Carbon Policy Surprises and Stock Returns
Signals from Financial Markets

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The views expressed in this presentation are those of the authors and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.
Outline

Motivation & research question

Conceptual framework & data

Empirical strategy

Results

Conclusions
Motivation

- Many countries have committed to reaching net-zero emissions

- Carbon pricing tools are key to reach emission reduction goals

- EU set up the Emissions Trading System (EU ETS) in 2005 → world’s first international emissions trading scheme

- Carbon pricing tools, if effective, could raise the cost of capital for emission-intensive firms relative to their low-emission counterparts
We use features of the EU ETS and firm-level data to examine whether:

1. Carbon policies affect stock returns
2. Transition risk plays a role
3. 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. Investors price in transition risk
3. The impact is larger when regulatory announcements result in an increase in carbon prices (but the difference is not statistically significant)
Related literature (selective)

Climate risk and financial markets:
▶ Carbon premium: investors demand a risk premium for exposure to carbon emissions in cross-section of firms (Bolton and Kacperczyk, 2021a, 2022)
▶ Pollution premium: cross-sectional variation in stock returns is linked to industrial pollution (Hsu et al., 2022)

Climate policy and financial markets:
▶ Correlation between stock returns and carbon price for EU ETS firms depends on free allowances (Bolton et al., 2022; Millischer et al., 2022)
▶ Climate risk associated with government interventions is priced into stocks (Faccini et al., 2021)
▶ Paris Agreement (Dec 2015) increased credit risk of listed companies with high carbon footprints (Seltzer et al., 2022)
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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 $\delta C$ ($\delta < 1$) with certainty
3. Value of asset is $\delta C$ ($\delta < 1$) and no longer certain ($\rho > 0$)
Cross-sectional returns vs. policy shock: 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)

\[ CPS_d = \Delta CP_d \times EV_d \]  

- $\Delta CP_d$ 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

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EU ETS carbon price

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Carbon policy surprises

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Empirical strategy I

Baseline:

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

(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
- \( \phi_i \) are firm fixed effects, \( \tau_{c,s,d(y)} \) are country-sector-time fixed effects

One key parameter of interest is \( \beta_3 \).

However, \( \beta_3 \) 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 surprise 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
Empirical strategy III

- $\beta_3$ in equation 2 does not measure the effect of a regulatory policy shock on stock returns.
- It is the difference between the correlation between $\Delta CP$ and $R$ on event days and the correlation between $\Delta CP$ 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:

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

(3)

where $k \geq 1$ is the ratio between the variance of $\Delta CP_t$ on event days and the variance of $\Delta CP_t$ on non-event days.

- $\hat{\beta}_3$ is smaller (in absolute value) than $\hat{g}$ as long as $\hat{\beta}_1(k - 1) < -\hat{\beta}_3$

$\Rightarrow$ In our baseline estimates: $\hat{g} \approx 2.3\hat{\beta}_3$. 

Proof
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Baseline estimations

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<td>$\hat{\vartheta} = \hat{\beta}_1 + \hat{\beta}_3 \times \frac{k}{k-1}$</td>
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<td>Yes</td>
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Robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

- Carbon policy surprises 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

\[
\hat{g} = \hat{\beta}_1 + \hat{\beta}_3 \times \frac{k}{k-1}
\]

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<tr>
<td>Firm-Year-Quarter FE</td>
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<td>Yes</td>
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</tr>
</tbody>
</table>

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

- Results unchanged when controlling for firm-year-quarter fixed effects → not driven by time-varying firm-level unobserved heterogeneity
Excluding EU ETS sectors

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<td>0.45* [0.249]</td>
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<td>CE \times EV</td>
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<td>-5.37*** [1.856]</td>
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<td>CE \times \Delta CP \times EV</td>
<td>-2.39*** [0.833]</td>
<td>-2.41*** [0.772]</td>
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<td>\hat{g} = \hat{\beta}_1 + \hat{\beta}_3 \times \frac{k}{k-1}</td>
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<td>-5.86*** [2.026]</td>
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<td>Country-Sector-Time FE</td>
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<tr>
<td>Firm-Year-Quarter FE</td>
<td>No</td>
<td>Yes</td>
</tr>
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Robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

▶ Results hold when firms in EU ETS sectors are excluded → investors price in transition risk
Testing for asymmetries

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<thead>
<tr>
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<tbody>
<tr>
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<td><strong>CE × ΔCP</strong></td>
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<td>1.23***</td>
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<td>[0.415]</td>
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<td><strong>CE × EV</strong></td>
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<td>[3.559]</td>
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<td><strong>CE × ΔCP × EV</strong></td>
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<td>-1.92**</td>
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<td>[0.920]</td>
<td>[0.851]</td>
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<td><strong>CE × ΔCP × D</strong></td>
<td>-1.10**</td>
<td>-1.17*</td>
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<tr>
<td></td>
<td>[0.552]</td>
<td>[0.603]</td>
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<tr>
<td><strong>CE × ΔCP × EV × D</strong></td>
<td>-0.16</td>
<td>-0.26</td>
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<td></td>
<td>[2.392]</td>
<td>[2.400]</td>
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</table>

| 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 asymmetric effects between positive and negative carbon policy surprises but magnitudes differ → positive surprises have larger effects
Robustness checks

- Placebo carbon policy surprises ✓
- Dropping one country at a time ✓
- Advanced Europe only ✓
- Continental Europe plus UK ✓
- Emerging Europe only X
- Excluding financial institutions ✓
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Key takeaways

We combine 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

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<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>Daily stock return (percent)</td>
<td>0.048</td>
<td>0.000</td>
<td>2.364</td>
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<tr>
<td>Scope 1 + 2 carbon emissions intensity (tCO2e/$m revenue)</td>
<td>169.24</td>
<td>26.26</td>
<td>503.96</td>
</tr>
<tr>
<td>Daily change in EUA futures price (percent)</td>
<td>0.11</td>
<td>0.00</td>
<td>3.21</td>
</tr>
<tr>
<td>Daily change in EUA futures price on event days only (percent)</td>
<td>-1.12</td>
<td>-0.72</td>
<td>5.24</td>
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</tbody>
</table>
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:

$$R_t = a_1 + bD_t + cU_t + \varepsilon_t$$  (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 ($D \rightarrow R$) and the indirect effect through carbon price ($D \rightarrow \Delta CP \rightarrow R$)
- 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:

$$R_t = a_2 + m_1 \Delta CP_t + \varepsilon_t$$  \hspace{1cm} (5)

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

$$\hat{m}_1 = b \frac{\text{cov}(D, \Delta CP_t)}{V(\Delta CP_t)} + c \frac{\text{cov}(U, \Delta CP_t)}{V(\Delta CP_t)}$$ \hspace{1cm} (6)

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

$$\hat{m}_1 = b \frac{V(D)}{V(D) + V(U)} + c \frac{V(U)}{V(D) + V(U)}$$ \hspace{1cm} (7)
Proof of equation 3

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

$$R_t = a_3 + bD_t + cU_t + gP_t + \varepsilon_t$$  \hspace{1cm} (8)

- $b$ is the total effect of the demand shock on returns ($D \rightarrow R$ plus $D \rightarrow \Delta CP \rightarrow R$)
- $g$ is the total effect of the policy on returns ($P \rightarrow R$ plus $P \rightarrow \Delta CP \rightarrow R$)  \hspace{1cm} → 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:

$$R_t = a_4 + m_2 \Delta CP_t + \varepsilon_t$$  \hspace{1cm} (9)

$m_2$ is a weighted average of $b$, $c$, and $g$, with:

$$m_2 = b \frac{V(D)}{V(D + U + P)} + c \frac{V(U)}{V(D + U + P)} + g \frac{V(P)}{V(D + U + P)}$$  \hspace{1cm} (10)

- We do not observe $V(D)$ and $V(U)$ separately, but we observe:
  - $V(\Delta CP_{\bar{E}}) = V(D + U)$ (the variance of $\Delta CP$ on non-event days)
  - $V(\Delta CP_E) = V(D + U + P)$ (the variance of $\Delta CP$ on event days)
Proof of equation 3

Let us write \( V(\Delta C P_E) = kV(\Delta C P_{\tilde{E}}) \), with \( k > 1 \) if \( V(P) > 0 \).

Using the fact that \( V(P) = V(\Delta C P_{\tilde{E}})(k - 1) \), we can write Equation 10 as:

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

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 \( R \):

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