland Exempt)	Mar 23, 2011	Apr 1, 2013	Apr 1, 2030	£4.94/ton CO2 in 2013, rising £9.55 in 2014, £18.08 in 2015 and incrementally to £30 in 2020 and £70 in 2030
CPS Price Freeze	Mar 19, 2014	Apr 1, 2014	Apr 1, 2019	Frozen to £18.08/ton CO2 from April 1, 2015 until 2020
CPS Compensation Scheme	May 22, 2014[10]	TBD (may be retroactive)	TBD	Up to 80% of CPS paid returned for energy-intensive industries

[7] An example of this may be the 19 highly-carbon intensive coal plants currently at various stages of planning in the EU (Mathiesen, 2014).
[8] In 2003 (well before the EU Emissions Trading Scheme's launch in 2005) the UK government regulator Ofgem expected price levels to have risen to 33-49€/ton by 2010 (Ofgem, Nov 2003), and the lowest price scenario for EU ETS permits forecasted for 2012 by McKinsey & Co was 20€/ton CO_2 (UBS, Sept 2003).
[9] Depending on the timeliness of financial reporting.
[10] Ratified by the EU Commission.

The CPS is a relevant case study for addressing our research question because it is one of the world's most recent and substantial carbon taxes, applied in a large developed economy with good financial micro-data. Within industry it has also been widely claimed that the CPS has had a significant effect on the production costs of manufacturers.[11] EEF (the UK manufacturers' association) has said the Carbon Price Support currently adds between 5 and 10% to the energy bills of energy-intensive companies, making them less competitive on the international stage,[12] and that energy prices and green taxes are worrying the industry more than any other issue.[13] Given these characteristics, internationally competitive manufacturing nations trialling carbon pricing may find the CPS applicable to their situations.

This paper proceeds as follows; first a brief literature review is presented on how optimal climate change policy is modelled in practice and the economic effects of climate policy generally. Next we outline how we measure corporate solvency and provide an exposition of the data used in this study. Finally, we present the results on the effects of the CPS on the corporate solvency of energy-intensive firms and draw conclusions.

[11] Energy price increases are most strongly felt in manufacturing, as energy expenditures are larger here than in any other industrial sector. However, within manufacturing there are a number of industries whose products are exceptionally energy-intensive. We examine the effect of the CPS on these sectors specifically.
[12] See Shankleman (2014).
[13] See Groom (2014).

2. Literature Review

The idea of using objective economic statistics to calibrate the optimal strictness of policy measures is not new. It is perhaps most prevalent in the views that fiscal and monetary policy can be used to smooth the business cycle. With regard to monetary policy, central banks may use measures of economic output, unemployment, inflation, and other economic statistics to determine lending strategies and money supply. In the case of climate change, models for optimal policy determination are based on cost-benefit assumptions and either analyse the best form that policy could take – for example taxes, permits, or subsidy,[14] or prescribe an optimal level of stringency and timing for a particular policy based on historical market dynamics and a specified emissions goal.[15] Refinements of these models explore how the optimality of this policy is influenced by relaxing certain assumptions, such by assuming that the damages anticipated from climate change are uncertain,[16] that abatement technology improves over time,[17] or that abatement policies are nationally unilateral.[18] Other analyses reject a quantitative cost-benefit framework for assessing climate change policies altogether, arguing that the complexity of climate change demands a qualitative analytical approach.[19]

Although the effects of carbon regulation on certain aspects of economic performance are well documented,[20] no previous studies of the effect of environmental regulation on corporate solvency in particular were found. Nor was it possible to identify previous research on general economic effects attributable to the Carbon Price Support specifically. In the UK, economic analysis of carbon taxes has primarily focused on the Climate Change Levy (CCL) which began in 2001. Early research on this tax by the industry lobby group, The Federation of Small Businesses, found that, net of various compensatory dispensations granted simultaneously, the CCL made 30% of small and medium-sized enterprises financially worse off, with the primary losers involved in plastics processing, hospitality, and retailing.[21] Another survey-based study by industry found that 42% of professionals in the energy industry felt that the CCL had caused a net increase in business costs.[22] Conversely, later academic research by Martin, de Preux, and Wagner[23] analysed the effects of the CCL by employing an instrumental variable for CCL incidence on micro-data of firm performance. They found that, although the CCL had a strong negative impact on the energy intensity of production and electricity use, no statistically significant economic effects were observed with respect to firm revenue, employment, or plant exit from the UK.

[14] See Nordhaus (1993); Strand (2013); and Wirl (2012).
[15] See Golosov, Hassler, Krusell, and Tsyvinski (2014); and Roughgarden and Schneider (1999).
[16] See Nordhaus (1994); Pizer (1999), and Baker and Shittu (2008).
[17] See Gerlagh, Kverndokk, and Rosendahl (2009); Goulder and Mathai (2000); Requate and von Dollen (2008); Ploeg and Withagen (2014); and Weber and Neuhoff (2010).
[18] See; Bohringer, Carbone, and Rutherford (2012); Eichener and Pethig (2013); and Felder and Rutherford (1993).
[19] See van den Bergh (2004).
[20] See for instance; Abrell, Ndoye Faye, and Zachmann (2011); Chan, Li, and Zhang (2013); Yu (2011); Zhang and Baranzini (2004); and Zhao (2011).
[21] Federation of Small Businesses (2002). The climate change levy: Another cost for small businesses
[22] London Electricity (2002). Climate change levy report
[23] Martin, R., de Preux, L., and U. Wagner (2014). The Impact of a Carbon Tax on Manufacturing: Evidence from Microdata. Journal of Public Economics, 117: 1-14.

3. Data

This study measures corporate solvency by constructing Altman's Z-Scores; produced with financial data from energy-intensive firms in the EU's five main economies. Altman[24] was among the first to put forward a quantitative model to predict corporate bankruptcy using financial data, and his various Z-Scores (for different types of firms) have been widely applied in industry and are regarded in academic circles as a research standard. The most recently published Altman's Z-Score for private manufacturing firms[25] is reproduced below.

$$\textbf{Z-Score} = 0.717\mathbf{X_1} + 0.847\mathbf{X_2} + 3.107\mathbf{X_3} + 0.420\mathbf{X_4} + 0.998\mathbf{X_5} \quad (1)$$

$\mathbf{X_1}$ = Working Capital/Total Assets

$\mathbf{X_2}$ = Retained Earnings/Total Assets

$\mathbf{X_3}$ = Earnings Before Interest and Taxes/Total Assets

$\mathbf{X_4}$ = Book Value of Equity/Total Liabilities

$\mathbf{X_5}$ = Sales/Total Assets

Although Altman's Z-score was originally developed as a tool to predict future default, like this study, previous research such as Sauer[26] has also used comparisons in Altman's Z-Scores over successive years to highlight variations in financial condition and alert firm management of the need to adjust strategy and operations. Altman[27] himself also advocates the use of his Z-Scores for the measurement of corporate financial risk generally, as opposed to bankruptcy specifically. Commensurate with this view, Platt and Platt[28] found that Z-score profiles for failing businesses often exhibit a consistent downward trend as they approach bankruptcy.

A number of other common models exist for predicting bankruptcy, perhaps most notable in the UK is Taffler's Z.[29] However, Taffler's Z would not have been ideal as the metric for this study as it is constructed from listed firms only and the additional data requirements of this model would have reduced our sample size to statistically trivial levels. Since the most recently publicised Altman Z-Score for private manufacturing firms is based on US firms and is now dated,[30] this study produces an updated Altman Z-Score for contemporary energy-intensive firms in the EU.

This updated Altman Z-score is constructed by applying Altman's Discriminant Analysis methodology to private energy-intensive firms in the UK, Germany, France, Italy, and Spain between 2000 and 2014. These advanced economies were chosen as it was thought that firms in these countries would have characteristics, such as technology and management practices, most similar to those present in the UK. Firms were deemed to be 'energy-intensive' (and therefore included in the initial sample) if the European Commission defined them as such according to their primary SIC codes (see Appendix). Financial data from the most recent year available was collected on firms which either had gone bankrupt or were active from Bureau Van Dyke. All firms in the relevant industries which could be identified in their description as 'retail or wholesale trading', and therefore not actually manufacturing firms, were removed. This yielded a dataset of 6,777 active firms and 177 bankrupt firms.

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[24] See Altman, E. (1968). Discriminant analysis and the prediction of corporate bankruptcy. The Journal of Finance, 23(4): 589-609.
[25] Altman, E. (1983). Corporate Financial Distress. Wiley Interscience, New York.
[26] Sauer, T. (2002) How may we predict bankruptcy
[27] Altman, E. (2002). Corporate distress prediction models in a turbulent economic and Basel II environment. NYU Working Paper No. S-CDM-02-11.
[28] Platt, H., and M. Platt (1991). A note on the use of industry-relative ratios in bankruptcy prediction. Journal of Banking & Finance, 15: 1183-1194.
[29] Taffler, R. (1983). The assessment of company solvency and performance using a statistical model. Accounting and Business Research, 15(52) 295-308.
[30] More recent Altman's Z-scores were identified such as Appiah and Abor (2009), but these failed to be both derived from EU firms and in the private manufacturing sector.

Discriminant Analysis of bankruptcy was run on the variables X_1-X_5 in Equation (1) above, with the exception that the Retained Earnings variable was proxied by the related variable 'Shareholder Funds' due to lack of data. This exercise yielded the following results:

Table II: Discriminant Analysis Diagnostic Statistics

Canonical Correlation	Likelihood Ratio	F-Statistic	Probability
0.1317	0.98262	24.536	0.0000

The results in Table II show that these five combined factors are a significant determinant of firm bankruptcy. The coefficients produced by this discriminant analysis are stated below.

Table III: Discriminant Analysis Estimated Coefficients

X_1	0.9677312
X_2	-0.0472769
X_3	0.3463303
X_4	0.0632979
X_5	0.3756524

Surprisingly, the X_2 coefficient yields a negative value, implying that, counterintuitively, increases in the (Shareholder Funds/Total Assets) ratio increases financial distress.[31] One possible explanation is that relatively high proportions of equity (low leverage) could in fact indicate that the company in question is having difficulty raising debt because of business problems that are not captured by its balance sheet. There are 85 firms in our sample which have data on Retained Earnings. For these firms the correlation between the original value of X_2 (Retained Earnings/Total Assets) and the proxied value of X_2 (Shareholder Funds/Total Assets) was found to be 0.47. Given that the coefficient on X_2 is close to zero, we could also attribute this result to error in our proxy choice for X_2.

In an analogous fashion to Equation (1), the coefficients in Table III are then combined linearly to produce a contemporary, EU-based, Energy-intensive Industry Altman's Z-Score model, and applied to the financial data described below. Again, data on corporate financials for energy-intensive firms in the UK, Germany, France, Italy, and Spain was collected from Bureau Van Dyke's Orbis database. This exercise produced a total sample of 16,223 firms. Internet research was then conducted in order to remove firms which were (i) involved solely in the retail and wholesale trade of energy-intensive goods rather than their manufacture;[32] (ii) UK firms which had any production facilities outside of Great Britain (including Northern Ireland); (iii) German, French, Italian, and Spanish firms which had production facilities outside of these same four 'control' countries; and (iv) firms which are listed on a stock exchange.[33] Naturally only firms which had published all required financial data to construct Altman Z-Scores for the 2012 and 2013 financial years were retained. This produced a sample of 463 firms, 74 of which were UK based.

[31] Discriminant Analysis was also run with a random sample stratified by country and industrial sector of 177 solvent firms on the 177 bankrupt firms. However, all coefficients on the five financial ratios from this exercise were unexpectedly negative, suggesting problematic sampling error.
[32] Orbis classifies firms involved solely in the retail and wholesale trade of energy-intensive goods as in the same industry as those firms involved in manufacture. For our purposes this is an erroneous classification.
[33] Listed firms were removed in order to ensure comparability. Researchers use different models and thresholds to categorise the solvency of listed and non-listed firms, and therefore it would not be clear how to integrate them. In any event, only six listed firms remained after the selection criteria i-iii were applied.

Table IV: Summary Statistics (n=463)

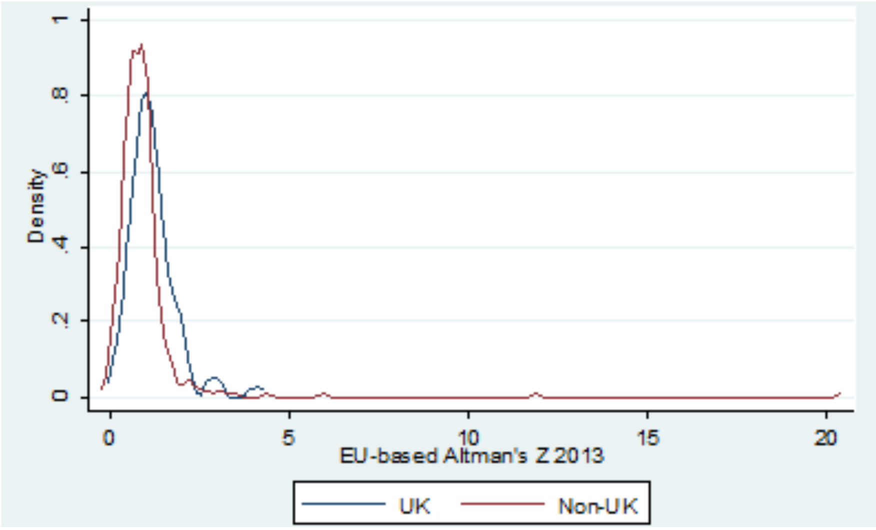
	Min	Max	Mean	Standard Deviation
EU-based Altman's Z-Score 2013	-0.21	20.38	0.97	1.20
Δ EU-based Altman's Z-Score (2012-13)	-2.62	11.35	0.04	0.67
Total Assets 2012 (£'000s)	8	3,060,205	32,019	171,384
Number of Observations				
Country				
UK	74			
Germany	33			
France	138			
Italy	216			
Spain	2			
Industry Sector				
Chemicals	156			
Metals	101			
Primary	7			
Textiles	146			
Paper	53			

Note that the effect of year-on-year currency exchange rate changes to financial statement values and inflation cannot be responsible for measured changes in solvency using Altman's Z-score. This is because the input variables in Altman's Z-score consist purely of financial ratios, which by construction are dimensionless, and therefore require no adjustments to make different currencies or years directly comparable.

4. Analysis

Figure 2 below plots the distributions of 2013 UK and Non-UK Z-Scores. We test whether the UK firm Z-Scores are below those of Non-UK firms using a Kolmogorov-Smirnov test for differences in distributions. Note that regression analyses are less appropriate in this case because we are primarily interested in determining the comparative financial condition of firms and not in isolating or quantifying the effect of the CPS.

Figure 2: EU Energy-intensive Firms 2013 EU-based Altman's Z-Score Histogram; UK (n=74), and Non-UK (n=389)



Kernel = epanechnikov, bandwidth = 0.1779

Table V: Kolmogorov-Smirnov Test for Equality of 2013 UK and Non-UK Z-Score Distributions

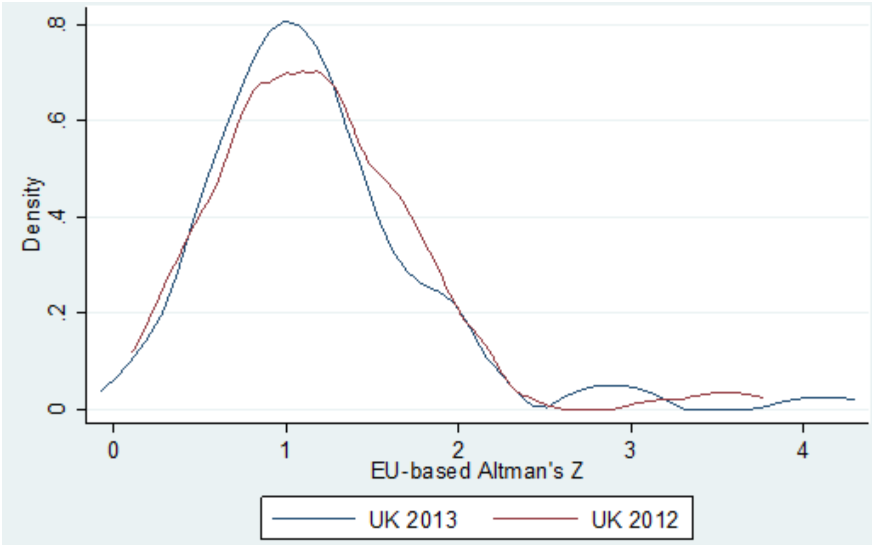
	Largest Difference	**P-value**
UK > Non-UK	0.3001	0.000
UK < Non-UK	-0.0103	0.987
Combined Test	0.3001	0.000

Surprisingly, the Kolmogorov-Smirnov test finds that the UK Z-Scores were in fact significantly greater than those from Non-UK firms in 2013. This implies that firms under the CPS were in an even stronger financial position than those that were not. A possible explanation for this counterintuitive result may be that economic conditions were generally better in the UK than the Non-UK sample, as evidenced by increases in UK GDP throughout 2013 of 1.73% versus 1.06% (Germany), 0.28% (France), -1.93% (Italy), and -1.23% (Spain).[34] Fixed-effects regression analyses in Appendix B also support the conclusion that macroeconomic improvements negated the solvency effect of the CPS.

The lack of an observed change in corporate solvency suggests that the financial position of UK energy-intensive firms was not, net of macroeconomic conditions, heavily impacted by the CPS at the end of the 2013 financial year. To examine this assertion, we compare 2012-13 Z-Scores for energy-intensive firms in the UK only.

[34] Source: World Bank Data, GDP growth (annual %).

Figure 3: UK-only Energy-intensive Firms 2012 and 2013 EU-based Altman's Z-Score Histogram, (n=74)



Kernel = epanechnikov, bandwidth = 0.1779

Table VI: Kolmogorov-Smirnov Test for Equality of UK 2012 and 2013 Z-Score Distributions

	Largest Difference	P-value
2013 > 2012	0.0541	0.806
2013 < 2012	-0.0946	0.516
Combined Test	0.0946	0.895

Visual inspection confirms the similarity of Z-Score distributions between 2012 and 2013 for firms in the UK-only, and as expected, the Kolmogorov-Smirnov test does not reject the null hypothesis of equivalence of the 2012 and 2013 UK distributions. This result also suggests that the CPS had not put undue financial pressure on the firms most affected by it.

As a further robustness check, we also examine the change in corporate death (bankruptcy) rates for energy-intensive firms in the UK between 2012 and 2013 in Table VII. Again we find that not only did corporate death rates for these firms not increase between 2012 and 2013, they in fact fell marginally.

Table VII: UK Business Deaths and Survival 2012 and 2013

	2012	2013
Deaths	665	690
Survival	6,190	6,410
Death Rate	10.80%	10.76%

Source: ONS Business Demography 2013. Represents annual data based on the 2007 SIC Code conversions of 2003 SIC Code data from Table VIII in the Appendix, and ending in November of the stated year.

5. Discussion

5.1 The Effect of the CPS

Given that (i) 2013 Z-Scores for energy-intensive firms in the UK are statistically higher than Non-UK Z-Scores; (ii) 2012 and 2013 UK-only energy-intensive firm Z-Scores are statistically indistinguishable; and (iii) that the death rate of energy-intensive firms in the UK in fact decreased between 2012 and 2013, we can infer that energy-intensive firms in the UK were not under undue financial pressure as a result of the CPS. Therefore, we would argue that the industrial outcry against the CPS and UK policymakers' decision to freeze it in response were unwarranted.

However, a number of qualifications to this result should be noted. To begin with, even when including the CPS, the magnitude of total carbon taxation in the UK currently falls short of the level that would be required to achieve the UNFCCC's ultimate goal of constraining greenhouse gas concentrations below dangerous levels. For instance, research by Anthoff, Tol, and Yohe[35] estimated the optimal social price of carbon at 60-200$/tn CO_2. Should the UK or other countries raise carbon taxation to such levels, the effect on carbon intensive industries could be dramatic. Indeed, the Carbon Price Support was slated to rise to 70£/tn CO_2 by 2030 in order to address this very need, but industry pressure caused policymakers to indefinitely postpone further increases from 2015.

Our results may also have been influenced by other policy changes that contemporaneously (2012-13) occurred both in the UK and control countries. However, in spite of this qualification, the most significant new policy affecting energy-intensive industries in the five countries and time frame under study was the CPS, and therefore the potential for this particular source of bias is limited. Furthermore, even if confounding effects from such policies do exist, this would not affect our conclusion that corporate solvency remained relatively robust following the introduction of the CPS.

There is also the criticism that it may take longer than a single financial year for the full effects of the Carbon Price Support to materialise. Nevertheless, previous research that has investigated time-varying effects of environmental regulation on economic outcomes tends to find negative effects initially, followed by positive effects in subsequent years.[36] Moreover for this study, extending the treatment period in attempting to capture a prolonged negative effect would increase the time frame around which contemporaneous policy changes could bias results. While it is almost certainly the case that solvency responses to climate-related legislation do develop cumulatively over a number of years, over even longer time frames it has been argued by Porter[37] and Porter and van der Linde[38] that properly designed environmental policies can stimulate innovation that may partially or even fully offset the costs of compliance. In addition, it has also been shown by Xepapadeas and DeZeeuw[39] and Commins, Lyons, Schiffbauer, and Tol[40] that increases in production costs due to a carbon price lead firms to increase average productivity. Hence, the long-term negative impacts of a carbon tax might also be less than those measured over the shorter-term, and potentially even a net positive to firm performance (a potentially cooler future world notwithstanding). Finally, this criticism would be easily addressed in practice via the continuous solvency monitoring proposed here.

Another possible criticism of the result that the CPS did not have a strong negative effect on solvency is that, since the CPS was implemented through the tax system rather than as a contractual arrangement, its repeal

[35] Anthoff, D., Tol, R.S.J., and G.W. Yohe (2009). Risk aversion, time preference, and the social cost of carbon. Environmental Research Letters, 4(2): 024002 (7pp).
[36] Kozluk, T., and V. Zipperer (2013). Environmental Policies and Productivity Growth: A Critical Review of Empirical Findings. OECD Economics Department Working Papers, No. 1096.
[37] Porter, M. (1991). America's Green Strategy. Scientific American, 264(4): 96-168.
[38] Porter, M., and C. van der Linde (1995) Toward a new conception of the environment-competitiveness relationship. Journal of Economic Perspectives, 9(4): 97-118.
[39] Xepapadeas, A., A. DeZeeuw (1999). Environmental policy and competitiveness: the Porter hypothesis and the composition of capital, Journal of Environmental Economics and Management, 37:165-182.
[40] Commins, N., Lyons, S., Schiffbauer, M., and R.S.J. Tol (2011). Climate Policy and Corporate Behaviour. Energy Journal, 32(4): 51-68.

and/or amendment is a comparatively simple exercise (as turned out to be the case). Hence, energy-intensive firms may have discounted the threat that the CPS posed to their future profitability. And even though the tax itself would have impacted corporate financials to a degree, firms may not have responded as dramatically as they would have if they had believed the CPS was credibly a long-term policy: for example, by investing in less carbon-intensive production methods.

In spite of these methodological and practical qualifications, given that the purpose of this exercise is to demonstrate the practicality of using corporate solvency to calibrate climate policy generally and not identify an effect on solvency specifically, we believe that this analysis of the CPS is still instructive.

5.2 Solvency Levels and Optimal Policy

The question of where the optimal solvency threshold should lie is important for the practical application of this policy. For instance, it could be argued that either (i) an average solvency level; (ii) a minimum solvency level for the most financially distressed firm; or (iii) a maximum solvency loss should be the relevant benchmark. Moreover, the policy goal may not just be solvency for affected firms but also their competitiveness, in which case, depending on the regulations also faced by international competitors, the optimal lower bound for solvency may need to be raised in Figure 1 from financial distress to some other higher level. The universal availability and timeliness of financial data will also influence the optimal threshold level. Since the financial position of firms may deteriorate between financial reports, it may be prudent to adjust thresholds upwards to add a margin of safety against rapid solvency losses. Of course, as in any such policy, it would be essential to ensure that firms could not 'game' their financial statements in order to present an artificially dire picture to sympathetic regulators. It may also be the case that within a given emissions target, it may not be possible to maintain the solvency of all affected firms. In such cases the emissions target may need to take precedence over solvency concerns, but nevertheless the use of policy calibration via solvency could still be an efficient way to minimise whatever bankruptcies may be necessary to achieve the desired emission reduction goal.

Future research may look to refining the Altman Z-Scores produced above, or compare other methods for producing metrics of corporate solvency, such as conditional probability models. Such research could also quantify and operationalise the 'optimal' trajectory of corporate solvency depicted in Figure 1 according to specific industries, macroeconomic conditions, financial reporting regimes, and climate change targets. Historical instances of other significant environmental regulation such as the sulfur dioxide cap and trade programme in the US or automobile emissions standards could also be evaluated from the standpoint of optimal corporate solvency trajectories for affected firms, improving our understanding of the efficiency of these interventions, and potentially suggesting implications for the improvement of current and future environmental policies.

6. Conclusion

This paper has introduced solvency targeting as a means for governments to efficiently calibrate the stringency of climate change policies, and applied this technique to the UK's recent CPS policy. Using Altman's Z-Scores as a measure of solvency for energy-intensive firms it was found that (i) after the introduction of the CPS in 2013, UK Z-Scores were in fact statistically higher than Non-UK Z-Scores; (ii) UK-only Z-Scores before and after the introduction of the policy (2012-13) are statistically indistinguishable; and (iii) the corporate death rate of energy-intensive firms in the UK actually decreased between 2012 and 2013. Therefore, the evidence uniformly points to the conclusion that energy-intensive firms in the UK were not under inordinate financial strain as a result of the CPS, and therefore that the subsequent postponement of CPS price increases was unjustified. In order to meet now deferred climate goals and to deal with the possibility of rising economic and climate uncertainty, governments may be compelled to enact increasingly strict carbon-limiting policies. Against this backdrop, the employment of an objective tool to calibrate the optimal stringency of climate policy will become ever more valuable in mitigating the social costs of this climate change transition.

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Appendix A

Table VIII: European Union Official Energy-intensive Industries

2003 SIC Code	2007 SIC Code	Description
27.42	24420	Aluminium production
14.3	08910	Mining of chemical and mineral fertilizer minerals
24.13	20130	Manufacture of other inorganic basic chemicals
27.43	24430	Lead, zinc and tin production
18.1	14110	Manufacture of leather clothes
27.1	24100	Manufacture of basic iron and steel and of ferro-alloys
21.12	17120	Manufacture of paper and paperboard
24.15	20150	Manufacture of fertilizer and nitrogen compounds
27.44	24440	Copper production
24.14	20140	Manufacture of other organic basic chemicals
17.11	13100	Preparation and spinning of cotton-type fibres
24.7	20600	Manufacture of man-made fibres
13.1	07100	Mining of iron ores
24.16	20160	The following sub-sectors within manufacture of plastics in primary forms 24161039 – Low-density polyethylene 24161035 – Linear low-density polyethylene 24161050 – High-density polyethylene 24165130 – Polypropylene 24163010 – Polyvinyl chloride 24164040 – Polycarbonate
21.11	17110	The following sub-sectors within manufacture of pulp 21111400 – Mechanical Pulp

Appendix B

In order to test for the likely causes of the lack of a measured effect of the CPS on corporate solvency, we employ a fixed-effects estimation with respect to each firm's Altman Z-Score between 2012 and 2013. For control variables we use Total Assets from the year before the CPS programme (ie 2012), industrial sector, and change in macroeconomic variables – GDP, Inflation Rate, Unemployment Rate, and GBP Exchange Rate. Note that for non-UK firms, increases in the 'Δ Exchange Rate with GBP' variable corresponds to a strengthening of the euro relative to the pound. For UK firms, the 'Δ Exchange Rate with GBP' variable is always zero.

A stepwise regression is run, sequentially incorporating first just the treatment variable (Carbon Price Support), secondly the firm specific controls, and finally the macroeconomic controls. We also run an interaction between the Carbon Price Support and Total Assets variable in order to test whether there may be a differential effect with respect to firm size; this might occur, for instance, due to economies of scale in the costs of CPS compliance.

A unique aspect of the Carbon Price Support as opposed to other studies of carbon prices is that approval for a compensation programme for energy-intensive industries was not granted until over a year after the imposition of the tax (see Table I).[41] Hence, for the first year of the programme the measured effect of the CPS on corporate solvency can be more accurately isolated.

[41] The EU ETS for instance used free permit allocations to affect this outcome, and countries imposing carbon taxes such as Finland, Sweden, and Norway all provided equivalent dispensations to their most vulnerable firms.

Table IX: Fixed-effects regression by firm 2012-2013, n=463 (74 UK firms), EU-based 2000-2014 Z-Score.

VARIABLES	(1) Δ Altman's Z Fixed-effects	(2) Δ Altman's Z Fixed-effects	(3) Δ Altman's Z Fixed-effects	(4) Δ Altman's Z Fixed-effects
Carbon Price Support	-0.0101	-0.0325	-0.237*	-0.246*
	(0.0776)	(0.0823)	(0.132)	(0.137)
Total Assets 2012 ('000s)		-2.18e-08	-4.04e-08	-4.96e-08
		(1.79e-07)	(1.82e-07)	(1.86e-07)
Carbon Price Support × Total Assets 2012				2.34e-07
				(9.32e-07)
Metals		0.000290	0.0570	0.0581
		(0.0699)	(0.0869)	(0.0870)
Primary		0.0664	-0.00939	-0.00972
		(0.251)	(0.260)	(0.260)
Textiles		0.165***	0.211***	0.212***
		(0.0552)	(0.0802)	(0.0803)
Paper		0.0252	0.0508	0.0499
		(0.0925)	(0.106)	(0.106)
Δ GDP 2012-13			0.333**	0.334**
			(0.152)	(0.153)
Δ Interest Rate 2012-13			0.322	0.322
			(0.201)	(0.201)
Δ Unemployment Rate 2012-13			0.772*	0.772*
			(0.422)	(0.422)
Δ Exchange rate with GBP 2012-13			-0.867	-0.876
			(1.743)	(1.745)
Observations	463	463	463	463
R-squared	0.000	0.019	0.034	0.034

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable is Δ Altman's Z-Score
Omitted industry sector dummy is Chemicals

As we can see from Table IX, with industry and macroeconomic controls the Carbon Price Support exhibits a statistically significant effect in the anticipated direction and at the 10% level, which can be considered significant given the one-tailed nature of this test. The macroeconomic control variables, 'Δ GDP' and 'Δ Exchange Rate', exhibit their theoretically expected signs, whereas the expected sign of 'Δ Interest Rate' and 'Δ Unemployment Rate' may be more ambiguous.[42] The control variables which demonstrate statistical significance are the Textile industry dummy, 'Δ GDP' and 'Δ Unemployment'. Although this analysis supports the conclusion that increases in GDP in the UK relative to control countries are responsible for the lack of a solvency loss as a result of the CPS, a notable limitation of these models is the low proportion of the total variance that the models explain.

[42] For instance, net of GDP changes, increases in the 'Δ Unemployment Rate' variable could in fact be proxying for lower wage costs to the firm.

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