Carbon Policy and Stock Returns

Signals from Financial Markets

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Outline

Motivation & research question

Conceptual framework & data

Empirical strategy

Results

Conclusions

Motivation

- Many countries have committed to reaching net-zero emissions in response to nearly unanimous consensus on human-caused climate change
  - Carbon pricing tools are key to reach emission reduction goals
- The EU is a pioneer in the effort to reduce carbon emissions
  - In 2005, it set a cap on CO2 emissions and established the Emissions Trading System (EU ETS)
  - This was the world's first international emissions trading scheme
- Reaching emission reduction goals requires redirecting financial resources towards low-emission activities
- Carbon pricing policies, such as the EU ETS, are therefore more effective if they cause financial markets to price in emission externalities, and ultimately raise the cost of capital for emission-intensive firms

This paper

We use features of the EU ETS and firm-level data to examine whether:

1. Carbon policies affect stock returns
2. There are asymmetric effects: tighter vs. looser-than-anticipated policies

Key findings:

1. Regulatory announcements that increase carbon prices have a negative impact on stock returns for carbon-intensive firms
2. The impact is larger when regulatory announcements result in an increase in carbon prices (but the difference is not statistically significant)

Literature (selective)

- Company-level carbon emissions lead to higher stock returns in a cross-section of firms (Bolton and Kacperczyk, 2021a, 2022)
- Higher carbon prices translate to lower returns for EU ETS firms with shortfalls in freely allocated allowances (Bolton et al., 2023; Millischer et al., 2022)
  $\rightarrow$ within the EU ETS, the cost channel dominates the risk compensation channel
- Financial markets respond to climate policy initiatives (Bauer et al., 2023; Seltzer et al., 2022)
- Investors monitor and differentiate firms across their perceived exposure to climate-related risks (Faccini et al., 2023; Krueger et al., 2020; Sautner et al., 2021)

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Cross-sectional returns vs. policy shock: three scenarios

- Evidence that carbon emissions affect the cross section of stock returns both in the US and globally (Bolton and Kacperczyk, 2021b, 2022)
- Two firms produce at no cost one asset which will have value C at time T
  - A produces a "green" asset and B a "brown" asset
  - Rate of return for both firms is r; firm value at time t is then

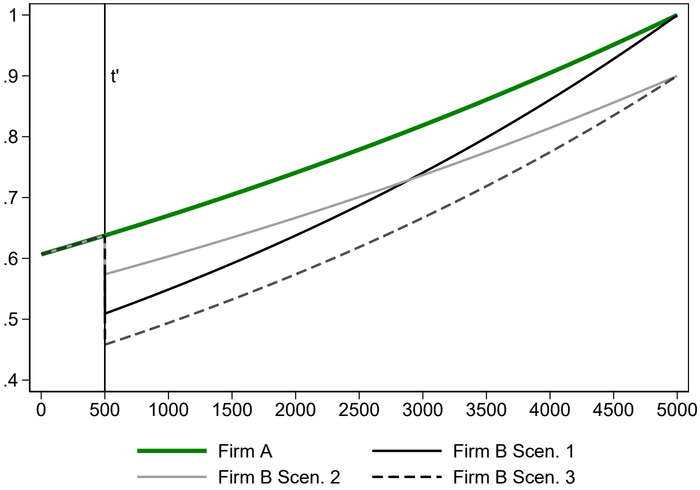
$$V_t^A = V_t^B = \frac{C}{(1+r)^{T-t}}$$

- At time $t' > t$ there is a policy shock which affects the value of the asset produced by firm B

  Three scenarios:

  1. Value of asset is still C; however, value is no longer certain (risk premium $\rho > 0$)
  2. Value of asset is δC ($\delta < 1$) with certainty
  3. Value of asset is δC ($\delta < 1$) and no longer certain ($\rho > 0$)

Cross-sectional returns vs. policy shock: an illustration

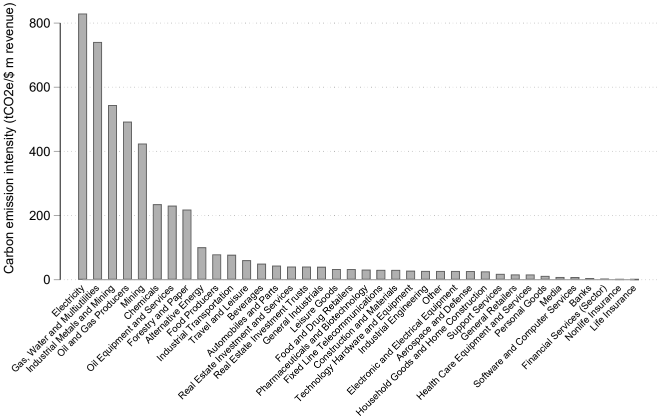


Data

- Scope 1 and 2 emission intensity: Urgentem
- Stock returns and EUA futures price: Datastream
- EU ETS regulatory events: Känzig (2022) + hand-collected

Sample: 2,149 firms across 38 sectors in 23 EU countries over January 2011–December 2021.

Carbon emission intensity



EU ETS: identifying regulatory events

EU ETS:

- Launched in 2005 as the first international emission trading scheme
- Operates under cap and trade principle → emission allowances (EUAs) can be traded in spot and futures markets
- Most liquid markets to trade EUAs are futures markets

Regulatory updates on the supply of emission allowances:

- 83 events over Jan 2011–Dec 2018 from Känzig (2022)
- Extend with 15 events over Jan 2019–Dec 2021

Carbon policy surprises

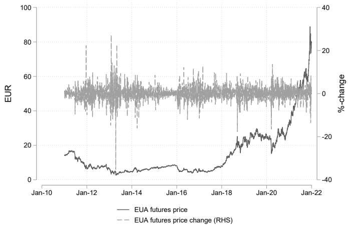
- High-frequency identification of carbon policy surprises based on unexpected changes in carbon prices following Känzig (2022)

$$CPS_d = \Delta CP_d \times EV_d \quad (1)$$

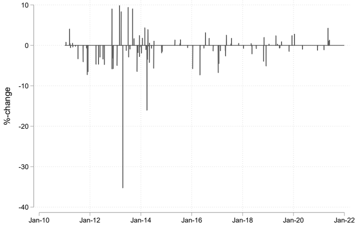
  - ΔCP_d is the daily change in EUA futures price (from ICE London)
  - EV_d is a dummy that takes value 1 on event days and 0 otherwise

- Positive values → tighter-than-anticipated policy announcement

EU ETS carbon price



Carbon policy surprises



Outline

Empirical strategy I

Baseline:

$$R_{i,d(y)} = CE_{i,y-1}\left(\alpha + \beta_1 \Delta CP_{d(y)} + \beta_2 EV_{d(y)} + \beta_3 \Delta CP_{d(y)} \times EV_{d(y)}\right) + \phi_i + \tau_{c,s,d(y)} + \varepsilon_{i,d(y)} \tag{2}$$

where:

- $R_{i,d(y)}$ measures stock return of company i on day d in year y
- $CE_{i,y}$ measures carbon intensity of company i in year y
- $\Delta CP_{d(y)}$ measures daily change in carbon price
- $EV_{d(y)}$ is dummy variable that takes value one on days of regulatory events
- ϕ_i are firm fixed effects, $\tau_{c,s,d(y)}$ are country-sector-time fixed effects

One key parameter of interest is β_3.

However, β_3 alone is not enough to estimate the causal effect of carbon policy on stock return for emission intensive firms.

Empirical strategy II

Two potential concerns:

- Proxy for the policy shock, *CPS*, potentially contaminated by other shocks
- Proxy for the policy suprise only captures indirect effect

Assume that carbon price depends on three *uncorrelated* **shocks:**
$\Delta CP = D + P + U$

* D is a demand shock
* P is the policy shock we care about
* U is a residual shock

$$\begin{tikzcd}
& D \arrow[d] \arrow[dr] & \\
U \arrow[r] & \Delta CP \arrow[r] & R \\
& P \arrow[u] \arrow[ur] &
\end{tikzcd}$$

Empirical strategy III

- β_3 in equation 2 does not measure the effect of a regulatory policy shock on stock returns
- It is the difference between the correlation between ΔCP and R on event days and the correlation between ΔCP and R on non-event days
- Recover the total impact of carbon policy on stock returns ($\hat{g}$ henceforth) from the the parameters of equation 2. Specifically:

$$\hat{g} = \hat{\beta}_1 + \hat{\beta}_3 \frac{k}{k-1} \tag{3}$$

  where $k \geq 1$ is the ratio between the variance of ΔCP_t on event days and the variance of ΔCP_t on non-event days. Proof
- $\hat{g}$ is larger (in absolute value) than $\hat{\beta}_3$ as long as $\hat{\beta}_1(k-1) < -\hat{\beta}_3$

  $\Rightarrow$ In our baseline estimates: $\hat{g} \approx 1.2\hat{\beta}_3$.

Outline

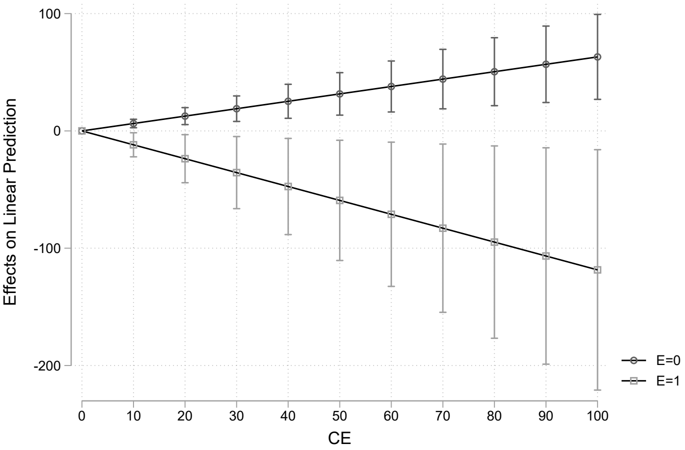
Baseline estimations

	(1)	(2)	(3)	(4)	(5)	(6)
CE	2.27***	1.27**	1.17**	1.36***	1.27**	1.25**
	[0.606]	[0.501]	[0.507]	[0.504]	[0.502]	[0.510]
CE $\times$ ΔCP			0.58***			0.63***
			[0.213]			[0.220]
CE $\times$ EV				-3.71*		-3.96*
				[2.212]		[2.198]
CE $\times$ ΔCP $\times$ EV					-1.08*	-1.81***
					[0.621]	[0.645]
$\hat{g} = \hat{\beta}_1 + \hat{\beta}_3 \times \frac{k}{k-1}$						-2.20**
						[0.969]
						[1.088]
Observations	1,247,870	1,247,870	1,247,870	1,247,870	1,247,870	1,247,870
R-squared	0.16	0.4	0.4	0.4	0.4	0.4
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	No	No	No	No	No
Country-Sector-Time FE	No	Yes	Yes	Yes	Yes	Yes

Robust standard errors in brackets, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

- Carbon policy surprises are negatively correlated with stock returns
  $\rightarrow$ a positive (tighter) surprise negatively impacts stocks returns

Stock returns and carbon prices on non-event and event days



Note: The figure is based on column 6 of the baseline estimations.

Controlling for time-varying firm characteristics

	(1)	(2)	(3)	(4)
CE $\times$ ΔCP	0.58***			0.63***
	[0.210]			[0.217]
CE $\times$ EV		-3.64*		-3.88*
		[2.171]		[2.199]
CE $\times$ ΔCP $\times$ EV			-1.06*	-1.80***
			[0.560]	[0.589]
$\hat{g} = \hat{\beta}_1 + \hat{\beta}_3 \times \frac{k}{k-1}$				-2.174**
				[0.880]
				[1.001]
Observations	1,247,870	1,247,870	1,247,870	1,247,870
R-squared	0.41	0.41	0.41	0.41
Country-Sector-Time FE	Yes	Yes	Yes	Yes
Firm-Year-Quarter FE	Yes	Yes	Yes	Yes

Robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

- Results are unchanged when controlling for firm-year-quarter fixed effects $\rightarrow$ not driven by time-varying firm-level unobserved heterogeneity

Excluding EU ETS sectors

	(1)	(2)
CE	0.94	
	[0.747]	
CE $\times$ ΔCP	0.44*	0.45*
	[0.246]	[0.249]
CE $\times$ EV	-5.43***	-5.37***
	[1.878]	[1.856]
CE $\times$ ΔCP $\times$ EV	-2.39***	-2.41***
	[0.833]	[0.772]
$\hat{g} = \hat{\beta}_1 + \hat{\beta}_3 \times \frac{k}{k-1}$	-5.81***	-5.86***
	[2.190]	[2.026]
Observations	1,025,509	1,025,509
R-squared	0.38	0.39
Firm FE	Yes	No
Country-Sector-Time FE	Yes	Yes
Firm-Year-Quarter FE	No	Yes

Robust standard errors in brackets, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

- Results hold when firms in EU ETS sectors are excluded
  $\rightarrow$ investors price in transition risk

Testing for asymmetries

	(1)	(2)
CE	2.39***	
	[0.697]	
CE $\times$ ΔCP	1.19***	1.23***
	[0.396]	[0.415]
CE $\times$ EV	-3.79	-3.57
	[3.482]	[3.559]
CE $\times$ ΔCP $\times$ EV	-1.98**	-1.92**
	[0.920]	[0.851]
CE $\times$ ΔCP $\times$ D	-1.10**	-1.17*
	[0.552]	[0.603]
CE $\times$ ΔCP $\times$ EV $\times$ D	-0.16	-0.26
	[2.392]	[2.400]
Observations	1,247,870	1,247,870
R-squared	0.40	0.41
Firm FE	Yes	No
Country-Sector-Time FE	Yes	Yes
Firm-Year-Quarter FE	No	Yes

Robust standard errors in brackets, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

- No statistically significant difference between positive and negative carbon policy surprises, but magnitudes differ
  $\rightarrow$ positive surprises have a larger effect

Robustness checks

- Placebo test for daily events ✓ Figure
- Window around events ✓ Figure
- Alternative emission lagging strategies ✓ Table
- Dropping one country at a time ✓ Figure
- Advanced Europe only ✓, Continental Europe plus UK ✓, Emerging Europe only X Table
- Excluding financial institutions Table ✓

Outline

Key takeaways

We combine features of EU ETS and firm-level data for over 2,000 European listed firms to explore whether carbon policy affects stock returns and find that:

- Regulatory events which result in an increase in carbon prices lower relative stock returns for firms with high carbon intensity

  ⇒ Policies that lead to an increase in carbon price are effective in raising the cost of equity capital for emission-intensive firms

- The effect extends to firms in sectors that *do not* participate in the EU ETS

  ⇒ The effect does not only go through higher costs
  ⇒ Investors seem to price in transition risk

- The response is larger when regulatory event results in an increase in carbon prices

  ⇒ Investors react more to tightening policy surprises

Additional slides

Summary statistics

	Variable	Mean	Median	SD
Daily stock return (percent)	R	0.048	0.000	2.364
Scope 1 + 2 carbon emissions intensity (tCO2e/$m revenue)	CE	169.24	26.26	503.96
Daily change in EUA futures price (percent)	ΔCP	0.11	0.00	3.21
Daily change in EUA futures price on event days only (percent)	$\Delta CP \times EV$	-1.12	-0.72	5.24

Proof of equation 3

- Without loss of generality, assume that $CE_i = 1$ for all firms
- Recall that $\Delta CP = D + P + U$
- If we could observe D and U we could estimate the effect of carbon prices on non-regulatory event days with the following equation:

$$R_t = a_1 + bD_t + cU_t + \varepsilon_t \tag{4}$$

  where b is the effect of the demand shock and c is the effect of a carbon price shock on stock returns
- Note that b is the *total* effect of the demand shock on returns
  - This the sum of the direct effect ($D \to R$) and the indirect effect through carbon price ($D \to \Delta CP \to R$)
- Instead, c measures the effect on returns of an independent shock U to carbon price

Proof of equation 3

As we do not observe D and U, we cannot separately estimate b and c. However, we observe $\Delta CP = D + U$ and can estimate the following model:

$$R_t = a_2 + m_1 \Delta CP_t + \varepsilon_t \tag{5}$$

where $\hat{m}_1$ is a weighted average of b and c Specifically:

$$\hat{m}_1 = b\frac{cov(D, \Delta CP_t)}{V(\Delta CP_t)} + c\frac{cov(U, \Delta CP_t)}{V(\Delta CP_t)} \tag{6}$$

As $E(DU) = 0$: $V(\Delta CP_t) = V(D) + V(U)$; $cov(D, \Delta CP_t) = V(D)$; $cov(U, \Delta CP_t) = V(U)$. Hence:

$$\hat{m}_1 = b\frac{V(D)}{V(D) + V(U)} + c\frac{V(U)}{V(D) + V(U)} \tag{7}$$

Proof of equation 3

Let us now consider regulatory event days. If we observed D, U and P, we could estimate:

$$R_t = a_3 + bD_t + cU_t + gP_t + \varepsilon_t \tag{8}$$

- b is the total effect of the demand shock on returns ($D \to R$ plus $D \to \Delta CP \to R$)
- g is the total effect of the policy on returns ($P \to R$ plus $P \to \Delta CP \to R$)

  $\to$ This is what we care about
- c is effect of U on returns (not the total effect of carbon price on returns)

- As we only observe $\Delta CP_t = D_t + U_t + P_t$, we estimate:

$$R_t = a_4 + m_2 \Delta CP_t + \varepsilon_t \tag{9}$$

$\hat{m}_2$ is a weighted average of b, c, and g, with:

$$\hat{m}_2 = b\frac{V(D)}{V(D+U+P)} + c\frac{V(U)}{V(D+U+P)} + g\frac{V(P)}{V(D+U+P)} \tag{10}$$

- We do not observe $V(D)$ and $V(U)$ separately, but we observe:
  - $V(\Delta CP_{\tilde{E}}) = V(D+U)$ (the variance of ΔCP on non-event days)
  - $V(\Delta CP_E) = V(D+U+P)$ (the variance of ΔCP on event days)

Proof of equation 3

- Let us write $V(\Delta CP_E) = kV(\Delta CP_{\tilde{E}})$, with $k > 1$ if $V(P) > 0$.
- Using the fact that $V(P) = V(\Delta CP_{\tilde{E}})(k-1)$, we can write Equation 10 as:

$$\hat{m}_2 = \left(b \frac{V(D)}{V(\Delta CP_{\tilde{E}})} + c \frac{V(U)}{V(\Delta CP_{\tilde{E}})} \right) \frac{1}{k} + g \frac{k-1}{k} \tag{11}$$

- Substituting Equation 7 into Equation 11, we get $\hat{m}_2 = \frac{\hat{m}_1}{k} + g\frac{k-1}{k}$
- Solving for g, we obtain:

$$g = \frac{\hat{m}_2 k - \hat{m}_1}{k-1} \tag{12}$$

- Given that we can estimate $\hat{m}_1$, $\hat{m}_2$, and we know k, we can recover g
- In the set up of Equation 2, $\hat{m}_1 = \hat{\beta}_1$ and $\hat{m}_2 = \hat{\beta}_1 + \hat{\beta}_3$
- Substituting into Equation 12, we can compute the total effect of P on R:

$$\hat{g} = \frac{(\hat{\beta}_1 + \hat{\beta}_3)k - \hat{\beta}_1}{k-1} = \hat{\beta}_1 + \hat{\beta}_3 \frac{k}{k-1} \tag{13}$$

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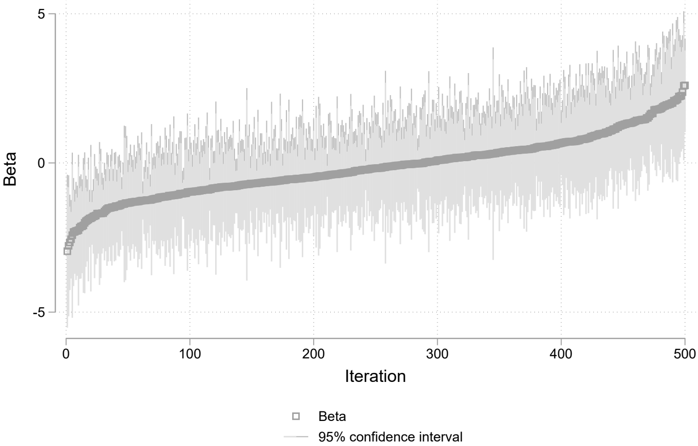
Placebo test for daily events



Note: This figure plots our main coefficient of interest, β_3^h, from our baseline specification together with 95 percent confidence intervals for 500 randomly simulated carbon policy surprise series.

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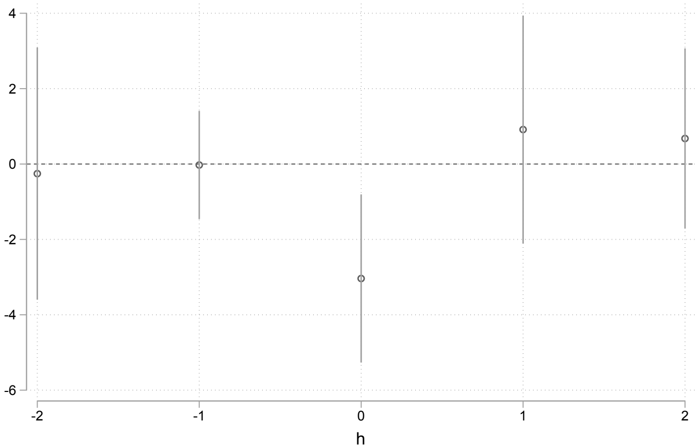
Window around events



Note: This figure plots our main coefficient of interest, $\beta_{\mathbf{3}}^{h}$, at different horizons together with 95 percent confidence intervals.

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Alternative emission lagging strategies

Column 2 shows the results for a specification in which returns are regressed on carbon emissions published in the previous year for observations in Q1 and Q2 and on carbon emissions published in the same year for observations in Q3 and Q4. Column 3 shows the results for a specification in which returns are regressed on carbon emissions published in the previous year for observations in Q1 and on carbon emissions published in the same year for observations in Q2, Q3, and Q4. For convenience, column 1 reproduces the baseline estimations in which returns are regressed on carbon emissions published in the previous year for observations in all quarters.

	(1)	(2)	(3)
CE	1.25**	1.27**	0.56
	[0.510]	[0.568]	[0.629]
CE $\times$ ΔCP	0.63***	0.86***	1.08***
	[0.220]	[0.246]	[0.267]
CE $\times$ EV	-3.96*	-4.98*	-1.85
	[2.198]	[2.874]	[2.876]
CE $\times$ ΔCP $\times$ EV	-1.82***	-1.50**	-2.77***
	[0.645]	[0.700]	[0.924]
Observations	1,247,870	1,246,917	1,245,577
R-squared	0.4	0.39	0.38
Firm FE	Yes	Yes	Yes
Country-Sector-Time FE	Yes	Yes	Yes

Robust standard errors in brackets
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

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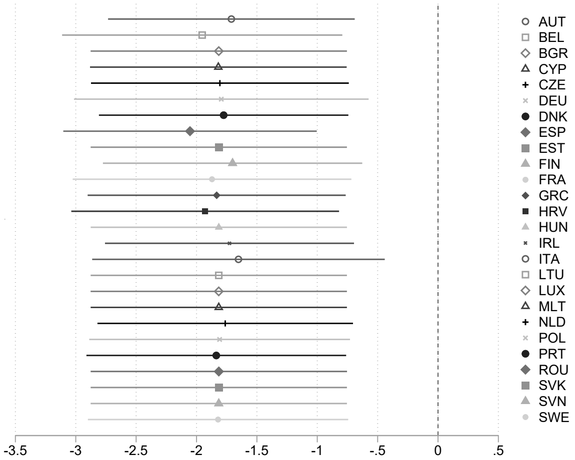
Dropping one country at a time



Note: This figure plots our main coefficient of interest, β_3^h, together with 90 percent confidence intervals. The regressions drop one country at a time from the estimation sample (the column to the right specifies the dropped country).

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Regional heterogeneity

Column 2 shows results for a subsample of advanced European economies; column 3 focuses on economies in emerging Europe; and column 4 uses all EU countries plus the UK. For convenience, column 1 reproduces the baseline estimations.

	(1)	(2)	(3)	(4)
CE	1.25**	1.29**	0.93	0.78
	[0.510]	[0.526]	[2.477]	[0.597]
CE $\times$ ΔCP	0.63***	0.65***	-0.12	0.65***
	[0.220]	[0.222]	[1.211]	[0.192]
CE $\times$ EV	-3.96*	-3.57	-14.72	-3.04
	[2.198]	[2.250]	[12.623]	[2.048]
CE $\times$ ΔCP $\times$ EV	-1.82***	-1.92***	4.27	-1.86***
	[0.645]	[0.683]	[8.043]	[0.477]
Observations	1,247,870	1,172,947	74,923	1,745,630
R-squared	0.4	0.41	0.34	0.39
Firm FE	Yes	Yes	Yes	Yes
Country-Sector-Time FE	Yes	Yes	Yes	Yes
Sample	All	AEs	EMs	All + UK

Robust standard errors in brackets, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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Excluding financial institutions

This table estimate the baseline estimations by dropping the stocks of financial institutions.

	(1)	(2)	(3)	(4)
CE	1.20**	1.39***	1.30***	1.28**
	[0.510]	[0.507]	[0.505]	[0.513]
CE $\times$ ΔCP	0.60***			0.65***
	[0.216]			[0.224]
CE $\times$ EV		-3.70*		-3.95*
		[2.199]		[2.186]
CE $\times$ ΔCP $\times$ EV			-1.06*	-1.82***
			[0.619]	[0.644]
Observations	1,056,020	1,056,020	1,056,020	1,056,020
R-squared	0.37	0.37	0.37	0.37
Firm FE	Yes	Yes	Yes	Yes
Country-Sector-Time FE	Yes	Yes	Yes	Yes

Robust standard errors in brackets, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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