Supplementary material to "Adoption of green technology with financial friction"

Appendix A. Proofs

Proof of Proposition 1: The Pigouvian tax, $\tau^* = \rho$, implements optimal abatement as a comparison of (4) and (6) reveals; i.e., $\hat{q}_T(\rho) = q_T^*$ for $T \in \{B, G\}$. For the Pigouvian tax, all types

$$\theta \leq \frac{1}{1+r}\left[K_B(\rho) - K_G(\rho)\right] = \hat{\theta}^* \tag{A.1}$$

adopt the green technology, which completes the proof. □

Proof of Lemma 1: A firm with adoption cost θ has no incentive to report adoption cost $\hat{\theta}$ if

$$U(\theta) = M(\theta) + U_0 \geq$$
$$\frac{1}{1+r}\pi_1 + p(\hat{\theta})\Big\{L(\hat{\theta}) - \theta - \frac{1}{1+r}\left[K_G(\tau) + R(\hat{\theta})\right]\Big\} - (1 - p(\hat{\theta}))\frac{1}{1+r}K_B(\tau) \tag{A.2}$$

Rearranging the above expression and using the definition of $M(\hat{\theta})$ yields

$$M(\theta) \geq M(\hat{\theta}) + p(\hat{\theta})[\hat{\theta} - \theta]. \tag{A.3}$$

Thus, for $\theta > \hat{\theta}$, incentive compatibility is equivalent to

$$-p(\theta) \geq \frac{M(\theta) - M(\hat{\theta})}{\theta - \hat{\theta}} \geq -p(\hat{\theta}). \tag{A.4}$$

Thus, local incentive compatibility is satisfied if and only if (Börgers, 2015)

$$M'(\theta) = -p(\theta). \tag{A.5}$$

This notation – and ignoring the monotonicity constraint that needs to be satisfied for global incentive compatibility – allows us to write the bank's maximization problem in the way stated in the main text.

Note that

$$M(\theta) = M(\bar{\theta}) - \int_{\theta}^{\bar{\theta}} M'(z)\,\mathrm{d}z = \int_{\theta}^{\bar{\theta}} p(z)\,\mathrm{d}z, \tag{A.6}$$

with $M(\bar{\theta}) = 0$ because the participation constraint will be binding for the type with the highest adoption cost in optimum. Moreover, using integration by parts, we can show that

$$\int_{\underline{\theta}}^{\bar{\theta}} \int_{\theta}^{\bar{\theta}} p(z)\,\mathrm{d}z\, f(\theta)\,\mathrm{d}\theta = \int_{\underline{\theta}}^{\bar{\theta}} p(\theta)\frac{F(\theta)}{f(\theta)}\, f(\theta)\,\mathrm{d}\theta. \tag{A.7}$$

Thus, the bank's problem can be simplified to: maximize

$$\int_{\underline{\theta}}^{\bar{\theta}} p(\theta)\left[\frac{1}{1+r}\left(K_B(\tau) - K_G(\tau)\right) - \left(\theta + \frac{F(\theta)}{f(\theta)}\right)\right] f(\theta)\,\mathrm{d}\theta \tag{A.8}$$

subject to (i) $p(\theta) \in [0, 1]$ and (ii) $p(\theta)$ non-increasing. Applying point-wise optimization to (A.8) leads to the second-best loan contract provided in the lemma. Note that this contract satisfies the monotonicity constraint. Moreover, not offering a contract to a given type θ is equivalent to offering a loan contract with $p(\theta) = 0$, which trivially satisfies (PC) even though the outside option is strictly positive. □

Proof of Proposition 2: The result follows immediately from the observation that $\psi(\theta) > \theta$ for $\theta > \underline{\theta}$ and that $\psi(\theta)$ is strictly increasing. $\square$

Proof of Proposition 3: The subsidy S reduces the effective adoption costs to $\theta - S$, which directly leads to condition (17) when applying Lemma 1. The result now follows from (17) and the definition of $\hat{\theta}^* = \frac{1}{1+r}[K_B(\rho) - K_G(\rho)]$. $\square$

Proof of Corollary 1: The adoption costs are distributed according to density $f(\theta|a)1 + a - 2a\theta$ and c.d.f. $F(\theta|a) = (1 + a)\theta - a\theta^2$. First, note that the efficient threshold $\hat{\theta}^*$ is independent of the distribution function. Applying the specific distribution function to the result that $S^* = F(\hat{\theta}^*)/f(\hat{\theta}^*)$ (Proposition 3) yields

$$S^* = \frac{(1 + a)\hat{\theta}^* - a(\hat{\theta}^*)^2}{1 + a - 2a\hat{\theta}^*}. \tag{A.9}$$

Taking the derivative of S^* with respect to a yields

$$\frac{dS^*}{da} = \left[\frac{\hat{\theta}^*}{1 + a - 2a\hat{\theta}^*}\right]^2 > 0. \tag{A.10}$$

$\square$

Proof of Proposition 4: The regulator minimizes

$$SC(\tau) = \int_{\underline{\theta}}^{\hat{\theta}^{SB}} \left\{\frac{1}{1 + r}[c_G(q^{BAU} - \hat{q}_G(\tau)) + \rho\hat{q}_G(\tau)] + \theta\right\} f(\theta)\,\mathrm{d}\theta + \int_{\hat{\theta}^{SB}}^{\bar{\theta}} \frac{1}{1 + r}[c_B(q^{BAU} - \hat{q}_B(\tau)) + \rho\hat{q}_B(\tau)] f(\theta)\,\mathrm{d}\theta. \tag{A.11}$$

The partial derivative with respect to τ is given by

$$\begin{aligned} SC'(\tau) = &\int_{\underline{\theta}}^{\hat{\theta}^{SB}} \frac{1}{1 + r}\left[-c_G'(q^{BAU} - \hat{q}_G(\tau))\frac{d\hat{q}_G}{d\tau} + \rho\frac{d\hat{q}_G}{d\tau}\right] f(\theta)\,\mathrm{d}\theta \\ &+ \left\{\frac{1}{1 + r}[c_G(q^{BAU} - \hat{q}_G(\tau)) + \rho\hat{q}_G(\tau)] + \hat{\theta}^{SB}\right\} f(\hat{\theta}^{SB})\frac{d\hat{\theta}^{SB}}{d\tau} \\ &+ \int_{\hat{\theta}^{SB}}^{\bar{\theta}} \frac{1}{1 + r}\left[-c_B'(q^{BAU} - \hat{q}_B(\tau))\frac{d\hat{q}_B}{d\tau} + \rho\frac{d\hat{q}_B}{d\tau}\right] f(\theta)\,\mathrm{d}\theta \\ &- \frac{1}{1 + r}\left[c_B(q^{BAU} - \hat{q}_B(\tau)) + \rho\hat{q}_B(\tau)\right] f(\hat{\theta}^{SB})\frac{d\hat{\theta}^{SB}}{d\tau}. \end{aligned} \tag{A.12}$$

Using that $c_T'(q^{BAU} - \hat{q}_T(\tau)) = \tau$ for $T \in \{B, G\}$ and rearranging yields

$$\begin{aligned} SC'(\tau) = &(\rho - \tau)\frac{1}{1 + r}\left[F(\hat{\theta}^{SB})\frac{d\hat{q}_G}{d\tau} + [1 - F(\hat{\theta}^{SB})]\frac{d\hat{q}_B}{d\tau}\right] \\ &+ f(\hat{\theta}^{SB})\frac{d\hat{\theta}^{SB}}{d\tau}\left\{\frac{1}{1 + r}\left[K_G(\tau) - K_B(\tau) + (\rho - \tau)(\hat{q}_G - \hat{q}_B)\right] + \hat{\theta}^{SB}\right\}. \end{aligned} \tag{A.13}$$

Note that

$$\hat{\theta}^{SB} = \frac{1}{1 + r}[K_B(\tau) - K_G(\tau)] - \frac{F(\hat{\theta}^{SB})}{f(\hat{\theta}^{SB})}. \tag{A.14}$$

Thus,

$$SC'(\tau) = (\rho - \tau)\frac{1}{1+r}\left[F(\hat{\theta}^{SB})\frac{d\hat{q}_G}{d\tau} + [1 - F(\hat{\theta}^{SB})]\frac{d\hat{q}_B}{d\tau}\right] - f(\hat{\theta}^{SB})\frac{d\hat{\theta}^{SB}}{d\tau}\left\{\frac{1}{1+r}(\rho - \tau)[\hat{q}_B - \hat{q}_G] + \frac{F(\hat{\theta}^{SB})}{f(\hat{\theta}^{SB})}\right\}. \quad \text{(A.15)}$$

From (A.15) it is apparent that $SC'(\tau) < 0$ for all $\tau \leq \rho$. Thus, the second-best optimal tax τ^{SB} exceeds the Pigouvian tax $\tau^* = \rho$. Rearranging the first-order condition, $SC'(\tau) = 0$, gives equation (20) provided in the proposition.

□