"Market Power *Is* Power": Online Appendix

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S.1 Omitted results from main text

Proposition S.1.1 presents the formal result underlying Remark 4. Before presenting the formal statement, we introduce some notation. Given $q \geq 1/2$ and $\mathcal{P}^* \geq q$, let t_q^* denote the profit-maximizing technology t such that $\mathcal{P}(t) \geq q$. Notice that, in the subgame following preemptive regulation, the firm optimally develops t_q^* and induces outcome $(t_q^*, 0)$. In the special case of $q = 1/2$ and $\mathcal{P}^* \geq 1/2$, the technology t_q^* is simply t_{maj}^* (as per the benchmark model).

Proposition S.1.1. *Suppose democratic first best is not attainable (and, hence, $\mathcal{P}^* \geq 1/2$). If there exists $q \in Q$ such that $\mathcal{P}^* \geq q$ and the outcome $(t_q^*, 0)$ is preferred to $(t_{maj}^*, 0)$ by strictly more than q consumers, then a democratic second-best outcome $(t_q^*, 0)$ can be attained.*

Proof. Suppose democratic first best is not attainable (and, hence, $\mathcal{P}^* \geq 1/2$). Consider preemptive regulation with a supermajoritarian instrument q such that $\mathcal{P}^* \geq q$. By Remark 3, if preemptive regulation is not passed, then the ensuing outcome is $(t_{\text{maj}}^*, 0)$. If preemptive regulation is passed, then, because $\mathcal{P}^* \geq q$, the outcome is $(t_q^*, 0)$. This follows via a similar argument as that of Proposition 2 but modified to incorporate the supermajority requirement q to repeal regulation. Therefore, preemptive regulation with supermajority q will pass if and only if strictly more than q consumers prefer the outcome $(t_q^*, 0)$ to $(t_{\text{maj}}^*, 0)$. The proposition statement then follows. ■

S.2 Timing figures

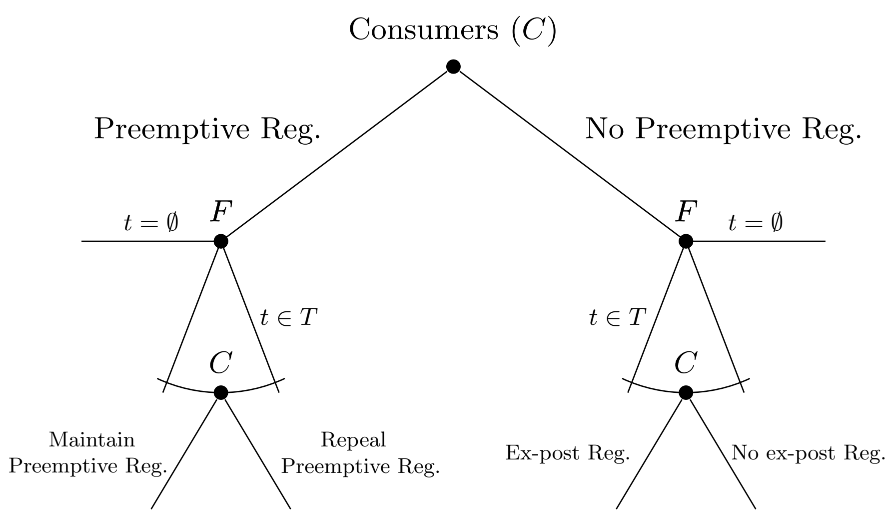

Figure S.2.1: Timing for benchmark model.

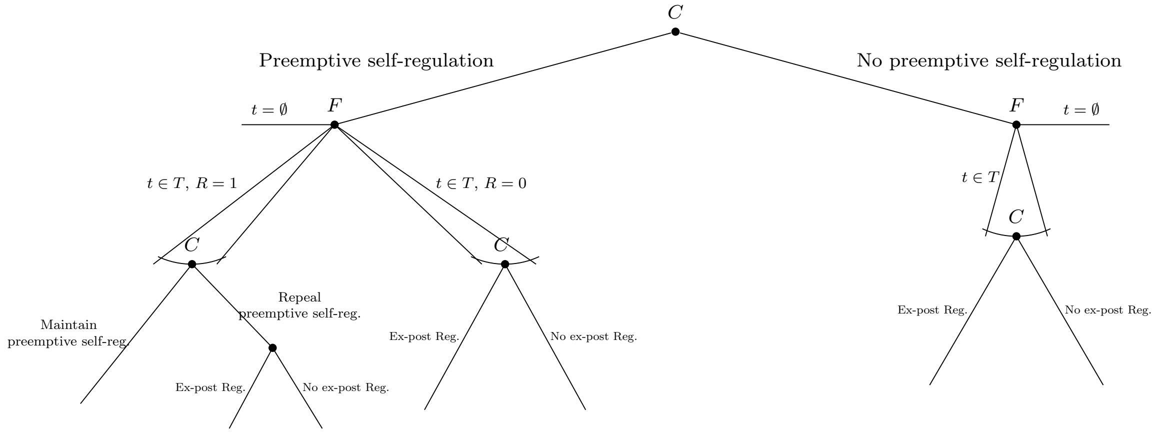

Figure S.2.2: Timing for benchmark model with preemptive self-regulation instrument.

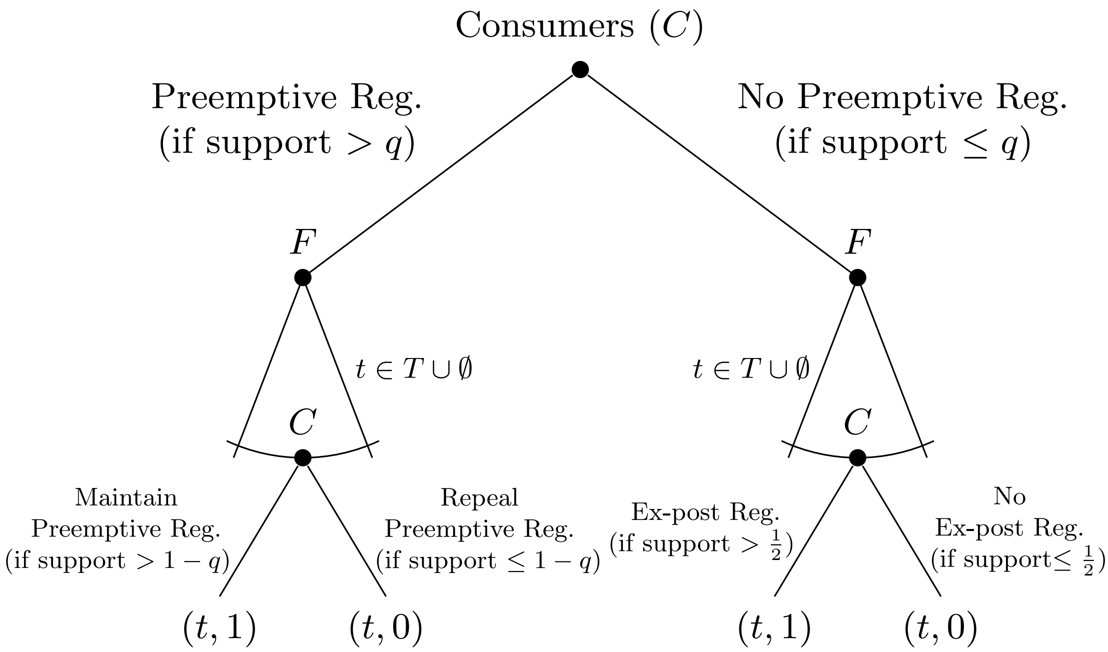

Figure S.2.3: Timing for generalized framework with supermajority instrument for preemptive regulation.

S.3 Extensions to the benchmark model

S.3.1 Extension: democratic first best entails no regulation

Suppose Assumption 3 is violated, so the democratic first best is $(t^*(0), 0)$. If the most profitable regulated technology is profitable ($\Pi(p^*, t^*(1), 1) > \gamma$), then Propositions 1 and 2 hold verbatim, $\mathcal{P}^* \geq 1/2$, $t^*_{\text{maj}} = t^*(0)$ and the equilibrium achieves the democratic first best. In this case, there is no conflict at all between the firm and the majority of consumers.

Suppose instead $\Pi(p^*, t^*(1), 1) \leq \gamma$. Proposition 1 holds verbatim. If $\mathcal{P}^* \geq 1/2$, the first part of Proposition 2 also holds verbatim: the firm develops t^*_{maj} and avoids regulation. However, the democratic first best is achieved if and only if $t^*_{\mathrm{maj}} = t^*(0)$, equivalently $\mathcal{P}(t^*(0)) \geq 1/2$. Whenever $t^*_{\mathrm{maj}} \neq t^*(0)$ or $\mathcal{P}^* < 1/2$, a hold-up problem arises that distorts technological development. In the first case, equilibrium features no regulation, but the democratic first best is not achieved because the firm chooses a less efficient technology. In the second case, the firm develops no technology at all. Consumers ex-ante prefer $(t^*(0), 0)$ to no development, but would regulate every profitable candidate technology after its development cost is sunk. Anticipating this, the firm does not invest in development. This is the conventional regulatory hold-up problem.

S.3.2 Per-unit externality

In this appendix, we modify our benchmark model so that the per-capita externality from unregulated production is increasing in the firm's total production (equivalently, total demand). Formally, if production is unregulated and the firm produces Q units, then the per-capita externality is $E(Q)$, where $E(\cdot)$ is positive and increasing. Otherwise, production is regulated and there is no externality.

Clearly, market equilibrium is unchanged relative to the benchmark model. As such (and maintaining Assumption 1), we have that Lemma 1 holds verbatim. Lemma 2 also holds but with one caveat. The technologies $t^*(0)$ and $t^*(1)$ (as defined in Definition 1) are the most profitable unregulated and regulated technologies, respectively; however, unlike in the benchmark model, $t^*(0)$ need not be the most efficient unregulated technology.

The difference in efficiency v. profitability arises because, in this extension, the per-capita externality from unregulated production is (implicitly) technology dependent. The externality increases in the equilibrium quantity demanded and, hence, a lower marginal cost generates lower prices for consumers but also a larger externality. The overall efficiency is, therefore, ambiguous. Formally, given any technology t, if production is unregulated, the (equilibrium) per-capita externality is

$$E(\mathcal{D}(p^*(c_t))), \tag{S.3.1}$$

where $\mathcal{D}(p^*(c_t)) = 1 - F(p^*(c_t) + s^M)$ is the equilibrium quantity sold.

We now turn to the democratic first best (per the benchmark model, we maintain Assumption 2).

Definition S.3.1 (Democratic first best.)**.** *With per-unit externality, the democratic first best* *entails regulation if and only if a (strict) majority of consumers prefers regulation subject to the incentive-compatibility constraint of Lemma 2. I.e., for a (strict) majority of consumers, (4) exceeds*

$$\max\left\{v_i - p^*(c_{t^*(0)}), s^M\right\} - E(\mathcal{D}(p^*(c_{t^*(0)}))). \tag{S.3.2}$$

As in the benchmark model, we can fully characterize when the democratic first best entails regulation. Lemma A.1 continues to hold once the externality e is substituted with the per-unit externality $E(\mathcal{D}(p^*(c_{t^*(0)})))$ and with the caveat that "(and, hence, most efficient)" should be removed. The proof argument is similar and, hence, omitted.

Lemma S.3.1 (De jure optimal regulation.)**.** *Let p^* satisfy (2). With per-unit externality, the democratic first best entails regulation if and only if either*

(i) *the profit-maximizing regulated technology is profitable and the pass through induced by regulation is less than the per-capita externality $E(\mathcal{D}(p^*(c_{t^*(0)})))$: $\Pi(p^*, t^*(1), 1) > \gamma$ and $p^*(c'_{t^*(1)}) - p^*(c_{t^*(0)}) < E(\mathcal{D}(p^*(c_{t^*(0)})))$; or*

(ii) *less than half of consumers value the firm's good enough that they would, when produced with the profit-maximizing unregulated technology, demand it even if the price internalized the per-capita value of the externality: $1 - F\left(p^*(c_{t^*(0)}) + s^M + E(\mathcal{D}(p^*(c_{t^*(0)})))\right) < 1/2$.*

As in the benchmark model (Assumption 3), we then assume that the democratic first best entails regulation, i.e., either (i) or (ii) in Lemma S.3.1 are satisfied.

Lemma S.3.2 redefines the term $\mathcal{P}(t) \in [0, 1]$, which captures the share of consumers prefer not to adopt ex-post regulation (and repeal any preemptive regulation) once the firm has developed technology t. The lemma statement is similar to Lemma 3 of the benchmark model. The only difference is that the per-capita externality in the benchmark model, e, is replaced with the per-unit externality (S.3.1). The proof argument follows that of Lemma 3 verbatim once e is replaced with $E(\mathcal{D}(p^*(c_t))$.

Lemma S.3.2 (Voters' regulatory preferences.)**.** *With per-unit externality, for any technology $t \in T$, if the firm develops t, then a share of consumers $\mathcal{P}(t) \in [0, 1]$ vote not to adopt ex-post regulation (and repeal any preemptive regulation). The share $\mathcal{P}(t)$:*

(i) *equals zero if the pass through induced by regulation of technology t is smaller than the per-capita externality $E(\mathcal{D}(p^*(c_t)))$: $p^*(c'_t) - p^*(c_t) < E(\mathcal{D}(p^*(c_t)))$; and*

(ii) *otherwise equals the share of consumers who value the firm's good enough that they would, when produced with unregulated technology t, demand it even if the price internalized the per-capita value of the externality: $\mathcal{P}(t) = 1 - F(p^*(c_t) + s^M + E(\mathcal{D}(p^*(c_t))))$.*

Given Lemma S.3.2 and the redefined $\mathcal{P}(t)$, Lemma 4 of the benchmark model holds verbatim (and with the same proof argument).

The benchmark model characterizes the political-economic equilibrium via the firm's political hold-up power via Definition 3. To be able to utilize this same definition of political hold-up power (albeit using the redefined term $\mathcal{P}(t)$, as per Lemma S.3.2), we must impose a final regularity condition—requiring that consumers have "time consistent" preferences (in Section II.1, we impose this same assumption). In particular, we require that if the firm develops the most profitable regulated technology, per the democratic first best outcome, then a majority of consumers will, in fact, want to impose regulation. Therefore, the implicit "outside option" described in the right-hand side of the constraint in (5) remains valid. Formally, we require that $\mathcal{P}(t^*(1)) < \frac{1}{2}$. This assumption is trivially satisfied in the benchmark model.

Assumption S.3.1 (The democratic first best is stable.)**.** $\mathcal{P}(t^*(1)) < \frac{1}{2}$.

With Assumption S.3.1, we can now utilize the benchmark model's definition of political hold-up power (Definition 3) to obtain the same core insights as the benchmark model: Propositions 1 and 2 continue to hold (again with the caveat that the most profitable unregulated technology need not be the most efficient). The proof arguments for both propositions in this extension are similar to the benchmark model and, hence, are omitted.

Therefore, this extension retains the core insight from Section I.4: market power is power. The firm has de facto power, $\mathcal{P}^* \geq 1/2$, whenever the firm is able to choose a technology $t \in T$ that exhibits three factors:

(i) The firm's equilibrium pass through is sufficiently large: the technology t induces $p^*(c_t') - p^*(c_t) \geq E(\mathcal{D}(p^*(c_t))$.

(ii) The firm's market share (brand penetration) is sufficiently large: [1]

$$\begin{aligned}
&\mathcal{D}(p^*(c_t) + E(\mathcal{D}(p^*(c_t))) \\
&\quad = \mathcal{D}(p^*(c_t)) - [F(p^*(c_t) + s^M + E(\mathcal{D}(p^*(c_t))) - F(p^*(c_t) + s^M)] \geq 1/2
\end{aligned}$$

(iii) The firm's equilibrium profits (markup times market share) are sufficiently large:

$$\Pi(p^*, t, 0) = \mathcal{D}(p^*(c_t))(p^*(c_t) - c_t) > \max\{\gamma, \Pi(p^*, t^*(1), 1)\}.$$

When these three conditions hold, the political-economic equilibrium features no

[1] In this extension (and unlike the benchmark model), increasing the firm's market share increases both the size of the externality and the pass through threshold described above in Part (i). Therefore, increasing the firm's market share will only monotonically increase the firm's political hold-up power if additional assumptions are imposed on the per-capita externality function $E(\cdot)$ — in particular, its slope must be sufficiently flat.

regulation and sufficiently large pass through, market share, and profits. However, one important difference between the benchmark model and this extension is that Proposition 3 need not hold. In particular, even when the firm has de facto power, $\mathcal{P}^* \geq 1/2$, and $\mathcal{P}(t^*(0)) < 1/2$, allocating de jure regulatory power to the firm may strictly reduce some consumers' equilibrium payoffs and total surplus. Intuitively, allocating de jure regulatory power to the firm will ensure that there is no regulation and the firm develops the most profitable unregulated technology, $t^*(0)$. This generates the lowest possible equilibrium prices $p^*(c_{t^*(0)})$ and an externality equal to $E(\mathcal{D}(p^*(c_{t^*(0)})))$. In contrast, when consumers retain de jure regulatory power, the equilibrium outcome is no regulation and the firm develops t^*_{maj}: the most profitable technology that deters regulation ($\mathcal{P}(t) \geq 1/2$). Therefore, consumers will face a higher equilibrium price $p^*(c_{t^*_{\text{maj}}})$ and, because higher prices imply lower demand, a smaller externality equal to $E(\mathcal{D}(p^*(c_{t^*_{\text{maj}}})))$. Whether consumers are better off (and whether total surplus is larger or smaller) will depend on the specific functional form of E. Nevertheless, when E is sufficiently "flat" over the interval $[\mathcal{D}(p^*(c_{t^*_{\text{maj}}}))), \mathcal{D}(p^*(c_{t^*(0)}))]$, a weaker form of Proposition 3 holds: the political-economic equilibrium induces strictly lower net consumer surplus, firm's profits *and total surplus including the collective cost of the externality* to an alternative scenario in which the firm has de jure regulatory power.

S.3.3 Regulation affects product quality

In our benchmark model, regulation increases the firm's marginal cost of production (in addition to removing the externality). In this extension, we consider the case that regulation decreases consumers' valuations for the good, e.g., by reducing the quality of the good. Formally, given a technology $t \in T$, consumer i has valuation $v_i - r_t$ for the good in the absence of regulation and valuation $v_i - r'_t$ with regulation, where $0 < r_t < r'_t$. Therefore, a consumer's (net) valuation of the good is technology dependent, and regulation has the effect of decreasing consumers' valuations of the good regardless of the firm's technology. As in the main text, for ease of exposition, we assume that no two technologies in T have the same quality when regulated or unregulated.

Regulation here has no effect on the firm's marginal cost. For simplicity, we assume that all technologies have the same constant marginal cost: $c_t \equiv c > 0$ for all $t \in T$.

To streamline our analysis, we assume that consumers' valuations are distributed according to the Pareto distribution, which has the convenient feature of inducing constant elasticity of demand (as previously utilized in Section I.4) in the quality-adjusted price $p + r + s_M$. The substantive implication of this assumption is that regulation—and, more generally, larger quality *decreases* (i.e., $\uparrow r$)—induce higher equilibrium prices. Therefore, and as per the benchmark model, if regulation did not remove the negative externality, then every consumer would prefer not to impose regulation. For alternative distributions, this need not be true.[2]

Assumption S.3.2 (Constant elasticity of demand.)**.** *Assume the distribution of consumer valuations is given by the Pareto distribution with shape parameter* $-\varepsilon > 1$ *and scale parameter* $\underline{v} > 0$*:*

$$F(v_i) = \begin{cases} 1 - \left(\frac{\underline{v}}{v_i}\right)^{-\varepsilon} & \text{if } v_i \geq \underline{v}, \\ 0 & \text{otherwise.} \end{cases}$$

Furthermore, assume the scale parameter $\underline{v}$ *is sufficiently small such that* $\min_{t \in T} r_t + s^M \geq \underline{v}$.

As in our analysis of the benchmark model, for any technology and regulation, the firm's equilibrium price satisfies the usual first order condition:

$$\left.\frac{\partial \mathcal{D}(p+r)\,(p-c)}{\partial p}\right|_{p^*(r)} \equiv 1 - F\left(p^*(r) + r + s^M\right) - f\left(p^*(r) + r + s^M\right)\left(p^*(r) - c\right) = 0,$$

where $r = Rr'_t + (1-R)r_t$. Note that, rather than defining a family of demand curves $\{\mathcal{D}_r(p)\}$ for each good quality r, we define the single demand curve induced by a good with quality $r = 0$ and, for simplicity, omit the subscript, i.e., $\mathcal{D}(p) := \mathcal{D}_r(p)|^{r=0}$. The family of demand curves for any given quality r can then be recovered via shift, i.e., $\mathcal{D}_r(p) = \mathcal{D}(p+r)$. Therefore,

$$p^*(r) = c + \frac{1 - F\left(p^*(r) + r + s^M\right)}{f\left(p^*(r) + r + s^M\right)},$$

and, using Assumption S.3.2, we have

$$p^*(r) = \frac{(-\varepsilon)c + r + s^M}{(-\varepsilon) - 1}.$$

Therefore, mirroring Lemma 1 of the benchmark model, for any technology t, the firm's equilibrium price is strictly higher with regulation, $p^*(r'_t) > p^*(r_t)$, with the price increase given by:

$$p^*(r'_t) - p^*(r_t) = \frac{r'_t - r_t}{(-\varepsilon) - 1} > 0.$$

It is also straightforward to show that the firm's equilibrium profits are lower with regulation: $\Pi(p^*(r'_t)) < \Pi(p^*(r_t))$.

In an analogy to Definition 1, we define the highest quality unregulated and regu-

[2]More precisely, the effect of an increase in r on equilibrium prices depends of the value of the derivative of the inverse hazard ratio (which must be strictly less than 1 to ensure the firm's profit maximization problem has a well-defined solution). An increase in r will: increase equilibrium prices if the derivative of the inverse hazard ratio is positive (e.g., as per the Pareto distribution); have no effect on equilibrium prices if the derivative of the inverse hazard ratio is zero (e.g., as per the Exponential distribution); decrease equilibrium prices if the derivative of the inverse hazard ratio is negative (e.g., as per the Uniform distribution).

lated technologies as

$$t^*(0) \equiv \arg\min_{t\in T} r_t \tag{S.3.3}$$

$$t^*(1) \equiv \arg\min_{t\in T} r'_t, \tag{S.3.4}$$

respectively. Given the regulatory environment R, the technology $t^*(R)$ simultaneously ensures the lowest equilibrium price and highest quality good. These technologies are also efficient given their respective regulatory environment: fixing regulation $R \in \{0,1\}$, both the firm and all consumers benefit from technologies that decrease r_t or r'_t. Therefore, and per the benchmark model, in the absence of regulation, the firm's and consumers' preferences over technologies are perfectly aligned.

It is immediate that Lemma 2 continues to hold verbatim. Therefore, we omit repeating the lemma statement and proof.

We now turn to the democratic first best (per the benchmark model, we maintain Assumption 2). Our definition of the democratic first best is conceptually the same as the benchmark model (Definition S.3.5) but has been appropriately modified to match the current setting.

Definition S.3.2 (Democratic first best when regulation affects quality.). *The democratic first best entails regulation if and only if a (strict) majority of consumers prefers regulation subject to the incentive-compatibility constraint of Lemma 2. I.e., when regulation affects quality, for a (strict) majority of consumers,*

$$\begin{cases} \max\left\{v_i - r'_{t^*(1)} - p^*(r'_{t^*(1)}), s^M\right\} & \text{if } \Pi(p^*, t^*(1), 1) > \gamma, \\ s^M & \text{if } \Pi(p^*, t^*(1), 1) \leq \gamma, \end{cases} \tag{S.3.5}$$

exceeds

$$\max\left\{v_i - r_{t^*(0)} - p^*(r_{t^*(0)}), s^M\right\} - e. \tag{S.3.6}$$

As in the benchmark model, we can fully characterize when the democratic first best entails regulation. The proof is delegated to Subsection S.3.7.

Lemma S.3.3 (De jure optimal regulation.). *When regulation affects quality, the democratic first best entails regulation if and only if either*

(i) *the profit-maximizing regulated technology is profitable and the quality cost plus the pass through induced by regulation of technology along the incentive-compatibility constraint of Lemma 2 is smaller than the per-capita externality e: $\Pi(p^*, t^*(1), 1) > \gamma$ and*

$$(r'_{t^*(1)} - r_{t^*(0)}) + (p^*(r'_{t^*(1)}) - p^*(r_{t^*(0)})) < e;$$

or

(ii) *less than half of consumers value the firm's good enough that they would, when produced with the profit-maximizing (and, hence, most efficient) unregulated technology, demand it even if the price internalized the per-capita value of the externality:* $1 - F\left(p^*(r_{t^*(0)}) + r_{t^*(0)} + s^M + e\right) < 1/2$.

As in the benchmark model (Assumption 3), we then assume that the democratic first best entails regulation, i.e., either (i) or (ii) in Lemma S.3.3 are satisfied.

Lemma S.3.4 redefines the term $\mathcal{P}(t) \in [0,1]$, which captures the share of consumers who vote not to adopt ex-post regulation (and to repeal any preemptive regulation) once the firm has developed technology t. The lemma statement is similar to Lemma 3 of the benchmark model. The only difference is that the pass through induced by regulation must also account for its effect on quality (similar to Part (i) of Lemma S.3.3) and consumer demand must account for the technology's quality (similar to Part (ii) of Lemma S.3.3). The proof is delegated to Subsection S.3.7.

Lemma S.3.4 (Voters' regulatory preferences.)**.** *When regulation affects quality, for any technology* $t \in T$*, if the firm develops* t*, then a share of consumers* $\mathcal{P}(t) \in [0,1]$ *vote not to adopt ex-post regulation (and to repeal any preemptive regulation). The share* $\mathcal{P}(t)$*:*

(i) *equals zero if the quality cost plus the pass through induced by regulation of technology* t *is smaller than the per-capita externality* e*:*

$$(r_t' - r_t) + (p^*(r_t') - p^*(r_t)) < e;$$

(ii) *otherwise equals the share of consumers who value the firm's good enough that they would, when produced with unregulated technology* t*, demand it even if the price internalized the per-capita value of the externality:*

$$\mathcal{P}(t) = 1 - F(p^*(r_t) + r_t + s^M + e)$$

Lemma 4 and its proof argument hold verbatim. Furthermore, we can utilize the same definition of political hold-up power (Definition 3) to obtain analogous versions of Propositions 1–3.

The only part of the proof argument of Proposition 1 that requires new justification in this extension is the claim that if the firm develops technology $t^*(1)$, then the firm obtains equilibrium payoff $\Pi(p^*, t^*(1), 1)) - \gamma$.

This is required to ensure that the implicit "outside option" described in the right-hand side of the constraint in (5) remains valid. This implication continues to hold in this extension because $\mathcal{P}(t^*(1)) < 1/2$ and then we can apply Lemma 4 (which holds verbatim in this extension). We provide the proof argument for this step in Subsection S.3.7.

Therefore, this extension retains the core insight from Section I.4: market power is power. The firm has de facto power, $\mathcal{P}^* \geq 1/2$, whenever the firm is able to choose a technology $t \in T$ that exhibits three factors:

(i) The firm's equilibrium "quality pass through" is sufficiently small: the technology t induces

$$(p^*(r'_t) + r'_t) - (p^*(r_t) + r_t) \geq e.$$

That is, prices fall sufficiently slowly with a decline in quality (in our special case, prices, in fact, increase).

(ii) The firm's market share (brand penetration) is sufficiently large:

$$\begin{aligned}
&\mathcal{D}(p^*(r_t) + r_t + e) \\
&\quad = \mathcal{D}(p^*(r_t) + r_t) - [F(p^*(r_t) + r_t + s^M + e) - F(p^*(r_t) + r_t + s^M)] \\
&\quad \geq 1/2.
\end{aligned}$$

Recall that $\mathcal{D}(p + r)$ is simply the quantity demanded when the firm chooses price p and its good has quality r.

(iii) The firm's equilibrium profits (markup times market share) are sufficiently large:

$$\Pi(p^*, t, 0) = \mathcal{D}(p^*(r_t) + r_t)(p^*(r_t) - c) > \max\{\gamma, \Pi(p^*, t^*(1), 1)\}.$$

When these three conditions hold, the political-economic equilibrium features no regulation and sufficiently large quality pass through, market share, and profits.

S.3.4 Taxes and Subsidies

In this appendix, we extend our benchmark model to include the possibility of a lump-sum tax $\ell > 0$ with income distributed in equal parts among consumers. Formally, the lump-sum tax ℓ is applied if and only if the firm *chooses* to produce the externality (i.e., choosing to produce at cost c_t instead of c'_t). When the lump-sum tax equals the externality, $\ell = e$, it resembles a Pigouvian-like tax.[3]

We begin by noting that, whenever Assumption 3 is satisfied, and absent any political hold-up problem (i.e., in our democratic first best benchmark) then there exists $\ell \geq e$ for which a majority of consumers prefers the firm to produce with the most profitable technology under levy ℓ to any other regulatory environment. I.e., the

[3]Figure S.3.1 formalizes the timing of the model. For simplicity, and consistently with tie-breaking rules in the benchmark model, we assume that consumers, whenever indifferent between the consequences of a levy and no levy, vote for no levy.

democratic first best entails a levy. The proof is in Subsection S.3.7.

Lemma S.3.5 (Democratic first best with levies.). *If levies are available, every levy $\ell \geq e$ induces a first-best outcome that is (weakly) majority-preferred to the first-best outcome induced by regulation (and also no regulation).*

Intuitively, a Pigouvian-like or larger levy either (i) induces the firm to produce without the externality and, hence, develop the profit-maximizing regulated technology—achieving the same result as banning the externality—or (ii) induces the firm to produce with the externality and, hence, develop the profit-maximizing unregulated technology—delivering consumers with the lowest possible price (given the incentive-compatibility constraints) and, via the levy, *at least* fully compensate them for the externality.

We now study under which circumstances the availability of any such levy $\ell > e$ induces a political-economic equilibrium with either a levy or (at least) regulation.[4] We begin by showing that even when voters have access to this more complex regulatory framework, market power yields de facto power to the firm to avoid regulation. The following lemma is an analogue to Lemma 4 and the proof is in Subsection S.3.7.

Lemma S.3.6 (*De jure* regulation with levies.). *Suppose a levy $\ell > e$ is available. For any technology $t \in T$, if the firm develops t, then consumers neither impose an ex-post levy nor regulate, and repeal any corresponding preemptive instrument, if and only if $\mathcal{P}(t) \geq 1/2$ and*

$$\Pi(p^*, t, 0) - \ell \leq \Pi\left(p^*, t, 1\right).$$

Intuitively, if the levy is so large that the firm prefers to produce without externality or not to produce at all, then the levy only achieves as much as regulation, and hence a majority of consumers vote to repeal (or not introduce) the levy if $\mathcal{P}(t) \geq 1/2$.

We can use this result to modify our measure of the firm's political hold-up power.

Definition S.3.3 (Political hold-up power with levies.). *Suppose a levy $\ell > e$ is available. The firm's political hold-up power with lump-sum levies is given by*

$$\begin{aligned} \mathcal{P}^*_\ell \equiv \max_{t \in T} & \mathcal{P}(t) \\ s.t.\ & \Pi\left(p^*, t, 0\right) - \gamma > \max\left\{0, \Pi\left(p^*, t^*(1), 1\right) - \gamma, \Pi\left(p^*, t^*(0), 0\right) - \ell - \gamma\right\} \\ & \Pi\left(p^*, t, 0\right) - \ell \leq \Pi\left(p^*, t, 1\right). \end{aligned} \tag{S.3.7}$$

For our main result, we focus on the case in which the policy choice is whether to introduce a levy ℓ that induces a democratic first-best outcome that is *strictly* better

[4]We focus on the levy being strictly greater than the externality, $\ell > e$, to avoid issues of indifference. Our results extend to the case of $\ell = e$ if an appropriate tie-breaking rule is applied when a consumer is indifferent between two regulatory outcomes.

than regulation for a majority of consumers. This occurs for some $\ell > e$ for which the firm strictly prefers to produce with the externality and pay the lump-sum tax than to produce without the externality (and avoid the tax). Formally, we assume[5]

$$\Pi\left(p^*, t^*(0), 0\right) - \ell - \gamma > \max\{0, \Pi\left(p^*, t^*(1), 1\right) - \gamma\} \tag{S.3.8}$$

Accordingly, for the purposes of Proposition S.3.1 (to come), we refer to such a levy ℓ as the *democratic first best* outcome.

As in the benchmark model, the firm has political hold-up power because it can choose to develop a technology such that a majority of consumers would, ex-post, prefer to repeal the levy. Hence, the democratic first best of a Pigouvian-like or larger levy ℓ is not achieved whenever the firm has sufficient political hold-up power. In such cases, the firm also avoids ex-post regulation.[6] The proof is in Subsection S.3.7.

Proposition S.3.1 (De facto regulation with levies.)**.** *Suppose Inequality (S.3.8) holds, so that the levy $\ell > e$ is the democratic first-best. The political-economic equilibrium does not achieve the democratic first best if and only if the firm's political hold-up power with lump-sum levies is greater than $1/2$: $\mathcal{P}_\ell^* \geq 1/2$.*

S.3.5 Extension: Oligopolistic competition

We now study an extension of our benchmark model in which there are $n \geq 2$ firms that produce a homogeneous good and simultaneously choose quantities. Firm 1 is "the firm" that is able to innovate and chooses whether to develop a new technology t. The other firms are assumed to have fixed technologies with constant marginal costs c_j, $j \in N_{-1} \equiv \{2, \ldots, n\}$, unaffected by the regulation policy R. We specialize to constant-elasticity demand. I.e., we make the same assumptions as in Corollary 1. Then, for interior solutions we have aggregate and inverse demand respectively:

$$D(p) = \left(\frac{\underline{v}}{p}\right)^{\eta}, \qquad p(Q) = \underline{v} Q^{-1/\eta},$$

where $\underline{v} > 0$ and $\eta > 1$. We say that a firm (or, equivalently, its product) is *unavailable* if it does not produce in equilibrium, and we say that a firm is active if it produces a

[5] For such an $\ell > e$ to exist, the assumption on model primitives is $\Pi\left(p^*, t^*(0), 0\right) - e - \gamma > \max\{0, \Pi\left(p^*, t^*(1), 1\right) - \gamma\}$. When the reverse inequality holds, the levy induces a first-best outcome that is equivalent to regulation. Accordingly, in equilibrium, a levy $\ell \geq e$ is never paid by the firm and the main implication of Proposition S.3.1 (to come) continues to hold. When, instead, equality holds, $\Pi\left(p^*, t^*(0), 0\right) - e = \Pi\left(p^*, t^*(1), 1\right)$, multiple equilibria can be sustained and the firm's political hold-up power $\mathcal{P}_\ell^* \geq 1/2$ is a sufficient but not necessary condition for the equilibrium to fail to achieve the democratic first best.

[6] We note that the democratic first best may entail a levy greater than the Pigouvian-like levy $\ell = e$, thus making it "easier" for the firm to develop a technology for which producing with externality is not sufficiently profitable. Nevertheless, an equivalent result holds if consumers are constrained to only use Pigouvian-like levies: ℓ arbitrarily close to e (recall also Footnote 4).

strictly positive quantity in equilibrium.

For any active firm j, the first-order condition is

$$p - c_j = -q_j p'(Q) = \frac{p}{\eta}\frac{q_j}{Q}, \tag{S.3.9}$$

where q_j is Firm j's quantity choice. We focus on interior market equilibria in which the price exceeds $\underline{v}$ and every firm in N_{-1} is active whether or not the firm (Firm 1) is present.[7] If the firm is absent, then, in such an equilibrium, the price is

$$p^{\emptyset} \equiv \frac{C_{-1}}{n-1-1/\eta}, \text{ with } C_{-1} \equiv \sum_{j \in N_{-1}} c_j,$$

Now suppose the firm is possibly active and has marginal cost c. Lemma S.3.7 characterizes the market equilibrium outcome.

Lemma S.3.7 (Constant-elasticity Cournot equilibrium)**.** *The unique market equilibrium outcome is*

$$p^*(c) = \begin{cases} \dfrac{C_{-1}+c}{n-1/\eta}, & c < p^{\emptyset}, \\ p^{\emptyset}, & c \geq p^{\emptyset}, \end{cases} \tag{S.3.10}$$

$$Q^*(c) = D(p^*(c)). \tag{S.3.11}$$

The firm chooses quantity

$$q^*(c) = s^*(c)Q^*(c), \text{ where } s^*(c) = \begin{cases} \eta\left(1 - \dfrac{c}{p^*(c)}\right), & c < p^{\emptyset}, \\ 0, & c \geq p^{\emptyset}. \end{cases} \tag{S.3.12}$$

The firm's equilibrium gross profits are

$$V(c) \equiv (p^*(c) - c)q^*(c). \tag{S.3.13}$$

When the firm is active, the equilibrium price is increasing and the firm's output, market share, Lerner index, and gross profits are decreasing in c.

Proof. Summing (S.3.9) across the n firms gives $np - \sum_j c_j = p/\eta$, which yields (S.3.10). The remaining expressions follow from demand and (S.3.9). Uniqueness of the equilibrium outcome can be readily verified from the firms' second-order conditions. The monotonicity claims for the equilibrium price, the firm's output, market share, and Lerner index $\mathcal{L}^*(c) \equiv (p^*(c) - c)/p^*(c) = s^*(c)/\eta$ follow from straightforward algebra.

[7] Such equilibria can be sustained if and only if the equilibrium price always exceeds c_j for every $j \in N_{-1}$.

For the firm's gross profits (when active), we have

$$\frac{dV(c)}{dc} = \left(\frac{dp^*(c)}{dc} - 1\right) q^*(c) + (p^*(c) - c)\frac{dq^*(c)}{dc} < 0.$$

The inequality follows because $\frac{dp^*(c)}{dc} < 1$, $q^*(c) > 0$, $p^*(c) - c > 0$, and $\frac{dq^*(c)}{dc} < 0$. ■

Thus, an analogue of Lemma 1 holds. Definitions 1 and 2, Lemma 2, and Assumptions 2 and 3 also apply without change, after replacing the benchmark monopoly profits with $V(c)$. In particular, $t^*(0)$ and $t^*(1)$ minimize, respectively, c_t and c'_t. We continue to assume that the democratic first best entails regulation.

We now consider the effects of regulation and, for simplicity of exposition, assume that—in *absence* of regulation—all technologies $t \in T$ lead the firm to be active. Suppose that the firm remains active under regulation. Then Equation (S.3.10) gives pass-through:

$$p^*(c'_t) - p^*(c_t) = \frac{c'_t - c_t}{n - 1/\eta} > 0. \tag{S.3.14}$$

Suppose instead that the firm is not active under regulation—in such cases, we say that the firm's technology t is *regulation-fragile*. To simplify calculations below, for any technology t, we write the unregulated outcomes as:

$$p_t \equiv p^*(c_t), \quad Q_t \equiv D(p_t), \quad s_t \equiv s^*(c_t), \quad q_t \equiv s_t Q_t, \quad L_t \equiv \frac{p_t - c_t}{p_t} = \frac{s_t}{\eta}. \tag{S.3.15}$$

If t is regulation-fragile, its pass-through is

$$\Delta p(t) \equiv p^{\emptyset} - p_t > 0. \tag{S.3.16}$$

Lemma 3 then holds verbatim. In the present notation,

$$\mathcal{P}(t) = \begin{cases} 0, & \Delta p(t) < e, \\ D(p_t + e) = Q_t \left(\dfrac{p_t}{p_t + e}\right)^{\eta}, & \Delta p(t) \geq e. \end{cases} \tag{S.3.17}$$

Definition 3 and Propositions 1 and 2 then hold verbatim. In particular, whenever it exists, t^*_{maj} is the most profitable unregulated technology such that $\mathcal{P}(t) \geq 1/2$.

The technological distortion we discussed in Proposition 3 relies on the fact that, when $t^*_{\text{maj}} \neq t^*(0)$, the political hold-up problem induces a higher marginal cost for the firm and, by (S.3.10), market price. In the present model, an increase in Firm 1's marginal cost raises the equilibrium price and, in turn, each competitors' profit. Therefore, as in our general model and in other applications, once competitors' profits are included, the political-economic equilibrium is not Pareto inferior to that alternative. Nevertheless, the political-economic equilibrium continues to produce a higher price, lower total output, lower consumer surplus, and lower profits for the firm than the alternative in which the firm is free to develop $t^*(0)$.

We now turn to discuss under which conditions we can neatly link market power to political hold up power in this oligopolistic model. Notice that the *pass-through* in (S.3.14) is independent of the firm's initial market share. As in the discussion of unavailability in Section I.5.2, the firm-level direct link between market power and political hold up power therefore applies only to technologies for which regulation makes the firm unavailable.

Corollary S.3.1 (Regulation-fragile technology.)**.** *A technology t is* regulation-fragile *if $c'_t \geq p^{\emptyset}$. If the firm develops a regulation-fragile technology and regulation is enacted ex post, then the firm produces no output and its competitors alone supply the market.*

Corollary S.3.2 (Market power *is* power.)**.** *Suppose every technology capable of inducing at least half of consumers to oppose regulation, $t : \mathcal{P}(t) \geq 1/2$, is regulation-fragile. The political-economic equilibrium features the firm developing a technology and no regulation if and only if there exists a technology $t \in T$ such that*

(i) *regulatory pass-through is sufficiently large:*

$$\frac{p_t L_t}{n - 1 - 1/\eta} \geq e; \tag{S.3.18}$$

(ii) *market penetration is sufficiently large:*

$$Q_t \left(\frac{p_t}{p_t + e} \right)^{\eta} \geq \frac{1}{2}; \tag{S.3.19}$$

(iii) *equilibrium gross profits—markup times market share and market size—are sufficiently large:*

$$p_t L_t s_t Q_t > \max\{\gamma, V(c'_{t^*(1)})\}. \tag{S.3.20}$$

In this case, in the political-economic equilibrium, the firm chooses the most profitable technology t^*_{maj} satisfying these conditions. Otherwise, the equilibrium achieves the democratic first best.

Moreover, among regulation-fragile technologies $a, b \in T$,

$$c_a < c_b \quad \Longrightarrow \quad \begin{array}{c} q_a > q_b, \quad s_a > s_b, \quad L_a > L_b, \\ V(c_a) > V(c_b), \quad \Delta p(a) > \Delta p(b), \quad \mathcal{P}(a) \geq \mathcal{P}(b). \end{array} \tag{S.3.21}$$

Consequently, if one regulation-fragile technology can profitably induce a majority to oppose regulation, every regulation-fragile technology with strictly greater market share or Lerner index can do so as well.

Proof. Conditions (i) and (ii) follow from Lemma 3, Equation (S.3.17), and noting that $C_{-1} = p_t(n-1/\eta) - c_t = p_t(n-1-1/\eta+L_t)$ and, hence, $\Delta p(t) \equiv p^{\emptyset} - p_t = \frac{p_t L_t}{n-1-1/\eta}$. Condition (iii) follows from noting that $V(c) = p^*(c)\mathcal{L}^*(c)s^*(c)Q^*(c)$ and the profitability constraint in Definition 3. Proposition 2 then gives the equilibrium statement. The ordering follows from Lemma S.3.7: a lower c_t lowers p_t, raises Q_t, s_t, q_t, L_t, and $V(c_t)$, and therefore raises both $p^{\emptyset} - p_t$ and $D(p_t+e)$. ∎

This is the same result as Corollary 1. Constant-elasticity Cournot competition changes only the market expressions. In particular, the firm's Lerner index and market share are now linked by $L_t = s_t/\eta$, while the price increase caused by regulatory unavailability is the markup $p_t L_t$ divided by $n-1-1/\eta$. Pass-through, market penetration, and profits otherwise play exactly the same roles as in the benchmark model.

S.3.6 Other implications with strategic competitors

Political hold-up power across firms. Fix an unregulated equilibrium in which all n firms are active. The equilibrium price p and market size Q are common across firms, and (S.3.15) implies

$$q_i \geq q_j \quad\iff\quad s_i \geq s_j \quad\iff\quad L_i \geq L_j.$$

If regulation makes firm i unavailable while leaving all other costs unchanged, then

$$\Delta p_i = \frac{pL_i}{n-1-1/\eta} = \frac{ps_i}{\eta(n-1-1/\eta)}, \qquad \pi_i = \frac{pQ}{\eta}s_i^2.$$

Thus, a firm with a larger equilibrium output, market share, or Lerner index has greater pass-through and gross profits. It also has weakly greater political hold-up power: conditional on crossing the pass-through threshold, the share of consumers opposing regulation is the common quantity $D(p+e)$. Hence, if a smaller firm can profitably induce a majority to oppose regulation, a larger firm in the same market can do so as well.

Industry standards and political cartels. The industry-standards argument in Section II.3 relies directly on several firms combining their political hold-up power. Let $S \subsetneq N$ contain $1 \leq m \leq n-1$ firms, and write $s_S \equiv \sum_{j\in S} s_j$ and $L_S \equiv \sum_{j\in S} L_j = s_S/\eta$. Suppose a common regulation makes every firm in S unavailable and leaves the other $n-m$ firms active. Using (S.3.9) and (S.3.15), the sum of total (unregulated) marginal costs $\sum_S c_j$ equals $p(n-1/\eta)$. Therefore, as in the proof of Lemma S.3.7, removing S yields equilibrium price and pass-through

$$p^{-S} = p\left(1 + \frac{L_S}{n-m-1/\eta}\right), \qquad \text{and} \quad \Delta p_S = \frac{pL_S}{n-m-1/\eta} = \frac{ps_S}{\eta(n-m-1/\eta)}. \tag{S.3.22}$$

The share of consumers opposing the common regulation is therefore

$$\mathcal{P}(S) = \begin{cases} 0, & \Delta p_S < e, \\ D(p+e), & \Delta p_S \geq e. \end{cases} \tag{S.3.23}$$

For $m > 1$, coalition pass-through is strictly superadditive:

$$\Delta p_S = \frac{pL_S}{n - m - 1/\eta} > \sum_{j \in S} \frac{pL_j}{n - 1 - 1/\eta}. \tag{S.3.24}$$

Thus, firms may each be unable to affect the regulatory vote but jointly able to induce a majority to oppose regulation.

To establish the incentive role of a standard, suppose all n firms have unregulated marginal cost c, an association contains $m \geq 2$ firms, and $r \equiv n - m \geq 1$ competitors remain outside the association. Association members can develop either a regulation-fragile technology H or a regulation-compatible technology C. Both have unregulated marginal cost c. Under regulation, H is unavailable while C remains active at marginal cost $c + \delta$, where $\delta \geq 0$. Let

$$p_k \equiv \frac{kc}{k - 1/\eta}, \qquad Q_k \equiv D(p_k), \qquad \pi_k \equiv \frac{p_k Q_k}{\eta k^2} \tag{S.3.25}$$

be the price, market size, and individual profit with k symmetric active firms. If one association member i develops C while all other members develop H, regulation leaves i and the r outsiders active and gives

$$p_i^R = \frac{(r+1)c + \delta}{r + 1 - 1/\eta}, \qquad s_i^R = \eta \left(1 - \frac{c+\delta}{p_i^R}\right), \qquad \pi_i^R = \frac{p_i^R D(p_i^R)}{\eta} (s_i^R)^2, \tag{S.3.26}$$

where parameters are such that $s_i^R > 0$.

Proposition S.3.2 (Industry standards can create a political cartel)**.** *Suppose*

$$p_i^R - p_n < e \leq p_r - p_n, \tag{S.3.27}$$

$$D(p_n + e) \geq \frac{1}{2}, \tag{S.3.28}$$

$$\pi_i^R > \pi_n > \gamma. \tag{S.3.29}$$

If every association member develops H, consumers reject regulation. Without an enforceable standard, however, this profile is not an equilibrium: any member can develop C, induce regulation, remain active while the other association members become unavailable, and earn strictly greater profits. An industry standard that admits only H eliminates this deviation and implements the all-H, no-regulation outcome. The standard therefore acts as a political cartel: it combines the association's market power and uses it to control the regulatory vote.

Proof. When every member chooses H, regulation raises the price from p_n to p_r. Equations (S.3.27) and (S.3.28), together with Lemma 3, imply that at least half of consumers oppose it. Each member earns $\pi_n - \gamma > 0$. If member i chooses C, regulation instead raises the price from p_n to p_i^R. The first inequality in (S.3.27) implies that every consumer supports regulation. Firm i remains active and earns $\pi_i^R - \gamma > \pi_n - \gamma$. A standard excluding C removes this deviation. ∎

S.3.7 Figures and proofs

Proof of Lemma S.3.3. Let $x_0 \equiv r_{t^*(0)} + p^*(r_{t^*(0)})$ and $x_1 \equiv r'_{t^*(1)} + p^*(r'_{t^*(1)})$, and define $q \equiv 1 - F(x_0 + s^M + e)$. For a share q of consumers , $v_i > x_0 + s^M + e$ and (excluding a measure-zero of consumers), for a share $1-q$ of consumers, $v_i < x_0 + s^M + e$.

Without regulation, consumer i's utility is $U_i^0 = \max\{v_i - x_0, s^M\} - e$. With regulation, it is

$$U_i^1 = \begin{cases} \max\{v_i - x_1, s^M\}, & \text{if } \Pi(p^*, t^*(1), 1) > \gamma, \\ s^M, & \text{if } \Pi(p^*, t^*(1), 1) \leq \gamma. \end{cases}$$

For all consumers with $v_i < x_0 + s^M + e$, $U_i^0 < s^M \leq U_i^1$, so they strictly prefer regulation. For all consumers with $v_i > x_0 + s^M + e$, $U_i^0 = v_i - x_0 - e > s^M$. If $\Pi(p^*, t^*(1), 1) \leq \gamma$, then $U_i^1 = s^M < U_i^0$, so they strictly prefer no regulation. If instead $\Pi(p^*, t^*(1), 1) > \gamma$, their preference depends on $\Delta \equiv x_1 - x_0$. Specifically:

if $\Delta < e$, they prefer regulation: $v_i - x_1 = v_i - x_0 - \Delta > v_i - x_0 - e = U_i^0 > s^M$, and hence $U_i^1 > U_i^0$;

if $\Delta = e$, they are indifferent: $U_i^1 = U_i^0$;

if $\Delta > e$, they strictly prefer no regulation: both $v_i - x_1 < U_i^0$ and $s^M < U_i^0$, so $U_i^1 < U_i^0$.

It follows that if $\Pi(p^*, t^*(1), 1) > \gamma$ and $\Delta < e$, then all consumers (except possibly the measure-zero at cutoff) strictly prefer regulation. This is Part (i).

In every remaining case—I.e., if regulated development is not profitable or if $\Delta \geq e$—the consumers who strictly prefer regulation are precisely those with $v_i < x_0 + s^M + e$. They are a strict majority if and only if

$$1 - q > \frac{1}{2} \iff 1 - F\left(p^*(r_{t^*(0)}) + r_{t^*(0)} + s^M + e\right) < \frac{1}{2}.$$ This is Part (ii). ∎

Proof of Lemma S.3.4. Follows from the same argument used in the Proof of Lemma S.3.3, after replacing $r_{t^*(0)}$ with r_t and $r'_{t^*(1)}$ with r'_t, noting that, because technology t has already been developed, the profitability condition in Part (i) of Lemma S.3.3 is irrelevant and recalling that indifferent consumers vote against regulation by the tie-breaking rule. ■

Proof that $\mathcal{P}(t^*(1)) < 1/2$. Recall that, by Assumption 3 as applied in this extension, either

$$(r'_{t^*(1)} - r_{t^*(0)}) + (p^*(r'_{t^*(1)}) - p^*(r_{t^*(0)})) < e; \tag{S.3.30}$$

or

$$1 - F\left(p^*(r_{t^*(0)}) + r_{t^*(0)} + s^M + e\right) < 1/2. \tag{S.3.31}$$

If the former, (S.3.30), holds, then

$$\begin{aligned}(r'_{t^*(1)} - r_{t^*(1)}) + (p^*(r'_{t^*(1)}) - p^*(r_{t^*(1)})) &\leq (r'_{t^*(1)} - r_{t^*(0)}) + (p^*(r'_{t^*(1)}) - p^*(r_{t^*(0)})) \\ &< e.\end{aligned}$$

The first inequality follows because, by the definition of $t^*(0)$,

$$r_{t^*(0)} \leq r_t \quad \text{and} \quad p^*(r_{t^*(0)}) \leq p^*(r_t) \qquad \text{for all } t \in T, \tag{S.3.32}$$

while the second follows from (S.3.30). Therefore, by Lemma S.3.4, $\mathcal{P}(t^*(1)) = 0 < 1/2$. If, instead, the latter (S.3.31) holds, then it follows that $1-F\left(p^*(r_{t^*(1)}) + r_{t^*(1)} + s^M + e\right) < 1/2$ because $F(\cdot)$ is an increasing function and the inequalities (S.3.31) and (S.3.32) hold. Therefore, by Lemma S.3.4, we then have $\mathcal{P}(t^*(1)) < 1/2$. ■

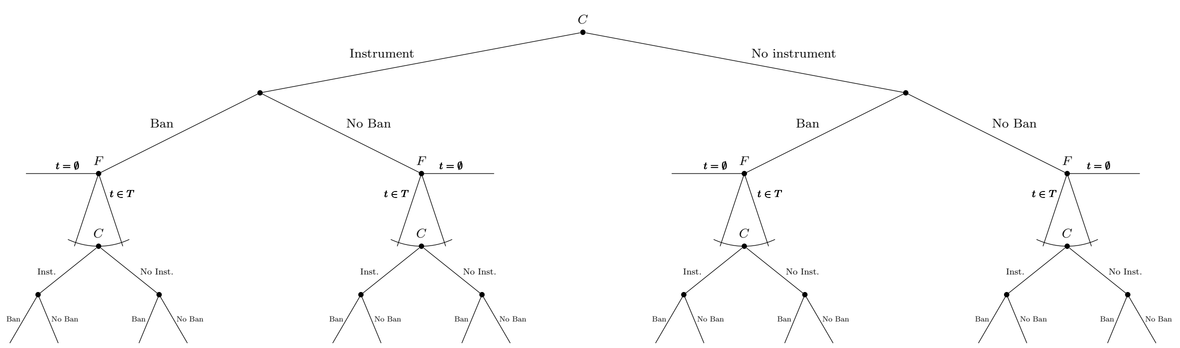

Figure S.3.1: Timing for benchmark model with additional instruments.

Proof of Lemma S.3.5. Consider a levy $\ell \geq e$. In the first-best exercise, the firm's optimal response is to either develop a profit-maximizing technology subject to the levy, i.e., maximizing $\Pi(p^*, t, 0) - \gamma - \ell$, or avoid the levy by either developing no technology (payoff 0) or develop a profit-maximizing technology that is not subject to the levy, i.e., maximizing $\Pi(p^*, t, 1) - \gamma$.

If the levy ℓ is such that the firm optimally avoids paying the levy, then the outcome is equivalent to regulation. The firm will optimally develop the profit-maximizing regulated technology $t^*(1)$ if it is profitable and, otherwise, develops no technology. In either case, the democratic first best is achieved and, hence, a majority of consumers (weakly) prefer the levy to regulation, and a strict majority of consumers prefer the levy to no regulation.

Now suppose the levy ℓ is such that the firm pays the levy. In this case, the firm optimally develops the most profitable unregulated technology $t^*(0)$ since the levy is independent of the technology developed. Accordingly, consumers face the lowest possible price $p^*(c_{t^*(0)})$ and the (net) externality after redistribution is non-negative $\ell - e \geq 0$. Whereas in the democratic first best outcome (induced by regulation), consumers face a strictly higher price $p^*(c'_{t^*(1)})$ (or, effectively, an infinite price if the firm optimally develops no technology) and the (net) externality is zero. Accordingly, every consumer prefers the levy to regulation (strictly so if $\ell > e$). Furthermore, every consumer prefers the levy to no regulation for any $\ell \geq e$. ■

Proof of Lemma S.3.6. Fix a technology $t \in T$ and solve the ex-post subgame by backward induction. If no levy is imposed, Lemma 4 implies that consumers reject ex-post regulation if and only if $\mathcal{P}(t) \geq 1/2$. Suppose instead that the levy is imposed. If

$$\Pi(p^*, t, 0) - \ell \leq \Pi(p^*, t, 1), \tag{S.3.33}$$

the firm produces without the externality to avoid paying the levy, where equality is resolved by the firm's tie-breaking rule. The resulting outcome is $(t, 1)$ regardless of whether consumers subsequently impose regulation. If instead

$$\Pi(p^*, t, 0) - \ell > \Pi(p^*, t, 1), \tag{S.3.34}$$

the firm pays the levy and produces with the externality unless regulation is imposed. Without regulation, consumer i receives $\max\{v_i - p^*(c_t), s^M\} + \ell - e$. With regulation, $\max\{v_i - p^*(c'_t), s^M\}$. Because $p^*(c'_t) > p^*(c_t)$ and $\ell > e$, every consumer strictly prefers the former outcome. Hence, conditional on the levy being imposed and (S.3.34) holding, consumers do not impose regulation.

Consider now the preceding vote on the levy. Suppose first that (S.3.33) holds. If $\mathcal{P}(t) < 1/2$, rejecting the levy induces regulation; adopting the levy induces the firm to produce without the externality. Consumers are therefore indifferent between the consequences of the levy and no levy and, by the tie-breaking rule, vote against the levy; regulation is then imposed. If instead $\mathcal{P}(t) \geq 1/2$, rejecting the levy induces no regulation (outcome $(t, 0)$); adopting the levy induces the firm to produce without the externality (outcome $(t, 1)$). By the definition of $\mathcal{P}(t)$ and the voting tie-breaking rule, the levy is rejected and then regulation is also rejected.

Finally, suppose (S.3.34) holds. Rejecting the levy induces either unregulated production and no transfer to consumers or regulated production at the higher price $p^*(c_t')$. Adopting the levy induces unregulated production and a transfer ℓ to consumers. Every consumer then strictly prefers adopting the levy to either alternative. Consumers then adopt the levy, and, as established above, do not adopt regulation.

Thus consumers collectively reject both the levy and regulation if and only if

$$\mathcal{P}(t) \geq \frac{1}{2} \quad \text{and} \quad \Pi(p^*, t, 0) - \ell \leq \Pi(p^*, t, 1).$$

The same continuation argument applies to the repeal of any preemptively established levy or regulation. ■

Proof of Proposition S.3.1. Suppose Inequality (S.3.8) holds, so that the levy $\ell^* > e$ is the democratic first-best. Because Inequality (S.3.8) holds and $\Pi(p^*, t^*(1), 1) > \Pi(p^*, t^*(0), 1)$, it then follows that

$$\Pi(p^*, t^*(0), 0) - \ell^* > \Pi(p^*, t^*(0), 1).$$

Therefore, conditional on the ex-post levy being imposed (and no regulation) and technology $t^*(0)$ having been developed, the firm optimally responds by producing with the unregulated technology and paying the levy. Furthermore, as noted within the proof of Lemma S.3.6, whenever (S.3.34) holds, the equilibrium features an ex-post levy and no ex-post regulation. The above inequality is precisely (S.3.34) with $t = t^*(0)$. Therefore, we conclude that if the firm develops $t^*(0)$, then their profit will be $\Pi(p^*, t^*(0), 0) - \ell$.

By Lemma S.3.6, the firm's optimal decision of which technology to develop is independent of any preemptive regulation or levies. We now consider alternative technologies that the firm could develop after the preemptive stage.

Case 1: Suppose $\mathcal{P}(t) \geq 1/2$ and (S.3.33) hold. By Lemma S.3.6, there is no ex-post regulation and no ex-post levy. Accordingly, the firm's profit is $\Pi(p^*, t, 0)$.

Case 2: Suppose Case 1 does not hold. By Lemma S.3.6, either ex-post regulation is imposed and/or an ex-post levy is imposed. In either case, the firm's profit is no larger than $\max\{\Pi(p^*, t, 0) - \ell^*, \Pi(p^*, t, 1)\}$. In fact, among all technologies in this case (Case 2), the technology that maximizes the firm's profit is the profit-maximizing unregulated technology $t^*(0)$, which delivers equilibrium profit $\Pi(p^*, t^*(0), 0) - \ell^*$. To see this, notice that

$$\Pi(p^*, t^*(0), 0) - \ell^* \geq \Pi(p^*, t, 0) - \ell \qquad \forall t \in T$$

and, because Inequality (S.3.8) holds,

$$\Pi(p^*, t^*(0), 0) - \ell^* > \Pi(p^*, t^*(1), 1) \geq \Pi(p^*, t, 1) \qquad \forall t \in T.$$

Furthermore, by (S.3.8), developing technology $t^*(0)$ delivers higher profit to the firm than developing no technology.

Combining the above analysis, we have that the firm's optimal decision is to either develop the profit-maximizing technology such that $\mathcal{P}(t) \geq 1/2$ and (S.3.33) hold (i.e., Case 1) or develop the profit-maximizing unregulated technology $t^*(0)$ (i.e., the most profitable technology among those in Case 2). Accordingly, if $\mathcal{P}_\ell^* \geq 1/2$, then the firm's optimal decision is to develop a technology such that $\mathcal{P}(t) \geq 1/2$ and (S.3.33) hold. In turn, the ex-post levy (nor regulation) is not imposed and the democratic first best is not achieved. If $\mathcal{P}_\ell^* < 1/2$, then the firm's optimal decision is to develop the most profitable unregulated technology $t^*(0)$. In turn, the ex-post levy is imposed and the democratic first best is achieved. ■