Online Appendix: Not For Publication

This appendix contains multiple additional analyses. Appendix A describes in more detail the data construction. Appendix B shows that our results are robust to accounting for competing policies in this time period. Appendix C shows that the program did not lead to a significant shift in production toward locations with higher emissions and population density. Appendix D provides a detailed derivation of our baseline model. Appendix E describes how we model alternative regulations. Appendix F examines the effects of the program when we shut down market and conglomerate-level spillovers. Finally, Appendix G details the extensions of the model.

A Details of the Data Merge

Table A.2 shows the results of our data construction. We merge the lists of regulated firms using both firm name and the unique legal identifier. Since the Top 1,000 and Top 10,000 firms are all large firms, the match rate with the ASIF is very high. We match over 99% of Top 1,000 firms and over 97% of Top 10,000 firms. We also have a fairly good match rate with the CESD, where we match over 80% of Top 1,000 and over 70% of Top 10,000 firms. Overall, our combined datasets capture the majority of the economic activity in Top 1,000 and Top 10,000 firms.

B Robustness of Effects on Regulated Firms to Competing Policies

This appendix explores the robustness of our results to competing polices. Specifically, in the same time period when the Top 1,000 program was implemented, the Chinese government also adopted the National Specially Monitored Firms (NSMF) program. This is an environmental policy targeting over 6,500 firms in China listed as high polluters in 2007 with a selection rule for firms' COD, NH_4^+, SO_2, smoke and industrial dust emissions in 2005. Half of Top 1,000 firms and 14% of Top 10,000 firms were included on the NSMF list.

We now show that our estimated effects of the Top 1,000 program are not driven by this competing policy. Consider first the effect of the NSMF program within the group of firms in the Top 1,000 program. Panel A of Table A.6 reports estimates of a difference-in-differences model of the effects of the NSMF program and shows that it had little effect on the energy use, output, and energy efficiency of Top 1,000 firms. We also consider whether the NSMF program impacts our estimates of the effects of the Top 1,000 program on regulated firms. Panel B reports estimates of the effects of the Top 1,000 program when we exclude all treated firms included under both polices. Panel B shows that we obtain results similar to those in our baseline regressions when we leave out the all Top 1,000 firms included under the NSMF program. These findings suggest that taking the NSMF program into account does not affect our main results.

C Heterogeneous Effects of Spillovers by Local Density and Pollution

One important concern is that the spillovers that we identify may have shifted the location of production and of related emissions to more populated areas and areas with higher levels of preexisting industrial emissions. To address this concern, we first use data on city-level sulphur dioxide emissions and population density to generate the following measure of exposure: $\frac{City\ SO_2\ Emission \times Population}{City Area}$. We then calculate the difference in this exposure measure between each pair of regulated and related firms. Next, we split our sample by terciles of this measure. Table A.20 shows that related firms in places with lower or similar exposure increased their output by 10%, while those in more exposed areas saw larger increases of close to 22%. However, because a higher share of the output of related firms was concentrated in less exposed areas (58% in relatively less exposed vs. 28% in relatively more exposed areas), we find similar increases in production across more and less exposed areas. Overall, the spillover effects of the regulation did not disproportionately shift production to areas with higher population density or higher preexisting levels of industrial emissions.

D Model Appendix

This appendix provides detailed model derivations.

D.1 Model Equilibrium

Recall that the conglomerate takes the prices of energy p_e, capital r, and the variable input bundle w as given. Given the Leontief technology, the conglomerate sets $l_i = e_i$ so that the cost of intermediate inputs is $w + p_e$. Holding the number of affiliates n constant, the conglomerate maximizes

$$\pi(\phi, n) = \max_{\{l_i\}_{i=1}^n, \{k_i\}_{i=1}^n} \left\{ R^{1-\rho} P^{\rho} \left[\sum_{i=1}^{n} \phi \delta^{i-1} k_i^{\alpha_k} l_i^{\alpha_l} \right]^{\rho} - (w + p_e) \sum_{i=1}^{n} l_i - r \sum_{i=1}^{n} k_i \right\}.$$

For a firm i, the first-order conditions for l_i and k_i imply that $l_i = \frac{\alpha_l}{\alpha_k} \frac{r}{(w+p_e)} k_i$.

Substituting this expression, we can write the profit maximization problem as

$$\pi(\phi, n) = \max_{\{k_i\}_{i=1}^n} \left\{ R^{1-\rho} P^{\rho} \left[\sum_{i=1}^{n} \phi \delta^{i-1} k_i^{\alpha} \left(\frac{\alpha_l}{\alpha_k} \frac{r}{(w + p_e)} \right)^{\alpha_l} \right]^{\rho} - \left(\frac{\alpha}{\alpha_k} r \right) \sum_{i=1}^{n} k_i \right\}.$$

Comparing the first-order conditions for k_1 and k_i, we find that $\frac{k_i}{k_1} = \delta^{\frac{i-1}{1-\alpha}}$. The final result from Proposition 1 follows since

$$q_i = \phi\delta^{i-1}k_i^{\alpha}\left(\frac{\alpha_l}{\alpha_k}\frac{r}{(w+p_e)}\right)^{\alpha_l} = \phi\delta^{\frac{i-1}{1-\alpha}}k_1^{\alpha}\left(\frac{\alpha_l}{\alpha_k}\frac{r}{(w+p_e)}\right)^{\alpha_l} = \delta^{\frac{i-1}{1-\alpha}}q_1.$$

Using these results, we can write the profit maximization problem in terms of $K_n = \sum_i^n k_i$. To do so, we define the conglomerate's total productivity $\phi\Delta_n = \phi[\sum_{i=1}^n(\delta^{i-1})^{\frac{1}{1-\alpha}}]^{1-\alpha}$ and the constant $C_\pi = (1-\alpha\rho)\left[\left(\frac{\rho\alpha_l}{w+p_e}\right)^{\alpha_l\rho}\left(\frac{\rho\alpha_k}{r}\right)^{\alpha_k\rho}\right]^{\frac{1}{1-\alpha\rho}}$ to obtain

$$\pi(\phi,n) = \max_{K_n}\left\{\frac{R^{1-\rho}P^{\rho}C_\pi^{1-\alpha\rho}}{(1-\alpha\rho)^{1-\alpha\rho}}\left(\frac{\rho\alpha_k}{r}\right)^{-\alpha\rho}(\phi\Delta_n)^{\rho}K_n^{\alpha\rho} - r\left(\frac{\alpha}{\alpha_k}\right)K_n\right\}.$$

The optimal capital K_n and the firm profits for a conglomerate of size n are then

$$K_n = \frac{R^{\frac{1-\rho}{1-\alpha\rho}}P^{\frac{\rho}{1-\alpha\rho}}C_\pi}{(1-\alpha\rho)}\frac{\rho\alpha_k}{r}(\phi\Delta_n)^{\frac{\rho}{1-\alpha\rho}} \quad \text{and} \quad \pi(\phi,n) = R^{\frac{1-\rho}{1-\alpha\rho}}P^{\frac{\rho}{1-\alpha\rho}}C_\pi(\phi\Delta_n)^{\frac{\rho}{1-\alpha\rho}}.$$

The optimal profit given ϕ is then

$$\pi(\phi) = \max_n \pi(\phi,n) - rfn = \max_n R^{\frac{1-\rho}{1-\alpha\rho}}P^{\frac{\rho}{1-\alpha\rho}}C_\pi \times (\phi\Delta_n)^{\frac{\rho}{1-\alpha\rho}} - rfn.$$

Solving for indifference points ϕ_n yields the result of Proposition 2 and the zero-profit condition (Equation 7).

We now compute the price level. For given quantities $q(\phi,n)$, the price level is given by

$$P^{-\rho} = R^{-\rho}\int_{\phi_1} q(\phi,n)^{\rho}\frac{g(\phi)M}{1-G(\phi_1)}d\phi.$$

To differentiate from the regulated case below, we use starred variables to denote prices and quantities in the unregulated case. To derive $q^*(\phi,n)$, note from Proposition 1 that $K_n = k_1\Delta_n^{\frac{1}{1-\alpha}}$ and also recall that $l_1 = \frac{\alpha_l}{\alpha_k}\frac{r}{(w+p_e)}k_1$. We then have

$$\begin{aligned} q^*(\phi,n) &= \Delta_n^{\frac{1}{1-\alpha}}q_1^*(\phi,n) \\ &= \Delta_n^{\frac{1}{1-\alpha}}\phi\left(\frac{\alpha_l}{\alpha_k}\frac{r}{(w+p_e)}\right)^{\alpha_l}k_1^{*\alpha} \\ &= (\phi\Delta_n)^{\frac{1}{1-\alpha\rho}}R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}}P^{*\frac{\rho\alpha}{1-\alpha\rho}}\underbrace{\rho^{\frac{\alpha}{1-\alpha\rho}}\left[\left(\frac{\alpha_l}{w+p_e}\right)^{\alpha_l}\left(\frac{\alpha_k}{r}\right)^{\alpha_k}\right]^{\frac{1}{1-\alpha\rho}}}_{=C_Q}. \end{aligned} \tag{D.1}$$

The price level absent the regulation is then

$$\begin{aligned}
P^{*-\rho} &= R^{-\rho}\int_{\phi_1}\left((\phi\Delta_n)^{\frac{1}{1-\alpha\rho}}R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}}P^{*\frac{\rho\alpha}{1-\alpha\rho}}C_Q\right)^{\rho}\frac{g(\phi)M}{1-G(\phi_1)}d\phi\\
P^{*\frac{-\rho}{1-\alpha\rho}}R^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}C_Q^{-\rho} &= \int_{\phi_1}(\phi\Delta_n)^{\frac{\rho}{1-\alpha\rho}}\frac{g(\phi)M}{1-G(\phi_1)}d\phi.\\
P^{*\frac{-\rho}{1-\alpha\rho}}R^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}C_Q^{-\rho}\frac{1-G(\phi_1)}{M} &= \int_{\phi_1}(\phi\Delta_n)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi\\
P^{*\frac{-\rho}{1-\alpha\rho}}R^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}C_Q^{-\rho}\frac{1-G(\phi_1)}{M} &= \sum_n\Delta_n^{\frac{\rho}{1-\alpha\rho}}\underbrace{\int_{\phi_n}^{\phi_{n+1}}(\phi)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi}_{=\pi_n} = \sum_n\Delta_n^{\frac{\rho}{1-\alpha\rho}}\pi_n.
\end{aligned}$$

Given the assumption that ϕ follows a log-normal distribution, we can express

$$\pi_n = \int_{\phi_n}^{\phi_{n+1}}(\phi)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi = \exp\left\{\frac{\tilde{\sigma}^2}{2}\right\}[\Phi(b_{n+1}-\tilde{\sigma})-\Phi(b_n-\tilde{\sigma})],$$

where $\tilde{\sigma} = \frac{\rho}{1-\alpha\rho}\sigma_\phi$ and $b_n = \frac{\rho}{1-\alpha\rho}\frac{\ln(\phi_n)}{\tilde{\sigma}}$. Note also that Equations 6 and 7 imply that

$$\phi_{n+1} = \frac{\phi_1}{\left(\Delta_{n+1}^{\frac{\rho}{1-\rho\alpha}}-\Delta_n^{\frac{\rho}{1-\rho\alpha}}\right)^{\frac{1-\rho\alpha}{\rho}}}.$$

Thus, π_n depends on ϕ_1; it does not directly depend on equilibrium prices P^*.

D.2 Response to Top 1,000 Program

The Top 1,000 program limits energy use at the largest firm e_1 to a fraction $\xi < 1$ of the energy use in the unregulated case e_1^*; recall that we use starred variables to denote the optimal choices in the unregulated case. We assume that the number of firms n and the capital allocations $\{k_i^*\}_{i=1}^n$ are quasifixed but that the conglomerate can adjust $\{l_i\}_{i=1}^n$.

Regulated Conglomerates

Using the fact that $k_i^* = k_1^*\delta^{\frac{i-1}{1-\alpha}}$, we can write the profit maximization problem as

$$\max_{\{l_i\}_1^n}\left\{R^{1-\rho}P^{\rho}\left[\phi^*\sum_{i=1}^n\delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}}l_i^{\alpha_l}\right]^{\rho}-(w+p_e)\sum_{i=1}^n l_i - r\sum_{i=1}^n k_i^*\right\}\ \text{subject to}\ \ l_1\le\xi l_1^*,$$

where $\phi^* = \phi(k_1^*)^{\alpha_k}$. The first-order conditions for l_i $(1\le i\le n)$ are then

$$\frac{\partial\pi}{\partial l_i} = \underbrace{\underbrace{R^{1-\rho}P^{\rho}}_{\text{Market Demand}}\rho\left[\phi^*\sum_{i=1}^n\delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}}l_i^{\alpha_l}\right]^{\rho-1}}_{\text{Residual Revenue}}\underbrace{\phi^*\delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}}\alpha_l(l_i)^{\alpha_l-1}}_{\text{Marginal Product}} = w+p_e+\underbrace{\lambda(\phi)\mathbb{I}[i=1]}_{\text{Shadow Cost of Regulation}}.$$

These conditions yield the results in Proposition 3.

We now show that given n, $\lambda(\phi)$ does not depend on ϕ. To do so, we note that an implication of Proposition 3 is that we can write total conglomerate production under the regulation as

$$q(\phi,n)=\sum_{i}^{n}q_i(\phi,n)=q_1(\phi,n)\left[1+\sum_{i>1}^{n}\delta^{\frac{i-1}{1-\alpha}}\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}\right].$$

In contrast, recall from Proposition 1 that in the unregulated case total conglomerate output is

$$q^*(\phi,n)=\sum_{i}^{n}q_i^*(\phi,n)=q_1^*(\phi,n)\sum_{i}^{n}\delta^{\frac{i-1}{1-\alpha}}.$$

To connect these expressions, note that since k_1^* is fixed and $l_1=\xi l_1^*$, we have that

$$q_1(\phi,n)=\phi(k_1^*)^{\alpha_k}(l_1)^{\alpha_l}=\phi(k_1^*)^{\alpha_k}(l_1^*)^{\alpha_l}\xi^{\alpha_l}=q_1^*(\phi,n)\xi^{\alpha_l}.$$

Together, the last three expression imply that

$$q(\phi,n)=q^*(\phi,n)\xi^{\alpha_l}\frac{\left[1+\sum_{i>1}^{n}\delta^{\frac{i-1}{1-\alpha}}\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}\right]}{\sum_{i}^{n}\delta^{\frac{i-1}{1-\alpha}}}=q^*(\phi,n)\underbrace{\left[\xi^{\alpha_l}\frac{1+(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}}{\Delta_n^{\frac{1}{1-\alpha}}}\right]}_{=\xi_{q,n}}, \tag{D.2}$$

where $\xi_{q,n}$ captures the impact of the regulation on conglomerate output.

Using this expression and the fact that $l_1=\xi l_1^*$, we can rewrite the first-order condition for l_1 in terms of the capital and labor choices in the unregulated case:

$$\underbrace{R^{1-\rho}P^{*\rho}\rho\left[\phi\sum_{i=1}^{n}\delta^{\frac{i-1}{1-\alpha}}(k_i^*)^{\alpha_k}(l_i^*)^{\alpha_l}\right]^{\rho-1}\times\phi\alpha_l(k_1^*)^{\alpha_k}(l_1^*)^{\alpha_l-1}}_{\text{FOC Unregulated Case}}$$

$$\times(\xi)^{\alpha_l-1}\left(\frac{P}{P^*}\right)^{\rho}\left[\xi^{\alpha_l}\frac{1+(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}}{\Delta_n^{\frac{1}{1-\alpha}}}\right]^{\rho-1}=w+p_e+\lambda(\phi),$$

where $\frac{P}{P^*}$ is the equilibrium change in the industry-level price. Using the fact that the first-order condition in the unregulated case equals $w+p_e$, we have

$$(\xi)^{\alpha_l-1}\left(\frac{P}{P^*}\right)^{\rho}\left[\xi^{\alpha_l}\frac{1+(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}}{\Delta_n^{\frac{1}{1-\alpha}}}\right]^{(\rho-1)}=1+\frac{\lambda(\phi)}{w+p_e}. \tag{D.3}$$

This expression shows that conditional on n, the shadow cost does not depend on ϕ, and so we now write λ_n. The expression above is equivalent to

$$\left[1+\frac{\lambda_n}{w+p_e}\right]^{\frac{1}{1-\rho}}\left[1+(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda_n}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}\right] \quad = \quad \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\rho}}\xi^{\frac{-(1-\alpha_l\rho)}{1-\rho}}\Delta_n^{\frac{1}{1-\alpha}}. \quad \text{(D.4)}$$

This expression does not have a general closed-form solution. Consider, however, the special case where $\frac{1}{1-\rho}=\frac{\alpha_l}{1-\alpha_l}$.[58] In this special case, we can write this expression as

$$(\Delta_n^{\frac{1}{1-\alpha}}-1)x^2+x-\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\rho}}\xi^{\frac{-(1-\alpha_l\rho)}{1-\rho}}\Delta_n^{\frac{1}{1-\alpha}}=0,$$

where $x=\left[1+\frac{\lambda_n}{w+p_e}\right]^{\frac{1}{1-\rho}}=\left[1+\frac{\lambda_n}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}$, which allows us to solve for λ_n using the quadratic formula. Focusing on the positive root implies

$$1+\frac{\lambda_n}{w+p_e}=\left\{\frac{-1+\sqrt{1+4(\Delta_n^{\frac{1}{1-\alpha}}-1)\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\rho}}\xi^{\frac{-(1-\alpha_l\rho)}{1-\rho}}\Delta_n^{\frac{1}{1-\alpha}}}}{2(\Delta_n^{\frac{1}{1-\alpha}}-1)}\right\}^{1-\rho}.$$

Note that λ_n depends on the equilibrium price P in both the expression above and in Equation D.4. In this case, we also have

$$\xi_{q,n}=\xi^{\alpha_l}\frac{1+\sqrt{1+4(\Delta_n^{\frac{1}{1-\alpha}}-1)\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\rho}}\xi^{\frac{-(1-\alpha_l\rho)}{1-\rho}}\Delta_n^{\frac{1}{1-\alpha}}}}{2\Delta_n^{\frac{1}{1-\alpha}}}.$$

Unregulated Conglomerates

Unregulated conglomerates are affected by the policy through the price adjustment in the product market. The first-order conditions for l_i $(1\le i\le n)$ are then

$$\frac{\partial\pi}{\partial l_i}=R^{1-\rho}P^\rho\rho\left[\phi^*\sum_{i=1}^n\delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}}l_i^{\alpha_l}\right]^{\rho-1}\phi^*\delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}}\alpha_l(l_i)^{\alpha_l-1} \quad = \quad w+p_e.$$

Since these firms do not face a shadow cost, the conditions of Proposition 1 continue to hold. Using these results to solve for l_1, we obtain

$$l_1=\left[\frac{R^{1-\rho}P^\rho\rho[\phi(k_1^*)^{\alpha_k}]^\rho\Delta_n^{\frac{\rho-1}{1-\alpha}}\alpha_l}{w+p_e}\right]^{\frac{1}{1-\alpha_l\rho}}.$$

This further implies that

$$l_1=l_1^*\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}} \quad \text{(D.5)}$$

[58]While this is a knife-edge case, it holds in the empirically relevant case of $\rho=.75$ and $\alpha_l=0.8$, so that $\frac{1}{1-\rho}=\frac{\alpha_l}{1-\alpha_l}=4$.

and both

$$q_1(\phi,n) = q_1^*(\phi,n)\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}} \quad \text{and} \quad q(\phi,n) = q^*(\phi,n)\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}. \tag{D.6}$$

D.2.1 Product Market Equilibrium

We now derive the equilibrium price under the Top 1,000 program. Recall that only conglomerates with $\phi \geq \tilde{\phi}$ have a regulated firm. Under the definition of $\xi_{q,n}$ in Equation D.2 for regulated firms and Equation D.6 for unregulated firms, the price level under the regulation is then

$$\begin{aligned} P^{-\rho} &= R^{-\rho}\int_{\phi_1}^{\tilde{\phi}}\left(\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}(\phi\Delta_n)^{\frac{1}{1-\alpha\rho}}R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}}P^{*\frac{\rho\alpha}{1-\alpha\rho}}C_Q\right)^{\rho}\frac{g(\phi)M}{1-G(\phi_1)}d\phi \\ &+ R^{-\rho}\int_{\tilde{\phi}}\left(\xi_{q,n}(\phi\Delta_n)^{\frac{1}{1-\alpha\rho}}R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}}P^{*\frac{\rho\alpha}{1-\alpha\rho}}C_Q\right)^{\rho}\frac{g(\phi)M}{1-G(\phi_1)}d\phi. \end{aligned}$$

As in the case of the unregulated equilibrium, we use π_n to denote the output of conglomerates with n affiliates. However, the regulation threshold $\tilde{\phi}$ in general does not line up with the size thresholds ϕ_n that define π_n. Let $\tilde{n}$ denote the smallest firm size for regulated conglomerates. We split $\pi_{\tilde{n}}$ into $\tilde{\pi}_1$ and $\tilde{\pi}_2$ as follows:

$$\tilde{\pi}_1 = \int_{\phi_{\tilde{n}}}^{\tilde{\phi}}(\phi)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi \quad \text{and} \quad \tilde{\pi}_2 = \int_{\tilde{\phi}}^{\phi_{\tilde{n}+1}}(\phi)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi.$$

We can then manipulate the expression for the equilibrium price as follows:

$$\begin{aligned} P^{-\rho}P^{*\frac{-\rho^2\alpha}{1-\alpha\rho}}R^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}C_Q^{-\rho}\frac{1-G(\phi_1)}{M} &= \left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}}\left(\sum_{n=1}^{\tilde{n}-1}\Delta_n^{\frac{\rho}{1-\alpha\rho}}\pi_n + \Delta_{\tilde{n}}^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_1\right) \\ &+ \xi_{q,\tilde{n}}^{\rho}\Delta_{\tilde{n}}^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2 + \sum_{n=\tilde{n}+1}\xi_{q,n}^{\rho}\Delta_n^{\frac{\rho}{1-\alpha\rho}}\pi_n. \end{aligned}$$

Note that this equation holds in the case absent the regulation if we set $\xi_{q,n} = 1$ and $P = P^*$. Let $s_{\tilde{\phi}} = \frac{\Delta_{\tilde{n}}^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2 + \sum_{n=\tilde{n}+1}\Delta_n^{\frac{\rho}{1-\alpha\rho}}\pi_n}{\sum_n \Delta_n^{\frac{\rho}{1-\alpha\rho}}\pi_n}$ be the output share of the Top 1,000 conglomerates prior to the regulation. Additionally, we introduce the notation:

$$\mathbb{E}_e\left[x_n \middle| \phi > \tilde{\phi}\right] = x_{\tilde{n}}\left(\frac{\Delta_n^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2}{\Delta_n^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2 + \sum_{n=\tilde{n}+1}\Delta_n^{\frac{\rho}{1-\alpha\rho}}\pi_n}\right) + \sum_{n=\tilde{n}+1}x_n\left(\frac{\Delta_n^{\frac{\rho}{1-\alpha\rho}}\pi_n}{\Delta_n^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2 + \sum_{n=\tilde{n}+1}\Delta_n^{\frac{\rho}{1-\alpha\rho}}\pi_n}\right)$$

to denote the average of a size-dependent variable x_n conditional on being part of the Top 1,000 program with respect to the distribution of energy use in the unregulated equilibrium.

Assuming that the regulation does not impact r and w, taking the ratio of price levels before and after the regulation, we obtain

$$\left(\frac{P}{P^*}\right)^{-\rho} = (1-s_{\tilde{\phi}})\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}} + s_{\tilde{\phi}}\mathbb{E}_e\left[\xi_{q,n}^{\rho}\middle|\phi>\tilde{\phi}\right]. \tag{D.7}$$

Equations D.4 and D.7 jointly determine the shadow costs of the regulation $\{\lambda_n\}_{n\geq\tilde{n}}$ and the increase in the price level $\frac{P}{P^*}$.

D.2.2 Characterizing Energy Use

Recall that the energy use in firm 1 before the regulation is

$$e_1^*(\phi,n) = l_1^*(\phi,n) = \left(\frac{\alpha_l}{\alpha_k}\frac{r}{(w+p_e)}\right)k_1^*(\phi,n) = \left(\frac{\alpha_l}{\alpha_k}\frac{r}{(w+p_e)}\right)\left(\frac{K_n^*}{\Delta_n^{\frac{1}{1-\alpha}}}\right).$$

The energy use for the conglomerate before the regulation is then

$$\begin{aligned} e^*(\phi,n) &= \left(\frac{\alpha_l}{\alpha_k}\frac{r}{(w+p_e)}\right)K_n^* \\ &= (\phi\Delta_n)^{\frac{\rho}{1-\alpha\rho}}R^{\frac{1-\rho}{1-\alpha\rho}}P^{*\frac{\rho}{1-\alpha\rho}}\underbrace{\rho^{\frac{1}{1-\alpha\rho}}\left[\left(\frac{\alpha_l}{w+p_e}\right)^{1-\alpha_k\rho}\left(\frac{\alpha_k}{r}\right)^{\alpha_k\rho}\right]^{\frac{1}{1-\alpha\rho}}}_{=C_E}. \end{aligned} \tag{D.8}$$

The total energy use prior to the regulation is then

$$\begin{aligned} E^* &= \int_{\phi_1} e^*(\phi,n)\frac{g(\phi)M}{1-G(\phi_1)}d\phi \\ &= R^{\frac{1-\rho}{1-\alpha\rho}}P^{*\frac{\rho}{1-\alpha\rho}}\frac{C_E M}{1-G(\phi_1)}\sum_n(\Delta_n)^{\frac{\rho}{1-\alpha\rho}}\pi_n. \end{aligned}$$

Regulated Conglomerates

We now characterize the change in energy use for regulated conglomerates. The fact that $e_i = l_i$ and the results of Proposition 1 imply that the energy use for an unregulated conglomerate is

$$e^*(\phi,n) = \sum_i e_i^*(\phi,n) = e_1^*(\phi,n)\sum_i^n \delta^{\frac{i-1}{1-\alpha}}.$$

Proposition 3 implies that the energy use for a regulated conglomerate is

$$e(\phi,n) = \sum_i e_i(\phi,n) = e_1(\phi,n)\left[1+\sum_{i>1}^n \delta^{\frac{i-1}{1-\alpha}}\left[1+\frac{\lambda_n}{w+p_e}\right]^{\frac{1}{1-\alpha_l}}\right].$$

Using the fact that $e_1 = \xi e_1^*$, we then have

$$e(\phi, n) = e^*(\phi, n) \underbrace{\frac{\xi \left[1 + \sum_{i>1}^{n} \delta^{\frac{i-1}{1-\alpha}} \left[1 + \frac{\lambda_n}{w+p_e}\right]^{\frac{1}{1-\alpha_l}}\right]}{\sum_{i}^{n} \delta^{\frac{i-1}{1-\alpha}}}}_{=\xi_{e,n}},$$

where $\xi_{e,n}$ captures the effect of the regulation on the energy use of a regulated conglomerate.

Unregulated Conglomerates

Proposition 1 and Equation D.5 imply that for unregulated conglomerates,

$$e_1(\phi, n) = e_1^*(\phi, n) \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}}$$

and additionally that

$$e(\phi, n) = e^*(\phi, n) \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}}.$$

Aggregate Change in Energy

Putting the above together, total energy use after the regulation is now

$$\begin{aligned} E &= \int_{\phi_1} e(\phi, n) \frac{g(\phi)M}{1 - G(\phi_1)} d\phi = \int_{\phi_1}^{\tilde{\phi}} \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}} e^*(\phi, n) \frac{g(\phi)M}{1 - G(\phi_1)} d\phi + \int_{\tilde{\phi}} \xi_{e,n} e^*(\phi, n) \frac{g(\phi)M}{1 - G(\phi_1)} d\phi \\ &= R^{\frac{1-\rho}{1-\alpha\rho}} P^{*\frac{\rho}{1-\alpha\rho}} \frac{C_E M}{1 - G(\phi_1)} \left[\left(\sum_{n=1}^{\tilde{n}-1} \Delta_n^{\frac{\rho}{1-\alpha\rho}} \pi_n + \Delta_{\tilde{n}}^{\frac{\rho}{1-\alpha\rho}} \tilde{\pi}_1\right) \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}} + \xi_{e,\tilde{n}} \Delta_{\tilde{n}}^{\frac{\rho}{1-\alpha\rho}} \tilde{\pi}_2 + \sum_{n=\tilde{n}+1} \xi_{e,n} \Delta_n^{\frac{\rho}{1-\alpha\rho}} \pi_n\right]. \end{aligned}$$

This implies that

$$\begin{aligned} \frac{E}{E^*} &= \frac{\left(\sum_{n=1}^{\tilde{n}-1} \Delta_n^{\frac{\rho}{1-\alpha\rho}} \pi_n + \Delta_{\tilde{n}}^{\frac{\rho}{1-\alpha\rho}} \tilde{\pi}_1\right) \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}} + \xi_{e,\tilde{n}} \Delta_{\tilde{n}}^{\frac{\rho}{1-\alpha\rho}} \tilde{\pi}_2 + \sum_{n=\tilde{n}+1} \xi_{e,n} \Delta_n^{\frac{\rho}{1-\alpha\rho}} \pi_n}{\sum_n (\Delta_n)^{\frac{\rho}{1-\alpha\rho}} \pi_n} \\ &= (1 - s_{\tilde{\phi}}) \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}} + s_{\tilde{\phi}} \mathbb{E}_e \left[\xi_{e,n} \middle| \phi > \tilde{\phi}\right]. \end{aligned} \quad \text{(D.9)}$$

Equation D.9—along with the equilibrium price increase and shadow costs determined by Equations D.4 and D.7—allows us to compute the effect of the regulation on welfare.

D.2.3 Solving the New Equilibrium Using Reduced-Form Estimates

In Section 6, we present the full solution to the model using the derivations above. This appendix shows that we can also solve for an approximation of the equilibrium based on our reduced-form estimates. To do so, we make the assumption that λ and Δ are constant for regulated firms. Taking the value of λ implied by our reduced-form estimate of 8.95% and $\Delta^{\frac{1}{1-\alpha}} = 1.6$ (which approximates the value for $n = 6$), we use Proposition 4 to compute the production distortion $\xi_q = 0.9648$. Equation 14 delivers the equilibrium price change: $\ln\left(\frac{P}{P^*}\right) = 4.2\%$. We then compute that regulated conglomerates lower their energy use by 5.6%. Finally, we use these numbers to implement Equation 15, where we find that $\ln\left(\frac{E}{E^*}\right) = -3.65\%$. The advantage of this calculation is that it relies on only a handful of calibrated parameter values and the result of the within-conglomerate difference-in-differences estimation. In particular, this calculation does not rely on distributional assumptions for $G(\phi)$. It is thus reassuring that we obtain aggregate quantities close to those in the full model solution.

E Alternative Regulations

Conglomerate-level Regulation

Suppose that instead of regulating the energy use of the top firm, the government restricted the energy use of all firms in a conglomerate to at most ξ of the energy use at the Top 1,000 firm plus the energy use at related firms. The regulatory constraint would be

$$e(\phi, n) \leq \xi_{e,n} e^*(\phi, n).$$

Arguments similar to the derivation for Equation D.9 imply that

$$\frac{E^C}{E^*} = (1 - s_{\tilde{\phi}}) \left(\frac{P^C}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}} + s_{\tilde{\phi}} \mathbb{E}_e \left[\xi_{e,n} | \, \phi > \tilde{\phi} \right], \tag{E.1}$$

where we use the superscript C to denote the case of the conglomerate-level regulation.

Since energy use in all firms contributes equally to the regulatory constraint, this regulation does not distort the allocation of inputs across related firms; i.e., Proposition 1 continues to hold. This implies that $l_i = \xi_{e,n} l_i^*$ for all firms i in the conglomerate. It further implies that

$$q(\phi, n) = (\xi_{e,n})^{\alpha_l} q^*(\phi, n).$$

Arguments similar to the derivation for Equation D.7 imply that

$$\left(\frac{P^C}{P^*}\right)^{-\rho} = (1 - s_{\tilde{\phi}}) \left(\frac{P^C}{P^*}\right)^{\frac{\alpha_l \rho^2}{1-\alpha_l \rho}} + s_{\tilde{\phi}} \mathbb{E}_e \left[(\xi_{e,n})^{\alpha_l \rho} | \, \phi > \tilde{\phi} \right]. \tag{E.2}$$

We now derive the shadow cost of this regulation. Substituting l_i into the first-order condition for firm 1 implies that

$$\underbrace{R^{1-\rho}P^{*\rho}\rho\left[\phi\sum_{i=1}^{n}\delta^{\frac{i-1}{1-\alpha}}(k_i^*)^{\alpha_k}(l_i^*)^{\alpha_l}\right]^{\rho-1}\times\phi\alpha_l(k_1^*)^{\alpha_k}(l_1^*)^{\alpha_l-1}}_{\text{FOC Unregulated Case}}$$
$$\times(\xi_{e,n})^{\alpha_l-1}\left(\frac{P^C}{P^*}\right)^{\rho}[(\xi_{e,n})^{\alpha_l}]^{\rho-1}=w+p_e+\lambda^C(\phi).$$

Using the fact that the first-order condition in the unregulated case equals $w+p_e$, we obtain

$$\left[1+\frac{\lambda_n^C}{w+p_e}\right]=\left(\frac{P^C}{P^*}\right)^{\rho}(\xi_{e,n})^{-(1-\alpha_l\rho)}.$$

Size-dependent Energy Tax

Suppose that the government instituted a per-unit energy tax for all the affiliates of conglomerates with $\phi>\tilde{\phi}$. As in the case above, this policy would not impact the within-conglomerate allocation of inputs of regulated firms, and Proposition 1 would continue to hold. That is, related firms would all reduce their energy use by the same proportion. Let λ_ξ^τ be the tax associated with a proportional energy reduction use of $1-\xi_\tau$. The first-order condition for firm 1 is then

$$\underbrace{R^{1-\rho}P^{*\rho}\rho\left[\phi\sum_{i=1}^{n}\delta^{\frac{i-1}{1-\alpha}}(k_i^*)^{\alpha_k}(l_i^*)^{\alpha_l}\right]^{\rho-1}\times\phi\alpha_l(k_1^*)^{\alpha_k}(l_1^*)^{\alpha_l-1}}_{\text{FOC Unregulated Case}}$$
$$\times(\xi_\tau)^{\alpha_l-1}\left(\frac{P^\tau}{P^*}\right)^{\rho}[\xi_\tau^{\alpha_l}]^{\rho-1}=w+p_e+\lambda_\xi^\tau,$$

where we use the superscript τ to denote this case. Using the fact that the first-order condition in the unregulated case equals $w+p_e$, we obtain

$$\left[1+\frac{\lambda_\xi^\tau}{w+p_e}\right]=\left(\frac{P^\tau}{P^*}\right)^{\rho}(\xi_\tau)^{-(1-\alpha_l\rho)}.$$

Since all related firms reduce their energy use by the same proportion, it follows that $e(\phi,n)=\xi_\tau e^*(\phi,n)$ for regulated firms. Arguments similar to the derivation for Equation D.9 imply that

$$\frac{E^\tau}{E^*}=(1-s_{\tilde{\phi}})\left(\frac{P^\tau}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}}+s_{\tilde{\phi}}\xi_\tau. \tag{E.3}$$

Noting that $q(\phi,n)=\xi_\tau^{\alpha_l}q^*(\phi,n)$ then implies that

$$\left(\frac{P^\tau}{P^*}\right)^{-\rho}=(1-s_{\tilde{\phi}})\left(\frac{P^\tau}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}}+s_{\tilde{\phi}}(\xi_\tau)^{\alpha_l\rho}. \tag{E.4}$$

To make this case comparable to the Top 1,000 regulation, we implement a tax that leads to the same average energy reduction:

$$\left[1+\frac{\lambda_\xi^\tau}{w+p_e}\right]=\left(\frac{P^\tau}{P^*}\right)^\rho\left(\mathbb{E}_e\left[\xi_{e,n}\middle|\phi>\tilde{\phi}\right]\right)^{-(1-\alpha_l\rho)};$$

that is, $\xi_\tau=\mathbb{E}_e\left[\xi_{e,n}\middle|\phi>\tilde{\phi}\right]$. Note that the aggregate effects differ to the extent that we obtain different price responses (and therefore different responses from unregulated firms).

F Inspecting the Effect Mechanisms of the Top 1,000 Regulation

Shutting down Market Leakage

In this case, firms believe that prices do not adjust. The perceived shadow cost is given by the solution to

$$\left[1+\frac{\lambda_n}{w+p_e}\right]^{\frac{1}{1-\rho}}\left[1+(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda_n}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}\right] \quad = \quad \xi^{\frac{-(1-\alpha_l\rho)}{1-\rho}}\Delta_n^{\frac{1}{1-\alpha}}.$$

We recompute $\xi_{e,n}$ and $\xi_{q,n}$ based on these shadow costs. Aggregate energy use is then given by

$$\frac{E}{E^*} \quad = \quad (1-s_{\tilde{\phi}})+s_{\tilde{\phi}}\mathbb{E}_e\left[\xi_{e,n}\middle|\phi>\tilde{\phi}\right].$$

The new price is given by

$$\left(\frac{P}{P^*}\right)^{-\rho} \quad = \quad (1-s_{\tilde{\phi}})+s_{\tilde{\phi}}\mathbb{E}_e\left[\xi_{q,n}^\rho\middle|\phi>\tilde{\phi}\right].$$

The actual shadow cost follows Equation 14 by incorporating the equilibrium price adjustment.

Shutting down Conglomerate Leakage

In this case, we set $e_1(\phi,n)\le\xi e_1^*(\phi,n)$. We further assume that firms related to regulated firms do not take into account the reduction in $e_1(\phi,n)$ but do respond to the market price increase, so that $e_i(\phi,n)=\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}}e_i^*(\phi,n)$ for $i\ge 2$. We then have

$$\begin{aligned}
e(\phi,n) \quad &= \quad \xi e_1^*(\phi,n)+\sum_{i=2}e_i^*(\phi,n)\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}}=e_1^*(\phi,n)\left(\xi+\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}}\left(\Delta_n^{\frac{1}{1-\alpha}}-1\right)\right)\\
&= \quad e^*(\phi,n)\frac{\xi+\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}}\left(\Delta_n^{\frac{1}{1-\alpha}}-1\right)}{\Delta_n^{\frac{1}{1-\alpha}}}.
\end{aligned}$$

Aggregate energy use is then

$$\frac{E}{E^*} = (1-s_{\tilde{\phi}})\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}} + s_{\tilde{\phi}}\mathbb{E}_e\left[\left.\frac{\xi+\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}}\left(\Delta_n^{\frac{1}{1-\alpha}}-1\right)}{\Delta_n^{\frac{1}{1-\alpha}}}\right|\phi>\tilde{\phi}\right].$$

Similarly, the effect on total production is

$$\begin{aligned} q(\phi,n) &= \xi^{\alpha_l}q_1^*(\phi,n)+\sum_{i=2} q_i^*(\phi,n)\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}} = q_1^*(\phi,n)\left(\xi^{\alpha_l}+\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}\left(\Delta_n^{\frac{1}{1-\alpha}}-1\right)\right) \\ &= q^*(\phi,n)\frac{\xi^{\alpha_l}+\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}\left(\Delta_n^{\frac{1}{1-\alpha}}-1\right)}{\Delta_n^{\frac{1}{1-\alpha}}}. \end{aligned}$$

Aggregate prices are then

$$\left(\frac{P}{P^*}\right)^{-\rho} = (1-s_{\tilde{\phi}})\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}} + s_{\tilde{\phi}}\mathbb{E}_e\left[\left.\left(\frac{\xi^{\alpha_l}+\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}\left(\Delta_n^{\frac{1}{1-\alpha}}-1\right)}{\Delta_n^{\frac{1}{1-\alpha}}}\right)^{\rho}\right|\phi>\tilde{\phi}\right].$$

We now derive the shadow cost of the regulation for the Top 1,000 firm. Substituting l_i into the first-order condition for firm 1 implies that

$$\underbrace{R^{1-\rho}P^{*\rho}\rho\left[\phi\sum_{i=1}^{n}\delta^{\frac{i-1}{1-\alpha}}(k_i^*)^{\alpha_k}(l_i^*)^{\alpha_l}\right]^{\rho-1}\times\phi\alpha_l(k_1^*)^{\alpha_k}(l_1^*)^{\alpha_l-1}}_{\text{FOC Unregulated Case}}$$

$$\times(\xi)^{\alpha_l-1}\left(\frac{P}{P^*}\right)^{\rho}\left[\frac{\xi^{\alpha_l}+\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}\left(\Delta_n^{\frac{1}{1-\alpha}}-1\right)}{\Delta_n^{\frac{1}{1-\alpha}}}\right]^{\rho-1} = w+p_e+\lambda(\phi)$$

Using the fact that the first-order condition in the unregulated case equals $w+p_e$, we obtain

$$\left[1+\frac{\lambda_n}{w+p_e}\right] = \left(\frac{P}{P^*}\right)^{\rho}\xi^{-(1-\alpha_l)}\left(\frac{\xi^{\alpha_l}+\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}\left(\Delta_n^{\frac{1}{1-\alpha}}-1\right)}{\Delta_n^{\frac{1}{1-\alpha}}}\right)^{-(1-\rho)}.$$

Shutting down Both Market and Conglomerate Leakage

Energy use and production at regulated conglomerates is the same as in the case in which only the conglomerate leakage is shut down. Unregulated firms assume that there will be no price increase, such that the aggregate energy use is then

$$\frac{E}{E^*} = (1-s_{\tilde{\phi}})+s_{\tilde{\phi}}\mathbb{E}_e\left[\left.\frac{\xi-1+\Delta_n^{\frac{1}{1-\alpha}}}{\Delta_n^{\frac{1}{1-\alpha}}}\right|\phi>\tilde{\phi}\right].$$

Aggregate prices are then

$$\left(\frac{P}{P^*}\right)^{-\rho} = (1 - s_{\tilde{\phi}}) + s_{\tilde{\phi}} \mathbb{E}_e \left[\left(\frac{\xi^{\alpha_l} - 1 + \Delta_n^{\frac{1}{1-\alpha}}}{\Delta_n^{\frac{1}{1-\alpha}}} \right)^{\rho} \middle| \phi > \tilde{\phi} \right].$$

The actual shadow cost follows Equation 14 using the following definition of $\xi_q(\phi) = \frac{\xi - 1 + \Delta_n^{\frac{1}{1-\alpha}}}{\Delta_n^{\frac{1}{1-\alpha}}}$ and the equilibrium price above.

G Model Extensions

G.1 Endogenous Energy Efficiency

Assume that the conglomerate can improve energy efficiency at firm i, ν_i, by spending $l_i c(\nu_i)$, where $c'(\nu_i) > 0$ and $c''(\nu_i) \geq 0$. The conglomerate's problem is then

$$\pi(\phi, n) = \max_{\{l_i\}_{i=1}^n, \{\nu_i\}_{i=1}^n} \left\{ R^{1-\rho} P^{\rho} \left[\phi^* \sum_{i=1}^n \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} l_i^{\alpha_l} \right]^{\rho} - \sum_{i=1}^n l_i \left(w + \frac{p_e}{\nu_i} + c(\nu_i) \right) \right\},$$

where we omit the cost of fixed capital. Absent the regulation, the conglomerate sets $c'(\nu^*)\nu^{*2} = p_e$ for all firms, so that Proposition 1 continues to hold.

We assume that $c(\nu) = \frac{\nu^{\gamma}}{1+\gamma}$, where $\gamma \geq 1$, so the effective price of energy is $(\nu^*)^{\gamma}$. Additionally, note that the Top 1,000 regulation does not impact the choice of ν_i for unregulated firms. Using these results and the fact that $\nu_i = \frac{l_i}{e_i}$, we can restate the conglomerate problem as

$$\pi(\phi, n) = \max_{\{l_i\}_{i=1}^n} \left\{ R^{1-\rho} P^{\rho} \left[\phi^* \sum_{i=1}^n \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} l_i^{\alpha_l} \right]^{\rho} - (w + (\nu^*)^{\gamma}) \sum_{i=1}^n l_i - l_1 \left[\frac{1}{1+\gamma} \left(\frac{l_1}{\xi e_1^*} \right)^{\gamma} - (\nu^*)^{\gamma} \right] \right\},$$

where we substitute the regulatory constraint into the cost of energy efficiency and abstract away from the cost of the regulated energy.

Deriving the Shadow Cost of Regulation

The conglomerate's first-order conditions for l_i ($1 \leq i \leq n$), i.e., $\frac{\partial \pi}{\partial l_i}$, are then

$$R^{1-\rho} P^{\rho} \rho \left[\phi^* \sum_{i=1}^n \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} l_i^{\alpha_l} \right]^{\rho-1} \phi^* \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} \alpha_l (l_i)^{\alpha_l - 1} = w + (\nu^*)^{\gamma} + \left[\left(\frac{l_1}{\xi e_1^*} \right)^{\gamma} - (\nu^*)^{\gamma} \right] \mathbb{I}[i = 1].$$

We can write the binding energy use constraint as $\xi e_1^* = e_1 = \frac{l_1}{\nu_1}$ so that $\nu_1 = \frac{l_1}{\xi e_1^*}$. It is also useful to write the share of variable input costs accounted for by energy as $s_e = \frac{(\nu^*)^{\gamma}}{w + (\nu^*)^{\gamma}}$. The shadow cost of the policy as a fraction of variable inputs is then

$$\frac{\lambda(\phi)}{w + (\nu^*)^{\gamma}} = \frac{1}{w + (\nu^*)^{\gamma}} \left[\left(\frac{l_1}{\xi e_1^*} \right)^{\gamma} - (\nu^*)^{\gamma} \right] = s_e \left(\left(\frac{\nu_1}{\nu^*} \right)^{\gamma} - 1 \right).$$

Using these expressions, we can then write the ratios of these first-order conditions between $j \geq 2$ and the Top 1,000 firm as

$$\frac{l_j}{l_1} = \delta^{\frac{j-1}{1-\alpha}} \left[1 + s_e \left(\left(\frac{\nu_1}{\nu^*}\right)^{\gamma} - 1\right)\right]^{\frac{1}{1-\alpha_l}} = \delta^{\frac{j-1}{1-\alpha}} \left[1 + \frac{\lambda(\phi)}{w + (\nu^*)^{\gamma}}\right]^{\frac{1}{1-\alpha_l}},$$

which confirms that the results of Proposition 3 extend to the case of endogenous energy efficiency. We can then write the first-order condition for the Top 1,000 firm as

$$\underbrace{R^{1-\rho}(P^*)^{\rho}\rho\left[\phi^* \sum_{i=1}^{n} \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} (l_i^*)^{\alpha_l}\right]^{\rho-1} \phi^* \alpha_l (l_1^*)^{\alpha_l - 1}}_{\text{FOC Unregulated}} \left(\frac{P}{P^*}\right)^{\rho} \tag{G.1}$$

$$\left[\underbrace{\left(\frac{\xi\nu_1}{\nu^*}\right)^{\alpha_l} \frac{\left[1 + \left[1 + \frac{\lambda(\phi)}{w + (\nu^*)^{\gamma}}\right]^{\frac{\alpha_l}{1-\alpha_l}} \sum_{j>1} \delta^{\frac{j-1}{1-\alpha}}\right]}{\sum_i \delta^{\frac{j-1}{1-\alpha}}}}_{\xi^{\nu}_{q,n}}\right]^{\rho-1} \times \left(\frac{\xi\nu_1}{\nu^*}\right)^{\alpha_l - 1} = (w + (\nu^*)^{\gamma}) \left[1 + \frac{\lambda(\phi)}{w + (\nu^*)^{\gamma}}\right].$$

This equation also defines the relevant decrease in conglomerate-level production $\xi^{\nu}_{q,n}$, which we use to solve the new product market equilibrium (cf. Propositions 4–5). Noting that the first-order condition for the unregulated firm equals $w + (\nu^*)^{\gamma}$, we can derive the following expression

$$\left[1 + \frac{\lambda(\phi)}{w + (\nu^*)^{\gamma}}\right]^{\frac{1}{1-\rho}} \left[1 + (\Delta_n^{\frac{1}{1-\alpha}} - 1)\left[1 + \frac{\lambda(\phi)}{w + (\nu^*)^{\gamma}}\right]^{\frac{\alpha_l}{1-\alpha_l}}\right] = \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\rho}} \left(\frac{\xi\nu_1}{\nu^*}\right)^{\frac{-(1-\alpha_l\rho)}{1-\rho}} \Delta_n^{\frac{1}{1-\alpha}}. \tag{G.2}$$

This equation has one difference from Equation D.4. Since conglomerates can avoid the impact of the regulation by increasing the energy efficiency of the Top 1,000 firm, the effective regulation is now $\frac{\xi\nu_1}{\nu^*}$. That is, conglomerates have less of a need to reduce their energy use if they increase ν_1. This also implies that $\lambda(\phi)$ is decreasing in ν_1. Similar to Equation D.4, note that in this equation, the ratio $\frac{\nu_1}{\nu^*}$ is an implicit function of quantities that are common for firms with the same number of affiliates n. This implies that firms with different values of ϕ have the same shadow cost and improvement to energy efficiency as long as they belong to a conglomerate of the same size. We then write λ_n and $\nu_{1,n}$ to signify the dependence of these variables on n.

Aggregate Energy Use

Prior to the regulation, we have that $e^*(\phi, n) = \frac{l^*(\phi,n)}{\nu^*}$ for both regulated and unregulated firms. For unregulated firms, we still have $e(\phi, n) = \frac{l(\phi,n)}{\nu^*}$ since these firms do not change their investment in energy efficiency. However, for regulated conglomerates, we have

$$\begin{aligned}
e(\phi,n) &= \frac{l_1}{\nu_{1,n}} + \frac{1}{\nu^*}\sum_{i>1} l_i = \frac{l_1}{\nu_{1,n}}\left(1+\frac{\nu_{1,n}}{\nu^*}(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda_n}{w+(\nu^*)^\gamma}\right]^{\frac{1}{1-\alpha_l}}\right)\\
&= e_1(\phi,n)\left(1+\frac{\nu_{1,n}}{\nu^*}(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda_n}{w+(\nu^*)^\gamma}\right]^{\frac{1}{1-\alpha_l}}\right)\\
&= e_1^*(\phi,n)\xi\left(1+\frac{\nu_{1,n}}{\nu^*}(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda_n}{w+(\nu^*)^\gamma}\right]^{\frac{1}{1-\alpha_l}}\right)\\
&= e^*(\phi,n)\underbrace{\left[\xi\frac{1+\frac{\nu_{1,n}}{\nu^*}(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda_n}{w+(\nu^*)^\gamma}\right]^{\frac{1}{1-\alpha_l}}}{\Delta_n^{\frac{1}{1-\alpha}}}\right]}_{\equiv\xi_{e,n}^\nu}.
\end{aligned}$$

The term $\xi_{e,n}^\nu$ incorporates the insight that the shifting of production to related firms now leads to a larger increase in total energy use since these firms do not improve their energy efficiency, i.e., $\frac{\nu_{1,n}}{\nu^*} > 1$. Using this term in Equation D.9 yields the aggregate change in energy use when firms can respond to the regulation by improving their energy efficiency.

Relation to Empirical Measures of Energy Efficiency

We now discuss how we connect the model to our difference-in-differences estimate of the effect of the Top 1,000 program on the energy efficiency of regulated firms. In the data, we measure energy efficiency as $\frac{R^{1-\rho}P^\rho q(\phi,n)^{\rho-1}q_1(\phi,n)}{e_1(\phi,n)}$. Note that for Top 1,000 firms,

$$\frac{R^{1-\rho}P^\rho q(\phi,n)^{\rho-1}q_1(\phi,n)}{e_1(\phi,n)} = \frac{R^{1-\rho}P^{*\rho}(q(\phi,n)^*)^{\rho-1}q_1^*(\phi,n)}{e_1^*(\phi,n)} \times \frac{\left(\frac{P}{P^*}\right)^\rho(\xi_{q,n}^\nu)^{\rho-1}\left(\xi\frac{\nu_{1,n}}{\nu^*}\right)^{\alpha_l}}{\xi}.$$

Note also that the first term after the equation is the energy efficiency prior to the regulation. We can then manipulate the second term using Equation G.1 as follows:

$$\frac{\left(\frac{P}{P^*}\right)^\rho(\xi_{q,n}^\nu)^{\rho-1}\left(\xi\frac{\nu_{1,n}}{\nu^*}\right)^{\alpha_l}}{\xi} = \left(\frac{\nu_{1,n}}{\nu^*}\right)\left[1+s_e\left(\left(\frac{\nu_{1,n}}{\nu^*}\right)^\gamma-1\right)\right].$$

The log time difference in energy efficiency for a given regulated firm is then

$$\ln\left(\frac{\nu_{1,n}}{\nu^*}\right)+\ln\left[1+s_e\left(\left(\frac{\nu_{1,n}}{\nu^*}\right)^\gamma-1\right)\right].$$

Note that the second term in this equation is equal to $\ln\left[1+\frac{\lambda_n}{w+(\nu^*)^\gamma}\right]$.

Since unregulated firms do not have an incentive to invest in energy efficiency, their energy efficiency depends only on the output price. Recall from above that we have

$$\frac{e_1(\phi,n)}{e_1^*(\phi,n)} = \frac{e(\phi,n)}{e^*(\phi,n)} = \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}} \quad\text{and}\quad \frac{q_1(\phi,n)}{q_1^*(\phi,n)} = \frac{q(\phi,n)}{q^*(\phi,n)} = \left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}.$$

We then have

$$\frac{R^{1-\rho}P^{\rho}q(\phi,n)^{\rho-1}q_1(\phi,n)}{e_1(\phi,n)} = \frac{R^{1-\rho}(P^*)^{\rho}(q(\phi,n)^*)^{\rho-1}q_1^*(\phi,n)\left(\frac{P}{P^*}\right)^{\rho}\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}}}{e_1^*(\phi,n)\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}}} = \frac{R^{1-\rho}(P^*)^{\rho}(q(\phi,n)^*)^{\rho-1}q_1^*(\phi,n)}{e_1^*(\phi,n)}.$$

That is, the Top 1,000 program does not impact the energy efficiency of unregulated firms.

Letting β^{EE} denote the difference-in-differences estimate of the effect of the Top 1,000 program on energy efficiency, we then have

$$\beta^{EE} = \mathbb{E}\left[\ln\left(\frac{\nu_{1,n}}{\nu^*}\right)\middle|\,\phi > \tilde{\phi}\right] + \mathbb{E}\left[\ln\left[1 + s_e\left(\left(\frac{\nu_{1,n}}{\nu^*}\right)^{\gamma} - 1\right)\right]\middle|\,\phi > \tilde{\phi}\right]. \tag{G.3}$$

Calibration of γ

For a range of values of γ, we compute the following:

1. Solve for the values of $\{\nu_{1,n}\}_{n\geq\tilde{n}}$ and $\frac{P}{P^*}$ that jointly satisfy Equation G.2 and
$$\left(\frac{P}{P^*}\right)^{-\rho} = (1 - s_{\tilde{\phi}})\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}} + s_{\tilde{\phi}}\mathbb{E}_e\left[(\xi^{\nu}_{q,n})^{\rho}\,\middle|\,\phi > \tilde{\phi}\right].$$
2. Implement the right-hand side of Equation G.3.

We then choose the value of γ that is consistent with our empirical estimates of β^{EE}. Since we estimate zero or negative values for β^{EE}, we can bound γ by choosing the value that implies the upper bound of the confidence interval of β^{EE}.

G.2 Heterogeneous Energy Efficiency

We now explore the potential that regulated firms differ in their energy efficiency from other firms in the economy. We assume that regulated firms have energy efficiency ν_1, that related firms in the same conglomerate have ν_R, and that other firms in the economy have ν_O.

Unregulated Conglomerates

Firms in these conglomerates face an effective price for variable inputs of $w + \frac{p_e}{\nu_O}$. The results of Propositions 1–3 continue to hold for these firms. We therefore have that in this case

$$\begin{aligned} q^*(\phi,n) &= (\phi\Delta_n)^{\frac{1}{1-\alpha\rho}} R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}} P^{*\frac{\rho\alpha}{1-\alpha\rho}} \rho^{\frac{\alpha}{1-\alpha\rho}} \left[\left(\frac{\alpha_l}{w + \frac{p_e}{\nu_O}}\right)^{\alpha_l}\left(\frac{\alpha_k}{r}\right)^{\alpha_k}\right]^{\frac{1}{1-\alpha\rho}} \\ &= (\phi\Delta_n)^{\frac{1}{1-\alpha\rho}} R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}} P^{*\frac{\rho\alpha}{1-\alpha\rho}} \underbrace{\rho^{\frac{\alpha}{1-\alpha\rho}} \left[\left(\frac{\alpha_l}{w + \frac{p_e}{\nu_1}}\right)^{\alpha_l}\left(\frac{\alpha_k}{r}\right)^{\alpha_k}\right]^{\frac{1}{1-\alpha\rho}}}_{=C_Q} (d_O)^{\frac{-\alpha_l}{1-\alpha\rho}}, \end{aligned}$$

where $d_O = 1 + s_e \frac{\nu_1 - \nu_O}{\nu_O}$ and $s_e = \frac{\frac{p_e}{\nu_1}}{w + \frac{p_e}{\nu_1}}$ is the share of energy in variable inputs for Top 1,000 firms. The optimal choice of l_1 is now

$$l_1 = \left[\frac{R^{1-\rho} P^\rho \rho [\phi (k_1^*)^{\alpha_k}]^\rho \Delta_n^{\frac{\rho-1}{1-\alpha}} \alpha_l}{w + \frac{p_e}{\nu_O}} \right]^{\frac{1}{1-\alpha_l \rho}} \quad \text{so that} \quad l_1 = l_1^* \left(\frac{P}{P^*} \right)^{\frac{\rho}{1-\alpha_l \rho}}.$$

That is, this difference in energy efficiency does not impact how unregulated firms respond to changes in the output price in terms of their use of intermediate inputs. Moreover, since $l_1 = \nu_O e_1$ and $l_1^* = \nu_O e_1^*$, we also have that $\frac{l_1}{l_*} = \frac{e_1}{e_1^*}$. These results then imply that

$$q_1(\phi, n) = q_1^*(\phi, n) \left(\frac{P}{P^*} \right)^{\frac{\alpha_l \rho}{1-\alpha_l \rho}} \quad \text{and} \quad q(\phi, n) = q^*(\phi, n) \left(\frac{P}{P^*} \right)^{\frac{\alpha_l \rho}{1-\alpha_l \rho}}. \tag{G.4}$$

Regulated Conglomerates

Since $\nu_1 \neq \nu_R$, the effective cost of inputs differs across regulated and related firms in the same conglomerate. This difference in input costs influences the within-conglomerate distribution of production. Within a given firm, we have that

$$l_i = \frac{\alpha_l}{\alpha_k} \frac{r}{w + \frac{p_e}{\nu_R}} k_i = \frac{\alpha_l}{\alpha_k} \frac{r}{w + \frac{p_e}{\nu_1}} k_i \frac{1}{1 + s_e \frac{\nu_1 - \nu_R}{\nu_R}} = \frac{\alpha_l}{\alpha_k} \frac{r}{w + \frac{p_e}{\nu_1}} k_i \frac{1}{d_i},$$

where $d_i = 1 + s_e \frac{\nu_1 - \nu_i}{\nu_i}$. The choice of capital across firms is now

$$\pi(\phi, n) = \max_{\{k_i\}_{i=1}^n} \left\{ R^{1-\rho} P^\rho \left[\sum_{i=1}^n \phi \delta^{i-1} k_i^\alpha \left(\frac{\alpha_l}{\alpha_k} \frac{r}{\left(w + \frac{p_e}{\nu_1} \right) d_i} \right)^{\alpha_l} \right]^\rho - \left(\frac{\alpha}{\alpha_k} r \right) \sum_{i=1}^n k_i \right\}.$$

Comparing the first-order conditions for k_1 and k_i, we find that $\frac{k_i}{k_1} = \delta^{\frac{i-1}{1-\alpha}} d_i^{\frac{-\alpha_l}{1-\alpha}}$. We then have

$$\frac{l_i}{l_1} = \delta^{\frac{i-1}{1-\alpha}} d_i^{\frac{-\alpha_l}{1-\alpha} - 1} = \delta^{\frac{i-1}{1-\alpha}} d_i^{\frac{-(1-\alpha_k)}{1-\alpha}}.$$

Production is then

$$q_i = \phi \delta^{i-1} k_i^\alpha \left(\frac{\alpha_l}{\alpha_k} \frac{r}{\left(w + \frac{p_e}{\nu_1} \right) d_i} \right)^{\alpha_l} = \phi \delta^{\frac{i-1}{1-\alpha}} k_1^\alpha \left(\frac{\alpha_l}{\alpha_k} \frac{r}{\left(w + \frac{p_e}{\nu_1} \right)} \right)^{\alpha_l} d_i^{\frac{-\alpha_l}{1-\alpha}} = \delta^{\frac{i-1}{1-\alpha}} d_i^{\frac{-\alpha_l}{1-\alpha}} q_1.$$

Let $d_R = d_i$ for $i > 1$, and recall that $d_1 = 1$. Total capital is then

$$K_n = k_1 \left(1 + d_R^{\frac{-\alpha_l}{1-\alpha}} \sum_{i>1} \delta^{\frac{i-1}{1-\alpha}} \right) = k_1 \left(1 + d_R^{\frac{-\alpha_l}{1-\alpha}} (\Delta_n^{\frac{1}{1-\alpha}} - 1) \right).$$

Define $\hat{\Delta}_n = \left(1 + d_R^{\frac{-\alpha_l}{1-\alpha}}(\Delta_n^{\frac{1}{1-\alpha}} - 1)\right)^{1-\alpha}$. The analysis for the optimal choice of K_n now holds with $\hat{\Delta}_n$ in place of Δ_n. In the case of regulated firms, we have

$$q^*(\phi, n) = \left(\phi\hat{\Delta}_n\right)^{\frac{1}{1-\alpha\rho}} R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}} P^{*\frac{\rho\alpha}{1-\alpha\rho}} \underbrace{\rho^{\frac{\alpha}{1-\alpha\rho}} \left[\left(\frac{\alpha_l}{w + \frac{p_e}{\nu_1}}\right)^{\alpha_l} \left(\frac{\alpha_k}{r}\right)^{\alpha_k}\right]^{\frac{1}{1-\alpha\rho}}}_{=C_Q}. \tag{G.5}$$

Moreover, the thresholds defining the optimal number of conglomerates in Proposition 2 continue to hold using $\hat{\Delta}_n$. Note, however, that our assumption that energy costs change discontinuously at $\tilde{\phi}$ implies that regulated and unregulated conglomerates have different thresholds ϕ_n. Let $\{\phi_n^O\}$ be the set of size thresholds for unregulated conglomerates and $\{\phi_n^R\}$ be the set of related conglomerates. Let n' be the largest firm size for unregulated firms (so that $\phi_{n'+1}^O > \tilde{\phi}$) and n'' be the smallest size of regulated conglomerates (so that $\phi_{n''}^R < \tilde{\phi}$). The combined set of size thresholds is then $\{\{\phi_n^O\}_{n=1}^{n'}, \tilde{\phi}, \{\phi_n^R\}_{n=n''+1}\}$. We include $\tilde{\phi}$ in this list since it is possible that the change in energy efficiency for regulated firms leads to a change in firm size, though (depending on the differences in energy efficiency) this may not always be the case.

Consider now the response of the firms to the regulation. Using the fact that $k_i^* = k_1^*\delta^{\frac{i-1}{1-\alpha}} d_i^{\frac{-\alpha_l}{1-\alpha}}$, we can write the profit maximization problem as

$$\max_{\{l_i\}_1^n} \left\{ R^{1-\rho} P^\rho \left[\phi^* \sum_{i=1}^n \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} l_i^{\alpha_l} d_i^{\frac{-\alpha_l\alpha_k}{1-\alpha}}\right]^\rho - \left(w + \frac{p_e}{\nu_1}\right)\sum_{i=1}^n d_i l_i - r\sum_{i=1}^n k_i^* \right\} \text{ subject to } l_1 \leq \xi l_1^*,$$

where $\phi^* = \phi(k_1^*)^{\alpha_k}$. The first-order conditions for l_i $(1 \leq i \leq n)$ are then

$$\underbrace{R^{1-\rho}P^\rho}_{\text{Market Demand}} \underbrace{\rho\left[\phi^* \sum_{i=1}^n \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} l_i^{\alpha_l} d_i^{\frac{-\alpha_l\alpha_k}{1-\alpha}}\right]^{\rho-1}}_{\text{Residual Revenue}} \underbrace{\phi^*\delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} \alpha_l (l_i)^{\alpha_l - 1} d_i^{\frac{-\alpha_l\alpha_k}{1-\alpha}}}_{\text{Marginal Product}} = \left(w + \frac{p_e}{\nu_1}\right) d_i + \underbrace{\lambda(\phi)\mathbb{I}[i=1]}_{\text{Shadow Cost of Regulation}}.$$

Taking the ratio of the conditions for l_1 and $l_i (i > 1)$, we have

$$\left(\frac{l_i}{l_1}\right)^{1-\alpha_l} = \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} \left[1 + \frac{\lambda(\phi)}{\left(w + \frac{p_e}{\nu_1}\right)}\right] d_i^{\frac{-\alpha_l\alpha_k}{1-\alpha} - 1}$$

$$\left(\frac{l_i}{l_1}\right)^{1-\alpha_l} = \delta^{\frac{(i-1)(1-\alpha_l)}{1-\alpha}} \left[1 + \frac{\lambda(\phi)}{\left(w + \frac{p_e}{\nu_1}\right)}\right] d_i^{\frac{-(1-\alpha_l)(1-\alpha_k)}{1-\alpha}}$$

$$\frac{l_i}{l_1} = \delta^{\frac{(i-1)}{1-\alpha}} \left[1 + \frac{\lambda(\phi)}{\left(w + \frac{p_e}{\nu_1}\right)}\right]^{\frac{1}{1-\alpha_l}} d_i^{\frac{-(1-\alpha_k)}{1-\alpha}}.$$

The residual revenue term now becomes

$$\phi(k_1^*)^{\alpha_k} l_1^{\alpha_l}\left[1+\sum_{i>1}\delta^{\frac{i-1}{1-\alpha}} d_i^{\frac{-\alpha_l}{1-\alpha}}\left[1+\frac{\lambda(\phi)}{\left(w+\frac{p_e}{\nu_1}\right)}\right]^{\frac{\alpha_l}{1-\alpha_l}}\right]=\phi(k_1^*)^{\alpha_k}(l_1^*)^{\alpha_l}\xi^{\alpha_l}\left[1+(\hat{\Delta}_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda(\phi)}{\left(w+\frac{p_e}{\nu_1}\right)}\right]^{\frac{\alpha_l}{1-\alpha_l}}\right].$$

The first-order condition for the regulated firm is then

$$\underbrace{R^{1-\rho}P^{*\rho}\rho\left[\phi\sum_{i=1}^{n}\delta^{\frac{i-1}{1-\alpha}}(k_i^*)^{\alpha_k}(l_i^*)^{\alpha_l}\right]^{\rho-1}\times\phi\alpha_l(k_1^*)^{\alpha_k}(l_1^*)^{\alpha_l-1}}_{\text{FOC Unregulated Case}}$$

$$\times(\xi)^{\alpha_l-1}\left(\frac{P}{P^*}\right)^{\rho}\left[\underbrace{\xi^{\alpha_l}\frac{1+(\hat{\Delta}_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda(\phi)}{\left(w+\frac{p_e}{\nu_1}\right)}\right]^{\frac{\alpha_l}{1-\alpha_l}}}{\hat{\Delta}_n^{\frac{1}{1-\alpha}}}}_{\equiv\xi_{q,n}^d}\right]^{\rho-1}=\left(w+\frac{p_e}{\nu_1}\right)+\lambda(\phi),$$

where $\frac{q(\phi,n)}{q^*(\phi,n)}=\xi_{q,n}^d$. Using the fact that the first-order condition in the unregulated case equals $\left(w+\frac{p_e}{\nu_1}\right)$, we obtain

$$1+\frac{\lambda(\phi)}{\left(w+\frac{p_e}{\nu_1}\right)} = (\xi)^{\alpha_l-1}\left(\frac{P}{P^*}\right)^{\rho}(\xi_{q,n}^d)^{(\rho-1)}. \tag{G.6}$$

Product Market Equilibrium

The price level absent the regulation is then

$$\begin{aligned}
P^{*-\rho} &= R^{-\rho}\int_{\phi_1}^{\tilde{\phi}}\left((\phi\Delta_n)^{\frac{1}{1-\alpha\rho}}R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}}P^{*\frac{\rho\alpha}{1-\alpha\rho}}C_Q(d_O)^{\frac{-\alpha_l}{1-\alpha\rho}}\right)^{\rho}\frac{g(\phi)M}{1-G(\phi_1)}d\phi\\
&+ R^{-\rho}\int_{\tilde{\phi}_1}\left(\left(\phi\hat{\Delta}_n\right)^{\frac{1}{1-\alpha\rho}}R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}}P^{*\frac{\rho\alpha}{1-\alpha\rho}}C_Q\right)^{\rho}\frac{g(\phi)M}{1-G(\phi_1)}d\phi\\
P^{*\frac{-\rho}{1-\alpha\rho}}R^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}C_Q^{-\rho}\frac{1-G(\phi_1)}{M} &= \int_{\phi_1}^{\tilde{\phi}}\left(\phi\Delta_n d_O^{-\alpha_l}\right)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi+\int_{\tilde{\phi}}\left(\phi\hat{\Delta}_n\right)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi\\
P^{*\frac{-\rho}{1-\alpha\rho}}R^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}C_Q^{-\rho}\frac{1-G(\phi_1)}{M} &= \sum_{n=1}^{\tilde{n}-1}(\Delta_n d_O^{-\alpha_l})^{\frac{\rho}{1-\alpha\rho}}\pi_n+(\Delta_{\tilde{n}}d_O^{-\alpha_l})^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_1\\
&+ (\hat{\Delta}_{\tilde{n}})^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2+\sum_{n=\tilde{n}+1}(\hat{\Delta}_n)^{\frac{\rho}{1-\alpha\rho}}\pi_n.
\end{aligned}$$

After the regulation, the equilibrium is then

$$\begin{aligned}
P^{-\rho} &= R^{-\rho}\int_{\phi_1}^{\tilde{\phi}}\left(\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho}{1-\alpha_l\rho}}(\phi\Delta_n)^{\frac{1}{1-\alpha\rho}}R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}}P^{*\frac{\rho\alpha}{1-\alpha\rho}}C_Q(d_O)^{\frac{-\alpha_l}{1-\alpha\rho}}\right)^{\rho}\frac{g(\phi)M}{1-G(\phi_1)}d\phi\\
&+ R^{-\rho}\int_{\tilde{\phi}}\left(\xi_{q,n}^d\left(\phi\hat{\Delta}_n\right)^{\frac{1}{1-\alpha\rho}}R^{\frac{(1-\rho)\alpha}{1-\alpha\rho}}P^{*\frac{\rho\alpha}{1-\alpha\rho}}C_Q\right)^{\rho}\frac{g(\phi)M}{1-G(\phi_1)}d\phi
\end{aligned}$$

$$P^{-\rho}P^{*\frac{-\rho^2\alpha}{1-\alpha\rho}}R^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}C_Q^{-\rho}\frac{1-G(\phi_1)}{M} = \int_{\phi_1}^{\tilde{\phi}}\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}}\left(\phi\Delta_n d_O^{-\alpha_l}\right)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi + \int_{\tilde{\phi}}(\xi_{q,n}^d)^{\rho}\left(\phi\hat{\Delta}_n\right)^{\frac{\rho}{1-\alpha\rho}}g(\phi)d\phi$$

$$P^{-\rho}P^{*\frac{-\rho^2\alpha}{1-\alpha\rho}}R^{\frac{(1-\alpha)\rho}{1-\alpha\rho}}C_Q^{-\rho}\frac{1-G(\phi_1)}{M} = \sum_{n=1}^{\tilde{n}-1}\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}}(\Delta_n d_O^{-\alpha_l})^{\frac{\rho}{1-\alpha\rho}}\pi_n + \left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}}(\Delta_{\tilde{n}} d_O^{-\alpha_l})^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_1$$
$$+ \ (\xi_{q,\tilde{n}}^d)^{\rho}(\hat{\Delta}_{\tilde{n}})^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2 + \sum_{n=\tilde{n}+1}(\xi_{q,n}^d)^{\rho}(\hat{\Delta}_n)^{\frac{\rho}{1-\alpha\rho}}\pi_n.$$

Comparing the regulated and unregulated equilibrium conditions, we then have

$$\left(\frac{P}{P^*}\right)^{-\rho} = (1-s_{\tilde{\phi}}^d)\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}} + s_{\tilde{\phi}}^d\mathbb{E}_e\left[(\xi_{q,n}^d)^{\rho}\middle|\phi > \tilde{\phi}\right],$$

where $s_{\tilde{\phi}}^d = \frac{(\hat{\Delta}_{\tilde{n}})^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2 + \sum_{n=\tilde{n}+1}(\hat{\Delta}_n)^{\frac{\rho}{1-\alpha\rho}}\pi_n}{(d_O)^{\frac{-\alpha_l\rho}{1-\alpha\rho}}\left[\sum_{n=1}^{\tilde{n}-1}(\Delta_n)^{\frac{\rho}{1-\alpha\rho}}\pi_n + (\Delta_{\tilde{n}})^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_1\right] + (\hat{\Delta}_{\tilde{n}})^{\frac{\rho}{1-\alpha\rho}}\tilde{\pi}_2 + \sum_{n=\tilde{n}+1}(\hat{\Delta}_n)^{\frac{\rho}{1-\alpha\rho}}\pi_n}$ and where $\mathbb{E}_e$ takes the expectation of the distribution of energy use among regulated firms. This case differs from our baseline case in that we use the $\hat{\Delta}_n$ expressions to calculate $\mathbb{E}_e$.

Aggregate Energy Use

Total intermediate inputs for a regulated conglomerate are

$$\frac{l(\phi,n)}{l^*(\phi,n)} = \xi\frac{\left[1+(\Delta_n^{\frac{1}{1-\alpha}}-1)d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\left[1+\frac{\lambda(\phi)}{\left(w+\frac{p_e}{\nu_1}\right)}\right]^{\frac{1}{1-\alpha_l}}\right]}{1+(\Delta_n^{\frac{1}{1-\alpha}}-1)d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}}.$$

To compute total energy use, however, we need to take into account differences in energy efficiency across firms in the conglomerate. Absent regulation, we have

$$e^*(\phi,n) = \frac{l_1^*}{\nu_1} + \frac{1}{\nu_R}\sum_{i>1}l_i^* = \frac{1}{\nu_1}\left(l_1^* + \frac{\nu_1}{\nu_R}\sum_{i>1}l_i^*\right) = \frac{1}{\nu_1}l_1^*\left(1+\frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}}-1)d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right).$$

After the regulation, we have

$$e(\phi,n) = \frac{1}{\nu_1}l_1\left(1+\frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}}-1)d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\left[1+\frac{\lambda(\phi)}{\left(w+\frac{p_e}{\nu_1}\right)}\right]^{\frac{1}{1-\alpha_l}}\right).$$

We then have

$$\frac{e(\phi,n)}{e^*(\phi,n)} = \xi\frac{1+\frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}}-1)d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\left[1+\frac{\lambda(\phi)}{\left(w+\frac{p_e}{\nu_1}\right)}\right]^{\frac{1}{1-\alpha_l}}}{1+\frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}}-1)d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}} \equiv \xi_{e,n}^d.$$

To obtain an expression for $e^*(\phi,n)$ for regulated firms, recall that

$$\begin{aligned} l^*(\phi,n) &= l_1^* \left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_n^{\frac{1}{1-\alpha}} - 1)\right) \\ l^*(\phi,n) &= \left(\phi\hat{\Delta}_n\right)^{\frac{\rho}{1-\alpha\rho}} R^{\frac{1-\rho}{1-\alpha\rho}} P^{*\frac{\rho}{1-\alpha\rho}} \underbrace{\rho^{\frac{1}{1-\alpha\rho}} \left[\left(\frac{\alpha_l}{w+\frac{p_e}{\nu_1}}\right)^{1-\alpha_k\rho} \left(\frac{\alpha_k}{r}\right)^{\alpha_k\rho}\right]^{\frac{1}{1-\alpha\rho}}}_{=C_E} \end{aligned}$$

so that

$$e^*(\phi,n) = \left(\phi\hat{\Delta}_n\right)^{\frac{\rho}{1-\alpha\rho}} R^{\frac{1-\rho}{1-\alpha\rho}} P^{*\frac{\rho}{1-\alpha\rho}} C_E \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_n^{\frac{1}{1-\alpha}} - 1)\right)},$$

where the last terms adjust for the composition of energy use across establishments with different energy efficiency.

Consider now the unregulated firms. Since all firms in unregulated conglomerates have the same energy efficiency, we have

$$\frac{e(\phi,n)}{e^*(\phi,n)} = \frac{l(\phi,n)}{l^*(\phi,n)} = \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}}$$

and

$$e^*(\phi,n) = \frac{l^*(\phi,n)}{\nu_O} = \frac{1}{\nu_O}\left(\phi\Delta_n\right)^{\frac{\rho}{1-\alpha\rho}} R^{\frac{1-\rho}{1-\alpha\rho}} P^{*\frac{\rho}{1-\alpha\rho}} \underbrace{\rho^{\frac{1}{1-\alpha\rho}} \left[\left(\frac{\alpha_l}{w+\frac{p_e}{\nu_1}}\right)^{1-\alpha_k\rho} \left(\frac{\alpha_k}{r}\right)^{\alpha_k\rho}\right]^{\frac{1}{1-\alpha\rho}}}_{=C_E} (d_O)^{\frac{-(1-\alpha_k\rho)}{1-\alpha\rho}}.$$

The total energy use prior to the regulation is then

$$\begin{aligned} E^* &= \int_{\phi_1} e^*(\phi,n) \frac{g(\phi)M}{1-G(\phi_1)} d\phi \\ &= R^{\frac{1-\rho}{1-\alpha\rho}} P^{*\frac{\rho}{1-\alpha\rho}} \frac{C_E M}{1-G(\phi_1)} \left[\frac{(d_O)^{\frac{-(1-\alpha_k\rho)}{1-\alpha\rho}}}{\nu_O}\left(\sum_{n=1}^{\tilde{n}-1} (\Delta_n)^{\frac{\rho}{1-\alpha\rho}} \pi_n + (\Delta_{\tilde{n}})^{\frac{\rho}{1-\alpha\rho}} \tilde{\pi}_1\right)\right. \\ &+ \left(\hat{\Delta}_{\tilde{n}}\right)^{\frac{\rho}{1-\alpha\rho}} \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_{\tilde{n}}^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_{\tilde{n}}^{\frac{1}{1-\alpha}} - 1)\right)} \tilde{\pi}_2 + \sum_{n=\tilde{n}+1} \left(\hat{\Delta}_n\right)^{\frac{\rho}{1-\alpha\rho}} \left.\frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_n^{\frac{1}{1-\alpha}} - 1)\right)} \pi_n\right] \end{aligned}$$

The total energy use after the regulation is then

$$
\begin{aligned}
E &= \int_{\phi_1} e(\phi, n) \frac{g(\phi) M}{1 - G(\phi_1)} d\phi \\
&= R^{\frac{1-\rho}{1-\alpha\rho}} P^{*\frac{\rho}{1-\alpha\rho}} \frac{C_E M}{1 - G(\phi_1)} \left[\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}} \frac{(d_O)^{\frac{-(1-\alpha_k \rho)}{1-\alpha\rho}}}{\nu_O} \left(\sum_{n=1}^{\tilde{n}-1} (\Delta_n)^{\frac{\rho}{1-\alpha\rho}} \pi_n + (\Delta_{\tilde{n}})^{\frac{\rho}{1-\alpha\rho}} \tilde{\pi}_1 \right) \right. \\
&+ \xi^d_{e,\tilde{n}} \left(\hat{\Delta}_{\tilde{n}}\right)^{\frac{\rho}{1-\alpha\rho}} \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_{\tilde{n}}^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_{\tilde{n}}^{\frac{1}{1-\alpha}} - 1)\right)} \tilde{\pi}_2 \\
&+ \left. \sum_{n=\tilde{n}+1} \xi^d_{e,n} \left(\hat{\Delta}_n\right)^{\frac{\rho}{1-\alpha\rho}} \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_n^{\frac{1}{1-\alpha}} - 1)\right)} \pi_n \right].
\end{aligned}
$$

The change in aggregate energy use is then

$$
\frac{E}{E^*} = (1 - s^e_{\tilde{\phi}}) \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}} + s^e_{\tilde{\phi}} \mathbb{E}_e \left[\xi^d_{e,n} \middle| \phi > \tilde{\phi} \right],
$$

where

$$
\frac{1 - s^e_{\tilde{\phi}}}{s^e_{\tilde{\phi}}} = \frac{\frac{(d_O)^{\frac{-(1-\alpha_k \rho)}{1-\alpha\rho}}}{\nu_O} \left(\sum_{n=1}^{\tilde{n}-1} (\Delta_n)^{\frac{\rho}{1-\alpha\rho}} \pi_n + (\Delta_{\tilde{n}})^{\frac{\rho}{1-\alpha\rho}} \tilde{\pi}_1 \right)}{\left(\hat{\Delta}_{\tilde{n}}\right)^{\frac{\rho}{1-\alpha\rho}} \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_{\tilde{n}}^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_{\tilde{n}}^{\frac{1}{1-\alpha}} - 1)\right)} \tilde{\pi}_2 + \sum_{n=\tilde{n}+1} \left(\hat{\Delta}_n\right)^{\frac{\rho}{1-\alpha\rho}} \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_n^{\frac{1}{1-\alpha}} - 1)\right)} \pi_n}
$$

and where we evaluate $\mathbb{E}_e$ using the conditional probabilities

$$
\mathbb{P}r \left[n = n' \middle| \phi > \tilde{\phi} \right] = \frac{\left(\hat{\Delta}_{n'}\right)^{\frac{\rho}{1-\alpha\rho}} \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_{n'}^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_{n'}^{\frac{1}{1-\alpha}} - 1)\right)} \pi_{n'}}{\left(\hat{\Delta}_{\tilde{n}}\right)^{\frac{\rho}{1-\alpha\rho}} \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_{\tilde{n}}^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_{\tilde{n}}^{\frac{1}{1-\alpha}} - 1)\right)} \tilde{\pi}_2 + \sum_{n=\tilde{n}+1} \left(\hat{\Delta}_n\right)^{\frac{\rho}{1-\alpha\rho}} \frac{\frac{1}{\nu_1}\left(1 + \frac{\nu_1}{\nu_R}(\Delta_n^{\frac{1}{1-\alpha}} - 1) d_R^{\frac{-(1-\alpha_k)}{1-\alpha}}\right)}{\left(1 + d_R^{\frac{-(1-\alpha_k)}{1-\alpha}} (\Delta_n^{\frac{1}{1-\alpha}} - 1)\right)} \pi_n}.
$$

G.3 Imperfect Substitution within Conglomerates

We now consider the possibility that the outputs of affiliates within the same conglomerate are not perfect substitutes. In particular, we assume that the conglomerate-level composite good $q(\omega)$ can be represented as affiliate output, such that

$$
q(\omega) = \left(\sum_i q(\omega, i)^{\rho_c} \right)^{1/\rho_c}, \quad \text{where } 0 < \rho < \rho_c < 1.
$$

The residual demand for the ith affiliate of conglomerate ω, i.e., (ω, i), is

$$p(\omega, i) = R^{1-\rho} P^{\rho} q(\omega)^{\rho-\rho_c} q(\omega, i)^{\rho_c - 1}.$$

The profit maximization problem for the conglomerate is now

$$\begin{aligned} & \max_{\{l_i\}_{i=1}^n, \{k_i\}_{i=1}^n} R^{1-\rho} P^{\rho} q(\phi)^{\rho-\rho_c} \sum_i q(\phi, i)^{\rho_c} - (w + p_e) \sum_i l_i - r \sum_i k_i \\ = & \max_{\{l_i\}_{i=1}^n, \{k_i\}_{i=1}^n} R^{1-\rho} P^{\rho} \left[\sum_i q(\phi, i)^{\rho_c} \right]^{\rho/\rho_c} - (w + p_e) \sum_i l_i - r \sum_i k_i, \end{aligned}$$

where $q(\phi, i) = \phi \delta^{i-1} k_i^{\alpha_k} l_i^{\alpha_l}$. The first-order conditions for $l_1, ... l_n$ imply that $\frac{l(\phi,i)}{l(\phi,1)} = \left(\frac{q(\phi,i)}{q(\phi,1)} \right)^{\rho_c}$. Since the capital-labor ratio remains $\frac{l_i}{k_i} = \frac{\alpha_l}{\alpha_k} \frac{r}{w+p_e}$, substituting into $q(\phi, i)$ allows us to express the first-order conditions as

$$\frac{k_i}{k_1} = \frac{l_i}{l_1} = \frac{e_i}{e_1} = \delta^{\frac{(i-1)\rho_c}{1-\alpha\rho_c}} \quad \text{and} \quad \frac{q_i}{q_1} = \delta^{\frac{(i-1)}{1-\alpha\rho_c}}.$$

These expression reduce to Proposition 1 when $\rho_c = 1$. To understand how values of $\rho_c < 1$ impact the use of inputs within the conglomerate, note that in the exponent for the first expression, a lower value of ρ_c decreases the numerator and increase the denominator. Both forces work to reduce the magnitude of the exponent such that the use of inputs depreciates more slowly in firm rank given the same δ.

We now define $\Delta_n^C = \left[\sum_{i=1}^n (\delta^{(i-1)})^{\frac{\rho_c}{1-\alpha\rho_c}} \right]^{\frac{1-\alpha\rho_c}{\rho_c}}$, so that $\frac{k_1}{K_n} = \frac{l_1}{L_n} = \frac{1}{(\Delta_n^C)^{\frac{\rho_c}{1-\alpha\rho_c}}}$. Total composite output is then

$$\begin{aligned} q(\phi)^{\rho_c} &= \left(\frac{\alpha_l}{\alpha_k} \frac{r}{w + p_e} \right)^{\alpha_l \rho_c} \phi^{\rho_c} \sum_i (\delta^{(i-1)\rho_c}) (\delta^{\frac{(i-1)\rho_c}{1-\alpha\rho_c}} k_1)^{\alpha\rho_c} \\ &= \left(\frac{\alpha_l}{\alpha_k} \frac{r}{w + p_e} \right)^{\alpha_l \rho_c} \phi^{\rho_c} k_1^{\alpha\rho_c} (\Delta_n^C)^{\frac{\rho_c}{1-\alpha\rho_c}} = \left(\frac{\alpha_l}{\alpha_k} \frac{r}{w + p_e} \right)^{\alpha_l \rho_c} (\phi \Delta_n^C)^{\rho_c} K_n^{\alpha\rho_c}. \end{aligned}$$

We can then rewrite the optimization problem as

$$\max_{K_n} R^{1-\rho} P^{\rho} \left(\frac{\alpha_l}{\alpha_k} \frac{r}{w + p_e} \right)^{\rho\alpha_l} (\phi \Delta_n^C)^{\rho} K_n^{\alpha\rho} - \left(\frac{\alpha_l}{\alpha_k} r + r \right) K_n,$$

where we represent total variable costs as $(w + p_e) L_n = \left(\frac{\alpha_l}{\alpha_k} r \right) K_n$. Note that this optimization problem is exactly the same as our in baseline model, except for the new definition of Δ_n^C. The within-conglomerate revenue share is now $\left(\frac{\delta^{i-1}}{\Delta_n^C} \right)^{\frac{\rho_c}{1-\alpha\rho_c}}$, which equals the share in the case of perfect substitution when $\rho_c = 1$. Similarly, the results of Proposition 2 continue to hold using the new Δ_n^C.

Regulated Conglomerates

Given ϕ and k_i^*, we can write $q(\phi)^{\rho_c}$ as

$$\phi^{\rho_c}\sum_i(\delta^{(i-1)\rho_c})(\delta^{\frac{(i-1)\rho_c}{1-\alpha\rho_c}}k_1^*)^{\alpha_k\rho_c}l_i^{\alpha_l\rho_c}\equiv(\phi(k_1^*)^{\alpha_k})^{\rho_c}\sum_i(\delta^{(i-1)\rho_c})^{\frac{(1-\alpha_l\rho_c)}{1-\alpha\rho_c}}l_i^{\alpha_l\rho_c}.$$

We can similarly define the short-run response as

$$\max_{\{l_i\}_{i=1}^n}R^{1-\rho}P^{\rho}\left[\phi^*\left(\sum_i\delta^{\frac{(i-1)\rho_c(1-\alpha_l\rho_c)}{1-\alpha\rho_c}}l_i^{\alpha_l\rho_c}\right)^{1/\rho_c}\right]^{\rho}-(w+p_e)\sum_i l_i.$$

The first-order condition in this case becomes

$$R^{1-\rho}P^{\rho}\rho\left[\phi^*\left(\sum_i\delta^{\frac{(i-1)\rho_c(1-\alpha_l\rho_c)}{1-\alpha\rho_c}}l_i^{\alpha_l\rho_c}\right)^{1/\rho_c}\right]^{\rho-1}\times\phi^*\delta^{\frac{(i-1)\rho_c(1-\alpha_l\rho_c)}{1-\alpha\rho_c}}\alpha_l\rho_c(l_i)^{\alpha_l\rho_c-1}=w+p_e+\lambda(\phi)I[i=1].$$

The within-conglomerate input allocation is now

$$\frac{l_j}{l_2}=\delta^{\frac{(j-2)\rho_c}{1-\alpha\rho_c}},j>2\quad\text{and}\quad\frac{l_i}{l_1}=\delta^{\frac{(i-1)\rho_c}{1-\alpha\rho_c}}\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{1}{1-\alpha_l\rho_c}}.$$

The conglomerate composite output is then

$$q(\phi,n)=q_1(\phi,n)\left[1+\sum_{i>1}\delta^{\frac{(i-1)\rho_c}{1-\alpha\rho_c}}\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{\alpha_l\rho_c}{1-\alpha_l\rho_c}}\right]^{1/\rho_c}.$$

Recalling that the original preregulation optimal composite output is

$$q^*(\phi,n)=q_1^*(\phi,n)\left[\sum_i^n\delta^{\frac{(i-1)\rho_c}{1-\alpha\rho_c}}\right]^{1/\rho_c}\equiv q_1^*(\phi,n)(\Delta_n^C)^{\frac{1}{1-\alpha\rho_c}}$$

and using the fact that $q_1(\phi,n)=q_1^*(\phi,n)\xi^{\alpha_l}$, we obtain

$$q(\phi,n)=q^*(\phi,n)\underbrace{\left[\xi^{\alpha_l}\frac{\left(1+((\Delta_n^C)^{\frac{\rho_c}{1-\alpha\rho_c}}-1)\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{\alpha_l\rho_c}{1-\alpha_l\rho_c}}\right)^{1/\rho_c}}{(\Delta_n^C)^{\frac{1}{1-\alpha\rho_c}}}\right]}_{\xi_{q,n}^C(\phi)}.$$

Using similar arguments from our baseline model, we have that the shadow cost of the regulation takes the form

$$1+\frac{\lambda(\phi)}{w+p_e}=(\xi)^{\alpha_l\rho_c-1}\left(\frac{P}{P^*}\right)^{\rho}(\xi_{q,n}^C)^{\rho-1}.$$

As in previous cases, the shadow cost depends only on n. Unregulated conglomerates are not affected by imperfect substitution within regulated conglomerates. We thus still have that

$$l_1 = l_1^* \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}}$$

and

$$q(\phi, n) = q^*(\phi, n) \left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l \rho}}.$$

Product Market Equilibrium

We now again define the industry price index in terms of quantity of both regulated and unregulated conglomerates. The equilibrium price is defined by

$$P = \left[\int_{\phi_1} p(\phi, n)^{\frac{\rho}{\rho-1}} \frac{M}{1-G(\phi_1)} dG\right]^{\frac{\rho-1}{\rho}} \quad \text{where} \quad p(\phi, n)^{\frac{\rho_c}{\rho_c-1}} = \sum_{i=1}^{n} p(\phi, i)^{\frac{\rho_c}{\rho_c-1}}.$$

Substituting the residual demand curve $p(\phi, i) = R^{1-\rho} P^{\rho} q(\phi, n)^{\rho-\rho_c} q(\phi, i)^{\rho_c - 1}$, we have the composite conglomerate price index

$$p(\phi, n) = R^{1-\rho} P^{\rho} q(\phi, n)^{\rho-\rho_c} \left(\sum_i q(\phi, i)^{\rho_c}\right)^{\frac{\rho_c-1}{\rho_c}} \equiv R^{1-\rho} P^{\rho} q(\phi, n)^{\rho-1}.$$

Substituting this expression into the aggregate price index P, we have

$$P^{\frac{\rho}{\rho-1}} = \int_{\phi_1} (R^{1-\rho} P^{\rho})^{\frac{\rho}{\rho-1}} q(\phi, n)^{\rho} \frac{M}{1-G(\phi_1)} dG,$$

which is equivalent to $P^{-\rho} = R^{-\rho} \int_{\phi_1} q(\phi, n)^{\rho} \frac{M}{1-G(\phi_1)} dG$. That is, the equation describing the change in equilibrium prices, Equation D.7, continues to hold with the new definition of Δ_n^C and $\xi_{q,n}^C$.

Aggregate Energy Use

Consider first the regulated conglomerate. Using the fact that $e^*(\phi, n) = e_1^*(\phi, n) \sum_i \delta^{\frac{(i-1)\rho_c}{1-\alpha\rho_c}} = e_1^*(\phi, n) (\Delta_n^C)^{\frac{\rho_c}{1-\alpha\rho_c}}$, we have that

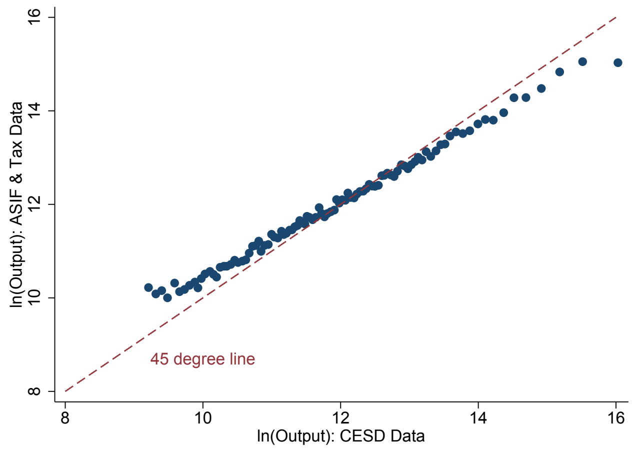
$$\begin{aligned} e(\phi, n) &= e_1(\phi, n) \left[1 + \sum_{i>1} \delta^{\frac{(i-1)\rho_c}{1-\alpha\rho_c}} \left[1 + \frac{\lambda_n}{w + p_e}\right]^{\frac{1}{1-\alpha_l \rho_c}}\right] \\ &= e^*(\phi, n) \underbrace{\left[\xi \frac{\left(1 + ((\Delta_n^C)^{\frac{\rho_c}{1-\alpha\rho_c}} - 1)\left[1 + \frac{\lambda_n}{w+p_e}\right]^{\frac{1}{1-\alpha_l \rho_c}}\right)}{(\Delta_n^C)^{\frac{\rho_c}{1-\alpha\rho_c}}}\right]}_{\xi_{e,n}^C}. \end{aligned}$$

The rest of the aggregation results then similarly carry through with $\xi_{e,n}^C$ defined as above.

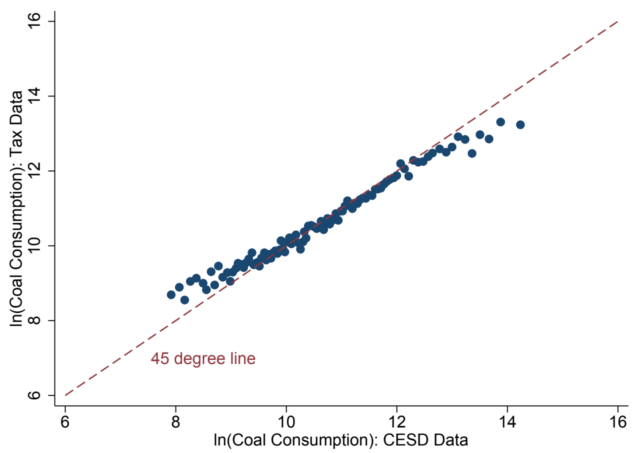
Appendix Figures

Figure A.1: Data Comparison: ASIF, CESD, Tax Data

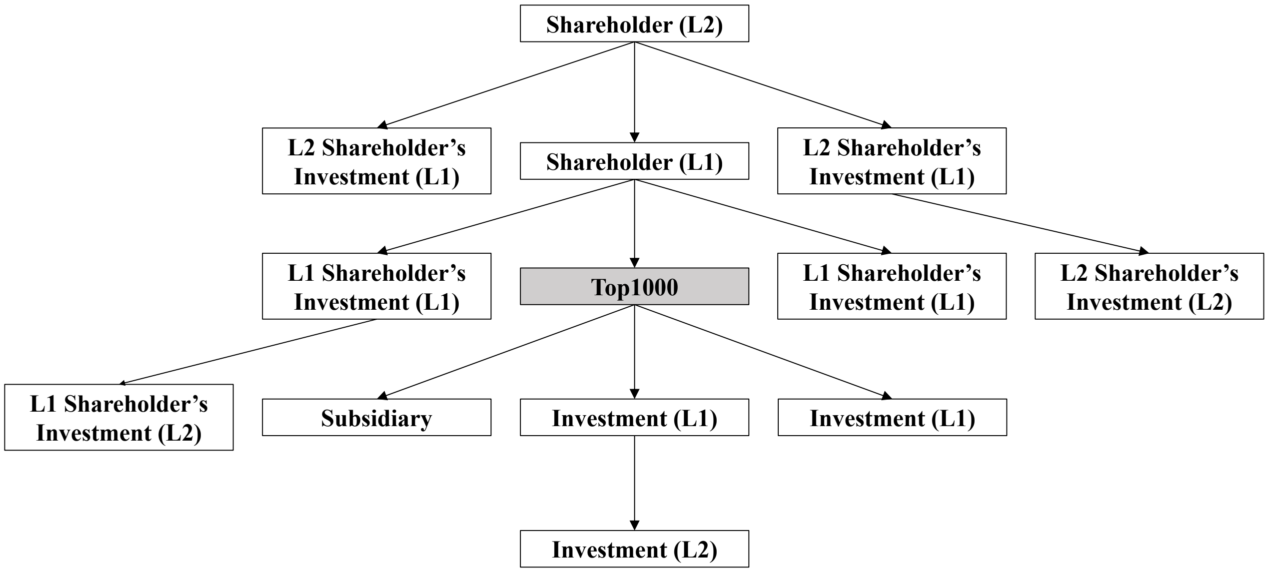
A. Comparison of Output Data, 2001–2010



B. Comparison of Coal Consumption, 2007–2010

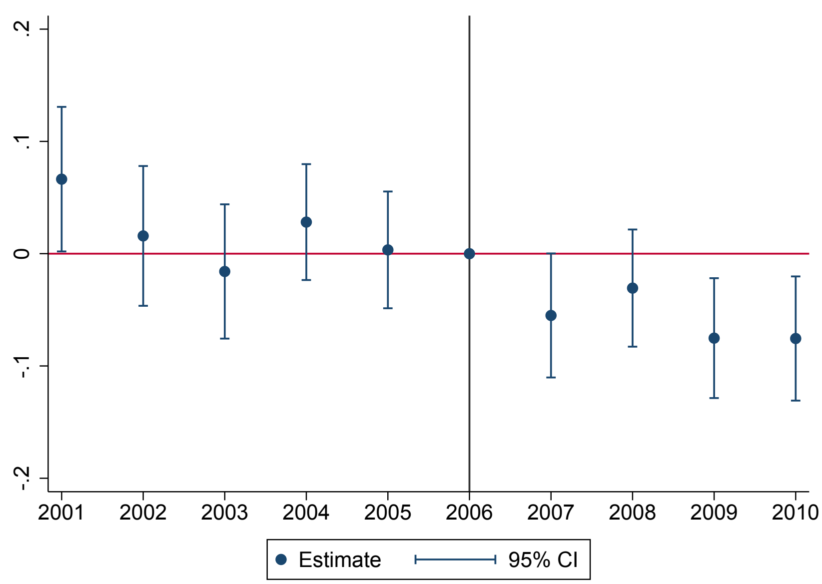


Notes: Authors' calculations using data from ASIF, CESD and ATS. This figure shows the comparison of output and energy consumption data between the ASIF, ATS and CESD. Panel A shows that the output data from ASIF and tax data are highly correlated with those from CESD. This panel uses data from the ASIF in 2001–2006 and ATS in 2007–2010. Panel B shows that coal consumption figures from the tax data almost mirror those from the CESD (tax data are available only after 2007).



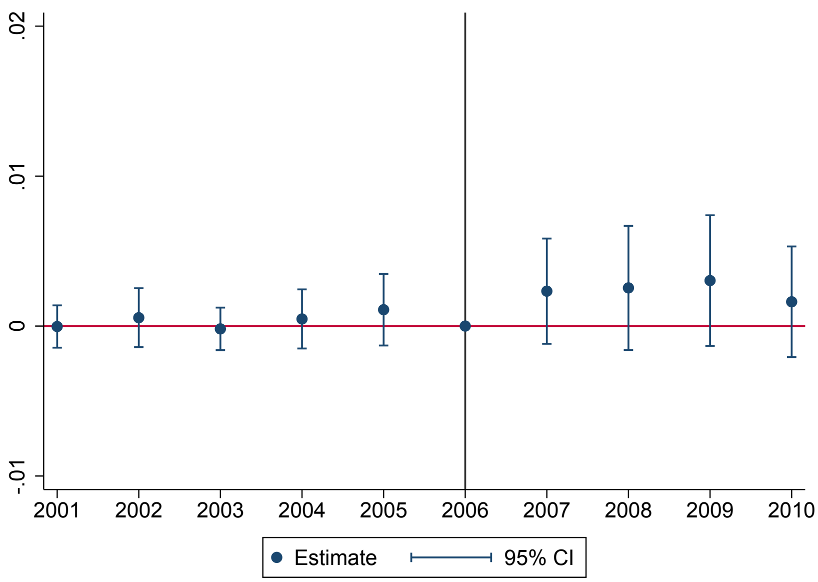
Notes: This figure depicts all possible types of firm relations within 2 levels of ownership. See Section 1.2 for the definition of each related type, and see Figure 2 for examples.

Figure A.3: Effects of Policy on the Investment of Regulated Firms



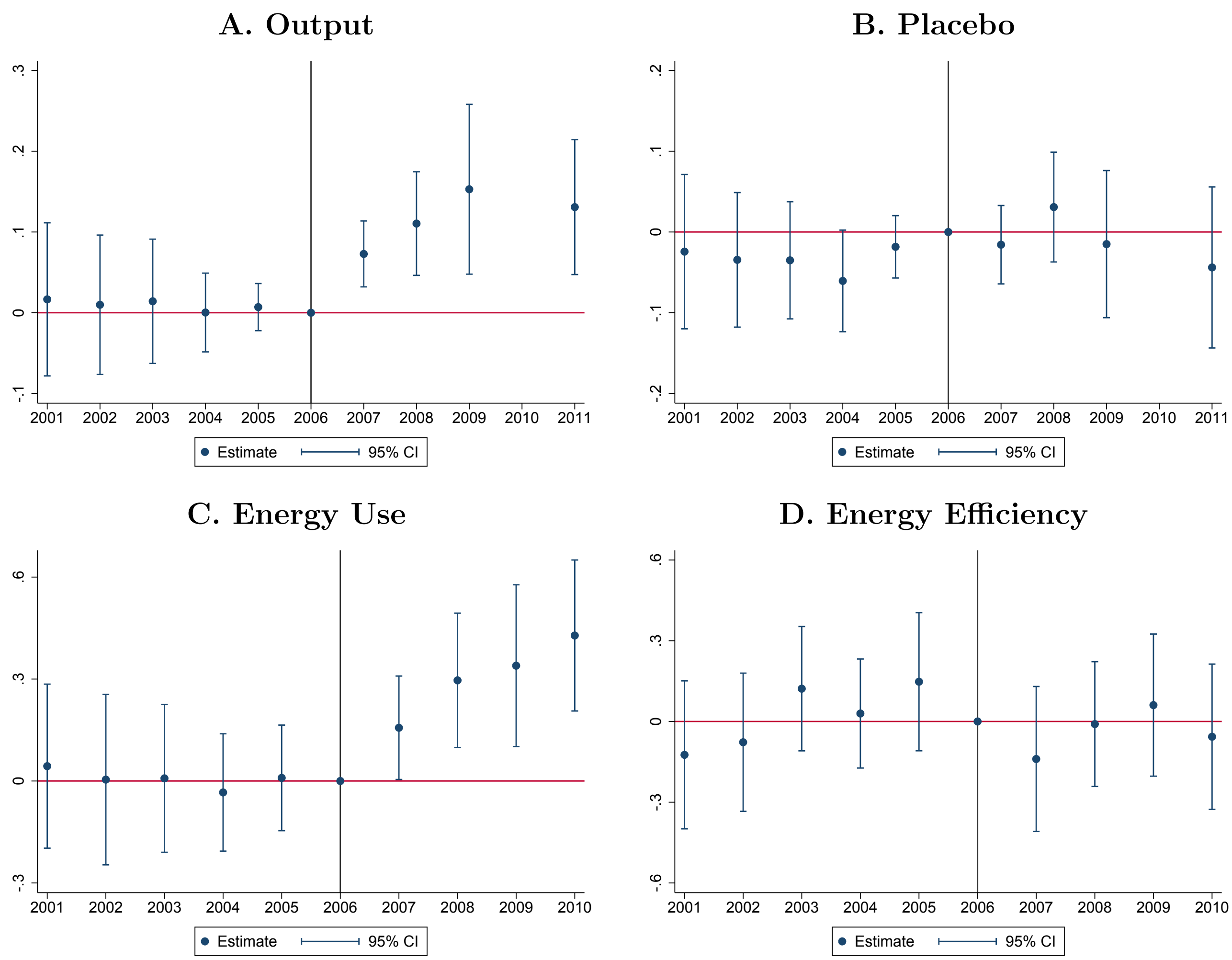
Notes: Authors' calculations using data from the ASIF and ATS. This figure shows estimates of Equation 1 where the dependent variable is firm investment choice. Investment choice is defined as whether a firm invests. See Section 1 for more information about the data-generating procedure. This figure shows that regulated firms were less likely to invest than similar control firms (Top 10,000 firms not related to Top 1,000 firms) after the regulation. The point estimates are displayed in Table A.8. See Section 2 for additional discussion. Standard errors are clustered at the firm level.

Figure A.4: Innovation in Top 1,000 Firms: Energy-Saving Patent Applications



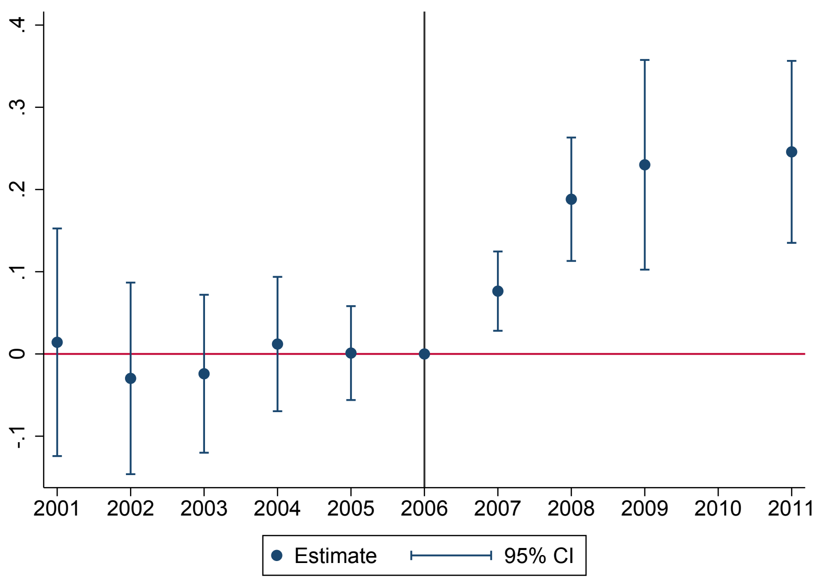
Notes: Authors' calculations using data from Incopat. This figure shows estimates of Equation 1 where the dependent variable is log firm patent applications. No significant effects on patent application can be found for regulated firms relative to similar control firms (Top 10,000 firms not related to Top 1,000 firms). Standard errors are clustered at the firm level.

Figure A.5: Robustness of Spillovers to Related Firms: Entropy Matching



Notes: Authors' calculations using data from the ASIF and CESD. This figure shows the coefficients for event studies of log output, log energy consumption and log energy efficiency for firms related to regulated firms and event studies of log firm output for placebo firms. This figure corresponds to Figure 5 but deploys the additional matching method of entropy matching. The point estimates are displayed in Table A.9 and Table A.10. Standard errors are clustered at the firm level.

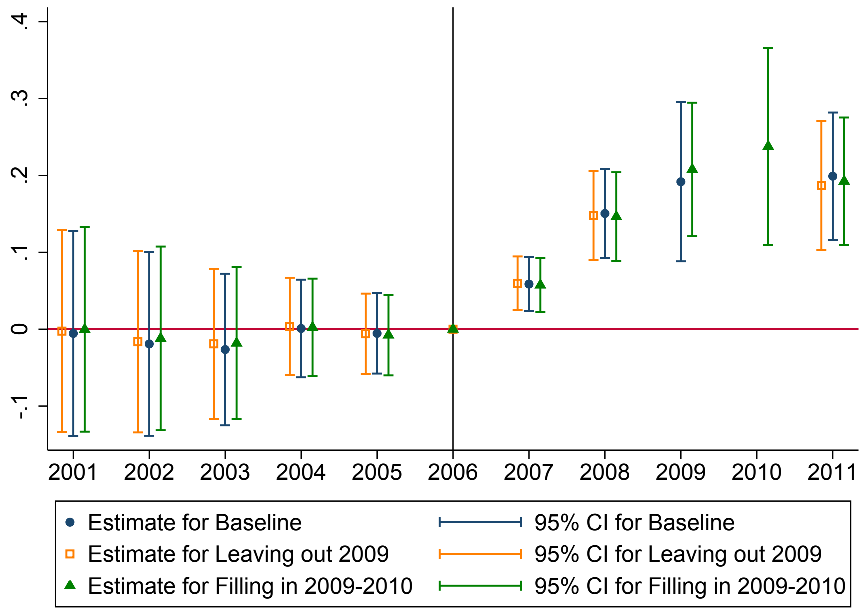
Figure A.6: Robustness to Dropping Electric Power Generation and Supply



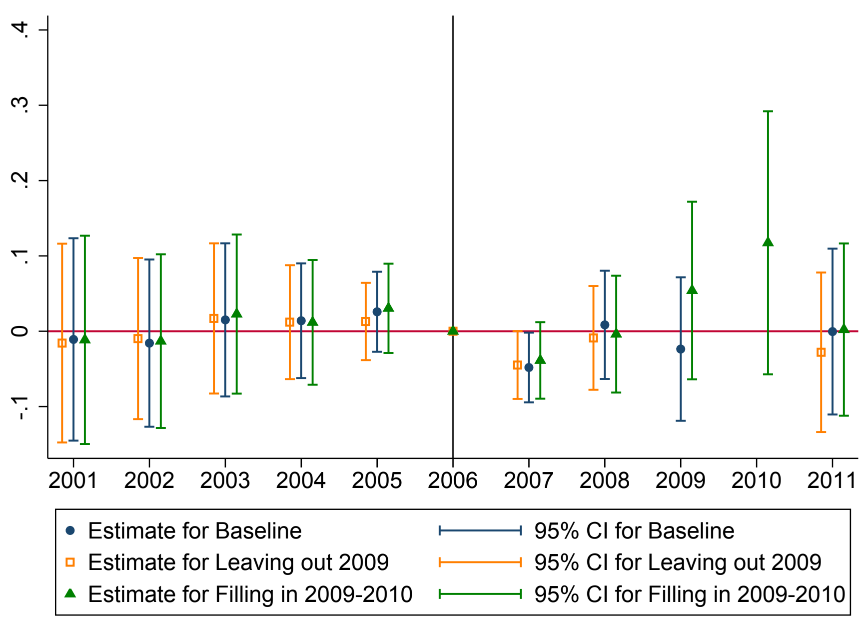
Notes: Authors' calculations using data from ASIF. This figure shows the coefficients for an event study of log firm output for firms related to regulated firms where related firms are restricted to those in industries other than electric power generation and supply. This figure corresponds to Panel A of Figure 5 but drops all observations in the electric power generation and supply industry. The point estimates are shown in Table A.12. Standard errors are clustered at the firm level.

Figure A.7: Data Quality Robustness for Related Spillovers

A. Output

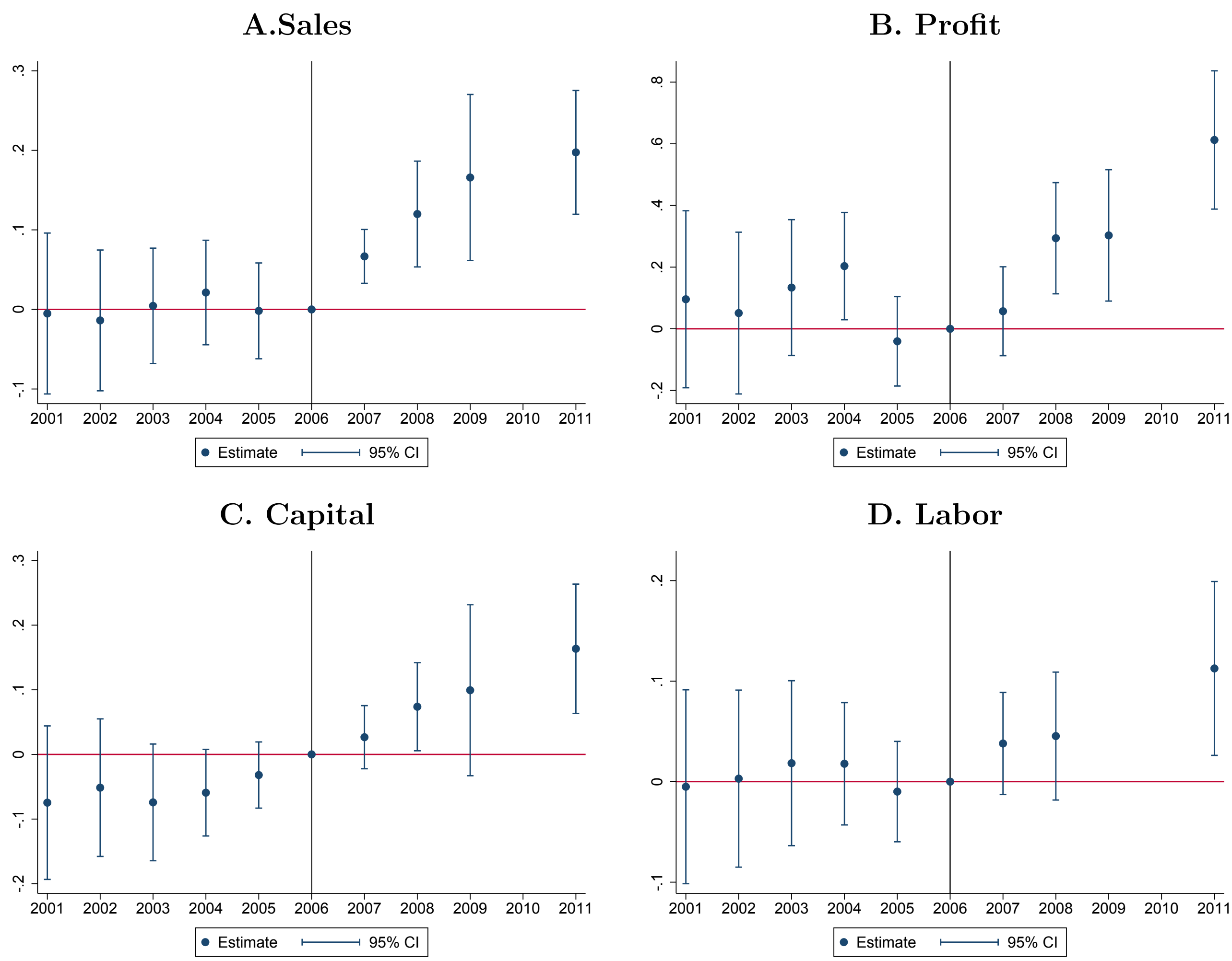


B. Placebo



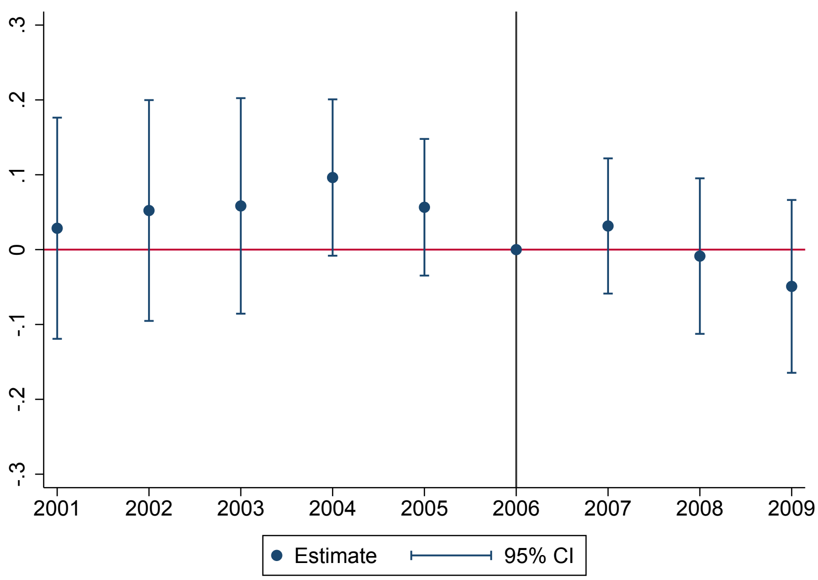
Notes: Authors' calculations using ASIF and ATS. This figure shows the coefficients for event studies of log firm output for related firms and placebo firms with different datasets. This figure corresponds to Panels A and B in Figure 5 but drops the data for 2009 from the ASIF on the yellow line and fills in the 2009–2010 data with tax data on the green line. The point estimates are shown in Table A.13. Standard errors are clustered at the firm level.

Figure A.8: Additional Spillover Effects of the Program



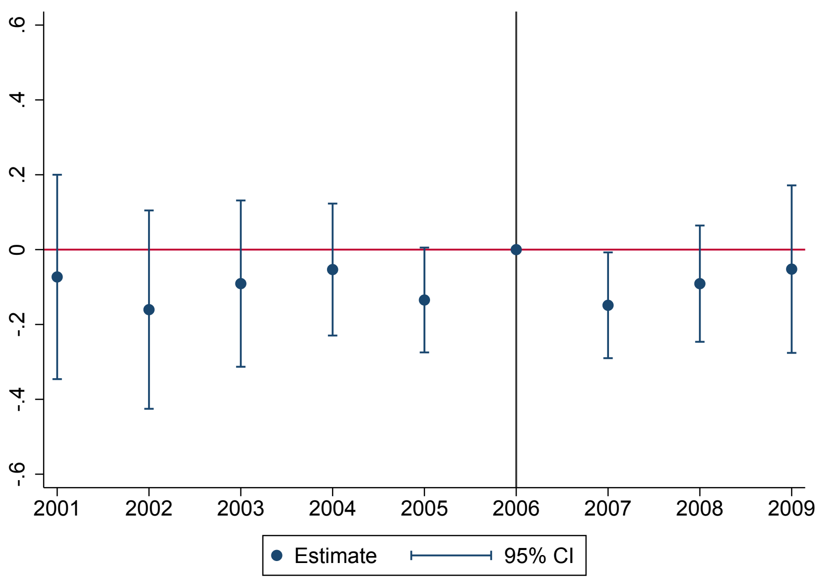
Notes: Authors' calculations using data from the ASIF. This figure shows the coefficients for event studies of log firm sales, profit, capital and labor for firms related to regulated firms. It shows that the Top 1,000 Energy Saving Program had a persistent effect on the production and performance of related firms. The point estimates are displayed in Table A.14. Standard errors are clustered at the firm level.

Figure A.9: Robustness of Effects on the Energy Efficiency of Regulated Firms



Notes: Authors' calculations using data from the CESD and ASIF. This figure shows the coefficients for an event study of log firm energy efficiency in regulated firms, where energy efficiency is defined as the inverse of the energy share in variable input costs. Variable input is calculated from the ASIF in terms of sales cost. This figure corresponds to Panel E of Figure 4 but with an alternative definition of energy efficiency. The point estimates are shown in Table A.18. Standard errors are clustered at the firm level.

Figure A.10: Robustness of Effects on the Energy Efficiency of Related Firms



Notes: Authors' calculations using data from the CESD and ASIF. This figure shows the coefficients for an event study of log firm energy efficiency in firms related to regulated firms, where energy efficiency is defined as the inverse of the energy share in variable input costs. Variable input is calculated from the ASIF in terms of sales cost. This figure corresponds to Panel D of Figure 5 but with an alternative definition of energy efficiency. The point estimates are shown in Table A.19. Standard errors are clustered at the firm level.

Appendix Tables

Table A.1: Policy Compliance

Type	Orig.list	Evaluation			
Year		2007	2008	2009	2010
Firm number	1008	953	922	901	881
Noncompliant firms	-	74	36	28	15
Noncompliance rate	-	7.76%	3.90%	3.11%	1.70%

Notes: Authors' calculations using data from the NDRC. This table shows the compliance of Top 1,000 firms during the 11FYP. The first row shows the number of Top 1,000 firms evaluated by the government in each year, the second row shows the number of noncompliant firms, and the last row shows the corresponding noncompliance rate. By the end of the 11FYP, 98.3% of evaluated Top 1,000 firms achieved their energy saving targets. See Section 1.1 for additional discussion.

Table A.2: Dataset Matching

Datasets	Top 1,000		Top 10,000	
	Number	Ratio	Number	Ratio
List	1008	-	14641	-
ASIF	1001	99.31%	14300	97.67%
CESD	818	81.15%	10722	73.23%
ASIF & CESD	809	80.26%	9481	64.76%
ASIF & ATS	446	44.25%	6622	45.23%

Notes: Authors' calculations using data from the ASIF, CESD and ATS. This table shows the result of dataset matching. Over 99% of the Top 1,000 firms and over 97% of the Top 10,000 firms can be found in the ASIF, and over 80% of the Top 1,000 firms and over 70% of the Top 10,000 firms can be found in the CESD. See Section 1.2 for additional discussion.

Table A.3: Robustness to Dropping Electricity-Intensive Industries

Variables	ln(Energy Use)	ln(Output)	ln(Energy Efficiency)
Electricity<15%	-0.123**	-0.207***	-0.083*
	(0.049)	(0.046)	(0.048)
Electricity<20%	-0.133***	-0.178***	-0.045
	(0.050)	(0.045)	(0.050)
Electricity<25%	-0.146***	-0.195***	-0.048
	(0.048)	(0.043)	(0.047)
Electricity<30%	-0.156***	-0.204***	-0.049
	(0.047)	(0.042)	(0.046)
Electricity<35%	-0.166***	-0.202***	-0.037
	(0.045)	(0.041)	(0.045)
Electricity<40%	-0.164***	-0.199***	-0.036
	(0.045)	(0.041)	(0.045)
Electricity<45%	-0.165***	-0.200***	-0.037
	(0.045)	(0.041)	(0.045)
Electricity<50%	-0.170***	-0.233***	-0.064
	(0.043)	(0.042)	(0.045)
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y

Notes: Authors' calculations using data from the CESD. This table reports the estimates from regressions of log firm energy consumption, output and energy efficiency on regulated firms interacted with an indicator for years after 2006 under varying data restrictions. The estimates shown in this table correspond to Equation 2 and the baseline estimates in Table 3 with the exclusion of various industries with electricity consumption accounting for more than 15%, 20%, 25%, 35%, 40%, 45%, or 50% (our baseline setting is 30%). Standard errors clustered at the firm level are shown in parentheses with p-values below. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table A.4: Robustness to Entry and Exit: Regulated Firm Response

Variables	ln(Energy Use)	ln(Output)	ln(Energy Efficiency)
Treat × Post	-0.141***	-0.170***	-0.029
	(0.049)	(0.044)	(0.048)
Observations	18,506	18,385	18,385
R^2	0.886	0.890	0.831
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y

Notes: Authors' calculations using data from the CESD. This table reports the estimates from regressions of log firm energy consumption, output and energy efficiency on regulated firms interacted with an indicator for years after 2006 when we exclude firm entry and exit. The estimates shown in this table correspond to Equation 2 and the baseline estimates in Table 3 with the exclusion of firms that enter the CESD data after 2006 or exit before 2010. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.5: Approximately Balanced Panel: Regulated Firm Response

Variables	ln(Energy Use)	ln(Output)	ln(Energy Efficiency)
Treat × Post	-0.153**	-0.145**	0.006
	(0.069)	(0.057)	(0.065)
Observations	10,336	10,265	10,265
R^2	0.892	0.910	0.835
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y

Notes: Authors' calculations using data from the CESD. This table reports the estimates from regressions of log firm energy consumption, output and energy efficiency on regulated firms interacted with an indicator for years after 2006 with an approximately balanced panel. The estimates shown in this table correspond to Equation 2 and the baseline estimates in Table 3 with the exclusion of firms with missing data for two years or more. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.6: Robustness to Consideration of Concurrent Policies

A. Effects of Concurrent Policies on Top 1,000 Firms

	ln(Energy Use)	ln(Output)	ln(Energy Efficiency)
Monitor × Post	-0.003	0.023	0.019
	(0.097)	(0.089)	(0.106)
Observations	3,358	3,322	3,322
R^2	0.865	0.899	0.812
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y

B. Robustness to Effects on Top 1,000 Firms

	ln(Energy Use)	ln(Output)	ln(Energy Efficiency)
Treat × Post	-0.186**	-0.234***	-0.046
	(0.075)	(0.080)	(0.083)
Observations	20,655	20,511	20,511
R^2	0.864	0.858	0.847
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y

Notes: Authors' calculations using data from the CESD. This table shows that our estimated effects of the Top 1000 program are robust to consideration of a concurrent policy—the National Specially Monitored Firms (NSMF) program. Panel A estimates a difference-in-differences model to show the effects of the NSMF program within the Top 1,000 firm sample. We can see that the NSMF program had little effect on the energy consumption, output and energy efficiency of Top 1,000 firms. Panel B estimates the same regression as in Table 3 while excluding all treated firms included under both polices. It shows that taking the NSMF program into account does not affect our main results. See Section B for both detailed description of the NSMF program and additional discussion. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.7: Heterogeneous Effects on Regulated Firms by Industry

Variables	ln(Output)				
	Baseline	Drop Power	Processing	Materials	Mining
Treat × Post	-0.204***	-0.206***	-0.219***	-0.153***	-0.251
	(0.042)	(0.042)	(0.073)	(0.053)	(0.275)
Observations	22,991	21,748	5,440	12,662	545
R^2	0.889	0.887	0.893	0.865	0.863
Firm FE	Y	Y	Y	Y	Y
Industry × Year FE	Y	Y	Y	Y	Y
Province × Year FE	Y	Y	Y	Y	Y

Notes: Authors' calculations using data from the CESD. This table shows estimates of Equation 2 by industry where Treat × Post is an indicator for regulated firms interacted with an indicator for years after 2006 and the dependent variable is log firm output, corresponding to Panel B of Table 3. Column (1) is our baseline result. Column (2) shows the results after we drop the production and supply of electric power and heating power industry. Column (3) shows the results for processing industries, including smelting and pressing of ferrous metals, smelting and pressing of nonferrous metals, processing of petroleum, coking, and processing of nuclear fuel. Column (4) shows the result for material industries, including the manufacture of raw chemical materials and chemical products and the manufacture of nonmetallic mineral products. Column (5) shows the result for mining industries, including mining and washing of coal and extraction of petroleum and natural gas. This table shows no significant differences in regulated firm response among different industries. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.8: Effects of Policy on Investment in Regulated Firms

Variables	If Firm Invest			
Treat × Post	-0.056***	-0.070***	-0.070***	-0.071***
	(0.013)	(0.014)	(0.014)	(0.014)
Observations	47,231	47,211	47,208	45,675
R^2	0.192	0.201	0.209	0.214
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

Notes: Authors' calculations using ASIF and ATS. This table shows estimates of Equation 2 where Treat × Post is an indicator for regulated firms interacted with an indicator for years after 2006 and the dependent variable is firm investment choice. Investment choice is defined as whether a firm invests. See Section 1 for more information about the data-generating procedure. This table corresponds to a pooled version of the regression displayed in Figure A.3. It shows that regulated firms decrease their possibility of investment by 5.6%–7.1% relative to similar control firms (Top 10,000 firms not related to Top 1,000 firms) after the policy implementation. See Section 2 for additional discussion. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.9: Robustness of Spillovers to Related Firms on Output: Entropy Matching

A. Output

Variables	ln(Output)			
Related × Post	0.143***	0.139***	0.106***	0.133***
	(0.039)	(0.038)	(0.037)	(0.036)
Observations	119,064	119,064	119,064	116,064
R^2	0.874	0.881	0.890	0.896

B. Placebo Test on Output

Variables	ln(Output)			
Related × Post	0.016	0.019	0.020	0.036
	(0.041)	(0.040)	(0.039)	(0.038)
Observations	150,997	150,997	150,997	147,431
R^2	0.909	0.914	0.922	0.929

C. Heterogeneous Effects on Output by Firm Size

Variables	ln(Output)			
Related × Post(0%-30%)	0.097	0.096	0.001	0.039
	(0.070)	(0.068)	(0.065)	(0.063)
Related × Post(30%-60%)	0.171***	0.166***	0.123**	0.156***
	(0.060)	(0.058)	(0.054)	(0.053)
Related × Post(60%-100%)	0.178***	0.172***	0.179***	0.191***
	(0.058)	(0.056)	(0.054)	(0.052)
Observations	95,258	95,258	95,258	92,847
R^2	0.874	0.881	0.891	0.897
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

Notes: Authors' calculations using data from the ASIF. This table shows estimates of Equation 2 with an alternative matching method, where Related × Post is an indicator for related firms in the same 4-digit industry interacted with an indicator for years after 2006 in Panels A and C and an indicator for related firms in the same 2-digit industry (but not the same 4-digit industry) interacted with an indicator for years after 2006 in Panel B. This table corresponds to Table 4 but deploys the additional matching method of entropy matching. Panels A and B correspond to a pooled version of the regression displayed in Panels A and B of Figure A.5. Standard errors clustered at the firm level are shown in parentheses with p-values below. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table A.10: Robustness of Spillovers to Related Firms on Energy Use and Energy Efficiency: Entropy Matching

A. Energy Use

Variables	ln(Energy Use)			
Related × Post	0.247**	0.248***	0.289***	0.263**
	(0.097)	(0.095)	(0.090)	(0.104)
Observations	20,254	20,254	20,101	14,507
R^2	0.855	0.858	0.871	0.879

B. Energy Efficiency

Variables	ln(Energy Efficiency)			
Related × Post	-0.021	-0.019	-0.056	-0.039
	(0.099)	(0.098)	(0.103)	(0.104)
Observations	20,122	20,122	19,971	14,424
R^2	0.822	0.826	0.839	0.845
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

Notes: Authors' calculations using data from the CESD and ASIF. This table shows estimates of Equation 2 with an alternative matching method, where Related × Post is an indicator for related firms in the same 4-digit industry interacted with an indicator for years after 2006 and the dependent variables are log firm energy consumption in Panel A and log firm energy efficiency in Panel B. This table corresponds to Table 5 but deploys the additional matching method of entropy matching and corresponds to a pooled version of the regression displayed in Panels C and D of Figure A.5. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.11: Spillover Effects on the Output of Related Firms: Robustness to Different Definitions of Related Parties

Variables	ln(Output)				
	Baseline	Drop Changes	6 Level, 20%	2 Level, 20%	2 Level, 51%
Related × Post	0.127***	0.125***	0.133***	0.124***	0.154***
	(0.035)	(0.036)	(0.033)	(0.035)	(0.039)
Observations	17,905	17,030	20,036	18,185	14,589
R^2	0.889	0.889	0.889	0.888	0.892
Firm FE	Y	Y	Y	Y	Y
Industry × Year FE	Y	Y	Y	Y	Y
Province × Year FE	Y	Y	Y	Y	Y
Firm-level Controls	Y	Y	Y	Y	Y

Notes: Authors' calculations using data from the ASIF. This table shows estimates of Equation 2 where Related × Post is an indicator for related firms interacted with an indicator for years after 2006 and the dependent variable is log firm output. This table corresponds to Table 4 but uses different definitions for related parties. Column (1) is our baseline result. Column (2) shows the results after we drop all related firms with shareholding changes after the policy implementation (which account for 3.89% of total related firms). It shows that our results are robust to dropping related firms with shareholding changes. Column (3) shows the results for related firms within six levels of shareholder links and with an ownership requirement of at least 20%. It shows that under this broader definition, related firms increased output by 13.3% after the policy implementation; this means that the conglomerate shift accounts for 46.0% ($\approx 2.80 \times 17.9\% \times 13.3\%/14.5\%$) of the output decline in regulated firms. Column (4) shows the results for related firms within two levels of shareholder links and with an ownership requirement of at least 20%. It shows that under this definition, related firms increased output by 12.4% after the policy implementation; this means that the conglomerate shift accounts for 41% ($\approx 2.49 \times 19.3\% \times 12.4\%/14.5\%$) of the output decline in regulated firms. Column (5) shows the results for related firms within two levels of shareholder links and with an ownership requirement of more than 50%. It shows that under this narrower definition, related firms increased output by 15.4% after the policy implementation; this means that the conglomerate shift accounts for 41% ($\approx 1.95 \times 19.9\% \times 15.4\%/14.5\%$) of the output decline in regulated firms. See Section 3 for additional discussion. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.12: Robustness to Dropping Electric Power Generation and Supply

Variables	ln(Output)			
Related*Post	0.180***	0.173***	0.163***	0.167***
	(0.043)	(0.041)	(0.039)	(0.037)
Observations	11,232	11,229	11,222	10,982
R^2	0.850	0.862	0.872	0.883
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

Notes: Authors' calculations using data from the ASIF. This table shows estimates of Equation 2 where Related × Post is an indicator for related firms in industries other than electric power generation and supply interacted with an indicator for years after 2006 and the dependent variable is log firm output. This table corresponds to Panel A of Table 4 but with the exclusion of all firms in the electric power generation and supply industry and corresponds to a pooled version of the regression displayed in Figure A.6. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.13: **Data Quality Robustness of Spillovers to Related Firms**

A. Output: Leave out 2009 in ASIF Data

Variables	ln(Output)			
Related × Post	0.131***	0.125***	0.102***	0.111***
	(0.034)	(0.033)	(0.033)	(0.031)
Observations	16,454	16,452	16,450	15,970
R^2	0.890	0.898	0.905	0.913

B. Output: Fill in 2009–2010 with Tax Data

Variables	ln(Output)			
Related × Post	0.159***	0.156***	0.137***	0.135***
	(0.037)	(0.037)	(0.037)	(0.035)
Observations	19,293	19,289	19,287	18,735
R^2	0.869	0.876	0.885	0.893

C. Placebo: Leave out 2009 in ASIF Data

Variables	ln(Output)			
Related × Post	-0.033	-0.031	-0.025	-0.019
	(0.039)	(0.037)	(0.038)	(0.037)
Observations	7,971	7,970	7,955	7,809
R^2	0.908	0.914	0.921	0.927

D. Placebo: Fill in 2009–2010 with Tax Data

Variables	ln(Output)			
Related × Post	0.000	-0.003	-0.005	-0.007
	(0.041)	(0.040)	(0.040)	(0.039)
Observations	9,289	9,288	9,268	9,104
R^2	0.875	0.880	0.889	0.897
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

Notes: Authors' calculations using ASIF and tax data. This table shows estimates of Equation 2 with different datasets, where Related × Post is an indicator for related firms in the same 4-digit industry interacted with an indicator for years after 2006, and the dependent variable is log firm output. Panels A and C correspond to Panels A and B in Table 4 but with the exclusion of the 2009 data from the ASIF. Panels B and D correspond to Panels A and B in Table 4 but with the 2009–2010 data filled in with tax data. The estimates in this table also correspond to a pooled version of the regression displayed in Figure A.7. Standard errors clustered at the firm level are shown in parentheses with p-values below. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table A.14: Additional Spillover Effects of the Program

Variables	ln(Sale)	ln(Profit)	ln(Capital)	ln(Labor)
Related × Post	0.115***	0.190***	0.114***	0.063**
	(0.033)	(0.055)	(0.040)	(0.026)
Observations	17,867	13,147	17,901	15,966
R^2	0.893	0.826	0.904	0.897
Firm FE	Y	Y	Y	Y
Industry × Year FE	Y	Y	Y	Y
Province × Year FE	Y	Y	Y	Y
Firm-level Controls	Y	Y	Y	Y

Notes: Authors' calculations using data from the ASIF. This table shows estimates of Equation 2 where Related × Post is an indicator for related firms interacted with an indicator for years after 2006 and the dependent variables are log firm sales, profit, capital and labor. The estimates in this table correspond to a pooled version of the regression displayed in Figure A.8. They show that related firms in the same 4-digit industries increased sales by 11.5%, profit by 19.0%, capital by 11.4%, and labor by 6.3% after the policy implementation. Standard errors clustered at the firm level are shown in parentheses with p-values below. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table A.15: Spillover Effects on the Output of Related Firms: Heterogeneous Effects by Industry

Variables	ln(Output)				
	Baseline	Drop Power	Processing	Materials	Mining
Related × Post	0.118***	0.164***	0.105	0.180***	0.197**
	(0.037)	(0.040)	(0.096)	(0.056)	(0.080)
Observations	18,418	11,152	2,586	5,566	2,641
R^2	0.881	0.872	0.871	0.846	0.883
Firm FE	Y	Y	Y	Y	Y
Industry × Year FE	Y	Y	Y	Y	Y
Province × Year FE	Y	Y	Y	Y	Y

Notes: Authors' calculations using data from the ASIF. This table shows estimates of Equation 2 by industry where Related × Post is an indicator for related firms interacted with an indicator for years after 2006 and the dependent variable is log firm output, corresponding to Panel A of Table 4. Column (1) is our baseline result. Column (2) shows the results after we drop the production and supply of electric power and heat power industry. Column (3) shows the result for processing industries, including smelting and pressing of ferrous metals, smelting and pressing of nonferrous metals, processing of petroleum, coking, and processing of nuclear fuel. Column (4) shows the result for material industries, including manufacture of raw chemical materials and chemical products and manufacture of nonmetallic mineral products. Column (5) shows the results for mining industries, including mining and washing of coal and extraction of petroleum and natural gas. This table shows that we do not find significant differences in the response of related firms across different industries. Standard errors clustered at the firm level are shown in parentheses with p-values below. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table A.16: Robustness to Entry: Market Spillovers

Variables	ln(Output)			
	All Sample		Energy-intensive Industries	
Spillover × Post	0.083***	0.075***	0.092***	0.092***
	(0.022)	(0.020)	(0.021)	(0.025)
Observations	2,129,911	2,129,911	716,518	716,518
R^2	0.847	0.862	0.837	0.853
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry-level Controls	Y	Y	Y	Y
Firm-level Controls		Y		Y

Notes: Authors' calculations using data from the ASIF. This table shows estimates of Equation 3 where Spillover × Post is an indicator for industry-level exposure to the Top 1,000 program interacted with an indicator for years after 2006 and the dependent variable is log firm output. This table corresponds Table 6 with the exclusion of firms that enter the CESD data after 2006. It shows that average market-level spillovers led to a 7.5%–9.2% increase in output for unregulated existing firms. See Section 3 for additional discussion. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.

Table A.17: Structural Estimation: Robustness to Alternative Specifications

	Data	Baseline	Low ρ	High ρ	Low α	High α	Imperfect Substitution
1. Fixed Values							
Elasticity of substitution ρ		0.750	0.700	0.900	0.750	0.750	0.750
Within-conglomerate Elasticity of substitution ρ_c							0.900
Return to scale α		0.900	0.900	0.900	0.850	0.950	0.900
2. Method of Moments							
Efficiency depreciation δ		0.900	0.900	0.900	0.853	0.949	0.800
		(0.003)	(0.003)	(0.003)	(0.005)	(0.001)	(0.007)
Dispersion of ln-ability σ_m		1.239	1.500	0.579	1.359	1.063	1.271
		(0.055)	(0.060)	(0.045)	(0.087)	(0.053)	(0.097)
Survival threshold ϕ_1		0.609	0.461	0.792	0.579	0.435	0.985
		(0.166)	(0.134)	(0.193)	(0.273)	(0.118)	(0.535)
3. Policy Parameters							
Policy threshold $\tilde{\phi}$		9.289	14.093	2.658	10.915	6.050	10.977
4. Moments							
Share of firms $< 1M$	0.336	0.347	0.350	0.350	0.347	0.351	0.344
Share of firms $5-20M$	0.105	0.155	0.155	0.160	0.157	0.156	0.156
Share of firms $20-100M$	0.071	0.072	0.072	0.076	0.073	0.074	0.071
Share of firms $100M+$	0.025	0.026	0.026	0.027	0.027	0.027	0.025
Share of Output $5-20M$	0.051	0.072	0.072	0.074	0.073	0.073	0.072
Share of Output $20-100M$	0.146	0.144	0.144	0.152	0.147	0.148	0.142
Share of Output $100M+$	0.722	0.733	0.733	0.723	0.729	0.729	0.734
Relative Output 1st-2nd	0.289	0.348	0.350	0.347	0.347	0.350	0.347
Relative Output 2nd-3rd	0.203	0.121	0.122	0.120	0.120	0.122	0.121

Notes: This table summarizes the parameters that we set or estimate. Panel 1 lists the various parameter values that we calibrate. Across all cases, we set α_l to match the cost share of variable inputs, given α. Panel 2 reports the estimated parameter moments with standard errors in parentheses. See Section 5.1 for the detailed estimation procedure. Panel 3 reports the policy threshold $\tilde{\phi}$. This threshold is selected to match the share of energy use by regulated firms, which itself depends on the parameter values. Panel 4 reports the data moments and the moments predicted by the model parameters. Section 7.3 discusses the results when we vary α or ρ, and Section 7.4 discusses the results when we set $\rho_c = 0.9$.

Table A.18: Robustness of Effects on the Energy Efficiency of Regulated Firms

Variables	ln(Variable Input/Energy)			
Treat × Post	-0.020	-0.082*	-0.053	-0.029
	(0.043)	(0.047)	(0.048)	(0.048)
Observations	17,096	17,091	16,824	16,452
R^2	0.865	0.868	0.872	0.873
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

Notes: Authors' calculations using data from the CESD and ASIF. This table shows estimates of Equation 2 where Treat × Post is an indicator for regulated firms interacted with an indicator for years after 2006 and the dependent variable is log energy efficiency. Energy efficiency in this table is defined as the inverse of the energy share in variable input costs, and variable input is calculated from the ASIF in terms of sales cost. This table corresponds to Panel C of Table 3 but with an alternative definition of energy efficiency and corresponds to a pooled version of the regression displayed in Figure A.9. Standard errors clustered at the firm level are shown in parentheses with p-values below. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table A.19: Robustness of Effects on the Energy Efficiency of Related Firms

Variables	ln(Variable Input/Energy)			
Related × Post	-0.026	-0.033	-0.026	-0.008
	(0.078)	(0.080)	(0.088)	(0.088)
Observations	2,503	2,497	2,449	2,424
R^2	0.904	0.907	0.917	0.918
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

Notes: Authors' calculations using data from the CESD and ASIF. This table shows estimates of Equation 2 where Related × Post is an indicator for related firms in the same 4-digit industry interacted with an indicator for years after 2006 and the dependent variable is log energy efficiency. Energy efficiency in this table is defined as the inverse of the energy share in variable input costs, and variable input is calculated from the ASIF in terms of sales cost. This table corresponds to Panel B of Table 5 but with an alternative definition of energy efficiency and corresponds to a pooled version of the regression displayed in Figure A.10. Standard errors clustered at the firm level are shown in parentheses with p-values below. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table A.20: Heterogeneous Spillover Effects by Local Pollution and Density

Variable	High to Low	Horizontal	Low to High
Related × Post	0.115**	0.101	0.224***
	(0.047)	(0.072)	(0.073)
Observations	10,256	3,740	3,457
R^2	0.895	0.883	0.897
Output Share	57.9%	13.9%	28.2%
Aggregate Effect	6.7%	1.4%	6.3%
Firm FE	Y	Y	Y
Year FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y
Firm-level Controls	Y	Y	Y

Notes: Authors' calculations using data from the ASIF. This table show estimates of Equation 2 where Related × Post is an indicator for related firms in the same 4-digit industry interacted with an indicator for years after 2006 and the dependent variable is log firm output. The estimates correspond to Panel A of Table 4 but divide related firms into three groups according to their pollution exposure. Column (1) includes related firms whose city-level pollution exposure is less than (by more than 10%) that of their corresponding Top 1,000 firms; Column (2) includes related firms whose city-level pollution exposure is similar to (within 10%) that of their corresponding Top 1,000 firms; and Column (3) includes related firms whose city-level pollution exposure is more than (by more than 10%) that of their corresponding Top 1,000 firms. City-level pollution exposure is defined by city-level so_2 density × city population. This table shows that related firms in places with lower pollution exposure increased output by 11.5% and related firms in places with similar pollution exposure increased output by 10.1% while related firms in places with more pollution exposure increased output by 22.4% after the policy implementation. However, considering that a higher share of the related output (57.9%) was concentrated in less exposed areas, we see similar output increases in more and less exposed areas. See Section C for additional discussion. Standard errors clustered at the firm level are shown in parentheses with p-values below. * p<0.1, ** p<0.05, *** p<0.01.