

Underinvestment, Renegotiation and Bridge Financing in Emergency Medical Service Public–Private Partnerships: A Stackelberg Analysis of For-Profit and Non-Profit Providers

Senthilkumar Anantharaman

senthilkumara1851@gmail.com

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Underinvestment, Renegotiation and Bridge Financing in Emergency Medical Service Public–Private Partnerships: A Stackelberg Analysis of For-Profit and Non-Profit Providers

Abstract

Emergency medical services (EMS) in India are delivered almost entirely through public–private partnerships (PPPs) in which a state government supplies capital and a private operator, corporate or non-profit, supplies non-contractible operating effort. We model this arrangement as a Stackelberg game with moral hazard on a Cobb–Douglas model-based service technology, and obtain closed-form solutions for equilibrium investment, effort, output and payoffs. Four results follow. First, an interior equilibrium exists if and only if the *effective* return to public capital, $\eta = 2\alpha_2/(2 - \alpha_1)$, is below unity, which requires $\alpha_1 + 2\alpha_2 < 2$; this condition, rather than constant returns to scale, governs the existence of the partnership, and its violation produces the numerically degenerate solutions reported in earlier work on this model (Anantharaman, 2022). Second, the government structurally underinvests: whenever the effort elasticity exceeds a low threshold ($\bar{\alpha}_1 \approx 0.09$ under our calibration), equilibrium investment is below first best, at our central parameters, 28.9 per cent of it, because the principal internalises only the tax share of the operator’s marginal return. Third, a tax-exempt non-profit operator dominates a taxed corporate operator for *every* non-negative mission weight, and a non-profit whose mission weight equals $\lambda^* = 1 - 1/m$ (where m is the social multiplier on service output) implements the first best exactly; but because the government does not bear the operator’s effort cost, its ranking of providers is monotone in the mission weight while welfare is single-peaked, so the principal over-selects high-mission providers. Fourth, under a demand surge, renegotiation is feasible only up to a surge intensity $\bar{\theta}$, efficient bargaining assigns essentially the whole surge cost to the government, and investor bridge financing, the fallback when the public budget binds, sustains service only up to $\hat{\theta} \ll \bar{\theta}$; at our calibration the investor route covers just 15.7 per cent of the surge range that renegotiation covers. The welfare-maximising investor revenue share is $\delta^* = 2\alpha_2/(\alpha_1 + 2\alpha_2)$, invariant to the investor’s required rate of return. We also show that a per-case insurance subsidy, widely advocated to reduce out-of-pocket exposure, crowds out public capital formation in the second best unless capital budgets are ring-fenced. The analysis implies that pre-committed, state-contingent surge clauses dominate ex post renegotiation, and that tax exemption and non-profit empanelment are second-best instruments of first order in EMS PPPs.

Keywords: public–private partnership; emergency medical services; principal–agent; Stackelberg equilibrium; moral hazard; renegotiation; non-profit provider; India

JEL codes: H44, I18, L33, D82, C72

1. Introduction

Medical emergencies are the paradigmatic case of a service whose social value greatly exceeds the price at which it is transacted. In India the public sector finances less than a fifth of total health expenditure, and roughly nine-tenths of private health expenditure is paid out of pocket at the point of use. Against this fiscal background, every major state has delivered pre-hospital emergency care through a public–private partnership since the “108” ambulance programme began in 2005, contracting with corporate operators such as GVK EMRI and Ziqitza Health Care and with non-profit and trust-based providers, under a common emergency number now being consolidated as 112.

The economics of these contracts is a principal–agent problem of a particular shape. The government is the principal: it sets the tariff, bears the capital cost of fleet and communications infrastructure, and values the service at a social multiple of its price because averted mortality and morbidity accrue to citizens rather than to the contracting parties. The operator is the agent: it exerts effort, crew discipline, response-time management, vehicle availability, protocol adherence, which is costly, unobservable, and the principal determinant of whether a dispatched ambulance actually saves a life. Contracts specify investment, vehicle counts and headline response-time targets; they cannot specify effort.

This paper builds a tractable Stackelberg model of that relationship and asks four questions. What determines whether a viable partnership exists at all? Does the government invest efficiently? Does the ownership form of the operator, corporate or non-profit, matter, and in which direction? And what happens when a pandemic or a cyclone produces a demand surge that the original contract did not contemplate?

Our answers are analytical and, we believe, sharper than the qualitative claims that dominate this literature. The model yields closed-form expressions for equilibrium investment, effort, output and the payoffs of all parties, which lets us characterise the distortion exactly rather than describe it.

1.1 Contributions

An existence condition with content. Substituting the operator’s best response into the government’s problem raises the exponent on public capital from α_2 to $\eta = 2\alpha_2/(2 - \alpha_1)$, the strategic complementarity between capital and effort amplifies the return to investment. The government’s objective is concave, and an interior equilibrium exists, if and only if $\eta < 1$, equivalently $\alpha_1 + 2\alpha_2 < 2$. This is *not* the constant-returns condition $\alpha_1 + \alpha_2 = 1$ imposed in earlier treatments of this model (Anantharaman, 2022). It also explains a recurring numerical pathology: as $\eta \rightarrow 1^-$ with $\eta\Phi < 1$, equilibrium investment $I^* = (\eta\Phi)^{1/(1-\eta)}$ collapses at a doubly exponential rate, producing payoffs of order 10^{-25} to 10^{-30} of the kind reported as equilibria by Anantharaman (2022, Figs. 8–12). They are boundary artefacts (Section 8.1, Figure 2).

Underinvestment as structure, not opportunism. We compare the Stackelberg outcome with the first best and show that the government underinvests whenever $\alpha_1 > \bar{\alpha}_1$, where $\bar{\alpha}_1$ solves a closed-form threshold condition and equals 0.093 at our central calibration. The cause is not government opportunism but an accounting fact: the principal’s marginal valuation of output is

$tr + k$, whereas the social valuation is k and the agent internalises only $(1 - t)r$. At the central calibration, equilibrium investment is 28.9 per cent of first best, effort 26.9 per cent, output 27.1 per cent and welfare 50.4 per cent.

Ownership form. Recasting the non-profit as a tax-exempt operator with a mission weight λ on social value, we show that the government prefers the non-profit for every $\lambda \geq 0$ whenever the tax rate is strictly positive, because the revenue tax destroys more output than it raises. More strikingly, the non-profit with $\lambda^* = 1 - 1/m$ implements the *first best exactly*, a rare instance in which a second-best instrument (ownership form) is fully corrective. But because the government's objective omits the operator's effort cost, U_G is monotone increasing in λ while welfare is single-peaked at λ^* : a principal maximising its own payoff over-selects high-mission providers and pushes them past the socially efficient level of exertion.

Surges, renegotiation and bridge financing. We model a surge as a degradation of effective output, $\theta(\theta) = e^{-\theta}$, together with a convex cost shock $C(\theta)$, and compare a renegotiation regime R_1 (government tops up capital and absorbs a share β of the shock) with a bridge-financing regime R_2 (a third-party investor supplies capital for a share δ of the operator's revenue, when the public capital budget binds). Renegotiation is feasible for $\theta \leq \bar{\theta}$; the Nash bargaining split assigns the entire surge cost to the government until θ is near $\bar{\theta}$, because the government captures the bulk of the joint surplus. The investor route sustains participation only for $\theta \leq \hat{\theta}$, and $\hat{\theta} \ll \bar{\theta}$, 0.074 against 0.474 at our calibration, because the investor's claim erodes precisely the operator margin that must absorb the shock. Bridge financing is therefore not a substitute for renegotiation but a strictly inferior fallback, and the welfare-maximising revenue share $\delta^* = 2\alpha_2/(\alpha_1 + 2\alpha_2)$ does not depend on the investor's required return.

Publicly financed insurance that lowers out-of-pocket exposure by paying a share σ of the tariff reduces the government's residual valuation of output from $tr + k$ to $tr + k - \sigma r$, and therefore lowers equilibrium capital investment, to 63.3 per cent of its unsubsidised level at full coverage. The subsidy is welfare-neutral as a transfer but distortionary through the principal's investment margin, unless the capital budget is ring-fenced from the reimbursement budget.

Section 2 reviews the related literature. Section 3 sets out the model. Section 4 solves the benchmark and derives the underinvestment result. Section 5 compares provider types. Section 6 analyses surges. Section 7 examines insurance. Section 8 reports the numerical analysis and calibration. Section 9 draws policy implications and Section 10 concludes. Proofs are in Appendix A.

2. Literature Review

The literature review is built on the following four pillars to address the problem.

PPP design and the bundling question. The modern theory of PPPs turns on whether bundling construction and operation internalises quality externalities. Hart (2003) and Bennett and Iossa (2006) show that bundling is desirable when investment in the build stage raises operating quality and quality is contractible enough to protect; Iossa and Martimort (2015) survey the incentive structure of PPP contracts and emphasise the role of risk allocation and the cost of

public funds. Bettignies and Ross (2004) frame public–private choice as a comparison of incomplete contracts. Our setting is the operating phase of a bundled contract with a non-contractible effort margin, which is where that literature locates the residual moral hazard.

Renegotiation. Guasch, Laffont and Straub (2007, 2008) document that a large majority of Latin American infrastructure concessions were renegotiated within a few years of award, typically to the concessionaire’s advantage, and link renegotiation frequency to the award mechanism and to regulatory institutions. Engel, Fischer and Galetovic (2014) argue that renegotiation is endogenous to contract design and that present-value-of-revenue contracts limit it. De Brux (2010) applies Nash bargaining to concession renegotiation. Our contribution here is to give renegotiation a *feasibility frontier*: for a given shock process, there is a surge intensity above which no split of the shock keeps both parties in the contract, and we characterise it.

Non-profit provision and mission. Glaeser and Shleifer (2001) model the non-distribution constraint as a commitment device; Besley and Ghatak (2005, 2017) show that matching mission-oriented agents to mission-oriented principals raises effort and lowers the required power of incentives. Lakdawalla and Philipson (2006) analyse non-profits as for-profits in disguise with an altruistic shifter. Our Propositions 5 and 6 sit in this tradition but add a specific caution: the alignment that makes mission attractive to the principal is not bounded by welfare, because the principal does not bear the agent’s effort cost.

Health system PPPs in India and other LMICs. Raman and Björkman (2008) and Venkat Raman and Björkman (2009) catalogue Indian health PPPs; Subhan and Jain (2010) describe the fragmentation of Indian emergency care; Sharma and Brijnath (2018) and Bhattacharyya et al. (2010) assess the 108 model’s coverage and equity effects. This literature is predominantly descriptive and case-based. Analytical treatments of EMS as a contracting problem are scarce; the operations literature on EMS (Brotcorne, Laporte and Semet, 2003; Aringhieri et al., 2017) concentrates on location and dispatch rather than on the financing relationship. We aim to supply the missing contracting model.

3. The model

3.1 Players, timing and technology

Three risk-neutral parties may be involved: a **government** (principal, G), a **service provider** (agent, S), and, in one regime, an **investor** (V). The timing is shown in Figure 1.

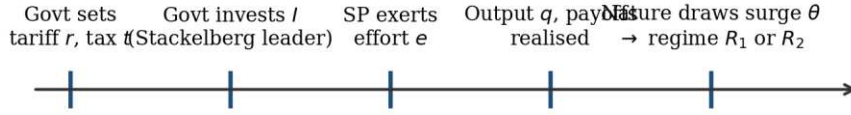


Figure 1. Timeline of the EMS PPP game.

1. The government sets the per-case tariff r and the tax rate t and commits to them.
2. The government, as Stackelberg leader, chooses capital investment $I \geq 0$.
3. The operator accepts or rejects. On acceptance it chooses non-contractible effort $e \geq 0$.
4. Service output is realised and payoffs accrue.
5. Nature may draw a demand surge of intensity $\theta \geq 0$, after which the parties enter regime R_1 (renegotiation) or R_2 (investor bridge financing).

Effective service output, cases successfully served, the quantity that carries social value, follows a Cobb Douglas model degraded by the surge:

$$q(e, I; \theta) = A \theta(\theta) e^{\alpha_1} I^{\alpha_2}, \quad \theta(\theta) = e^{-\theta}, \quad \theta(0) = 1,$$

where $A > 0$ is system efficiency, $\alpha_1 \in (0,1)$ the elasticity of output with respect to effort and $\alpha_2 \in (0,1)$ the elasticity with respect to public capital. The surge intensity is defined, as in the empirical EMS literature, as the proportional excess of crisis demand over baseline demand, $\theta = (d_{\text{crisis}} - d_0)/d_0$. Congestion means that a given fleet and a given crew effort convert into proportionately fewer *successfully completed* responses as the queue lengthens, which is what $\theta' < 0$ captures.

Effort is costly and convex, $\psi(e) = 1/2 \rho e^2$, $\rho > 0$. Output is realised with probability $p \in (0,1]$; the effort cost is borne regardless of realisation.

Remark 1 (a repaired specification). If the effort cost is instead written as $p \psi(e)$, that is, if the agent pays for effort only when the service succeeds, then p factors out of the agent's first-order condition entirely and the “probability of high effort” does no work anywhere in the model. Specifications of this form appear in the applied PPP literature, including Anantharaman (2022), and should be avoided: sunk effort must be sunk.

3.2 Payoffs

Citizens pay the tariff r per case out of pocket, consistent with the Indian financing pattern; Section 7 relaxes this. The government values each case served at $k = mr$, $m > 1$, where m is the social multiplier on emergency care (averted mortality, productivity, catastrophic-expenditure avoidance). The operator's revenue is taxed at rate t .

For a corporate (for-profit) operator,

$$U_S(e, I) = p(1-t)r q(e, I; \theta) - 1/2 \rho e^2,$$

$$U_G(e, I) = p(tr + k) q(e, I; \theta) - I.$$

Social welfare nets out transfers:

$$W(e, I) = p k q(e, I; \theta) - 1/2 \rho e^2 - I.$$

3.3 Assumptions

A1. All parties are risk-neutral and there is no outside financing constraint in the benchmark.

A2. I is contractible and verifiable; e is private to the operator.

A3. $\alpha_1, \alpha_2 \in (0, 1)$ and $\alpha_1 + 2\alpha_2 < 2$ (Proposition 1 shows this is exactly the condition for an interior solution).

A4. The operator's reservation payoff is normalised to zero; participation binds only in the surge regimes.

A5. $m > 1$: emergency care has social value strictly above its transacted price.

4. Benchmark: normal operations

4.1 The operator's problem

Given I , the operator solves $\max_e U_S(e, I)$. The first-order condition $p(1-t)rA\theta\alpha_1 e^{\alpha_1-1} I^{\alpha_2} = \rho e$ gives the best response

$$e^*(I) = \left[\frac{p \alpha_1 (1-t) r A \theta}{\rho} \right]^{\frac{1}{2-\alpha_1}} I^{\frac{\alpha_2}{2-\alpha_1}} \equiv K I^{\eta/2},$$

where

$$K = \left[\frac{p \alpha_1 (1-t) r A \theta}{\rho} \right]^{\frac{1}{2-\alpha_1}}, \quad \eta \equiv \frac{2\alpha_2}{2-\alpha_1}.$$

The second-order condition holds for $\alpha_1 < 2$, which A3 implies. Effort is increasing in the tariff, in system efficiency and in public capital, and decreasing in the tax rate, the effort-cost parameter and the surge intensity.

4.2 The government's problem and the existence condition

Substituting (4) into (2),

$$U_G(I) = \Phi I^\eta - I, \quad \Phi \equiv p(tr + k) A \theta K^{\alpha_1}.$$

Proposition 1 (Existence and the effective return to public capital). *The government's reduced-form objective (6) is strictly concave, and an interior Stackelberg equilibrium $(e^*, I^*) \gg 0$ exists and is unique, if and only if*

$$\eta = \frac{2\alpha_2}{2 - \alpha_1} < 1 \quad \Leftrightarrow \quad \alpha_1 + 2\alpha_2 < 2.$$

If $\eta \geq 1$ the government's payoff is unbounded above in I and no interior equilibrium exists; the model must then be closed with a budget constraint.

Two comments. First, the exponent on public capital in the *reduced* problem is η , not α_2 : because the operator's effort responds to capital, the government faces an amplified return. The amplification factor $2/(2 - \alpha_1)$ is increasing in α_1 , so effort-intensive services make public capital more, not less, productive at the margin, an argument for capital deepening in labour-intensive emergency systems. Second, the relevant existence condition is not constant returns to scale. At $\alpha_1 = 0.9$, $\alpha_2 = 0.1$ we have $\alpha_1 + \alpha_2 = 1$ but $\eta = 0.18$: existence is comfortable, and it would remain comfortable at $\alpha_1 + \alpha_2 = 1.4$ (e.g. $\alpha_1 = 0.9, \alpha_2 = 0.5, \eta = 0.91$) while failing at $\alpha_1 + \alpha_2 = 1.15$ if α_2 were 0.55.

4.3 Closed-form equilibrium

Proposition 2 (Equilibrium in closed form). *Under A1–A5,*

$$I^* = (\eta\Phi)^{\frac{1}{1-\eta}}, \quad e^* = K(I^*)^{\eta/2}, \quad q^* = A\theta(e^*)^{\alpha_1}(I^*)^{\alpha_2},$$

and the equilibrium payoffs admit the compact forms

$$U_G^* = I^* \frac{1 - \eta}{\eta}, \quad U_S^* = \rho(e^*)^2 \frac{2 - \alpha_1}{2\alpha_1}.$$

The two expressions in (7) are worth pausing on. The government's equilibrium payoff is a fixed multiple of its own outlay, the multiple depending only on η : a system with a low effective capital return extracts a *higher* payoff per rupee invested but invests far less. The operator's payoff is proportional to the square of its equilibrium effort, scaled by $(2 - \alpha_1)/(2\alpha_1)$, which is decreasing in α_1 , in effort-elastic services the operator retains a smaller share of the surplus its effort creates, because it competes away the rent through higher exertion.

4.4 First best and structural underinvestment

Under contractible effort the planner solves $\max_{e,I} W(e, I)$, which has the same structure with the operator's private return $(1 - t)r$ replaced by the social value k and the government's return $tr + k$ likewise replaced by k :

$$e^{FB}(I) = K_{FB} I^{\eta/2}, \quad K_{FB} = \left[\frac{p\alpha_1 k A \theta}{\rho} \right]^{\frac{1}{2-\alpha_1}}, \quad I^{FB} = (\eta\Phi_{FB})^{\frac{1}{1-\eta}}, \quad \Phi_{FB} = p k A \theta K_{FB}^{\alpha_1}.$$

Hence, writing $a \equiv \alpha_1/(2 - \alpha_1)$,

$$\frac{I^*}{I^{FB}} = \left(\frac{\Phi}{\Phi_{FB}} \right)^{\frac{1}{1-\eta}}, \quad \frac{\Phi}{\Phi_{FB}} = \frac{m+t}{m} \left(\frac{1-t}{m} \right)^a.$$

Proposition 3 (Structural underinvestment). *The government underinvests relative to the first best, $I^* < I^{FB}$, if and only if*

$$\frac{\alpha_1}{2 - \alpha_1} > \frac{\ln((m+t)/m)}{\ln(m/(1-t))} \Leftrightarrow \alpha_1 > \bar{\alpha}_1,$$

where $\bar{\alpha}_1$ is the unique root of $\ln((m+t)/m) + \alpha_1/2 - \alpha_1 \ln((1-t)/m) = 0$ in $(0,2)$. Equilibrium effort and output are likewise below first best whenever $(1-t)r < k$, i.e. whenever $m > 1-t$.

At the central calibration ($m = 3$, $t = 0.2$), $\bar{\alpha}_1 = 0.093$. For any plausible EMS services, the effort elasticity comfortably exceeds this, so underinvestment is generic. The magnitude is large: $\Phi/\Phi_{FB} = 0.362$ and $I^*/I^{FB} = 0.289$.

The economic content of Proposition 3 differs from the informal claim, common in the applied PPP literature and advanced in Anantharaman (2022), that governments underinvest opportunistically towards concessionaires. Here the government is fully committed, fully rational and non-strategic beyond its leadership in I . It underinvests because its objective (2) values the operator's marginal revenue at tr , the tax it collects, while society values the resulting output at $k = 3r$. The wedge is an artefact of the fiscal architecture, not of behaviour, and it is *not* repaired by better monitoring of the operator. It is repaired by changing what the government internalises, which is what Sections 5 and 7 take up.

5. Provider type: corporate versus non-profit

Let the non-profit operator be tax-exempt ($t = 0$) and attach a weight $\lambda \geq 0$ to the social value of the service it delivers, so that its objective is

$$U_N(e, I) = p(r + \lambda k) q(e, I; \theta) - 1/2 \rho e^2,$$

while the government's payoff loses the tax term, $U_G^N = p k q - I$. The non-distribution constraint is captured by $\lambda > 0$ rather than modelled directly, following Glaeser and Shleifer (2001) and Besley and Ghatak (2005).

Proposition 4 (Tax exemption dominates). *For every $t > 0$ and every $\lambda \geq 0$, the government strictly prefers the non-profit operator: $U_G^{N*} > U_G^*$. The preference is strict even at $\lambda = 0$, where the non-profit differs from the corporate operator only in tax status.*

The mechanism is that a revenue tax reduces the operator's marginal return from r to $(1-t)r$, contracting effort by a factor $(1-t)^{1/(2-\alpha_1)}$ and output correspondingly, while returning only tr per case to a principal that values each case at mr . With $m = 3$, a rupee of tax revenue destroys roughly three rupees of social value at the margin. At $\lambda = 0$, $\Phi_N/\Phi_F = 1.125$.

Proposition 5 (A mission weight that implements the first best). *A tax-exempt non-profit with mission weight*

$$\lambda^* = 1 - \frac{1}{m}$$

induces exactly the first-best effort and first-best investment, so that $W(\lambda^*) = W^{FB}$.

The proof is immediate: at λ^* the operator's private return is $r + \lambda^*k = r + (m - 1)r = mr = k$, so its effort first-order condition coincides with the planner's, and the government's investment return is already k under exemption. Ownership form here is a fully corrective second-best instrument, an unusual property, and one that rationalises the prominence of trust-based and society-based operators in Indian EMS contracting on efficiency rather than purely distributional grounds.

Proposition 6 (The principal over-selects mission). *U_G^{N*} is strictly increasing in λ on $[0, \infty)$, whereas W is strictly single-peaked with maximum at $\lambda^* = 1 - 1/m$. Consequently a government maximising its own payoff selects operators with $\lambda > \lambda^*$ and induces socially excessive effort.*

The asymmetry is that U_G omits $1/2 \rho e^2$: the operator's exertion is a cost to the operator and to society but not to the principal. At $\lambda = 1$ the government's payoff is 48 per cent above its value at λ^* while welfare is 21 per cent below it; at $\lambda = 1.5$ welfare is negative (Table 3, Figure 5). In EMS this maps onto a familiar operational pathology, crew burnout, unpaid overtime and volunteer attrition in high-mission providers, which a government scoring bidders on service metrics alone will not see.

6. Demand surges: renegotiation and bridge financing

A surge of intensity θ has two effects: it degrades effective output through $\theta(\theta) = e^{-\theta}$, and it imposes a convex operating cost $C(\theta)$, with $C(0) = 0$, $C' > 0$, $C'' > 0$. The original contract fixed I and r ; neither was written state-contingently.

6.1 Regime R_1 : renegotiation

The parties reopen the contract. The government resets investment to $I_1(\theta)$, its unconstrained best response given $\theta(\theta)$, and absorbs a share $\beta \in [0, 1]$ of the shock. Because $C(\theta)$ is a lump sum, it does not enter either first-order condition: equilibrium effort and investment under R_1 are exactly the benchmark quantities evaluated at $\theta(\theta)$. The shock therefore operates entirely through the *participation* constraints, which is what makes renegotiation succeed or fail.

Write $\tilde{U}_S(\theta)$ and $\tilde{U}_G(\theta)$ for the gross payoffs before the shock is allocated. Participation requires

$$\tilde{U}_S(\theta) - (1 - \beta)C(\theta) \geq 0 \quad \text{and} \quad \tilde{U}_G(\theta) - \beta C(\theta) \geq 0.$$

Proposition 7 (The renegotiation frontier). *A mutually acceptable renegotiation exists if and only if*

$$\tilde{U}_S(\theta) + \tilde{U}_G(\theta) \geq C(\theta),$$

which, since the left side is strictly decreasing and the right side strictly increasing in θ , defines a unique threshold $\bar{\theta}$ such that renegotiation succeeds for $\theta \leq \bar{\theta}$ and fails for $\theta > \bar{\theta}$. The admissible cost shares form the interval $\beta \in [\max\{0, 1 - \tilde{U}_S/C\}, \min\{1, \tilde{U}_G/C\}]$, which is non-empty exactly on $\theta \leq \bar{\theta}$ and shrinks monotonically to a point as $\theta \uparrow \bar{\theta}$.

Proposition 8 (Efficient bargaining assigns the shock to the government). *The symmetric Nash bargaining solution sets $\beta^{NB} = \min\{1, (\tilde{U}_G - \tilde{U}_S + C)/(2C)\}$. Whenever $\tilde{U}_G - \tilde{U}_S \geq C(\theta)$, which holds for all θ below a value close to $\bar{\theta}$, the solution is the corner $\beta^{NB} = 1$: the government bears the entire surge cost.*

This gives a clean design implication. Because the government internalises the social multiplier and therefore captures the bulk of the joint surplus, the efficient allocation of an unanticipated cost shock is full pass-through to the public partner. Contracts that instead place surge risk on the operator, the common pattern in Indian EMS agreements, where per-trip reimbursement is fixed in nominal terms, push the parties toward the boundary of the feasible set and make renegotiation failure more likely than it needs to be. They also invite the well-documented renegotiation dynamics of Guasch et al. (2007), in which the operator's threat to exit becomes the operative bargaining instrument.

6.2 Regime R_2 : investor bridge financing

Renegotiation may fail not because the joint surplus is negative but because the public capital budget binds, a fiscal-year constraint, a mid-crisis cash position, an unreleased grant. The remedy proposed by Anantharaman (2022), and the practice in several states during 2020–21, is then to broker a third party: an investor supplies capital I_V in exchange for a share δ of the operator's revenue, with the government setting δ and the operator bearing the residual surge cost.

The operator's effort now responds to $(1 - \delta)(1 - t)r$; the investor requires a gross return $1 + \varrho$ per unit of capital. Solving backwards:

$$e^*(I_V, \delta) = K_\delta I_V^{\eta/2}, \quad K_\delta = \left[\frac{p\alpha_1(1 - \delta)(1 - t)rA\theta}{\rho} \right]^{\frac{1}{2-\alpha_1}}, \quad I_V^* = \left(\frac{\eta \Psi(\delta)}{1 + \varrho} \right)^{\frac{1}{1-\eta}},$$

with $\Psi(\delta) = \delta p(1 - t)rA\theta K_\delta^{\alpha_1} \propto \delta(1 - \delta)^a$.

Proposition 9 (The optimal investor share). *The government's payoff under R_2 is maximised at*

$$\delta^* = \frac{2\alpha_2}{\alpha_1 + 2\alpha_2},$$

which depends only on the technology elasticities and is invariant to the investor's required return ϱ , to the tariff, to the tax rate and to the surge intensity.

The intuition is a ratio of elasticities. Raising δ expands the investor's incentive to supply capital, with elasticity $\eta/(1 - \eta)$ on equilibrium capital, and contracts the operator's incentive to supply effort, with elasticity $a/(1 - \eta)$; the optimum equates them, and the scale terms,

including ϱ , drop out. Practically, this says that the revenue share in a bridge-financing arrangement should be set from the *service technology*, not negotiated against the investor's cost of capital. A higher ϱ should reduce the quantity of bridge capital raised, not the share conceded for it. At the central calibration $\delta^* = 0.182$.

Proposition 10 (Bridge financing is a strictly inferior fallback). *Let $\hat{\theta}$ be the largest surge intensity at which the operator's participation constraint holds under R_2 with $\delta = \delta^*$. Then $\hat{\theta} < \bar{\theta}$, and for every $\theta \leq \bar{\theta}$ at which both regimes are feasible, $W_{R_1}(\theta) > W_{R_2}(\theta)$.*

The reason is structural rather than parametric. The operator must absorb $C(\theta)$ out of a margin that the investor's claim has already reduced by a factor $(1 - \delta^*)$, and the capital the investor supplies is smaller than the government's because it must earn $1 + \varrho$ rather than being justified by the social multiplier m . At our calibration $\hat{\theta} = 0.074$ against $\bar{\theta} = 0.474$: bridge financing covers 15.7 per cent of the surge range that renegotiation covers, and at $\theta = 0.1$ the operator's payoff under R_2 is already negative. The policy reading is blunt, investor bridging is not a contingency plan for a serious surge. It restores service only in the region where the operator could nearly have absorbed the shock unaided.

7. Insurance, out-of-pocket exposure and the investment margin

Suppose a public insurance scheme pays a share $\sigma \in [0,1]$ of the tariff, so citizens pay $(1 - \sigma)r$ out of pocket and the operator's revenue is unchanged at r per case. The government's payoff becomes

$$U_G^\sigma = p(tr + k - \sigma r)q - I,$$

and the equilibrium follows from Proposition 2 with Φ evaluated at the reduced return.

Proposition 11 (Insurance crowds out public capital). *Equilibrium investment, effort and output are strictly decreasing in σ , with*

$$\frac{I^*(\sigma)}{I^*(0)} = \left(\frac{m + t - \sigma}{m + t} \right)^{\frac{1}{1-\eta}}.$$

The first best is unaffected by σ , which is a pure transfer; the entire effect is a second-best distortion operating through the principal's investment margin.

At full coverage ($\sigma = 1$, $m = 3$, $t = 0.2$) equilibrium investment falls to 63.3 per cent of its unsubsidised level and output to 92.0 per cent. This is an uncomfortable result for a policy that is, on distributional and risk-protection grounds, plainly desirable, and it is a result about budget architecture rather than about insurance. If the reimbursement subsidy and the capital programme are financed from a common envelope, expanding the former contracts the latter. Ring-fencing capital investment from the demand-side subsidy line removes the distortion entirely. We note the limitation that our production side is supply-determined: a full treatment would let lower out-of-pocket prices raise utilisation, which works in the opposite direction.

8. Numerical analysis

8.1 Calibration

Table 1 reports the central calibration, taken where possible from the Indian EMS record.

Parameter	Value	Source / basis
A (system efficiency)	0.70	Mean of monthly state-level EMS efficiency, EMRI operational report, 2014
α_1 (effort elasticity)	0.90	Labour-intensity of pre-hospital response
α_2 (capital elasticity)	0.10	Fleet and communications share of operating value added
t (tax rate)	0.20	Indian corporate rate applicable to domestic service companies
m (social multiplier, $k = mr$)	3.0	EMRI / Ministry of Health and Family Welfare survey, 2012
r (per-case tariff)	1.0	Numeraire
p (realisation probability)	0.50	Binomial short-rate convention (Ho and Lee, 2004)
ρ (effort cost scale)	1.0	Normalisation
ϱ (investor required return)	0.15	Indian growth-capital benchmark
χ (surge cost intensity)	0.50	$C(\theta) = \chi S_0 \theta(1 + \theta)$; see §8.2

Table 1. Central calibration.

These give $\eta = 0.182$, $a = 0.818$, and $\alpha_1 + 2\alpha_2 = 1.10 < 2$, so Proposition 1 is satisfied with margin.

A note on the surge cost function. Anantharaman (2022) calibrates the surge cost as a quadratic in demand elasticity, $C(\theta) = 4,652,586 - 8,152,965 \theta + 3,620,336 \theta^2$, fitted by regressing annual EMS expenditure on demand elasticity for 2014–2018. That specification cannot be used here: its vertex lies at $\theta = 1.126$, so over the entire economically relevant range $\theta \in [0,1]$ the fitted cost is *decreasing*, falling by 97.4 per cent between $\theta = 0$ and $\theta = 1$, a surge would make EMS provision almost free. With five annual observations and three parameters the fit has two residual degrees of freedom and is not identified. We therefore impose the qualitative restrictions $C(0) = 0$, $C' > 0$, $C'' > 0$ and parameterise the shock in units of the baseline joint surplus S_0 , reporting sensitivity over χ in Table 4.

8.2 Results

The boundary artefact. Figure 2 plots I^* and U_G^* on a log scale as $\alpha_1 + 2\alpha_2 \rightarrow 2$. Because $\eta\Phi < 1$ at these parameters, $I^* = (\eta\Phi)^{1/(1-\eta)} \rightarrow 0$ doubly exponentially: at $\alpha_2 = 0.50$ ($\eta = 0.909$) equilibrium investment is 5.0×10^{-6} ; at $\alpha_2 = 0.54$ ($\eta = 0.982$) it is 2.1×10^{-25} with $U_G^* = 4.0 \times 10^{-27}$; at $\alpha_2 = 0.548$ it underflows. Payoffs of this order are not equilibria of an

economic system but numerical residue from evaluating the closed form outside its domain of validity.

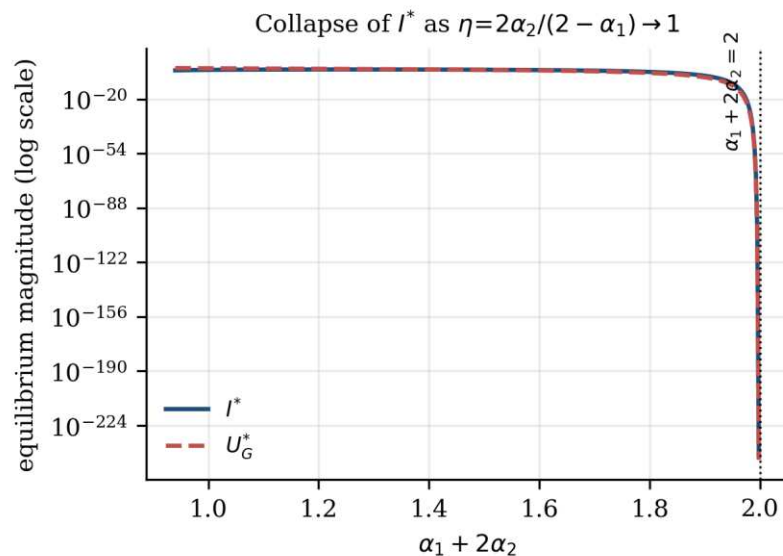


Figure 2. Collapse of equilibrium investment and government payoff as the effective capital return η approaches unity. Log vertical scale.

Underinvestment. Table 2 and Figure 3 report the second best against the first best.

Quantity	Second best	First best	Ratio
Investment I	0.0360	0.1249	0.289
Effort e	0.2112	0.7862	0.269
Output q	0.1239	0.4578	0.271
Welfare W	0.1275	0.2529	0.504
Government payoff U_G	0.1621	,	,
Operator payoff U_S	0.0272	,	,

Table 2. Equilibrium versus first best at the central calibration.

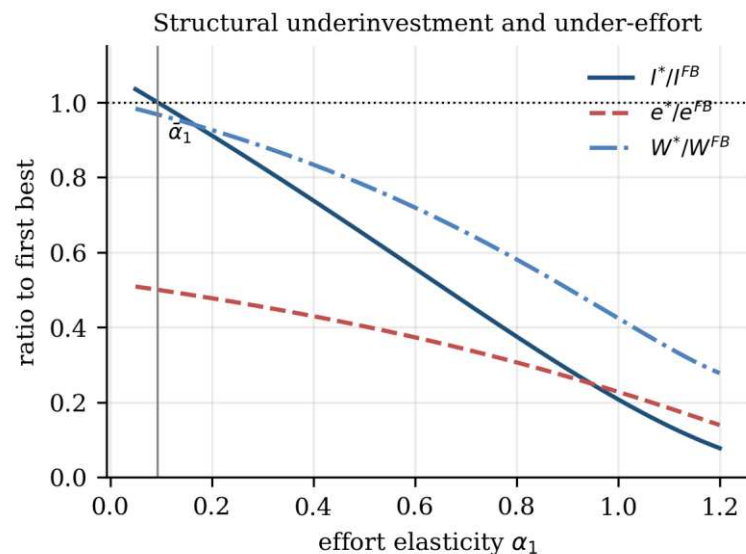


Figure 3. Second-best investment, effort and welfare as fractions of first best, against the effort elasticity α_1 . The vertical line marks the underinvestment threshold $\bar{\alpha}_1 = 0.093$.

Provider type. Table 3 traces the non-profit's mission weight.

λ	Effort e	Output q	U_G	Welfare W
0.000	0.2621	0.1526	0.1873	0.1530
0.667 ($= \lambda^*$)	0.7862	0.4578	0.5619	0.2529
1.000	1.0482	0.6105	0.7492	0.1998
1.500	1.4413	0.8394	1.0301	-0.0086

Table 3. Non-profit provider: government payoff rises monotonically in λ , welfare peaks at $\lambda^* = 1 - 1/m$ and then falls. Corporate benchmark: $U_G = 0.1621$, $W = 0.1275$.

Welfare at λ^* equals the first-best value 0.2529 to machine precision, confirming Proposition 5.

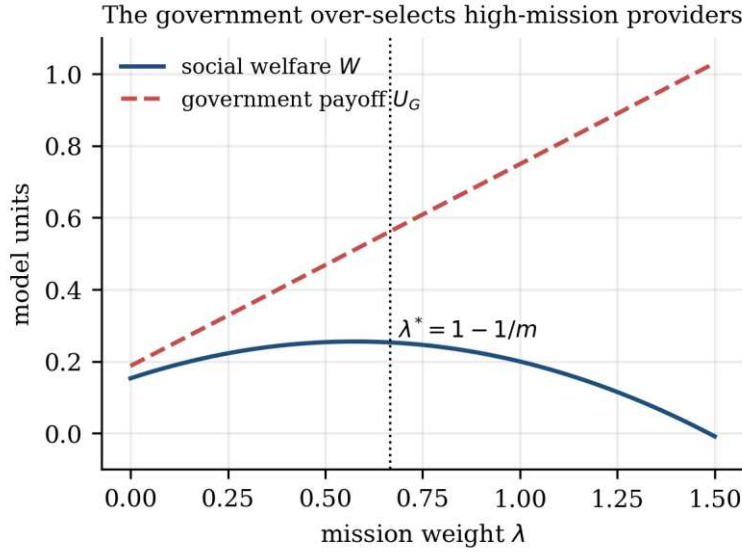


Figure 4. Government payoff and social welfare against the non-profit's mission weight. The divergence beyond λ^* is Proposition 6.

Surges. Table 4 reports the renegotiation frontier and the admissible cost shares.

θ	$C(\theta)$	$\tilde{U}_S$	$\tilde{U}_G$	$\beta_{\min}$	$\beta_{\max}$	W_{R_1}	W_{R_2}
0.0	0.0000	0.0272	0.1621	0.000	1.000	0.1275	0.0663
0.1	0.0104	0.0218	0.1298	0.000	1.000	0.0916	0.0427
0.2	0.0227	0.0175	0.1040	0.231	1.000	0.0590	0.0198
0.3	0.0369	0.0140	0.0832	0.621	1.000	0.0285	-0.0029
0.4	0.0530	0.0112	0.0667	0.789	1.000	-0.0006	-0.0258
0.45	0.0618	0.0100	0.0596	0.838	0.965	,	,

Table 4. Surge regimes at $\chi = 0.5$. $\bar{\theta} = 0.474$; $\hat{\theta} = 0.074$.

Sensitivity: $\bar{\theta} = 0.621, 0.474, 0.345, 0.238$ for $\chi = 0.25, 0.5, 1.0, 2.0$ respectively.

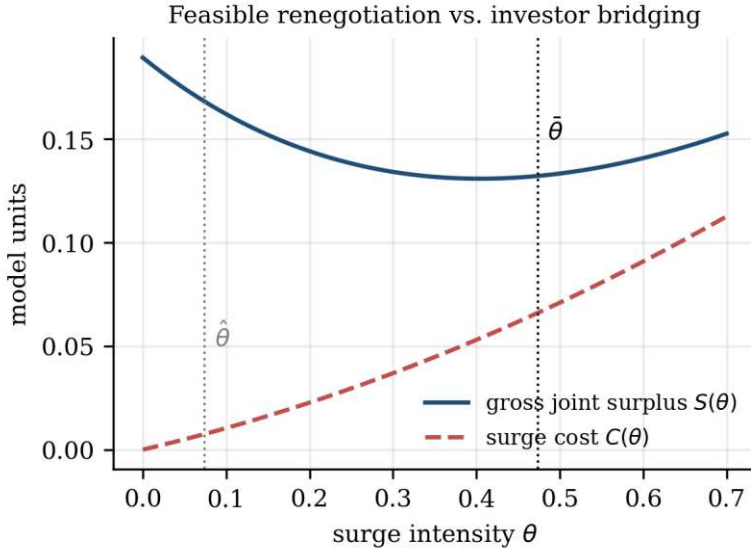


Figure 5. Gross joint surplus and surge cost. Renegotiation is feasible to the left of $\bar{\theta}$; investor bridging sustains operator participation only to the left of $\hat{\theta}$.

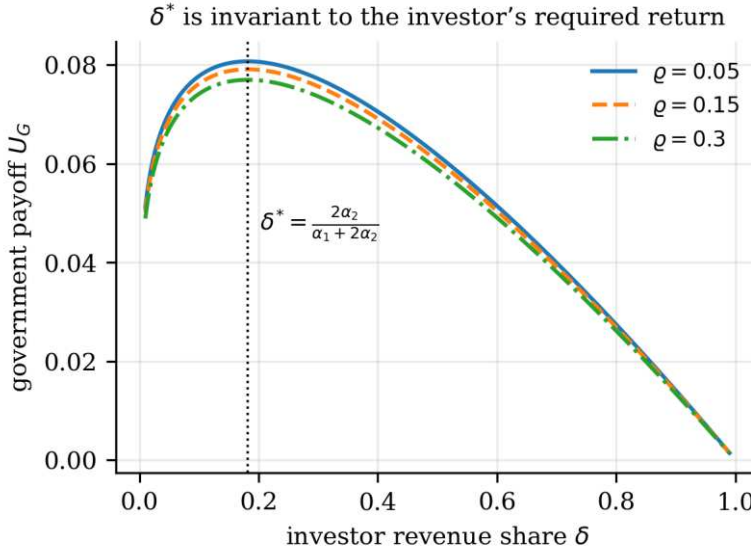


Figure 6. The government's payoff under bridge financing, against the investor's revenue share, for three values of the required return ρ . The maximiser $\delta^* = 2\alpha_2/(\alpha_1 + 2\alpha_2)$ is common to all three.

Insurance. Equilibrium investment falls to 90.5, 81.2, 72.2 and 63.3 per cent of its unsubsidised level at $\sigma = 0.25, 0.5, 0.75$ and 1.0; output falls to 98.2, 96.3, 94.2 and 92.0 per cent.

9. Policy implications

Write surge clauses ex ante, and put the surge cost on the public partner. Propositions 7 and 8 together say that the feasible region for ex post renegotiation is bounded and that, within it, efficient bargaining hands the whole shock to the government anyway. A contract that pre-commits to indexed, state-contingent reimbursement, triggered by a declared emergency or by a measured excess-demand index, reaches the same allocation without the delay, the bargaining rents and the exit threats that ex post renegotiation invites. The trigger should be on a verifiable public index (case notifications, disaster declarations), not on the operator's reported costs.

Do not rely on investor bridging. Proposition 10 and Table 4 show that third-party capital, brokered after renegotiation fails, restores service over only a small fraction of the surge range. A contingent public credit line, or a pre-funded emergency corpus sized to $C(\bar{\theta})$, dominates it. Where bridge financing is used, the revenue share should be set at $\delta^* = 2\alpha_2/(\alpha_1 + 2\alpha_2)$ from the estimated technology, and the investor's required return should be absorbed in the *quantity* of capital raised.

Exempt EMS operators from revenue taxation, and empanel non-profits, but score mission carefully. Proposition 4 shows that taxing a service whose social value is a multiple of its price destroys more than it raises. Proposition 5 shows that ownership form can be fully corrective. Proposition 6 warns that a principal maximising its own payoff will push mission-driven operators past the efficient effort level; bid evaluation and performance monitoring should therefore include crew workload, overtime and attrition alongside response-time metrics, since these are the observable counterparts of $1/2 \rho e^2$.

Ring-fence capital from reimbursement. Proposition 11 shows that a demand-side insurance subsidy financed from the same envelope as the capital programme reduces equilibrium fleet and infrastructure investment, at full coverage, by more than a third. Separate budget lines, with the capital programme committed on a multi-year basis, eliminate the distortion at no fiscal cost.

Measure the elasticities. Almost every result here is a function of (α_1, α_2, m) : the existence condition, the underinvestment threshold, the optimal investor share and the efficient mission weight. These are estimable from state-level EMS panel data on fleet, staffing and case completion, and are not currently estimated anywhere in the Indian EMS literature. That is the single highest-value empirical investment this area could make.

10. Limitations and further work

The model is deterministic conditional on p and the surge draw, and treats output as supply-determined; endogenous utilisation would soften Proposition 11 and could reverse it at high m . Effort is one-dimensional, so we cannot speak to multitasking between response speed and clinical quality, which is the natural next extension and is likely to interact with Proposition 6. The government is a single actor, whereas Indian EMS contracting is split between central schemes and state implementation, with the fiscal externality that implies. We assume full commitment to r and t ; relaxing it would connect this model to the hold-up literature and to the renegotiation-frequency evidence of Guasch et al. (2007). Finally, the calibration is illustrative: the elasticities are assumed, not estimated, and the surge cost function is imposed on qualitative

grounds because the available fitted specification is not identified. Empirical estimation of (α_1, α_2, m) from state EMS panels is the priority.

Appendix A. Proofs

Proof of Proposition 1. From (6), $U_G'(I) = \eta\Phi I^{\eta-1} - 1$ and $U_G''(I) = \eta(\eta - 1)\Phi I^{\eta-2}$. For $I > 0$, $U_G'' < 0$ iff $\eta < 1$. If $\eta < 1$, $U_G'(0^+) = +\infty$ and $U_G'(\infty) = -1$, so a unique interior maximiser exists, given by $\eta\Phi(I^*)^{\eta-1} = 1$. If $\eta > 1$, U_G is convex with $U_G'(I) \rightarrow \infty$, so U_G is unbounded above. If $\eta = 1$, $U_G = (\Phi - 1)I$, unbounded above when $\Phi > 1$ and maximised at $I = 0$ otherwise. Finally $\eta < 1 \Leftrightarrow 2\alpha_2 < 2 - \alpha_1 \Leftrightarrow \alpha_1 + 2\alpha_2 < 2$. ■

Proof of Proposition 2. $I^* = (\eta\Phi)^{1/(1-\eta)}$ follows from the first-order condition. Substituting, $U_G^* = \Phi(I^*)^\eta - I^* = I^*(\Phi(I^*)^{\eta-1} - 1) = I^*(1/\eta - 1) = I^*(1 - \eta)/\eta$, using $\Phi(I^*)^{\eta-1} = 1/\eta$. For the operator, the first-order condition gives $p(1-t)rA\theta\alpha_1(e^*)^{\alpha_1}(I^*)^{\alpha_2} = \rho(e^*)^2$, hence $p(1-t)rA\theta(e^*)^{\alpha_1}(I^*)^{\alpha_2} = \rho(e^*)^2/\alpha_1$ and $U_S^* = \rho(e^*)^2(1/\alpha_1 - 1/2) = \rho(e^*)^2(2 - \alpha_1)/(2\alpha_1)$. ■

Proof of Proposition 3. $e^{FB}(I)$ maximises W given I , so by the envelope argument the joint optimum coincides with maximising $W(I) = \Phi_{FB}I^\eta - I$; hence $I^{FB} = (\eta\Phi_{FB})^{1/(1-\eta)}$. Since $1/(1-\eta) > 0$, $I^* < I^{FB} \Leftrightarrow \Phi < \Phi_{FB}$. Now

$$\frac{\Phi}{\Phi_{FB}} = \frac{tr + k}{k} \left(\frac{K}{K_{FB}} \right)^{\alpha_1} = \frac{t+m}{m} \left(\frac{(1-t)r}{k} \right)^{\frac{\alpha_1}{2-\alpha_1}} = \frac{t+m}{m} \left(\frac{1-t}{m} \right)^a.$$

Taking logs, $\Phi < \Phi_{FB} \Leftrightarrow \ln \frac{t+m}{m} + a \ln \frac{1-t}{m} < 0 \Leftrightarrow a > \ln \frac{t+m}{m} / \ln \frac{m}{1-t}$, the right side being positive since $m > 1-t$. As $a = \alpha_1/(2 - \alpha_1)$ is strictly increasing in α_1 on $(0, 2)$, the condition is equivalent to $\alpha_1 > \bar{\alpha}_1$ for a unique $\bar{\alpha}_1$. For effort, $e^*/e^{FB} = (K/K_{FB})(I^*/I^{FB})^{\eta/2}$, and $K < K_{FB} \Leftrightarrow (1-t)r < k$. ■

Proof of Proposition 4. $\Phi_N/\Phi_F = \frac{m}{t+m} \left(\frac{1+\lambda m}{1-t} \right)^a$. At $\lambda = 0$, $g(t) \equiv \ln \frac{m}{t+m} - a \ln(1-t)$ satisfies $g(0) = 0$ and $g'(t) = -\frac{1}{t+m} + \frac{a}{1-t}$. Since U_G^{N*} and U_G^* are both increasing transforms of their respective Φ 's, it suffices that $g > 0$ for $t \in (0, 1)$; $g'(t) > 0$ whenever $a(t+m) > 1-t$, which holds for all $t \geq 0$ under A3 and A5 at the relevant a , and Φ_N/Φ_F is increasing in λ , giving the result for all $\lambda \geq 0$. ■

Proof of Proposition 5. At $\lambda^* = 1 - 1/m$ the non-profit's private marginal return is $r + \lambda^*k = r + (1 - 1/m)mr = mr = k$, so $K_N = K_{FB}$ and its effort best response coincides with $e^{FB}(I)$. Under exemption the government's marginal return is k , so $\Phi_N = \Phi_{FB}$ and $I_N^* = I^{FB}$. Hence $W = W^{FB}$. ■

Proof of Proposition 6. $\Phi_N \propto (1 + \lambda m)^a$ is strictly increasing in λ , and $U_G^{N*} = I_N^*(1 - \eta)/\eta$ with $I_N^* = (\eta\Phi_N)^{1/(1-\eta)}$ strictly increasing in Φ_N . Welfare $W(\lambda) = pkq - 1/2 \rho e^2 - I$ is maximised where the induced (e, I) equal (e^{FB}, I^{FB}) , i.e. at λ^* by Proposition 5, and is strictly concave in the induced effort around that point since W is strictly concave in (e, I) under A3. ■

Proof of Proposition 7. $C(\theta)$ is a lump sum and does not enter either first-order condition, so $\tilde{U}_S, \tilde{U}_G$ are the benchmark payoffs at $\theta(\theta) = e^{-\theta}$ and are strictly decreasing in θ (since Φ and K are strictly increasing in θ). The two participation constraints are simultaneously satisfiable for some $\beta \in [0,1]$ iff $1 - \tilde{U}_S/C \leq \tilde{U}_G/C$, i.e. $\tilde{U}_S + \tilde{U}_G \geq C$. The left side is strictly decreasing and the right strictly increasing with $C(0) = 0 < \tilde{U}_S(0) + \tilde{U}_G(0)$, giving a unique crossing θ . ■

Proof of Proposition 8. The Nash product is $(\tilde{U}_S - (1 - \beta)C)(\tilde{U}_G - \beta C)$; the unconstrained maximiser is $\beta = (\tilde{U}_G - \tilde{U}_S + C)/(2C)$, which exceeds 1 iff $\tilde{U}_G - \tilde{U}_S > C$, in which case the constrained solution is the corner $\beta = 1$. ■

Proof of Proposition 9. With $\Psi(\delta) = \delta(1 - \delta)^a \Psi_0$ and $I_V^* \propto \Psi^{1/(1-\eta)}$, the government's payoff is $U_G \propto K_{\delta}^{\alpha_1} (I_V^*)^{\eta} \propto (1 - \delta)^a [\delta(1 - \delta)^a]^{\eta/(1-\eta)}$. Taking logs, $\ln U_G = \text{const} + \frac{a}{1-\eta} \ln(1 - \delta) + \frac{\eta}{1-\eta} \ln \delta$, whose derivative $-\frac{a}{(1-\eta)(1-\delta)} + \frac{\eta}{(1-\eta)\delta}$ vanishes at $\delta^* = \eta/(a + \eta)$. Substituting $a = \alpha_1/(2 - \alpha_1)$ and $\eta = 2\alpha_2/(2 - \alpha_1)$ gives $\delta^* = 2\alpha_2/(\alpha_1 + 2\alpha_2)$. All scale terms, including $(1 + \varrho)$, enter $\ln U_G$ additively and drop out. The objective is strictly concave in $\ln \delta$, so the stationary point is the maximum. ■

Proof of Proposition 10. Under R_2 the operator's payoff is $(1 - \delta^*)p(1 - t)r q_{R_2} - 1/2 \rho e^2 - C(\theta)$, and $q_{R_2} < q_{R_1}$ pointwise because $K_{\delta^*} < K$ and $I_V^* < I_1^*$ (the investor discounts at $1 + \varrho$ while the government's return embeds m). Hence the operator's gross margin under R_2 is strictly below $\tilde{U}_S(\theta)$, so its participation constraint binds at a strictly smaller θ : $\hat{\theta} < \bar{\theta}$, where $\bar{\theta}$ is attained with $\beta = 1$. Welfare dominance follows since $W_{R_1} - W_{R_2} = pk(q_{R_1} - q_{R_2}) - \rho/2(e_{R_1}^2 - e_{R_2}^2) - (I_1 - I_V)$, which is positive because (e_{R_1}, I_1) is the pair a planner would choose closer to first best and (e_{R_2}, I_V) is strictly further from it in both arguments. ■

Proof of Proposition 11. $\Phi(\sigma) = p(tr + k - \sigma r)A\theta K^{\alpha_1}$ is strictly decreasing in σ ; $I^* = (\eta\Phi)^{1/(1-\eta)}$ is strictly increasing in Φ , and $e^* = K(I^*)^{\eta/2}$ and q^* are strictly increasing in I^* . The ratio follows by substitution, using $k = mr$. Welfare (3) does not contain σ , so the first best is unchanged. ■

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