Appendix to

Using a Free Permit Rule to Forecast the Marginal Abatement Cost of Proposed Climate Policy

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Appendix A A model of cap-and-trade policy

This theoretical appendix serves two purposes. First, I introduce a standard model of cap-and-trade to establish the canonical "equivalence" result following Rubin (1996)'s dynamic extension of Montgomery (1972). This states that in a perfectly competitive setting, the least-cost marginal abatement cost of an economy-wide constraint on greenhouse gas emissions is equal to the equilibrium permit price under a cap-and-trade system with the same constraint. This provides the theoretical basis for how the initial period permit price can be recovered using my regression discontinuity design. I then consider the potential biases in the recovered permit price due to two violations of the standard model present in the Waxman-Markey bill: restrictions on permit borrowing and output-based permit allocation.

Appendix A.1 Marginal abatement cost and permit price equivalence

I first characterize the properties of how a hypothetical regulator could achieve a total level of emissions abatement over time across heterogeneous firms at least-cost. Because it would be impractical for any regulator to achieve this allocation, I then demonstrate how a cap-and-trade system with auctioned or freely allocated permits and unlimited banking and borrowing of permits can achieve the same allocation. In particular, the equilibrium permit price from the cap-and-trade system equals the marginal abatement cost of the least-cost solution to the regulator's problem.

Regulator's problem: joint-cost minimization

There are $i = 1...N$ firms in sector j that, in the aggregate, must deplete a fixed known stock of R emissions over the period $y \in [0, Y]$.[1] R is the aggregate emissions constraint, or cap. Consider an instantaneous profit function, $\pi_i(x_{ijy})$, that is concave and strictly increasing in emissions with standard Inada conditions. The regulator's problem with choice variable x_{ijy} and state variable b_y is to maximize discounted total profit:[2]

$$\begin{aligned} \max_{x_{ijy}} \quad & \int_0^Y e^{-\delta y} \sum_{i=1}^{N} \pi_i(x_{ijy}) dy \\ s.t. \quad & \dot{b}_y = -\sum_{i=1}^{N} x_{iy} \\ & b_0 = R, \quad b_Y \geq 0, \quad x_{ijy} \geq 0 \end{aligned}$$

[1] I assume that cap-and-trade regulation ends in 2050 as written in Waxman-Markey to avoid explicit assumptions about both business-as-usual emissions and cap-and-trade regulation beyond 2050.

[2] This setup differs from the Rubin (1996) model along two dimensions. First, the objective function is written in terms of firm profits and not the difference between unconstrained and constrained profits. Second, I write an equation of motion over depletion rather than accumulation. These choices were made for expository simplicity and are mathematically immaterial.

where δ is the exogenously determined rate of interest. Solving the current value Hamiltonian yields the following first order conditions:

$$\pi_i'(x_{ijy}) = \Lambda_y \quad \forall i \tag{A.1}$$

$$\dot{\Lambda}_y - \delta\Lambda_y = 0 \tag{A.2}$$

$$\Lambda_Y b_Y e^{-\delta Y} = 0 \tag{A.3}$$

where Λ_y is the positive current value shadow price at year y and can be naturally interpreted as the marginal abatement cost as it corresponds to the marginal profit associated with an extra unit of allowed emissions under the aggregate cap. Equations A.2-A.3 summarize two well-established features of this problem. First, a simple rearrangement of Equation A.2 yields Hotelling's rule (Hotelling, 1931), $\Lambda_y = \Lambda_0 e^{\delta y}$: the marginal abatement cost rises at the rate of interest. Second, defining the optimal allocation of emissions for the joint problem $X_t^{**} = (x_{1jy}^{**}...x_{Njy}^{**})$, Hotelling's rule together with the transversality condition in Equation A.3 yield $\int_0^Y \sum_{i=1}^N x_{ijy}^{**} dy = R$. That is, total emissions must equal the cap R by the end of the policy period.

Cap-and-trade

In practice, implementation of the joint-cost solution requires that the regulator know a lot of information. In particular, it needs to know the marginal abatement cost curves of every firm. Alternatively, the regulator can introduce a cap-and-trade system. Here, it's role is to create R cumulative permits such that in each period A_{ijy} is given freely to firm i in sector $j \in F$ and A_y^a is auctioned off.[3] Denote d_{ijy} as the number of permits sold (>0) or purchased (<0). Under the cap-and-trade policy, the firm's dynamic problem is to choose x_{ijy} and d_{ijy} with permit banking:

$$\begin{aligned} \max_{x_{ijy}, d_{ijy}} \quad & \int_0^Y e^{-\delta y} \left[\pi_i(x_{ijy}) + \tau_y d_{ijy}\right] dy \\ s.t. \quad & \dot{b}_{ijy} = A_{ijy}\mathbf{1}\{j \in F\} - x_{ijy} - d_{ijy} \\ & b_{ij0} = 0, \quad b_{ijY} \geq 0, \quad x_{ijy} \geq 0 \end{aligned} \tag{A.4}$$

where τ_y is the permit price and b_{ijy} is the state variable denoting the number of banked (> 0) or borrowed (< 0) permits carried into the subsequent period. First order conditions for the current value Hamiltonian are:

$$\pi_i'(x_{ijy}) = \lambda_{ijy} \tag{A.5}$$

$$\tau_y = \lambda_{ijy} \tag{A.6}$$

$$\dot{\lambda}_{ijy} - \delta\lambda_{ijy} = 0 \tag{A.7}$$

$$\lambda_{ijY} b_Y e^{-\delta Y} = 0 \tag{A.8}$$

[3] Observe that Montgomery (1972) and Rubin (1996) assume that all permits are distributed freely, that is $A_y^a = 0 \ \forall y$. This is inconsistent with Waxman-Markey.

where λ_{ijy} is the positive current value shadow price. Defining the market equilibrium as $X_y^* = (x_{1jy}^* ... x_{Njy}^*)$, $D_y^* = (d_{1jt}^* ... d_{Njt}^*)$, and τ_y^* and further imposing market clearing and terminal conditions:

$$\textstyle\sum_{i=1}^{N} d_{ijy}^* + A_y^a = 0 \quad \forall y \tag{A.9}$$

$$\tau_Y^* \left[\textstyle\int_0^Y \sum_{i=1}^{N} (A_{ijy} - x_{ijy}^* - d_{ijy}^*) dy \right] = 0 \tag{A.10}$$

Rubin (1996) shows that the market equilibrium satisfying Equations A.5 - A.10 achieves $X_y^{**} = X_y^*$ and $\Lambda_y = \tau_y^*$ for each period y. That is, the decentralized emissions trading solution yields the same least-cost emissions allocation as the joint cost problem and the marginal abatement cost obtained from the joint cost problem equals the equilibrium permit price under cap-and-trade.[4]

Next, consider specifically the Waxman-Markey cap-and-trade policy, $p = w$. Optimal firm value can be written as:

$$\begin{aligned} v_{ij}(w) = & \int_0^Y e^{-\delta y} \left[\pi(x_{ijy}^*(w))dy - \tau_y [x_{ijy}^*(w) + \dot{b}_{ijy}^*(w) - A_{ijy}(w)\mathbf{1}\{j \in F(w)\}] \right] dy \\ = & \tau_0(w) A_{ij}(w) \mathbf{1}\{j \in F(w)\} + \int_0^Y e^{-\delta y} \pi(x_{ijy}^*(w))dy - \tau_0(w) \int_0^Y x_{ijy}^*(w) dy \end{aligned} \tag{A.11}$$

where $A_{ij}(w) = \int_0^Y A_{ijy}(w)dy$ is the cumulative number of free permits granted to firm i over the lifetime of the policy. The second line follows by applying Hotelling's rule, $\tau_y(w) = \tau_0(w)e^{\delta y}$ and noting that the boundary conditions on banked emissions imply $\int_0^Y \dot{b}_{ijy}^*(w)dy = 0$. Writing now in terms of firm value relative to expected firm value under all non-Waxman-Markey policies, we have:

$$\gamma_{ij} = \frac{\tau_0(w) A_{ij}(w) \mathbf{1}\{j \in F(w)\}}{v_{ij}(\mathbb{O})} + \frac{\int_0^Y e^{-\delta y} \pi(x_{ijy}^*(w))dy - \tau_0(w) \int_0^Y x_{ijy}^*(w)dy}{v_{ij}(\mathbb{O})} - 1 \tag{A.12}$$

which is the trading date-invariant, structural version of Eq. 4 in the main text. In particular, the reduced-form RD parameter is:

$$\beta = \frac{\tau_0(w) A_{ij}(w)}{v_{ij}(\mathbb{O})} \tag{A.13}$$

[4] Observe that the Coase independence property, whereby the equilibrium permit prices are unaffected by the initial distribution of free permits, holds throughout this framework (Coase, 1960; Montgomery, 1972; Hahn and Stavins, 2011).

Appendix A.2 Recovering the permit price

To see how the reduced-form RDD parameter β maps onto the first period permit price, $\tau_o(w)$, consider the following estimated version of Eq. A.13:

$$\hat{\beta} = E_{it}\left[\frac{\tau_{0t}(w)A_{ij}(w)}{v_{ijt}(\mathbb{O})}\right] \tag{A.14}$$

$$= E_{it}\left[\frac{\tau_0(w)A_{ij}(w)}{v_{ijt}(\mathbb{O})}\right] + E_{it}\left[\frac{\xi_t A_{ij}(w)}{v_{ijt}(\mathbb{O})}\right] \tag{A.15}$$

$$= \tau_0(w)E_i\left[A_{ij}(w)E_t\left[\frac{1}{v_{ijt}(\mathbb{O})}\right]\right] + E_i\left[A_{ij}(w)E_t\left[\frac{\xi_t}{v_{ijt}(\mathbb{O})}\right]\right] \tag{A.16}$$

$$= \tau_0(w)E_i\left[A_{ij}(w)E_t\left[\frac{1}{v_{ijt}(\mathbb{O})}\right]\right] \tag{A.17}$$

$$= \tau_0(w)E_i\left[A_{ij}(w)E_t\left[\frac{1+\gamma_{ijt}\theta_t}{v_{ijt}}\right]\right] \tag{A.18}$$

$$= \tau_0(w)\left(E_i\left[A_{ij}(w)E_t\left[\frac{1}{v_{ijt}}\right]\right] + \hat{\beta}E_i\left[A_{ij}(w)E_t\left[\frac{\theta_t}{\nu_{ijt}}\right]\right] + E_i\left[A_{ij}(w)E_t\left[\frac{\widehat{f(EI_j)}\theta_t}{v_{ijt}}\right]\right]\right) \tag{A.19}$$

where Eq. A.15 applies the permit price decomposition, $\tau_{0t}(w)+\tau_o(w)+\xi_t$. Eq. A.16 applies the Law of Iterated Expectations. Eq. A.17 applies Assumption 4, $cov(\xi_t, \frac{1}{v_{ijt}(\mathbb{O}}))=0$. Eq. A.18 substitutes $v_{ijt}(\mathbb{O})$ using Eq. 1 in the main text. Eq. A.19 applies Eq. 11 in the main text, $\gamma_{ijt} = \hat{\beta} + \widehat{f(EI_j)} + \mu_{ijt}$, and a further covariance assumption, $cov(\mu_{ijt}, \frac{\theta_t}{v_{ijt}}) = 0$.[5] Rearranging Eq. A.19:

$$\tau_0(w) = \frac{\widehat{\beta}}{E_i\left[A_{ij}(w)E_t\left[\frac{1}{v_{ijt}}\right]\right] + \hat{\beta}E_i\left[A_{ij}(w)E_t\left[\frac{\theta_t}{\nu_{ijt}}\right]\right] + E_i\left[A_{ij}(w)E_t\left[\frac{\widehat{f(EI_j)}\theta_t}{v_{ijt}}\right]\right]} \tag{A.20}$$

Eq. 18 in the main text is the sample analog to Eq. A.20.

Appendix A.3 Deviations from the benchmark model

Restrictions to permit borrowing

The benchmark model allows unlimited permit banking and borrowing over time. While permit banking is unlimited in Waxman-Markey, there are restrictions on permit borrowing through the use of vintage-specific permits. In particular, a firm would incur a $\rho = .08$ annual borrowing cost for each future permit. While it is unclear whether this borrowing restriction would ever bind during the lifetime of the policy, one could assume that the

[5] This is plausible as estimates from the trading-date fixed effects models shown in Panels (D-F) of Table 1 in the main text controls for trading date variation.

borrowing restriction binds in every period to generate an upper bound on the recovered initial period permit price.

Formally, define τ_{vy} as the permit price of vintage v permit in compliance period y. τ_{vy} is dictated by two equalities. To help with intuition, consider the case with only two periods and vintages. For the first equality, no-arbitrage across periods implies that permit prices for any vintage v must follow Hotelling's rule: $\tau_{v1} = \tau_{v0}e^{\delta}$. The second equality relates permit prices across vintages during the initial period: $\tau_{00} = \tau_{10}e^{\rho}$. Combining these two equalities yields:

$$\tau_{00} = \tau_{11}\frac{e^{\rho}}{e^{\delta}} \tag{A.21}$$

Eq. A.21 has a cost-benefit interpretation.[6] The left hand side of Eq. A.21 indicates the marginal benefit of borrowing one permit. A borrowed $v = 1$ permit for initial period compliance has a value equivalent to a $v = 0$ permit, or τ_{00}. Borrowing a $v = 1$ permit requires repayment of $1 + \rho$ permits during the next period. The discounted value of this marginal cost during the initial period is captured by the right hand side of Eq. A.21. Optimal borrowing implies equality in Eq. A.21.

In the general case with $y \in [0, Y]$ periods and vintages, the two equalities become $\tau_{vy} = \tau_{v0}e^{\delta y}$ and $\tau_{00} = \tau_{v0}e^{\rho v}$. The relationship between the price of a v vintaged permit when it is issued (i.e. $y = v$) and the initial period price of the initial vintaged permit is:

$$\tau_{yy} = \tau_{00}e^{(-\rho+\delta)y} \tag{A.22}$$

which, consistent with the prior literature on borrowing restrictions, rises over time below the interest rate (Rubin, 1996; Schennach, 2000). The resulting expression for the reduced-form parameter β becomes:

$$\beta = \frac{\tau_{00}(w)}{v_{ij}(\mathbb{O})}\int_{y=0}^{Y} e^{-\rho y}A_{ijy}(w)dy \tag{A.23}$$

which for a given value of β implies a higher initial period permit price $\tau_{00}(w)$.

Output-based permit allocation

The benchmark model assumes that permits are allocated in a lump-sum manner. In reality, the Waxman-Markey bill allocates free permits based on an output-based allocation rule. This section demonstrates how an output-based allocation may impact firm-level output in the short run as well as exit decisions in the long-run, both of which affects the recovered first period permit price. The rule states that the free permits received by firm i in sector j year y is:

[6] I thank Steve Salant for this interpretation.

$$A_{ijy}(w) = q_{ijy}\frac{X_{jy}}{Q_{jy}} \tag{A.24}$$

where q_{ijy} is output of firm i in year y and X_{jy} and Q_{jy} are total emissions and output in sector j such that X_{jy}/Q_{jy} is sector-level emissions intensity.[7] For simplicity, I maintain the benchmark assumption that sector j is perfectly competitive such that X_{jy}/Q_{jy} is exogenous to the firm. Under output-based allocation, the allocation of free permits is no longer exogenous to the firm as the firm faces an additional incentive to increase output. This implies that all things equal, firms that receive free permits also have higher output levels than firms that do not receive free permits such that one can no longer attribute the RD parameter β entirely to the allocation of free permits.

To see how output based allocation affects firm decisions in the short and long run, consider the following instantaneous profit function:

$$\pi_{ijy} = p_y q(x_{ijy}) - z_y x_{ijy} \tag{A.25}$$

where $q()$ is an increasing, concave production function. z_y is unit cost for a carbon intensive input that results in one ton of emission for each unit used for production. In the short run, an operating firm cannot exit the industry. Inserting Eqs. A.24 and A.25 into the optimization problem in Eq. A.4 yields the following modified version of Eq. A.5:

$$\frac{\pi_i'(x_{ijy})}{1 - q_i'(x_{ijy})\frac{X_{jy}}{Q_{jy}}\mathbf{1}\{j \in F(w)\}} = \lambda_{ijy}^O \tag{A.26}$$

There are two implications of Eq. A.26, one for the cost of the policy overall and another for the distribution of optimal emissions across firms. First, because of the denominator in Eq. A.26, the marginal abatement cost under output-based allocation is higher than under lump-sum allocation at every emission level for a firm receiving free permits. And since marginal abatement costs must be equalized across firms in equilibrium, the permit price must also be higher, resulting in a higher overall cost of compliance. Second, Eq. A.26 together with the concavity of the profit function imply that all else equal, emissions, and hence output, of a firm receiving free permits is higher than that of a firm not receiving free permits during every period of the policy. This implies that the structural expression for the RD parameter β from Eq. A.13 becomes:

[7] Technically, Waxman-Markey requires average output over the previous two periods be used to determine current period free permits. I do not consider this for ease of exposition as implications are unaltered.

$$\beta = \frac{\tau_0(w)A_{ij}(w)}{v_{ijt}(\mathbb{O})} + \frac{\int_0^Y e^{-\delta y} p_y [q(x^*_{i,j\in F(w),y}) - q(x^*_{i,j\in A(w),y})]dy}{v_{ijt}(\mathbb{O})} - \frac{\int_0^Y e^{-\delta y}[z_y + \tau_y(w)][x^*_{i,j\in F(w),y} - x^*_{i,j\in A(w),y}]dy}{v_{ijt}(\mathbb{O})} \tag{A.27}$$

where the second term and third terms, which was previously zero under lump-sum permit allocation, now capture the difference in firm revenue and costs, respectively, for firms receiving free permits and those buying auctioned permits. The second term is positive and the third term is negative. However, the sum of these two terms is negative. This is because a firm that buys auctioned permits optimally emits at a level where marginal revenue, $q'(x^*_{i,j\in A(w),y})$, equals marginal cost, $z_y + \tau_y(w)$. By comparison, an otherwise similar firm facing output-based free permits would produce higher emissions with marginal revenue below marginal cost. Thus, the gain in the second term of Eq. A.27 is smaller than the loss in the third term, resulting in a downward biased estimate of β and a lower implied first period permit price. The magnitude of this bias depends on the concavity of the production function and expectations over future output and input prices.

The output based allocation under Waxman-Markey is conditional on ongoing operation. In the long-run, this acts as an operating subsidy which distorts firm exit decisions by lowering long-run average costs, allowing a firm to operate longer than it would in the absence of free permits. To see this, suppose without the free permits, future input and output prices are such that a firm would exit the industry in period $y = \bar{y} < Y$ or $x^*_{ijy} = 0$ for $y > \bar{y}$. If instead, the output-based allocation allows the firm to operate longer until $y = \tilde{y} > \bar{y}$, Eq. A.13 becomes:

$$\beta = \frac{\tau_0(w)A_{ij}(w)}{v_{ijt}(\mathbb{O})} + \frac{\int_0^{\bar{y}} e^{-\delta y} p_y [q(x^*_{i,j\in F(w),y}) - q(x^*_{i,j\in A(w),y})]dy}{v_{ijt}(\mathbb{O})} - \frac{\int_0^{\bar{y}} e^{-\delta y}[z_y + \tau_y(w)][x^*_{i,j\in F(w),y} - x^*_{i,j\in A(w),y}]dy}{v_{ijt}(\mathbb{O})} + \frac{\int_{\bar{y}}^{\tilde{y}} e^{-\delta y} p_y q(x^*_{ij\in F(w)y}) - [z_y + \tau_y(w)]x^*_{ij\in F(w)y}dy}{v_{ijt}(\mathbb{O})} \tag{A.28}$$

If output-based allocation allows a firm to operate over a longer period, profits during this extended period, captured by the fourth term in Eq. A.28, should be negative by definition. Thus, the downward bias in β is reinforced by the presence of firm exits in the long run.

Appendix B Potential consequences of a thinly traded prediction market

To understand how thin trading may effect estimates of β, I consider three possible sources of deviation between the observed change in prediction market price, $\Delta\theta_t$ and the true unobserved change in cap-and-trade probabilities, Δq_t:

$$\Delta\theta_t = \alpha_1 + \alpha_2 \Delta q_t + \omega_t \tag{B.1}$$

where α_1 is additive bias, α_2 is multiplicative bias, and $\omega_t \sim (0, \sigma_\omega^2)$ is an error term which is uncorrelated with Δq_t as in the classical measurement error setup. I now consider the consequences of each term in isolation.

Additive bias Suppose only additive bias existed such that $\alpha_2 = 1$ and $\omega_t = 0$. Eq. 5 in the main text becomes:

$$r_{ijt} = \beta \mathbf{1}\{j = F\}\Delta\theta_t + \boldsymbol{Z_{it}\Psi_i} + \eta_{ij}\Delta\theta_t - \alpha_1(\beta\mathbf{1}\{j = F\} + \eta_{ij}) + \nu_{ijt}$$

where the error term is now augmented by $\alpha_1(\beta\mathbf{1}\{j = F\} + \eta_{ij})$. Observe that this extra term is absorbed by the inclusion of a firm fixed effect in $\boldsymbol{Z_{it}}$, which is present in all my regression models.

Multiplicative bias Suppose only multiplicative bias existed such that $\alpha_1 = 0$ and $\omega_t = 0$. Then Eq. 5 in the main text becomes:

$$r_{ijt} = \frac{\beta}{\alpha_2}\mathbf{1}\{j = F\}\Delta\theta_t + \boldsymbol{Z_{it}\Psi_i} + \frac{\eta_{ij}\Delta\theta_t}{\alpha_2} + \nu_{ijt}$$

where now the estimated coefficient of interest is no longer an unbiased estimate of β.

Measurement error Suppose now only classical measurement existed such that $\alpha_1 = 0$ and $\alpha_2 = 0$. Eq. B.1 becomes $\Delta\theta_t = \Delta q_t + \omega_t$. I consider the consequences of classical measurement error in prediction market prices when the mismeasured variable is interacted with a Bernoulli variable which is the treatment under my regression discontinuity design.[8]

As a benchmark, consider the following true uninteracted model:

$$r_{jt} = \beta^o_{uninteract}\Delta q_t + \epsilon_{jt} \tag{B.2}$$

where ϵ_{jt} is a mean zero error term. I make an additional standard assumption that $cov(\Delta\theta_t, \epsilon_{jt}) = 0$. Using the mismeasured prediction market price $\Delta\theta_t$ instead of the

[8] I am grateful to Doug Steigerwald for this particular formulation.

true probability Δq_t, produces in the limit an estimate $plim\ \hat{\beta}_{uninteract} = \beta^o_{uninteract} * bias_{uninteract}$ where $bias_{uninteract}$ is the attenuation bias multiplier:

$$bias_{uninteract} = \quad 1 - 1/(1+S) \tag{B.3}$$

where $\sigma^2_{\Delta q}$ is the variance of Δq_t and S is the signal-to-noise ratio $\frac{\sigma^2_{\Delta q}}{\sigma^2_\omega}$.

Consider now the following interacted model which is a simplified version of my regression discontinuity specification in Eq. 7 in the main text:

$$r_{ijt} = \beta^o_{interact} D_j \Delta q_t + \epsilon_{jt} \tag{B.4}$$

where $D_j \sim Bernoulli(p)$ is the RD treatment variable. Because D_j is indexed by j, I make the additional assumption that the D_j is independent of $(\Delta q_t, \omega_t)$. If then one uses mismeasured prediction market price $\Delta\theta_t$ instead of the true probability Δq_t, the OLS estimate is $plim\ \hat{\beta}_{interact} = \beta^o_{interact} * bias_{interact}$ where $bias_{interact}$ is the attenuation bias multiplier:

$$bias_{interact} \quad = 1 - 1/(1+\tilde{S}) \tag{B.5}$$

where $\tilde{S} = \frac{var(D_j \Delta q_t)}{var(D_j \omega_t)}$. Considering each component of $\tilde{S}$ separately:

$$\begin{aligned} var(D_j \Delta q_t) = & \quad E(D_j^2 \Delta q_t^2) - (E(D_j \Delta q_t))^2 \\ = & \quad E(D_j^2) E(\Delta q_t^2) - (E(D_j) E(\Delta q_t))^2 \\ = & \quad pE(\Delta q_t^2) - p^2 E(\Delta q_t)^2 \end{aligned} \tag{B.6}$$

where the second line follows by independence between D_j and Δq_t and the third line follows by applying the mean and variance of a Bernoulli random variable. Similarly:

$$\begin{aligned} var(D_j \omega_t) = & \quad E(D_j^2 \omega_t^2) - (E(D_j \omega_t))^2 \\ = & \quad E(D_j^2) E(\omega_t^2) - (E(D_j) E(\omega_t))^2 \\ = & \quad p\sigma^2_\omega \end{aligned} \tag{B.7}$$

where the second line follows by independence between D_j and ω_t and the third line follows by the earlier assumption that $\omega_t \sim (0, \sigma^2_\omega)$. Plugging Eqs. B.6 and B.7 into B.5 yields:

$$bias_{interact} \quad = 1 - 1/\left(1 + S + \frac{(1-p)(E[\Delta q_t])^2}{\sigma^2_\omega}\right) \tag{B.8}$$

Because $\frac{(1-p)(E[\Delta q_t])^2}{\sigma^2_\omega} > 0$, observe that $bias_{uninteract} > bias_{interact}$ for any signal-to-noise ratio, S, such that my interacted regression discontinuity estimate will always be closer to the true estimate than if one were to directly estimate the effects of prediction market prices. That is, attenuation bias is always smaller in the interacted model. The degree in which attenuation bias is lessened depends on both the probability of treatment p and on the expected true change in policy probabilities, $E[\Delta q_t]$.

Prior field and experimental evidence on the influence of thin trading Prior experimental and field research show that prediction market prices are relatively unaffected by thin trading or manipulation by individual traders. Intuitively, efforts to manipulate a prediction market by some should increase arbitrage opportunities for others such that distortions, if they do exist, is unlikely to last for long periods. Camerer (1998) places temporary bets designed to manipulate racetrack markets and concludes that successful long-term manipulation was unlikely even when considering efforts to distort relatively thinly traded markets. A similar conclusion is reached for both historical presidential betting markets (Rhode and Strumpf, 2004) and recent presidential prediction markets (Rhode and Strumpf, 2008). In particular, Rhode and Strumpf (2008) find that experimental efforts to manipulate the 2000 Iowa Electronic Market during thinly traded moments and observed efforts to manipulate the 2004 Tradesport market had effects that dissipated hours afterwards. Similarly, recent experimental work shows that price manipulators in prediction markets were unable to distort price accuracy (Robin, Oprea and Porter, 2006) nor influence the beliefs of third party observers (Hanson et al., 2011). A notable exception is Rothschild and Sethi (2016) who find evidence of possible manipulation in the 2012 Intrade presidential prediction market.

Appendix C Adjusting for contract expiration

Intrade prediction markets are traded up to a certain date upon which contract holders are paid $1 if the event is realized for each contract held. For the cap-and-trade prediction market, that expiration date was December 31, 2010, coinciding with the end of the 111th Congress. Because it is rare that a piece of legislation, having failed passage in the current Congress, is reintroduced with identical features in a subsequent Congress, this expiration date should coincide with the expected final possible date of Waxman-Markey approval.

However, it is difficult to ascertain whether markets expected Waxman-Markey prospects to exist following the end of the 111th Congress. If so, this introduces a bias between the prediction market price and average market beliefs which would increase as the expiration date nears. To remove this bias, one would like to weight prediction price levels using a kernel that varies with the number of remaining trading days.

Formally, the true variable of interest is $q_t(\overline{T})$ where $\overline{T} = 12/31/2011$, the date in which the cap-and-trade system begins under the policy. I do not observe $q_t(\overline{T})$. Instead, I observe a prediction market price for a contract expiring on date $T^1 = 12/31/2010 < \overline{T}$. I now define this as $\theta_t(d, T^1)$, where $d = T^1 - t$, the number of remaining days until expiration.

Specifically, it has the following piece-wise form:

$$\theta_t(d, T^1) = \begin{cases} k(d)q_t(\overline{T}), & \text{if } d < \widehat{D} \\ q_t(\overline{T}), & \text{otherwise} \end{cases} \tag{C.1}$$

where $k(d)$ is a weighting kernel which is a function of d and exists only when the remaining number of days is less than some threshold $\widehat{D}$. In other words, $k(d)$ captures any concerns about an impending contract expiration. Importantly for this exercise, I assume $k(d)$ to be discontinuous such that prediction market participants only become concerned about contract expiration after a certain point when there are fewer than $\widehat{D}$ days remaining.

The problem lies in estimating $k(d)$. Fortunately, the availability of additional Intrade data allows for an empirical estimate of $k(d)$. The prediction market contract shown in Figure 1 in the main text was not the first cap-and-trade contract offered by Intrade. Around the same time that the 2010-expiring contract begin trading, InTrade offered an identical contract with an earlier expiration date set for $T^2 = 12/31/2009 < T^1 < \overline{T}$. This contract, with prices denoted as $\theta_t(d, T^2)$, lasted only eight months and is shown as a dashed line in Figure A.3.

Estimating $k(d)$ requires the following assumption: for all trading days when both contracts exist, $d \geq \widehat{D}$ for $\theta_t(d, T^1)$ and $d < \widehat{D}$ for $\theta_t(d, T^2)$. That is during 5/1/2009-12/31/2009, prices from the 2010-expiring contract were unaffected by concerns over expiration while prices from the 2009-expiring contract incorporated such concerns. Thus:

$$k(d) = \frac{\theta_t(d, T^2)}{\theta_t(d, T^1)} \quad \forall t \in [5/1/2009, 12/31/2009] \tag{C.2}$$

The solid line in Figure A.4 plots $k(d)$ and appears trend stationary. To remove noise in $k(d)$, the following linear regression is performed:

$$k(d) = \alpha_0 + \alpha_1 d + \epsilon_d \tag{C.3}$$

where ϵ_d is a mean zero disturbance. The predicted kernel, $\widehat{k(d)}$, is shown as the dashed line in Figure A.4. The threshold $\widehat{D}$ is defined as the point at which $\widehat{k(d)} = 1$. To recover q_t, I simply rewrite Equation C.1 to obtain:

$$q_t(\overline{T}) = \text{adjusted } \theta_t(d, T^1) = \begin{cases} \frac{\theta_t(d, T^1)}{\widehat{k(d)}}, & \text{if } d < \widehat{D} \\ \theta_t(d, T^1), & \text{otherwise} \end{cases} \tag{C.4}$$

Figure A.5 plots the original $\theta_t(d, T^1)$ against the adjusted $\theta_t(d, T^1)$ using the predicted kernel from Equation C.3. Observe that the two time series begin diverging at the beginning of 2010 when $d < \hat{D}$. This divergence, which increases until the end of the 2010, inflates the original price series to remove any concerns about contract expiration. Thus, while the prospects for cap-and-trade indeed collapsed when the Senate formally withdrew cap-and-trade legislation on July 23, 2010, market beliefs over cap-and-trade prospects were actually higher than what the original prediction market indicated.

Table A.3 replicates Table 1 in the main text using the adjusted Intrade prices. Resulting estimates are slightly smaller but are not statistically different than those presented in Table 1 in the main text.

Appendix D Data summary

Prediction market prices Intrade publicly provides daily closing prices and trading volume for the contract "A cap and trade system for emissions trading to be established before midnight ET on 31 Dec 2010". Intrade publicly provides a similar contract ending in 31 Dec 2009 used for constructing the expiration-adjusted prediction market prices discussed in Appendix C. Transaction-level data for the 2010-expiring contract was acquired privately from Intrade and was used to identify large individual traders and to construct a daily buyer-based normalized Herfindahl-Hirshman Index.

Stock returns and market indices 2-day returns for publicly listed U.S. stocks over the 2007-2011 period derived based on data from the US Stock Database ©2012 Center for Research in Security Prices (CRSP), The University of Chicago Booth School of Business. 2-day Fama-French factors were constructed out of variables downloaded from Kenneth French's website.[9] Daily West Texas Intermediate crude oil prices downloaded from the U.S. EIA.[10]

Sector-level energy intensity, trade intensity, and covariates Average 2004-2006 energy and trade intensity at the 6-digit NAICS level for manufacturing sectors (NAICS 31-33) was constructed based on data from the U.S. Census Bureau's Annual Survey of Manufacturers (ASM)[11] and the U.S. International Trade Commission (USITC).[12]

Manufacturing greenhouse gas emissions Total U.S. manufacturing greenhouse gas emissions and for specific subsectors [13] in 2006 and 2010 was obtained from the U.S. DOE Manufacturing Energy and Carbon Footprints analysis of the Manufacturing Energy and

[9]Available: `www.mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`
[10]Available: `https://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm`
[11]Available: `census.gov/manufacturing/asm/`
[12]Available: `dataweb.usitc.gov/`
[13]Specifically, Petroleum Refining (324110), Food and Beverage (311;312), Iron and Steel (3311; 3312), Computers, Electronics and Electrical Equipment (334; 335), Forest Products (321;322), Fabricated Metals (332), Plastics (326), Alumina and Aluminum (3313), Machinery (333), Cement (327310), Glass (3272), Transportation Equipment (336), Foundries (3315), Textiles (313-316)

Consumption Surveys.[14] Number of firms at the 6-digit NAICS level provided by the U.S. Census Bureau's Statistics of U.S. Businesses.

Lobbying expenditures Since the passage of the Lobbying and Disclosure Act of 1995, all individuals engaged in lobbying members of the federal government are required to register with the Clerk of the House of Representatives and the Senate Office of Public Records (SOPR).[15] Each lobbying record indicates lobbyist name (or names in the case of a team of lobbyists), the name of the firm hiring lobbying services, the amount spent, and in some cases the specific issue or legislation that is the target of lobbying efforts (see Blanes i Vidal, Draca and Fons-Rosen (2012) for further background on reports). Lobbying records were were obtained from the Center for Responsible Politics (CPR) who maintains and organizes this data.

To extract all lobbying records related to the Waxman-Markey bill, I search the "Specific Lobbying Issues" variable for records that contain any of the following strings: i) H.R.2454 or H.RES.2454 (Waxman-Markey), ii) H.R.587 or H.RES.587 (House bill accompanying Waxman-Markey), iii) H.R.2998 or H.RES. 2998 (House bill accompanying Waxman-Markey), and iv) S.1733 or S.RES.1733 (Senate bill related to Waxman-Markey sponsored by John Kerry).

To extract all lobbying records related to climate policy prior to the Waxman-Markey bill, I search the "Specific Lobbying Issues" variable for records that contain any of the following strings: i) S.R.139 or S.RES.139 (2003 McCain-Lieberman Bill), ii) S.R.1151 or S.RES.1151 (2005 McCain-Lieberman Bill), iii) S.R.280 or S.RES.280 (2007 McCain-Liberman Bill), iv) S.2191 or S.RES.2191 (2007 Lieberman-Warner Bill), and v) S.R.3036 or S.RES.3036 (2008 Boxer-Lieberman-Warner Bill).

CPR codes firms according to their own sectoral definitions which is generally coarser than 6-digit NAIC definitions. To aggregate lobbying expenditures to the 6-digit NAICS level, I use the CPR-provided crosswalk from their own sectoral definition to 6-digit NAICS. In cases where 1 CRP sector is assigned to multiples 6-digit NAICS sectors, I divide the lobbying expenditure evenly across the linked 6-digit NAICS sectors.

[14] Available: `energy.gov/eere/amo/downloads/us-manufacturing-energy-use-and-greenhouse-gas-emissions-analysis`

[15] The Lobbying and Disclosure Act defines a lobbyist "any individual who is employed or retained by a client for financial or other compensation for services that include more than one lobbying contact, other than an individual whose lobbying activities constitute less than 20 percent of the time engaged in the services provided by such individual to that client over a six month period." From 1998-2006, lobbyists were required to file reports on a semi-annual basis. Since the Honest Leadership and Open Government Act of 2007, reports are required every quarter.

Appendix E Specific cap-and-trade related events

The period between the passage of Waxman-Markey on June 26, 2009 and the withdrawal of cap-and-trade from the Senate on July 23, 2010 marked the peak and decline of U.S. cap-and-trade prospects. This section provides a short summary of several critical events during this period along with a news link. As shown by the vertical lines in Figure 1 in the main text, these events were well captured by prediction market price movements.

(1) June 26, 2009: House passes Waxman-Markey

Initial hearings on draft legislation were held on the week of April 20, 2009 with the full bill introduced into the House shortly thereafter on May 15, 2009. The bill was approved on June 26, 2009 by a vote of 219-212 with 8 supporting Republicans and 44 Democrats opposed.[16]

(2) November 4, 2009: Lindsay Graham joins Senate climate effort

After passage of Waxman-Markey, efforts to pass legislation in the Senate were lead by Senators Lieberman, an independent, and Kerry, a Democrat. The arrival of Lindsay Graham, a Republican Senator from South Carolina buoyed cap-and-trade prospects.[17]

(3) December 20, 2009: UNFCCC Copenhagen negotiations concluded

With the Kyoto Protocol expiring in 2012, countries were expected to negotiate a new international climate treaty at Copenhagen. While a general agreement was reached in the final hour, the agreement was non-binding and was generally regarded as not substantial enough to succeed the Kyoto Protocol.[18]

(4) January, 19, 2010: Scott Brown wins Mass Senate seat

The Democrat's tenuous supermajority in the Senate was lost when Scott Brown won Edward Kennedy's Massachusetts Senate seat in a special election.[19]

(5) January 27, 2010: Graham, Kerry, Lieberman seek cap-and-trade alternatives

With cap-and-trade looking unlikely, Senate sponsors look for alternative policy ideas.[20]

(6) March 31, 2010: Obama supports offshore drilling

After months of political pressure, President Obama agrees to expand domestic oil produc-

[16] Article:`http://www.nytimes.com/2009/06/27/us/politics/27climate.html`

[17] Article:`abcnews.go.com/blogs/politics/2009/11/graham-joins-dems-wh-to-write-new-climate-change-bill/`

[18] Article:`nytimes.com/cwire/2009/12/21/21climatewire-obama-negotiates-copenhagen-accord-with-senat-6121.html`

[19] Article:`www.denverpost.com/latin/ci_14337907`

[20] Article:`nytimes.com/cwire/2010/01/27/27climatewire-got-ideas-about-a-climate-bill-kerry-graham-64375.html`

tion.[21]

(7) April 23, 2010: Lindsay Graham drops support of Senate bill
After political pressure from his constituents and party, Senator Graham criticizes Senate Democratic Leadership over disagreements regarding immigration reform on April 23, 2010. Graham formally withdrew from Senate climate efforts on April 24, 2010.[22]

(8) June 15, 2010: Obama oval office speech
President Obama focuses on energy issues in his first oval office speech.[23]

(9) July 22, 2010: Senate drops cap-and-trade legislation
Without a filibuster-proof supermajority, Senate democrats drop consideration of cap-and-trade bill.[24]

Appendix F Comparing Waxman-Markey with later Senate climate bills

In the bicameral U.S. legislative system, a piece of legislation must pass both Houses of Congress before being sent to the President for ratification. Thus, passage of Waxman-Markey by the House of Representatives needed to be followed by a similar cap-and-trade bill approved by a Senate filibuster-proof supermajority. There were two prominent Senate bills considered during the Fall of 2009 and into 2010. Critical to my use of prediction markets from 2009-2010 is the assumption that the Senate variant of the bill was similar along key features such that the expected permit price for those bills was similar to that of Waxman-Markey (WM). In Table A.4, I compare the Waxman-Markey bill with the two most prominent Senate climate bills, the Kerry-Boxer (KB) and Kerry-Lieberman (KL) bills along four key features that may affect the equilibrium permit price: i) cap schedule, ii) sectoral coverage, iii) permit allocation rule, and iv) domestic and international offset provisions.

Table A.4 shows that KB and KL had the same sectoral coverage and permit allocation rule as WM and only a slightly altered cap schedule. In particular KB required slightly greater abatement in 2020 while KL required slightly greater abatement in 2013. This difference implies that KB and KL may result in slightly higher permit prices.

The overall limit from domestic agriculture and international offsets was the same across the three bills. For domestic agricultural offsets, KB allowed five additional types of offsets

[21] Article:nytimes.com/gwire/2010/03/31/31greenwire-obama-proposes-opening-vast-offshore-areas-to-74696.html
[22] Article: nytimes.com/2010/04/25/us/politics/25graham.html
[23] Article: nytimes.com/2010/06/16/us/politics/16obama.html
[24] Article: www.nytimes.com/2010/07/23/us/politics/23cong.html

not permitted under WM.[25] Compared to WM, KL added two new practices and eliminated one.[26] For international offsets KB and KL bills lowered the annual limit on international offsets from 1 to 0.5 billion tons. However, both Senate bills increased the threshold under the "exceedance policy" whereby if the annual domestic offsets amount is below 0.9 (KB) or 1.5 (KL) billion tons, the regulator can increase international offsets by up to an addition 0.75 (KB) or 1 billion (KL) tons. Because of uncertainty regarding both domestic and international offset markets, it is unclear whether these differences had a major effect on the expected permit price.

Appendix G CGE models of cap-and-trade policy

This section summarizes the most prominent CGE analyses of the Waxman-Markey bill during 2009 as well as the time when each analysis was first publicized.

During deliberations for Waxman-Markey, several CGE modeling groups were contracted by organizations and government agencies. The Environmental Protection Agency hired RTI and Dale W. Jorgenson Associates to run the ADAGE and IGEM models respectively. The EPA analyses were first released on April 20, 2009.[27] Kolstad et al. (2010) provide a detailed peer review of ADAGE and IGEM commissioned by the EPA. With the exception of IGEM which estimates parameters econometrically, parameters within CGE models are calibrated to match observed macroeconomic activity. The offset usage assumptions adopted in this paper were based on EPA analysis (EPA, 2009). The Department of Energy's Energy Information Agency (EIA) model the policy using its National Energy Modeling System (NEMS) model with results released in August 2009.[28] The EPPA model is run by the Joint Program on the Science and Policy of Climate Change at MIT.[29] The EPPA model results were first released in April 2009. Model runs were also commissioned by several advocacy organizations. The American Council for Capital Formation (ACCF) and National Association for Manufacturers (NAM) hired SAIC to run the EIA's NEMS model with results released on August 12, 2009.[30] The National Black Chamber of Commerce hired CRA international to run the MRN-NEEM model with results first released on May 21,

[25] Specifically, they were: i) planting and cultivation of permanent tree crops; ii) greenhouse gas emission reductions from improvements and upgrades to mobile or stationary equipment (including engines); iii) practices to reduce and eliminate soil tillage; iv) reductions in greenhouse gas emissions through restoration of wetlands, forestland, and grassland; and v) sequestration of greenhouse gases through management of tree crops

[26] Specifically, KL added i) resource-conserving crop rotations of at least 3 years; and ii) practices that will increase the sequestration of carbon in soils on cropland, hayfields, native and planted grazing land, grassland, or rangeland; and removed i) reduction in greenhouse gas emissions from manure and effluent

[27] Final report: `www.epa.gov/climatechange/economics/economicanalyses.html`

[28] Final report: `http://www.eia.gov/analysis/requests/2009/hr2454/pdf/sroiaf(2009)05.pdf`

[29] Final report: `globalchange.mit.edu/files/document/MITJPSPGC_Rpt173_AppendixC.pdf`

[30] Initial press release: `http://accf.org/accfnam-study-on-waxman-markey-bill/`. Final report: `http://instituteforenergyresearch.org/analysis/the-accfnam-estimate-of-waxman-markey/`

2009.[31] The Heritage foundation hired Global Insight to run its IHS model with results first reported via a Congressional testimony on June 22, 2009.[32]

These models differ along many dimensions (see Fawcett, Calvin and de la Chesnaye (2009) for a review). One important distinction pertinent for this analysis is whether agents in the models are myopic or exhibit perfect foresight. Myopic CGE models are solved iteratively at each time step while in models with perfect foresight agents optimize simultaneously over the entire policy time-horizon. The Hotelling model introduced in Appendix A exhibits perfect foresight. Of the CGE models analyzing Waxman-Markey, IGEM, ADAGE, and MRN-NEEM have perfect foresight whereas EPPA, NEMS, and IHS are myopic.

Another important area of distinction is whether the CGE models incorporated non-cap-and-trade components of the Waxman-Markey bill. ADAGE, NEMS, and MRN-NEEM models include many non-cap-and-trade provisions. IGEM and EPPA do not model those provisions. It is not clear from available IHS documentation whether non-cap-and-trade provisions are modeled.

[31] Initial press release: http://www.prnewswire.com/news-releases/nbcc-study-finds-waxman-markey-reduces-gdp-by-350-billion-61941032.html Final report: www.nationalbcc.org/images/stories/documents/CRA_Waxman-Markey_Aug2008_Update_Final.pdf

[32] Initial testimony: http://www.heritage.org/research/testimony/the-economic-impact-of-the-waxman-markey-cap-and-trade-bill. Final report: www.heritage.org/research/reports/2009/08/the-economic-consequences-of-waxman-markey-an-analysis-of-the-american-clean-energy-and-security-act-of-2009

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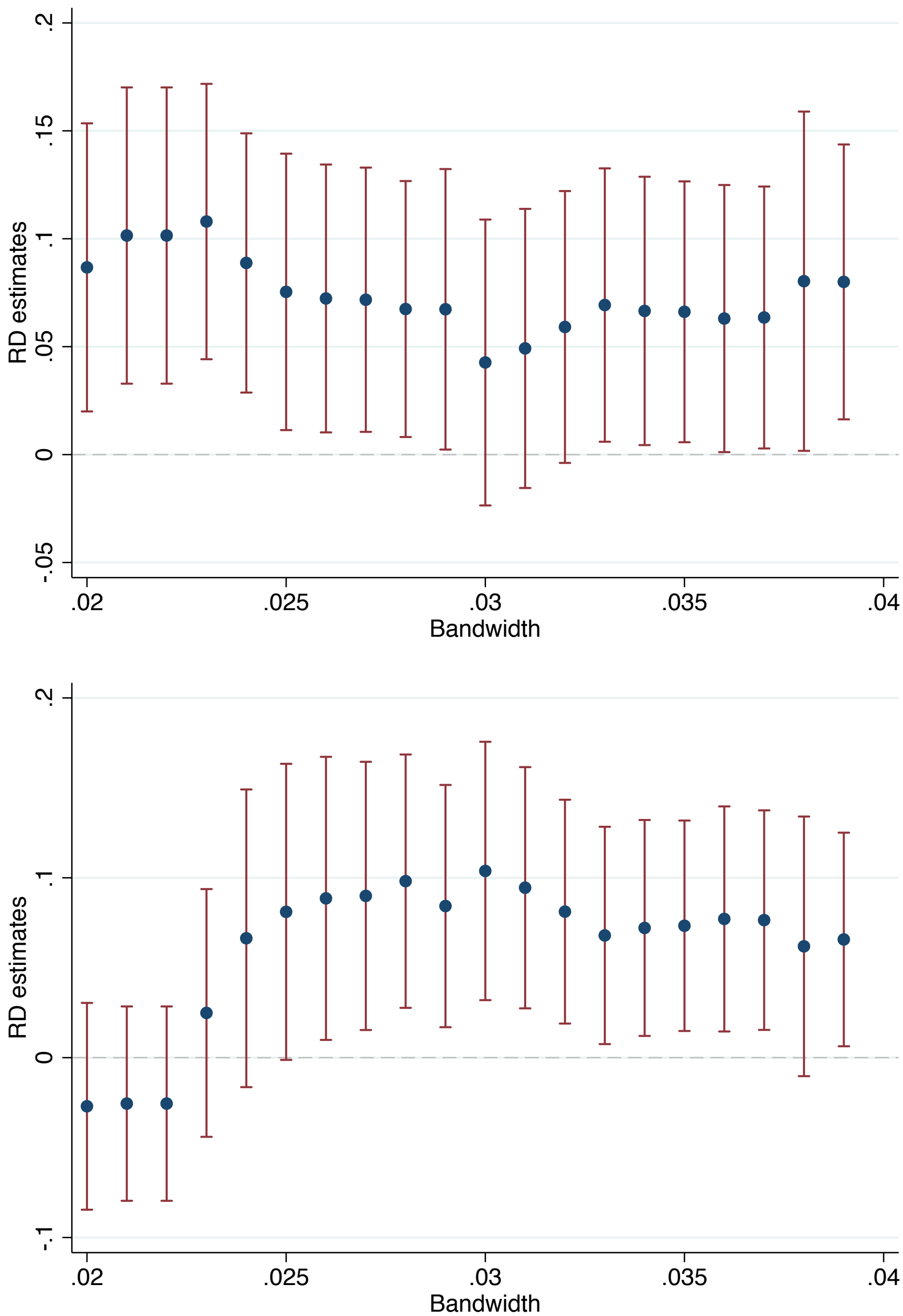
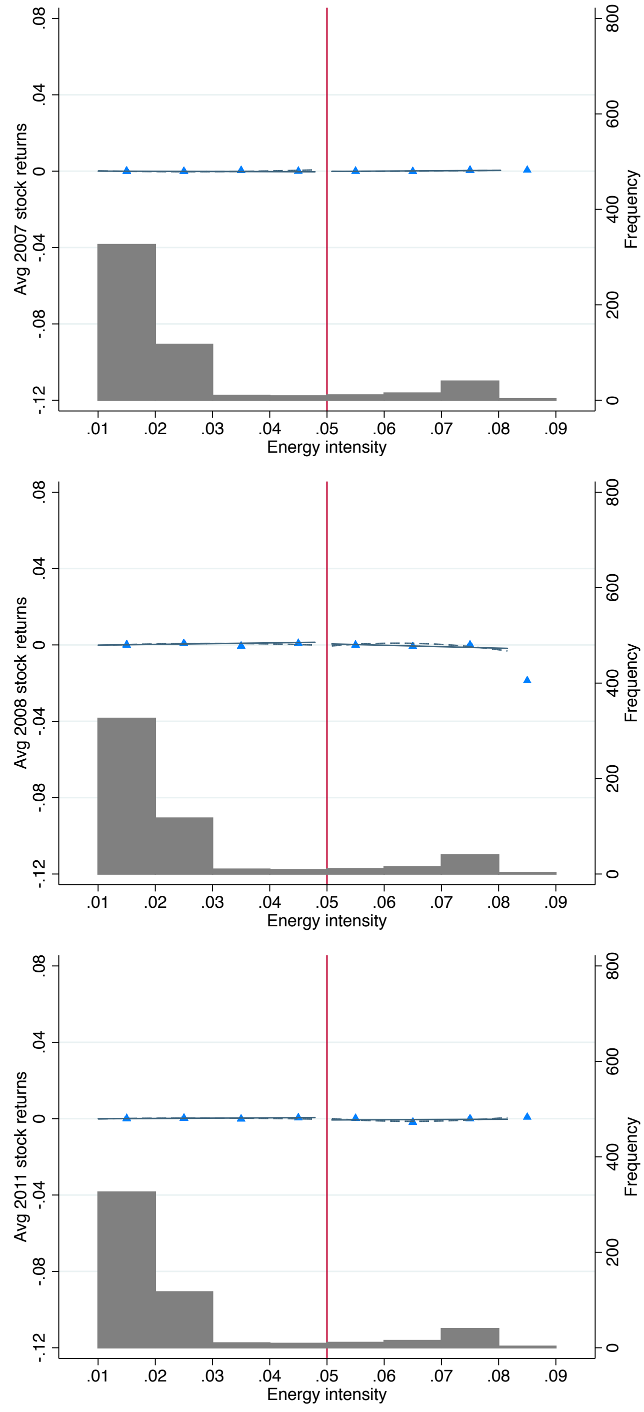
Appendix Figures

Figure A.1: RD estimates at 0.1% incremental bandwidths



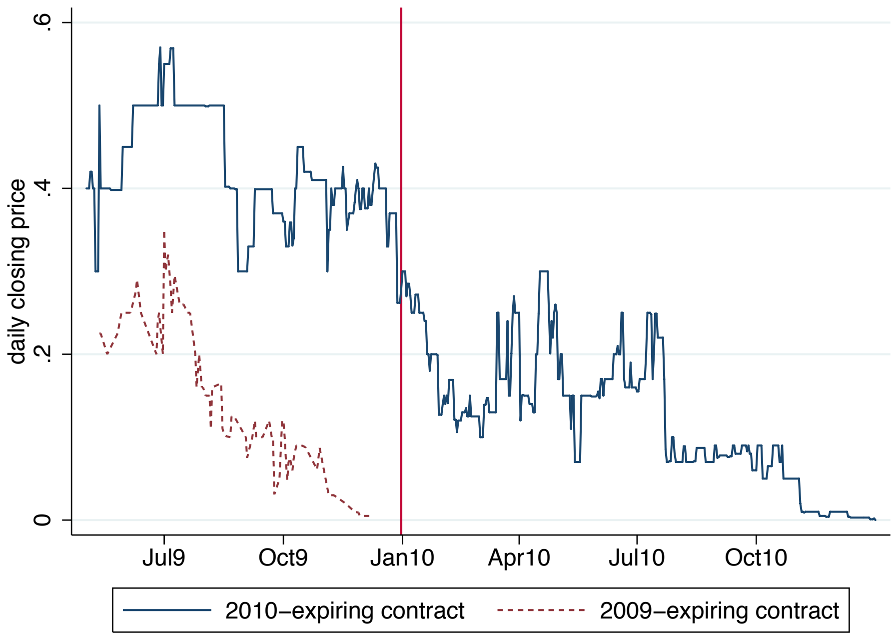
Notes: All RD estimates of β from a version of Eq. 7 in main text with firm and trading date fixed effects. Top panel uses a linear function in energy intensity. Bottom panel uses a quadratic function in energy intensity. 90% confidence interval shown.

Figure A.2: Average stock returns in 2007, 2008, and 2011 at 5% energy intensity



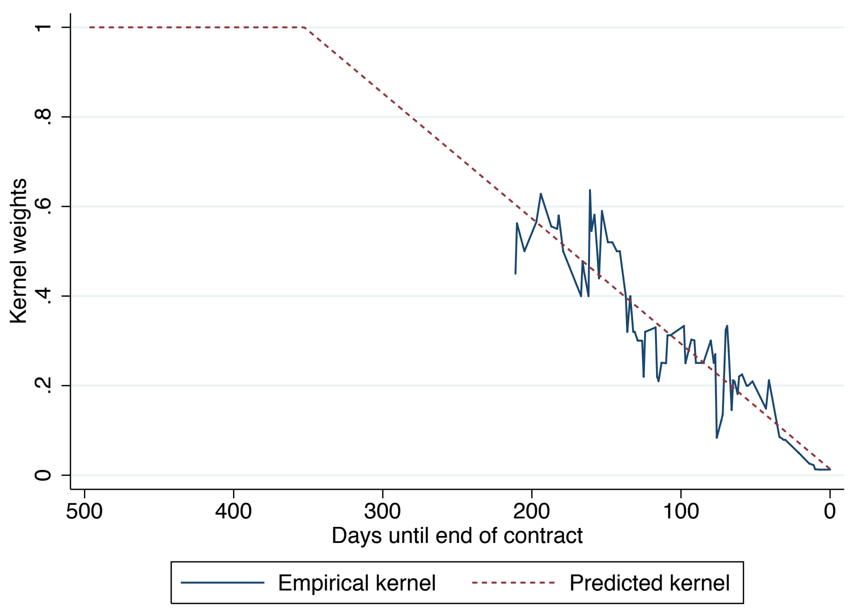
Notes: Triangles indicate local averages of firm-level average stock returns in 2007, 2008 and 2011 within a 0.01 wide bin of 6-digit NAICS energy intensity. Solid (dashed) line shows a linear (quadratic) fit over the unbinned data. Distribution of sample firms by 6-digit NAICS energy intensity shown in gray histogram.

Figure A.3: Price for Intrade 2009-expiring and 2010-expiring cap-and-trade contracts



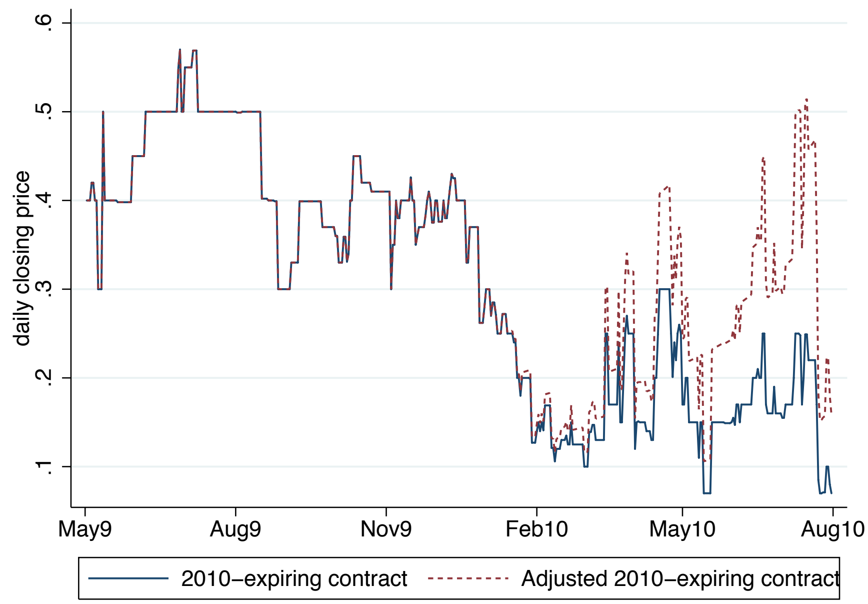
Notes: Time series of daily prices for Intrade cap-and-trade contracts expiring at end of 2009 (dashed) and 2010 (solid). Red vertical line marks start of 2010.

Figure A.4: Empirical and estimated weighting kernel for expiring cap-and-trade contracts



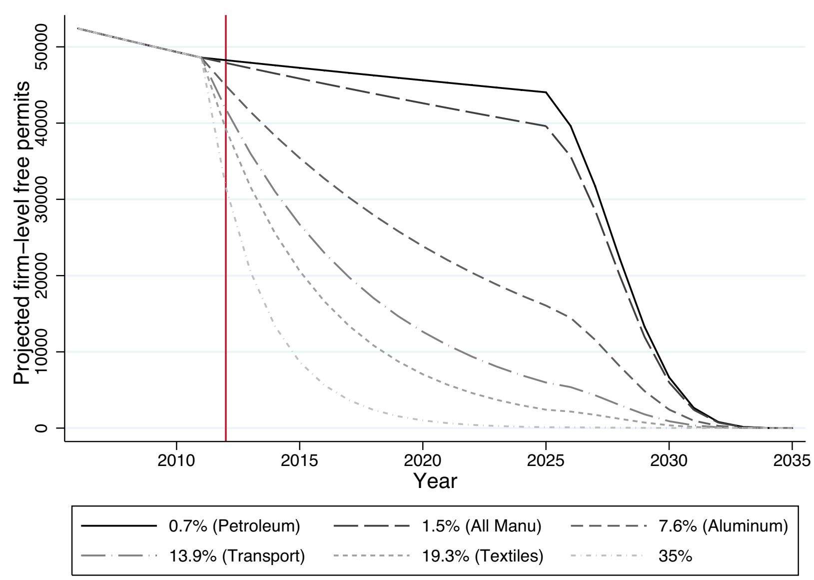
Notes: Time series of empirical (solid, blue) and predicted (dashed, red) weighting kernel, $\widehat{k(D)}$ as a function of D days remaining until contract expiration.

Figure A.5: Price for Intrade 2010-expiring contract with termination date adjustment



Notes: Time series of daily prices for Intrade cap-and-trade contracts expiring in 2010 (solid) and with adjustment for termination date using predicted weighting kernel in Figure A.4.

Figure A.6: Assumed free permits for firm in Plastics Material & Resin Manufacturing



Notes: Example of an assumed time path of freely permits for an average firm in the Plastics Material and Resin Manufacturing Sector (NAICS=325211). Each line assumes different annual rate of permit decline from 2012-2025. Solid line assumes -1.5% annual decline, the 2006-2010 average decline in emissions for all U.S. manufacturing firms. Dashed gray lines assumes annual declines associated with various manufacturing subsectors in 2006-2010. Permits are gradually phased out from 2026-2035 according to Waxman-Markey.

Appendix Tables

Table A.1: 6-digit NAICS sectors by energy intensity bins

Energy Intensity $\in [.02, .025)$
Soybean Processing (311222)
Cane Sugar Refining (311312)
Frozen Fruit, Juice, and Vegetable Manufacturing (311411)
Frozen Specialty Food Manufacturing (311412)
Fruit and Vegetable Canning (311421)
Other Hosiery and Sock Mills (315119)
Sawmills (321113)
Hardwood Veneer and Plywood Manufacturing (321211)
Coated and Laminated Packaging Paper and Plastics Film Manufacturing (322221)
Coated and Laminated Paper Manufacturing (322222)
Sanitary Paper Product Manufacturing (322291)
Asphalt Shingle and Coating Materials Manufacturing (324122)
Medicinal and Botanical Manufacturing (325411)
Plastics Bag Manufacturing (326111)
Plastics Packaging Film and Sheet (including Laminated) Manufacturing (326112)
Resilient Floor Covering Manufacturing (326192)
All Other Plastics Product Manufacturing (326199)
Tire Manufacturing (except Retreading) (326211)
Rubber and Plastics Hoses and Belting Manufacturing (326220)
Glass Product Manufacturing Made of Purchased Glass (327215)
Ball and Roller Bearing Manufacturing (332991)
Ammunition (except Small Arms) Manufacturing (332993)
Bare Printed Circuit Board Manufacturing (334412)
Energy Intensity $\in [.025, .03)$
Petroleum Refineries (324110)
Rolled Steel Shape Manufacturing (331221)
Steel Wire Drawing (331222)
Nonferrous Metal (except Copper and Aluminum) Rolling, Drawing, and Extruding (331491)
Electron Tube Manufacturing (334411)
Storage Battery Manufacturing (335911)
Energy Intensity $\in [.03, .05)$
Yarn Texturizing, Throwing, and Twisting Mills (313112)
Broadwoven Fabric Mills (313210)
All Other Petroleum and Coal Products Manufacturing (324199)
Inorganic Dye and Pigment Manufacturing (325131)
Synthetic Organic Dye and Pigment Manufacturing (325132)
Phosphatic Fertilizer Manufacturing (325312)
Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing (326113)
Polystyrene Foam Product Manufacturing (326140)
Vitreous China, Fine Earthenware, and Other Pottery Product Manufacturing (327112)
Other Aluminum Rolling and Drawing (331319)
Aluminum Foundries (except Die-Casting) (331524)
Iron and Steel Forging (332111)
Nonferrous Forging (332112)
Energy Intensity $\in (.05, .07]$
Gum and Wood Chemical Manufacturing (325191)
Ethyl Alcohol Manufacturing (325193)
All Other Basic Organic Chemical Manufacturing (325199)
Plastics Material and Resin Manufacturing (325211)
Ceramic Wall and Floor Tile Manufacturing (327122)
Primary Smelting and Refining of Nonferrous Metal (except Copper and Aluminum) (331419)
Steel Investment Foundries (331512)
Carbon and Graphite Product Manufacturing (335991)
Energy Intensity $\in (.07, .075]$
Carbon Black Manufacturing (325182)
All Other Basic Inorganic Chemical Manufacturing (325188)
Energy Intensity $\in (.075, .08]$
Paper (except Newsprint) Mills (322121)
Newsprint Mills (322122)
Iron and Steel Mills (331111)
Electrometallurgical Ferroalloy Product Manufacturing (331112)

Table A.2: Examining potential multiplicative bias in prediction market prices

Poly. order		(1) Main	(2) Trading volume	(3) Big trader volume	(4) Herfindahl index	(5) Only 2009	(6) Only 2010
1	Uninteracted	0.077	0.085	0.083	0.075	0.088	0.078
		(0.032)	(0.030)	(0.030)	(0.142)	(0.035)	(0.069)
	Interacted		-0.000	-0.000	0.003		
			(0.000)	(0.000)	(0.193)		
2	Uninteracted	0.071	0.074	0.074	0.235	0.070	0.110
		(0.035)	(0.034)	(0.033)	(0.148)	(0.044)	(0.043)
	Interacted		-0.000	-0.000	-0.239		
			(0.000)	(0.000)	(0.224)		
Number of firms		531	531	531	531	531	531
Number of dates		109	109	109	109	84	25

Estimates from interacted model in Eq. 12 in main text with firm and date fixed effects within 4% bandwidth. Robust standard errors clustered at 6-digit NAICS level in parentheses.

Table A.3: RD estimate using expiration date adjusted prediction market prices

		(1)	(2)	(3)	(4)	(5)
				Bandwidth		
Model	Poly. order	2%	2.5%	3%	3.5%	4%
Firm fixed effects				Panel (A)		
	1	0.070	0.068	0.047	0.060	0.067
		(0.030)	(0.030)	(0.031)	(0.029)	(0.025)
	2	-0.009	0.066	0.082	0.066	0.063
		(0.027)	(0.039)	(0.034)	(0.029)	(0.029)
CAPM				Panel (B)		
	1	0.072	0.078	0.070	0.071	0.066
		(0.038)	(0.038)	(0.035)	(0.030)	(0.024)
	2	-0.028	0.047	0.076	0.077	0.079
		(0.031)	(0.041)	(0.041)	(0.040)	(0.039)
3-factor Fama-French				Panel (C)		
	1	0.073	0.078	0.063	0.071	0.066
		(0.033)	(0.036)	(0.035)	(0.031)	(0.025)
	2	-0.023	0.051	0.082	0.076	0.082
		(0.033)	(0.036)	(0.038)	(0.036)	(0.036)
Firm, date fixed effects				Panel (D)		
	1	0.070	0.068	0.047	0.059	0.066
		(0.031)	(0.030)	(0.032)	(0.029)	(0.025)
	2	-0.009	0.066	0.082	0.066	0.063
		(0.027)	(0.039)	(0.034)	(0.029)	(0.029)
Firm, date fixed effects; oil×sector				Panel (E)		
	1	0.074	0.072	0.048	0.060	0.065
		(0.033)	(0.032)	(0.032)	(0.028)	(0.025)
	2	-0.013	0.064	0.082	0.066	0.063
		(0.027)	(0.039)	(0.034)	(0.030)	(0.029)
Firm, date×sector fixed effects				Panel (F)		
	1	0.050	0.047	0.045	0.061	0.058
		(0.025)	(0.029)	(0.030)	(0.028)	(0.024)
	2	0.059	0.071	0.070	0.067	0.067
		(0.054)	(0.041)	(0.031)	(0.029)	(0.029)
Number of firms		45	106	202	264	531

Each coefficient shows a separate estimate of β from Eq. 7 in main text using expiration date adjusted prediction market prices (see Appendix C). Controls for normal market performance vary by panel. Functional forms for energy intensity vary by rows within a panel. Sample bandwidths around the 5% threshold vary across columns. All models include 109 2-day intervals from May 1, 2009 to July 31, 2010. Robust standard errors clustered at 6-digit NAICS level in parentheses.

Table A.4: Comparing key features between Waxman-Markey and Senate climate bills

Feature	Criteria	Waxman-Markey	Climate bills Kerry-Boxer	Kerry-Lieberman
Cap schedule	Baseline Year	2005	2005	2005
	2012(WM/KB) /2013(KL)	97%	97%	95.25%
	2020	83%	80%	83%
	2030	58%	58%	58%
	2050	17%	17%	17%
Coverage	Number of sectors	10	same as W-M	same as W-M
Free permit rule	Threshold	≥5% EI ≥15% TI	same as W-M	same as W-M
All Offsets	Annual max (tons)	2 billion	same as W-M	same as W-M
Domestic Ag.	Number of eligible practices*	7	12	8
International	Annual max (tons)	1 billion	.5 billion	.5 billion
	Exceedence policy*	.5 billion	.75 billion	1 billion

* See details in Appendix F

Table A.5: CGE estimates of 2015 marginal abatement cost (in 2009$)

Institution	Sector	CGE model (scenario)	Perfect foresight?	Other W-M components?	Marginal abatement cost (2009$)
ACCF	Private	NEMS (high cost)	No	YES	37.73
ACCF	Private	NEMS (low cost)	No	YES	31.18
EIA	Government	NEMS (full offset)	No	YES	14.86
EIA	Government	NEMS (med offset)	No	YES	22.99
EPA	Government	ADAGE	Yes	YES	17.33
EPA	Government	IGEM	Yes	NO	17.12
Heritage	Private	IHS	No	YES	17.59
MIT	Academic	EPPA (full offset)	No	NO	7.99
MIT	Academic	EPPA (med offset)	No	NO	23.41
NBCC	Private	NEEMS	Yes	YES	24.02
				Mean	21.42
				Min	7.99
				Max	37.73

CGE estimates of 2015 marginal abatement cost (in 2009$) under Waxman-Markey. See Appendix G for summary of CGE models.

Table A.6: 2015 marginal abatement cost (in 2009$) implied by RD estimates under full borrowing restriction

Assumed annual emissions rate	Corresponding sector (NAICS)	5th percentile	Mean	95th percentile
0	–	2.19	8.02	13.47
-0.70%	Petro. refining (324110)	2.3	8.41	14.13
-1.45%	All manufacturing (31-33)	2.42	8.85	14.86
-5.20%	Forest products (321, 322)	3.08	11.28	18.94
-7.60%	Alumina & Aluminum (3313)	3.57	13.05	21.92
-11.60%	Cement (327310)	4.48	16.41	27.55
-12.80%	Glass (3272)	4.78	17.51	29.41
-13.90%	Transport. Equip. (336)	5.07	18.56	31.17
-19.30%	Textiles (313-316)	6.64	24.29	40.79
-25%	–	8.58	31.41	52.74
-30%	–	10.57	38.68	64.95
-35%	–	12.86	47.09	79.07

First column shows assumed annual emissions rate. Second column shows corresponding manufacturing subsector with 2006-2010 emissions changing at each rate. RD estimates (see Eq. 7 in main text) based on Table 1 in main text, Panel (C), Row (1), and Column (5)). 90% confidence interval generated using 250 Monte Carlo draws from estimated parameter and variance-covariance matrix. Marginal abatement cost recovered using Eq. 18 in main text but assuming permit borrowing restriction binds during duration of policy (see Appendix A.3 for details). 5% interest rate assumed.