EUROPEAN SUMMER SYMPOSIUM IN ECONOMIC THEORY

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Social Insurance, Information Revelation, and Lack of Commitment

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Liquidity Insurance with Market Information

Luigi Iovino*

Abstract

1 Introduction

Y y V

Y w V

V V

Y V

Yá V

V Y V

V W

Y

u

Y y V

Y s

Yt

Yá R bj j h S i aO

á Yz V

R z á R aba S t Y R aba S S Y w V

V Yw

V bi Y gj J e R SWc

R SW dgR SW de

V V

Yz

Yw Vz

Y

y Rojji S Yu

V

” — Y–

Y y V

Yr V r Ww

“ “ Rojfi S V

W

Y r V

z f Y

z

Yz V V

Yá V

R V S

Y

r

Y V V V V

Y– V

V V *before*

Y V

Y y V W V

Ys V

W Yz V

V

Y t

V V W

Y V

W Y

Related Literature.

Y
Yz
Vff á Rbj hgS
Y á V

Y r V
ff á Rbj hgS Y w Vz
V
Y
V z r bYeY

Y á
Y z Vr YRcabaS
Y
z V
Y
Y z
V k
Yr V
Ys
x Rcabb S
Y
Yz s
YRcabaS V
V Y– z
Yr V
R V V SV
after Y V V
W Y
w V

W Rff á Rbj i i SVs
Rcaah SSY á V

Yw V

Rs x

Rbjij S fl “ Rbjjh SS[b] Y

Y z c z W

Yz d z Yá e

Y z

f z Yz

Vz W

Yá g Yw V

r bY z

Y

2 The Model

$t = 0, 1, 2$ Y

w V A Yv W

2Yr

2Y Vθ^H

α θ^L $1 - \alpha$V $\theta^H > \theta^L$Y ’ $\tilde{y}(\theta)$

2 θYw Vz $\tilde{y}(\theta)$

$$\tilde{y}(\theta) = \begin{cases} R & \text{YY}\theta \\ 0 & \text{YY}1 - \theta \end{cases}$$

’ Θ V V$\Theta = \{\theta^L, \theta^H\}$Y

2 Y

v V

Y 2

z L L

Y r V

V Y

[b]á r RbjjhSV’ RbjjfSVt w RbjjhSVr YRbjjjSV ff RaaeSVt YRaaeSVx ’ RaajSV s YRbjjjSY

z V I 0V

$\rho \sim f_\theta(\cdot)$ 1Y I

Y V 2V

θ I $\tilde{y}(\theta)$ IY– V

V $l(\theta)$ IV $l(\theta) < R\theta$Y

z 1 L LY z

$f_\theta(\cdot)$ R" ' —S θY

w Vz $f_{\theta^L}(\rho) / f_{\theta^H}(\rho)$ ρY " ' —

1Y z V V

R

1 SY

Y–

1

Y t Y r V

V V

Y V

f aO baaO Y

r ρ 1V

V 1Y Vρ

1Y z ρ

V V V

Yw V

Y

z V Vz ρ V

Y

w Vz Yz

α θ^H $1-\alpha$

θ^LY YY Y $f_\theta(\cdot)$

θY

Y

Assumption 1. *Both projects have positive NPV:*

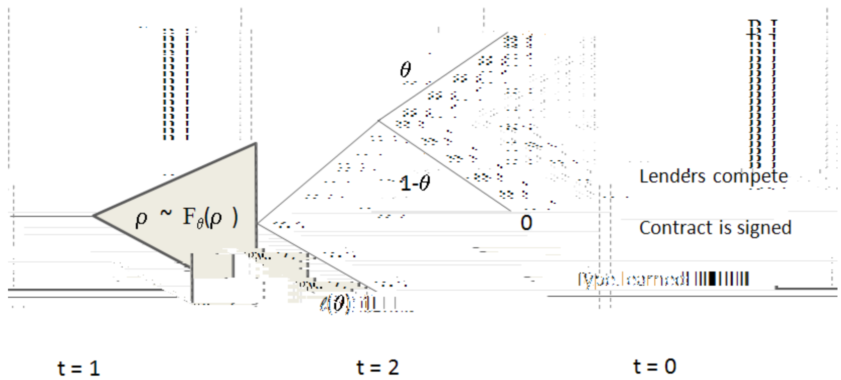
$$\max_{\tilde{\rho}} \left\{ R\theta F_\theta(\tilde{\rho}) - 1 - \int_0^{\tilde{\rho}} \rho f_\theta(\rho)\, d\rho \right\} > 0, \quad \theta \in \Theta$$

1 θYz 1
” — Yz V
ρV ” — Yy V
V R
SV ” — Y

Yz W
2 Y V Y
r Y s YY Y
R V V
W SYw W
Y w Vz
W rY
V W
V Yz
0 W
Y“ Vy RojjiS
R S
1 Y v
YY Y Y
r
1 0Y “ Vz
0
1 Yr 1V
Y s x RojihS
0
1Y
1 R fi RojihS r x RojjhSSYr V z
1V V
Y
y V z
V Y

Y

r V V
V Y
Y z
V V W Y V
Y v W
Y Yw
Vz $\tilde{y}(\theta)$
$l(\theta)$ Y
Y– V θY
$\tilde{s}_{\theta}$ 1 Y
θ Y
Yz
V
Y
r V Vz
$\tilde{s}_{\theta}$ Y w Vz
$\tilde{s}_{\theta} = \theta$Y
w Vz V V
ρ Y
Y
' $D_i(\theta, p, \rho)$ iV
θV ρV pYz
$D_i(\theta, p, \rho)$ V i κ
Y á V
z i $D_i(\theta, p, \rho)$Y
$u \sim N\left(0, \sigma_u^2\right)$Y
u κ
Y
Yz $\phi_P(\cdot|\theta, \rho)$
θ
ρ Y – V
Yw V
$\kappa = 1$ Y



Timing and Information. Yv V V I V ρV Yw V r bY Vz *after* Y Y V Yz W W Y – V V Y Y z r bY z Y Yw Vz Ys V V W Y

2.1 Contracts

w V 0 I V ρV Yw V V Y r Y

De…nition. *A contract C is a tuple $\left[I, \chi, \bar{c}^e, \underline{c}^e, c^e_L, \bar{c}^i, \underline{c}^i, c^i_L\right]$, which specifies:*

1. *payments* $\vec{c}^e : \mathbb{R} \times \varrho \times \Omega \rightarrow \mathbb{R}_+$, $\underline{c}^e : \mathbb{R} \times \varrho \times \Omega \rightarrow \mathbb{R}_+$, *and* $c^e_L : \mathbb{R} \times \varrho \rightarrow \mathbb{R}_+$ *to the entrepreneur after observing a price* p *and a liquidity shock* ρ*, in the case the project is succesful, completed but unsucessful, and liquidated, respectively;*

2. *payments to the investor* $\vec{c}^i : \mathbb{R} \times \varrho \times \Omega \rightarrow \mathbb{R}$, $\underline{c}^i : \mathbb{R} \times \varrho \times \Omega \rightarrow \mathbb{R}$, *and* $c^i_L : \mathbb{R} \times \varrho \rightarrow \mathbb{R}$*;*

3. *an initial investment* $I \in \mathbb{R}_+$ *in the project;*

4. *a continuation rule* $\chi : \mathbb{R} \times \varrho \rightarrow \{0, 1\}$ *which, for each value of* p *and* ρ*, is equal to* 1 *whenever the project is continued.*

ff V

Yy V Yz

Y

V Y

’ $\mathbb{C}$ Yr *menu of contracts* $\mathbb{C}$Y

2.2 Moral Hazard

“ “ Rbjfi S V V

Yz V

V Yz V

Y

Yw

R V

SYw V

“ W“

Yr

Y

y Rbjji SYy

V

V ” —

Yz V

Y

“ W“
Y

Y
Yá V
V Y
y V V $f_\theta(\rho)$
$\tilde{y}(\theta)$V Y
V Y

V Y
V z V
$R-\rho_0$ Y ρ_0
Yr z *all*
$l(\theta)\,I$ Y y V
Yu
Y
s V $R-\rho_0$
Y z $\mathcal{C}$
$(R-\rho_0)\,I$ V
Y V $\mathcal{C}$
$\forall C \in \mathcal{C}$

$$\bar{c}^e(p,\rho,R) \geq (R-\rho_0)\,I \quad \text{RbS}$$

V $\mathbb{C}^{MH}$ $\mathbb{C}$ RbSY

2.3 Payo¤s

x $\mathcal{C} \subseteq \mathbb{C}$V $C \in \mathcal{C}$
θY *conditional*
θ k

$$U(C;\theta) = \mathbb{E}\left[\theta\chi(p,\rho)\,\bar{c}^e(p,\rho) + (1-\theta)\,\chi(p,\rho)\,\underline{c}^e(p,\rho) + (1-\chi(p,\rho))\,c_L^e(p,\rho)\,|\theta\right]$$

pVρ $y(\theta)$Y w
z C_θ $\mathcal{C}$ θ z
θ C_θY

$\mathcal{C}$ *before*

$$U(\mathcal{C}) = \alpha U(C_\theta;\theta) + (1-\alpha) U\left(C_{\theta'};\theta'\right)$$

$\pi(C;\theta)$

$\mathcal{C} \subseteq \mathbb{C}$ θ $C \in \mathcal{C}$

$$\pi(C;\theta) = \mathbb{E}\left[\theta\chi(p,\rho)\,\bar{c}^i(p,\rho) + (1-\theta)\,\chi(p,\rho)\,\underline{c}^i(p,\rho) + (1-\chi(p,\rho))\,c_L^i(p,\rho)\right] - \mathbb{E}\left[1+\rho\chi(p,\rho)\right] I$$

p ρ $y(\theta)$

$\pi(C;\theta)$ C

I

$\chi(p,\rho)$

$\pi(C;\theta)$

$$\pi(\mathcal{C}) = \alpha\pi(C_\theta;\theta) + (1-\alpha)\,\pi\left(C_{\theta'};\theta'\right)$$

$\pi(C;\theta)$

$\mathcal{C}$

$$\pi(\mathcal{C}) \geq 0$$

2.4 Equilibrium Definition

Definition. *An equilibrium for the economy is a menu of contracts $\mathcal{C}^* \subseteq \mathbb{C}^{MH}$, a distribution for the asset price $\Phi_P : \mathbb{R}\times\Theta\times\varrho \to [0,1]$, and a demand schedule $D_i : \Theta\times\mathbb{R}\times\varrho\to\mathbb{R}$ for each trader $i\in[0,1]$ such that*

1. *Investors choose* $\mathcal{C}^*\subseteq\mathbb{C}^{MH}$ *to maximize their profits*

$$\mathcal{C}^* \in \arg\max_{\mathcal{C}\subseteq\mathbb{C}^{MH}} \pi\left(\mathcal{C}\right)$$

2. *After an entrepreneur learns his type, he selects the contract* $C_\theta \in \mathcal{C}^*$ *to maximize his expected utility*

$$C_\theta \in \arg\max_{C\in\mathcal{C}^*} U\left(C;\theta\right)$$

3. *Free-entry among investors drive expected profits to zero*

$$\pi\left(\mathcal{C}^*\right) = 0$$

4. *For each value of* θ, p, *and* ρ, *each trader chooses* $D_i\left(\theta,p,\rho\right)$ *to maximize expected profits*

$$D_i\left(\theta,p,\rho\right) \in \arg\max_x \mathbb{E}\left[\left(\tilde{y}\left(\theta\right)\chi_\theta\left(p,\rho\right)+l\left(\theta\right)\left(1-\chi_\theta\left(p,\rho\right)\right)-p\right)x|\theta,p,\rho\right]-\frac{x^2}{2}+W$$

5. *For each value of* θ *and* ρ, $\Phi_P\left(\cdot|\theta,\rho\right)$ *is the distribution of prices generated by the equilibrium in the financial market. That is, for each value of* θ, ρ, *and noisy traders* u, $\Phi_P\left(\cdot|\theta,\rho\right)$ *is the cdf of the distribution of prices* p *which solve the equation*

$$p = \mathbb{E}\left[\tilde{y}\left(\theta\right)\chi_\theta\left(p,\rho\right)+l\left(\theta\right)\left(1-\chi_\theta\left(p,\rho\right)\right)|\theta,p,\rho\right]-u$$

3 Symmetric Information Benchmark

z z

Y

y RaaaSV

Y Y

w V

Yz z

Y

á V W

y RaaaSY

Yz

V

R V ” — SYz

V V

Yw V V

V

Y W

Y

” V Y

– V RcSYz

Y r

V

Yá V

Y

r V W

Yr V 0V

Yv V 0V

Yw V V θ

Y

W Yw V

$\mathcal{C}^{sym}$ k

$$\max_{\mathcal{C}\subseteq\mathbb{C}^{MH}} U(\mathcal{C}) \quad \text{RbS}$$

$$\pi(\mathcal{C}) = 0$$

— V gV

RbSY

Proposition 1. *The solution to problem (P1) is given by a menu of contracts $\mathcal{C}^{sym}$ with the following properties*

1. *The entrepreneur consumes the minimum share of output if the project is successful and nothing otherwise:*

$$\bar{c}^{e}_{\theta}(p,\rho) = (R-\rho_0)\, I_{\theta},\ \ \underline{c}^{e}_{\theta}(p,\rho) = 0,\ \ c^{e}_{\theta,L}(p,\rho) = 0$$

2. *The investor receives all the pleadgeble income if the project is successful and the liquidation value if the project is liquidated:*

$$\bar{c}^{i}_{\theta}(p,\rho) = \rho_0 I_{\theta},\ \ \underline{c}^{i}_{\theta}(p,\rho) = 0,\ \ c^{i}_{\theta,L}(p,\rho) = l(\theta)\, I_{\theta}$$

3. *For each θ there exists a threshold ρ_θ^* such that $\theta\rho_0 < \rho^*(\theta) < \theta R$ and*

$$\chi_\theta(p,\rho) = 1 \text{ if and only if } \rho \leq \rho_\theta^*$$

4. *Initial investment is given by:*

$$I_\theta = \frac{A}{1 - l(\theta) + \int_{\rho_\theta^*}^{\infty} (\rho - \theta\rho_0 + l(\theta))\, dF_\theta(\rho)}$$

w — b Y

" — Y

V V

Y

r y RcaaaSV— b

Yy

V

$R - \rho_0$Yr

Y

V

Y " —

Y " — V

I_θYw V

Y

r θ

ρ_θ^* W

Y V

0Yz V 1 ρ

V $\rho \leq \theta\rho_0$Y V

Y— b

$\rho_\theta^* > \theta\rho_0$Y Y I_θ

Y

4 Asymmetric Information without ...nancial markets

z z Yz V

V

$$\pi\left(\mathcal{C}\right)=0$$

Rzt S

$$U\left(C_{\theta^i};\theta^i\right)\geq U\left(C_{\theta^j};\theta^i\right) \text{ V } \quad i,j=L,H$$

V zt

Yz zt Y V

gV —eY

Proposition 2. *The solution to problem P2 is given by a menu of contracts $\mathcal{C}^{asym}$ with the following properties:*

1. *The entrepreneur consumes the minimum share of output if the project is successful and nothing otherwise:*

$$c^e_\theta\left(p,\rho\right)=\left(R-\rho_0\right)I_\theta,\ \ c^e_\theta\left(p,\rho\right)=0,\ \ c^e_{\theta,L}\left(p,\rho\right)=0$$

2. *The investor receives all the pleadgeble income if the project is successful and the liquidation value if the project is liquidated:*

$$c^i_\theta\left(p,\rho\right)=\rho_0 I_\theta,\ \ c^i_\theta\left(p,\rho\right)=0,\ \ c^i_{\theta,L}\left(p,\rho\right)=l\left(\theta\right)I_\theta$$

3. *For each θ there exists a threshold $\rho^{**}_\theta\left(\theta\right)$ such that*

$$\chi_\theta\left(p,\rho\right)=1 \textit{ if and only if } \rho\leq\rho^{**}_\theta$$

where

   (a) *the continuation rule for the low type is the same as in the symmetric information benchmark:*

$$\rho^{**}_{\theta^L}=\rho^*_{\theta^L}$$

   (b) *the continuation rule for the high type is distorted:*

$$\rho^{**}_{\theta^H}<\rho^*_{\theta^L}.$$

4. Initial investment is given by:

$$I_{\theta^H} = \frac{A}{\left(\begin{array}{c} \alpha \left(1 - l\left(\theta^H\right) + \int_{\rho^{**}_{\theta H}}^{\infty} \left(\rho - \theta^H \rho_0 + l\left(\theta^H\right)\right) dF_{\theta^H}(\rho) \right) \\ + (1-\alpha) \frac{1 - F_{\theta^L}\left(\rho^{**}_{\theta H}\right)}{1 - F_{\theta^L}\left(\rho^{**}_{\theta L}\right)} \left(1 - l\left(\theta^L\right) + \int_{\rho^{**}_{\theta L}}^{\infty} \left(\rho - \theta^L \rho_0 + l\left(\theta^L\right)\right) dF_{\theta^L}(\rho) \right) \end{array} \right)}$$

and

$$I_{\theta^L} = \frac{1 - F_{\theta^L}\left(\rho^{**}_{\theta H}\right)}{1 - F_{\theta^L}\left(\rho^{**}_{\theta L}\right)} I_{\theta^H}$$

ff RbS RcS — c

— bYr V

2

Y V

Y

V V Yff RdS — c

Y W

ρ Yy V

V

Yz V

V

Y

V

V

Y

ff RcabaS

Y V V Y z ff

RcabaS Y

V V

Y Yw Vz V

Y “ Vz

V V Y z

V V

Y“ V V V

V

Y

Y

Y

s p z I_{θ^L}V

Y I_{θ^H}Yr V

Y

V V I_{θ^H}

Yz V

Y

V W

y W dY V

ρ Y ” V—

c V V

ρY V

$\rho^{**}_{\theta^H}$ W V$\theta^H \rho_0$Y“ V

$\rho^{**}_{\theta^H} \geq \theta^H \rho_0$V V

more

Y – V

$\rho^{**}_{\theta^H} < \theta^H \rho_0$V

Yz VI_{θ^H} Y

5 Asymmetric Information with …nancial markets

,

Y

ﬀ V

after Yá V

before V

Y

$\Phi_p\left(\cdot|\theta,\rho\right)$

$$\max_{\mathcal{C}\subseteq\mathbb{C}^{MH}} U\left(\mathcal{C};\Phi_p\left(\cdot|\theta,\rho\right)\right)$$

$$\pi\left(\mathcal{C};\Phi_p\left(\cdot|\theta,\rho\right)\right)=0$$

$$U\left(C_{\theta^i};\theta^i,\Phi_p\left(\cdot|\theta^i,\rho\right)\right)\geq U\left(C_{\theta^j};\theta^i,\Phi_p\left(\cdot|\theta^i,\rho\right)\right)\ \mathrm{V}\quad i,j=L,H$$

R-dS z Y ff

cYb k

$$p = \mathbb{E}\left[\tilde{y}(\theta)\,\chi_\theta(p,\rho) + l(\theta)\left(1-\chi_\theta(p,\rho)\right)|\theta,p,\rho\right] - u \qquad \text{RdS}$$

t θV$\chi_\theta(p,\rho)$Yz (p,ρ) V

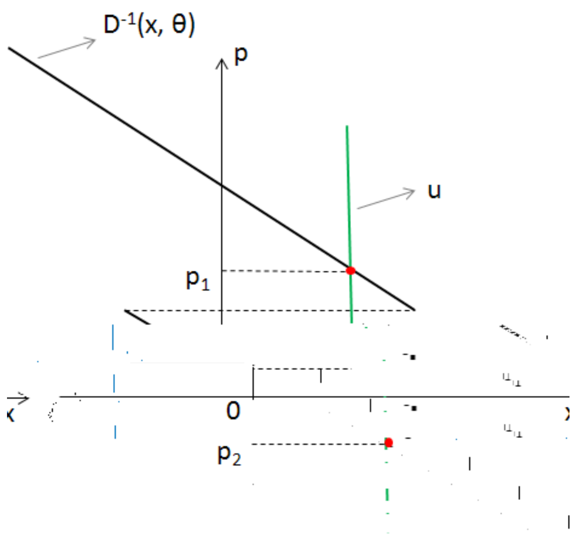
$\mathbb{E}[\tilde{y}(\theta)\,|\theta] = R\theta$V V $l(\theta)$Y

$R\theta - p$ V

$l(\theta) - p$ Y

uY

θ ρY



Y

$\chi_\theta(p,\rho)$ uYz

V

Y

Yz V

V V Y

r V Y

Y w Vz

Y " Vz

V γY

Y z r bY: z V

R.g.SV $\bar{p}_{\theta}(\rho)$ $\chi_{\theta}(p,\rho)$

k

$$\chi_{\theta}(p,\rho)=\begin{cases}1 & p\geq\bar{p}_{\theta}(\rho)\\ 0 & \end{cases} \tag{R.e.S}$$

pV

Y

Y

$\chi_{\theta}(p,\rho)$V

k

$$\phi_{P}(p|\theta,\rho)=\begin{cases}\phi_{u}(R\theta-p) & p\geq R\theta+\bar{p}_{\theta}(\rho)-l(\theta)\\ \gamma\phi_{u}\left(R\theta^{L}-p\right) & \bar{p}_{\theta}(\rho)\leq p<R\theta+\bar{p}_{\theta}(\rho)-l(\theta)\\ (1-\gamma)\phi_{u}(l(\theta)-p) & \bar{p}_{\theta}(\rho)-R\theta+l(\theta)\leq p<\bar{p}_{\theta}(\rho)\\ \phi_{u}(l(\theta)-p) & p<\bar{p}_{\theta}(\rho)-R\theta+l(\theta)\end{cases} \tag{R.f.S}$$

R.d.S V p

V γY

Y

p ϕ_{u} u

Yr V p

V Y γ

R.f.S $p\in[\bar{p}_{\theta}(\rho)-R\theta+l(\theta),R\theta+\bar{p}_{\theta}(\rho)-l(\theta)]$Y

Optimal continuation rules.

R.f.S —d Yz r bY:Vz

$\chi_{\theta}(p,\rho)$ —d

(p,ρ)Y z Y" V

r bY:Vz

V V$\chi_{\theta^{L}}(p,\rho)=\chi_{\theta^{L}}(\rho)V\forall p$Y k

$\bar{\rho}_{\theta^L}$ $\bar{p}_{\theta^L}(\rho) = -\infty$ $\rho \leq \bar{\rho}_{\theta^L}$ $\bar{p}_{\theta^L}(\rho) = \infty$

$\rho > \bar{\rho}_{\theta^L}$

$$\chi_{\theta^L}(\rho) = \begin{cases} 1 & \rho \leq \bar{\rho}_{\theta^L} \\ 0 & \end{cases}$$

$\bar{\rho}_{\theta^L}$

$\chi_{\theta^H}(p, \rho)$

V^*

V_L^*

before

$\bar{p}_{\theta^H}(\rho)$

Lemma 1. *The optimal threshold for the high type $\bar{p}_H(\rho)$ in (4) is the solution to:*

$$\frac{g_P^L\left(\bar{p}_{\theta^H}(\rho)\right) f_{\theta^L}(\rho)}{g_P^H\left(\bar{p}_{\theta^H}(\rho)\right) f_{\theta^H}(\rho)} = \frac{\alpha}{1-\alpha} \frac{\left(\theta^H R - l\left(\theta^H\right)\right) - V^*\left(\rho - \theta^H \rho_0 + l\left(\theta^H\right)\right)}{\left(\theta^L R - l\left(\theta^L\right)\right)\left(\frac{V^*}{V_L^*} - 1\right)}$$

where

$$g_P^i\left(\bar{p}_{\theta^H}(\rho)\right) \equiv \gamma \phi_u\left(R\theta - \bar{p}_{\theta^H}(\rho)\right) + (1-\gamma)\,\phi_u\left(l(\theta) - \bar{p}_{\theta^H}(\rho)\right), \quad i = L, H$$

is the pdf of a mixture of two Normal random variables with mean $R\theta$ and $l(\theta)$, respectively, evaluated at the optimal threshold $\bar{p}_{\theta^H}(\rho)$.

$(\bar{p}_H(\rho), \rho)$ $g_P^i\left(\bar{p}_{\theta^H}(\rho)\right)$

$\bar{p}_{\theta^H}(\rho)$ $g_P^i\left(\bar{p}_{\theta^H}(\rho)\right)$

$\gamma \in (0,1)$

V V^* V_L^* z

RgS $\bar{p}_{\theta^H}(\rho)$ ρ

ρ V^* V_L^*Yz

$\bar{p}_{\theta^H}(\rho)$ R V

V^* V_L^*SY

V^* V_L^*V W

W RgS Y V ρ W

V V

$$\rho > \frac{\theta^H R - l\left(\theta^H\right)}{V^*} + \theta^H \rho_0 - l\left(\theta^H\right)$$

∞Y V ρV

Y

r V $g_P^L\left(\bar{p}_{\theta^H}(\rho)\right)/g_P^H\left(\bar{p}_{\theta^H}(\rho)\right)$

Y $l\left(\theta^H\right) \neq l\left(\theta^L\right)$V

Y $g_P^L\left(\bar{p}_{\theta^H}(\rho)\right)/g_P^H\left(\bar{p}_{\theta^H}(\rho)\right)$

V V γY

RgS V^*V $\chi_{\theta^H}(p,\rho)$[c]

$\bar{p}_{\theta^H}(\rho)$ Y y V

ρ $\bar{p}_{\theta^H}(\rho)$ $\bar{p}_{\theta^H}(\rho')V\rho' \neq \rho$V

V^*Vz —d V^*Yz V V^*V

V_0^*Vz RgS $\left\{\bar{p}_{\theta^H}(\rho; V_0^*)\right\}$ Rz

V_0^*S —dV V_1^*Y

V^* V V $\bar{p}_{\theta^H}(\rho; V^*) \equiv \bar{p}_H(\rho)$Yz

g z Y

Y

Proposition 3. *The solution to P3 is given by a menu of contracts $\mathcal{C}^{asymp}$ with the following properties:*

1. *The entrepreneur consumes the minimum share of output if the project is successful and nothing otherwise:*

$$\bar{c}_\theta^e(p,\rho) = (R - \rho_0)\, I_\theta,\ \ \underline{c}_\theta^e(p,\rho) = 0,\ \ c_{\theta,L}^e(p,\rho) = 0$$

[c] V_L^* V_L^* $\chi_{\theta^L}(\rho)$V
$\chi_{\theta^H}(p,\rho)$Y

2. *The investor receives all the pleadgeble income if the project is successful and the liquidation value if the project is liquidated:*

$$\bar{c}^i_\theta(p,\rho) = \rho_0 I_\theta,\ \underline{c}^i_\theta(p,\rho) = 0,\ c^i_{\theta,L}(p,\rho) = l(\theta) I_\theta$$

3. *The low type obtains the same liquidity insurance as in the symmetric information benchmark:*

$$\chi_{\theta^L}(\rho) = \begin{cases} 1 & \text{if } \rho \leq \bar{\rho}_{\theta^L} \\ 0 & \text{otherwise} \end{cases}$$

4. *The continuation rule for the high type $\chi_{\theta^H}(p,\rho)$ depends on the asset price. Formally, for each ρ there exists a threshold $\bar{p}_{\theta^H}(\rho)$ such that*

$$\chi_{\theta^H}(p,\rho) = \begin{cases} 1 & \text{if } p \geq \bar{p}_{\theta^H}(\rho) \\ 0 & \text{otherwise} \end{cases}$$

where $\bar{p}_{\theta^H}(\rho)$ is the unique solution to (6).

5. *The initial investment levels are given by (15) and (16) in appendix 1.*

6. *The optimal contract determines an equilibrium distribution for the asset price $\Phi_P(p|\theta,\rho)$ given by (5).*

5.1 Comparative Statics

” z Vz
Y z
V
σ_u^2Yr
Y
“ Vz σ_u^2V
V
Y– V σ_u^2
Y– V W σ_u^2V
W Y
σ_u^2 V W
Y V
W
Yz V V

V V

Y

Y

Y V

R

SY

V Y

r ' RcabaSY y Vz

σ_u^2Yz V V

Y

ff σ_u^2 R(SYz V

$\bar{p}_{\theta^H}(\rho)$V σ_u^2 $\Phi_P(p|\theta,\rho)$

Y– V z V σ_u^2

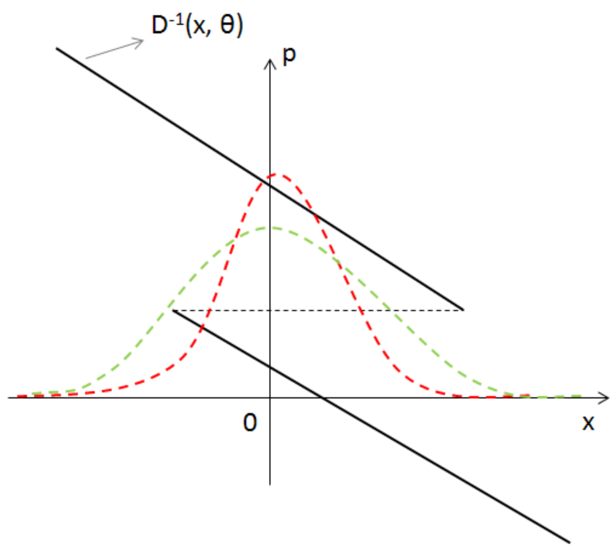
V V $\bar{p}_{\theta^H}(\rho)$ Y'

Ys V 0

σ_u^2 V V $\bar{p}_{\theta^H}(\rho)$

Y 1 V

$\Phi'_P(p|\theta,\rho)$Y



r W

Yw $\bar{p}_{\theta^H}(\rho)$V

V Y r

σ_u^2V V

Y

Proposition 4. *At the optimal contract $\mathcal{C}^{asymp}$, for each ρ the probability of continuation is given by*

$$\Pr\left(p \geq \bar{p}_{\theta^H}(\rho)\,|\rho\right) = \gamma\Phi\left(R\theta^H - \bar{p}_{\theta^H}(\rho)\right) + (1-\gamma)\,\Phi\left(l\left(\theta^H\right) - \bar{p}_{\theta^H}(\rho)\right)$$

Furthermore, there exists a threshold $\tilde{p}_{\theta^H}(\gamma) > 0$ such that $\Pr\left(p \geq \bar{p}_{\theta^H}(\rho)\,|\rho\right)$ is decreasing in σ_u^2 for $\bar{p}_{\theta^H}(\rho) \leq \tilde{p}_{\theta^H}(\gamma)$ and it is increasing in σ_u^2 for $\bar{p}_{\theta^H}(\rho) > \tilde{p}_{\theta^H}(\gamma)$.
Finally, $d\tilde{p}_{\theta^H}(\gamma)/d\gamma < 0$.

— e σ_u^2

$\bar{p}_{\theta^H}(\rho)$ ρY w

V V RYW $\bar{p}_{\theta^H}(\rho)$ S

Y σ_u^2

Y

ρY

Y z

Y r V Y z

V

eY RgSY

σ_u^2V σ_u^2

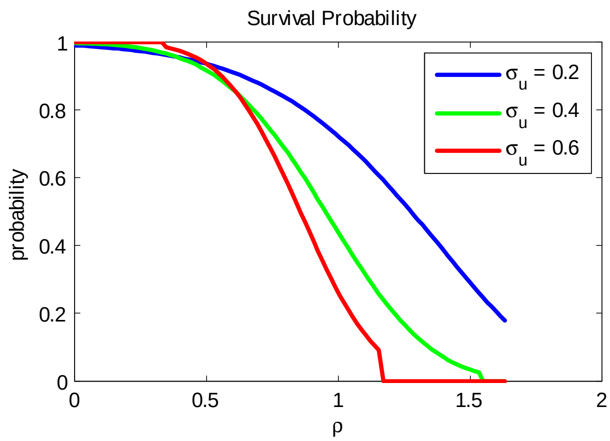
$g_P^L\left(\bar{p}_{\theta^H}(\rho)\right)/g_P^H\left(\bar{p}_{\theta^H}(\rho)\right)$Y' V $g_P^L\left(\bar{p}_{\theta^H}(\rho)\right)/g_P^H\left(\bar{p}_{\theta^H}(\rho)\right)$ σ_u^2

1Y V

RgS $\rho_{\theta^H}^{**}$ — cY

V$\Pr\left(p \geq \bar{p}_{\theta^H}(\rho)\,|\rho\right)$ ρ

σ_u^2Yz z $l\left(\theta^H\right) = l\left(\theta^L\right) = 0$ $\gamma = 1$Y


Survival Probability
1
0.8
0.6
0.4
0.2
0
probability
0
0.5
1
1.5
2
ρ
σu = 0.2
σu = 0.4
σu = 0.6

Y V

V

Y

w Vz

Yz Vz

Y

References

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Economy*VbagRbSkb eaVw bjjiY

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of Financial Economics*VjhRdSkdbj ddiVá cabaY

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Review*VifRfSkbbag bhVu bjjfY

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Y *Journal of Finance* Vgf RgSkccj d cdcc Vu cabaY

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Y *Journal of Economic Theory* Vef RbSkbi j bj j Vfi bj i i Y

t ff Y Y *Journal of Risk & Insurance* Vhi RcSkcgh ci f Vfi cabbY

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Y *Journal of Money, Credit and Banking* Vcj ReSkf bh deV’ bj j hY

“ á Y— Y *Journal of Public Economics* VbaRdSkech eehVu bj hi Y

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Y *Finance Research Letters* VbRbSkbb cdV“ caaeY

t Yr Y *Journal of Economic Theory* VbgRcSkbgh cahVu bj hhY

—

A1.1 Proof of results (1) and (2) in Propositions 1, 2, and 3

u S V

$$
\begin{aligned}
S\left(\chi_{\theta^H}, \chi_{\theta^L}, I_{\theta^H}, I_{\theta^L}\right) \equiv\; & \alpha \theta^H R I_{\theta^H} \int\int \chi_{\theta^H}(p,\rho)\, d\Phi_P\left(p|\theta^H,\rho\right) dF_{\theta^H}(\rho) \\
& + (1-\alpha)\,\theta^L R I_{\theta^L} \int\int \chi_{\theta^L}(p,\rho)\, d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho) \\
& + \alpha l\left(\theta^H\right) I_{\theta^H} \int\int \left(1-\chi_{\theta^H}(p,\rho)\right) d\Phi_P\left(p|\theta^H,\rho\right) dF_{\theta^H}(\rho) \\
& + (1-\alpha)\, l\left(\theta^L\right) I_{\theta^L} \int\int \left(1-\chi_{\theta^L}(p,\rho)\right) d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho)
\end{aligned}
$$

$\mathbb{E}^{\theta}\left[\mathbf{c}^e_{\theta'}\chi_{\theta'}\right]$ θ θ'V

V

$$
\begin{aligned}
\mathbb{E}^{\theta}\left[\mathbf{c}^e_{\theta'}\chi_{\theta'}\right] =\; & \theta \int\int \bar{c}^e_{\theta}(p,\rho)\, \chi_{\theta}(p,\rho)\, d\Phi_P\left(p|\theta',\rho\right) dF_{\theta'}(\rho) \\
& + (1-\theta) \int\int \underline{c}^e_{\theta}(p,\rho)\, \chi_{\theta}(p,\rho)\, d\Phi_P\left(p|\theta',\rho\right) dF_{\theta'}(\rho) \\
& + \int c^e_{\theta,L}(p,\rho)\left(1-\chi_{\theta}(p,\rho)\right) d\Phi_P\left(p|\theta',\rho\right) dF_{\theta'}(\rho)
\end{aligned}
$$

$$
\max_{\left\{\mathbf{c}^e, \chi_{\theta^H}, \chi_{\theta^L}, I_{\theta^H}, I_{\theta^L}\right\}} S\left(\chi_{\theta^H}, \chi_{\theta^L}, I_{\theta^H}, I_{\theta^L}\right)
$$

$$
S\left(\chi_{\theta^H}, \chi_{\theta^L}, I_{\theta^H}, I_{\theta^L}\right) - \alpha \mathbb{E}^{\theta^H}\left[\mathbf{c}^e_{\theta^H}\chi_{\theta^H}\right] - (1-\alpha)\,\mathbb{E}^{\theta^L}\left[\mathbf{c}^e_{\theta^L}\chi_{\theta^L}\right] - \alpha I_{\theta^H} - (1-\alpha) I_{\theta^L} + A \qquad \text{RnS}
$$

$$
- \quad \alpha I_{\theta^H} \int\int \rho \chi_{\theta^H}(p,\rho)\, d\Phi_P\left(p|\theta^H,\rho\right) dF_{\theta^H}(\rho) - (1-\alpha) I_{\theta^L} \int\int \rho \chi_{\theta^L}(p,\rho)\, d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho) \geq 0
$$

$$
\mathbb{E}^{\theta^L}\left[\mathbf{c}^e_{\theta^L}\chi_{\theta^L}\right] \geq \mathbb{E}^{\theta^L}\left[\mathbf{c}^e_{\theta^H}\chi_{\theta^H}\right] \qquad \text{R S}
$$

$$
\mathbb{E}^{\theta^H}\left[\mathbf{c}^e_{\theta^H}\chi_{\theta^H}\right] \geq \mathbb{E}^{\theta^H}\left[\mathbf{c}^e_{\theta^L}\chi_{\theta^L}\right] \qquad \text{RjS}
$$

$$
\bar{c}^e_{\theta^H}(p,\rho) \geq (R-\rho_0)\, I_{\theta^H}, \quad \bar{c}^e_{\theta^L}(p,\rho) \geq (R-\rho_0)\, I_{\theta^L} \qquad \text{RbaS}
$$

$$
\begin{aligned}
\underline{c}^e_{\theta^H}(p,\rho) &\geq 0, \quad \underline{c}^e_{\theta^L}(p,\rho) \geq 0 \qquad \text{RbbS} \\
c^e_{\theta^H,L}(p,\rho) &\geq 0, \quad c^e_{\theta^L,L}(p,\rho) \geq 0
\end{aligned}
$$

z V W

R1SV VRj S R SV

RbaSV

RbbSY

V Y

V z zt Y

, μVνV$\theta^H \gamma_H(p,\rho)\, \phi_P\left(p|\theta^H,\rho\right) f_{\theta^H}(\rho)V\theta^L \gamma_L(p,\rho)\, \phi_P\left(p|\theta^L,\rho\right) f_{\theta^L}(\rho)$V

$\left(1-\theta^H\right) \varphi_H(p,\rho)\, \phi_P\left(p|\theta^H,\rho\right) f_{\theta^H}(\rho)V\left(1-\theta^L\right) \varphi_L(p,\rho)\, \phi_P\left(p|\theta^L,\rho\right) f_{\theta^L}(\rho)$, W

V Y YYY$\bar{c}^e_{\theta^H}(p,\rho)V\underline{c}^e_{\theta^H}(p,\rho)V\bar{c}^e_{\theta^L}(p,\rho)$V

$\underline{c}^e_{\theta^L}(p,\rho)$ V V

$$-\mu\alpha\chi_{\theta^H}(p,\rho) - \nu\frac{\theta^L}{\theta^H}\chi_{\theta^H}(p,\rho) + \gamma_H(p,\rho) \geq 0$$

$$-\mu\alpha\chi_{\theta^H}(p,\rho) - \nu\frac{1-\theta^L}{1-\theta^H}\chi_{\theta^H}(p,\rho) + \varphi_H(p,\rho) \geq 0$$

$$-\mu(1-\alpha)\chi_{\theta^L}(p,\rho) + \nu\chi_{\theta^L}(p,\rho) + \gamma_L(p,\rho) \geq 0$$

$$-\mu(1-\alpha)\chi_{\theta^L}(p,\rho) + \nu\chi_{\theta^L}(p,\rho) + \varphi_L(p,\rho) \geq 0$$

$$-\mu\alpha\left(1-\chi_{\theta^H}(p,\rho)\right) - \nu\frac{\theta^L}{\theta^H}\left(1-\chi_{\theta^H}(p,\rho)\right) + \delta_H(p,\rho) \geq 0$$

$$-\mu(1-\alpha)\left(1-\chi_{\theta^L}(p,\rho)\right) + \nu\left(1-\chi_{\theta^L}(p,\rho)\right) + \delta_L(p,\rho) \geq 0$$

" $\bar{c}^e_{\theta^H}(p,\rho) \geq (R-\rho_0)\, I_{\theta^H}$ $\underline{c}^e_{\theta^H}(p,\rho) \geq 0$

(p,ρ) RYW $\chi_{\theta^H}(p,\rho) = 1$SV $\gamma_H(p,\rho) = 0$

$\varphi_H(p,\rho) = 0$Y

$\bar{c}^e_{\theta^H}(p,\rho) \geq (R-\rho_0)\, I_{\theta^H}$ $\underline{c}^e_{\theta^H}(p,\rho) \geq 0$ Y

V

$$\bar{c}^e_{\theta^H}(p,\rho) = (R-\rho_0)\, I_{\theta^H}$$

$$\underline{c}^e_{\theta^H}(p,\rho) = 0$$

r V

$$-\mu(1-\alpha)R\chi_{\theta^L}(p,\rho) + \nu R\chi_{\theta^L}(p,\rho) + \gamma_L(p,\rho) \leq 0$$

$$-\mu(1-\alpha)R\chi_{\theta^L}(p,\rho) + \nu R\chi_{\theta^L}(p,\rho) + \varphi_L(p,\rho) \leq 0$$

– V $\bar{c}^e_{\theta^L}(p,\rho) = \infty$ $\underline{c}^e_{\theta^L}(p,\rho) = \infty$ R1SY

z

Y

z (p,ρ) $\chi_{\theta^L}(p,\rho)=1$V

$\bar{c}^e_{\theta^L}(p,\rho)$ $\underline{c}^e_{\theta^L}(p,\rho)$ $\bar{c}^e_{\theta^L}(p,\rho)\geq(R-\rho_0)I_{\theta^L}$ $\underline{c}^e_{\theta^L}(p,\rho)\geq 0$

Yz V $\gamma_L(p,\rho)=0$ $\varphi_L(p,\rho)=0$ k

$$-\mu(1-\alpha)+\nu=0$$

s V $\gamma_L(p,\rho)=0$ $\varphi_L(p,\rho)=0$ (p,ρ) $\chi_{\theta^L}(p,\rho)=1$Y

V (p,ρ) $\gamma_L(p,\rho)>0$ $\varphi_L(p,\rho)>0$V

$\bar{c}^e_{\theta^L}(p,\rho)$ $\underline{c}^e_{\theta^L}(p,\rho)$ Y

” V $-\mu(1-\alpha)+\nu=0$V (p,ρ) $\chi_{\theta^L}(p,\rho)=0$Y

á $\gamma_L(p,\rho)>0$ R S $\varphi_L(p,\rho)>0$ R

SY $\bar{c}^e_{\theta^L}(p,\rho)=\infty$V

$\underline{c}^e_{\theta^L}(p,\rho)=\infty$Y s V V

Y V $\gamma_L(p,\rho)=0$

$\varphi_L(p,\rho)=0$ (p,ρ) $\chi_{\theta^L}(p,\rho)=0$Yz $\gamma_L(p,\rho)=0$

(p,ρ) $\chi_{\theta^L}(p,\rho)=1$Y V$\gamma_L(p,\rho)=0$ (p,ρ)Y V V

$$\int\gamma_L(p,\rho)\left(\bar{c}^e_{\theta^L}(p,\rho)-(R-\rho_0)I_{\theta^L}\right)=0$$

I_{θ^L} V V $I_{\theta^L}=\infty$Y R1S Y

V

$$\bar{c}^e_{\theta^H}(p,\rho)\geq(R-\rho_0)I_{\theta^H},\quad \bar{c}^e_{\theta^L}(p,\rho)\geq(R-\rho_0)I_{\theta^L}$$

$$\begin{aligned}\underline{c}^e_{\theta^H}(p,\rho) &\geq 0,\quad \underline{c}^e_{\theta^L}(p,\rho)\geq 0\\ c^e_{\theta^H,L}(p,\rho) &\geq 0,\quad c^e_{\theta^L,L}(p,\rho)\geq 0\end{aligned}$$

A1.2 Proof of Lemma 1

t k

$$\max_{\{\chi_{\theta^H},\chi_{\theta^L},I_{\theta^H},I_{\theta^L}\}} S\left(\chi_{\theta^H},\chi_{\theta^L},I_{\theta^H},I_{\theta^L}\right)$$

$$\begin{aligned}&S\left(\chi_{\theta^H},\chi_{\theta^L},I_{\theta^H},I_{\theta^L}\right)-\alpha\mathbb{E}^{\theta^H}\left[\mathbf{c}^e_{\theta^H}\chi_{\theta^H}\right]-(1-\alpha)\mathbb{E}^{\theta^L}\left[\mathbf{c}^e_{\theta^L}\chi_{\theta^L}\right]-\alpha I_{\theta^H}-(1-\alpha)I_{\theta^L}+A\\ -\quad&\alpha I_{\theta^H}\int\int\rho\chi_{\theta^H}(p,\rho)\,d\Phi_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)-(1-\alpha)I_{\theta^L}\int\int\rho\chi_{\theta^L}(p,\rho)\,d\Phi_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)\geq 0\end{aligned}$$

$$\mathbb{E}^{\theta^L}\left[\mathbf{c}^e_{\theta^L}\chi_{\theta^L}\right] \geq \mathbb{E}^{\theta^L}\left[\mathbf{c}^e_{\theta^H}\chi_{\theta^H}\right]$$

s V z I_{θ^H}

I_{θ^L}Yr $\mathbf{c}^e$ V

k

$$V^* = \max_{\{\chi^H,\chi^L\}} A\frac{\tilde{S}\left(\chi_{\theta^H},\chi_{\theta^L}\right)}{\tilde{D}\left(\chi_{\theta^H},\chi_{\theta^L}\right)}$$

$$\begin{aligned}\tilde{S}\left(\chi_{\theta^H},\chi_{\theta^L}\right) \equiv\ & \alpha l\left(\theta^H\right) + \alpha\left(\theta^H R - l\left(\theta^H\right)\right)\int\int \chi_{\theta^H}(p,\rho)\, d\Phi_P\left(p|\theta^H,\rho\right) dF_{\theta^H}(\rho) \\ & + (1-\alpha)\, l\left(\theta^L\right) + (1-\alpha)\left(\theta^L R - l\left(\theta^L\right)\right)\int\int \chi_{\theta^H}(p,\rho)\, d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho)\end{aligned}$$

$$\begin{aligned}\tilde{D}\left(\chi_{\theta^H},\chi_{\theta^L}\right) \equiv\ & \alpha\left(1 - l\left(\theta^H\right) + \int\int\left(\rho - \theta^H\rho_0 + l\left(\theta^H\right)\right)\chi_{\theta^H}(p,\rho)\, d\Phi_P\left(p|\theta^H,\rho\right) dF_{\theta^H}(\rho)\right) \\ & + (1-\alpha)\frac{\int\int \chi_{\theta^H}(p,\rho)\, d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho)}{\int\int \chi_{\theta^L}(p,\rho)\, d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho)} \\ & \times\left(1 - l\left(\theta^L\right) + \int\int\left(\rho - \theta^L\rho_0 + l\left(\theta^L\right)\right)\chi_{\theta^L}(p,\rho)\, d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho)\right)\end{aligned}$$

z $\chi_\theta(p,\rho)$

$$\chi_\theta(p,\rho) = \begin{cases} 1 & p \geq \bar{p}_\theta(\rho) \\ 0 & \end{cases}$$

$\bar{p}_\theta(\rho)$Y z

Yr V $\bar{p}_\theta(\rho)$V

p k

$$\phi_P\left(p|\theta,\rho;\bar{p}_\theta(\rho)\right) = \begin{cases} \phi_u(R\theta - p) & p \geq R\theta + \bar{p}_\theta(\rho) - l(\theta) \\ \gamma\phi_u\left(R\theta^L - p\right) & \bar{p}_\theta(\rho) \leq p < R\theta + \bar{p}_\theta(\rho) - l(\theta) \\ (1-\gamma)\,\phi_u(l(\theta) - p) & \bar{p}_\theta(\rho) - R\theta + l(\theta) \leq p < \bar{p}_\theta(\rho) \\ \phi_u(l(\theta) - p) & p < \bar{p}_\theta(\rho) - R\theta + l(\theta) \end{cases}$$

k

$$V^* = \max_{\left\{\bar{p}_{\theta^H}(\rho),\bar{p}_{\theta^L}(\rho)\right\}} A\frac{\tilde{S}\left(\bar{p}_{\theta^H}(\rho),\bar{p}_{\theta^L}(\rho)\right)}{\tilde{D}\left(\bar{p}_{\theta^H}(\rho),\bar{p}_{\theta^L}(\rho)\right)}$$

dg

$$\tilde{S}\left(\bar{p}_{\theta^H}(\rho),\bar{p}_{\theta^L}(\rho)\right) \equiv \alpha l\left(\theta^H\right)+\alpha\left(\theta^H R-l\left(\theta^H\right)\right)\int\int_{\bar{p}_{\theta^H}(\rho)}^{\infty} d\Phi_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)$$
$$+(1-\alpha)\,l\left(\theta^L\right)+(1-\alpha)\left(\theta^L R-l\left(\theta^L\right)\right)\int\int_{\bar{p}_{\theta^H}(\rho)}^{\infty} d\Phi_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)$$

$$\tilde{D}\left(\bar{p}_{\theta^H}(\rho),\bar{p}_{\theta^L}(\rho)\right) \equiv \alpha\left(1-l\left(\theta^H\right)+\int\int_{\bar{p}_{\theta^H}(\rho)}^{\infty}\left(\rho-\theta^H\rho_0+l\left(\theta^H\right)\right)d\Phi_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)\right)$$
$$+(1-\alpha)\frac{\int\int_{\bar{p}_{\theta^H}(\rho)}^{\infty} d\Phi_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)}{\int\int_{\bar{p}_{\theta^L}(\rho)}^{\infty} d\Phi_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)}$$
$$\times\left(1-l\left(\theta^L\right)+\int\int_{\bar{p}_{\theta^L}(\rho)}^{\infty}\left(\rho-\theta^L\rho_0+l\left(\theta^L\right)\right)d\Phi_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)\right)$$

” YYY$\bar{p}_{\theta^L}(\rho)$

$$\max_{\bar{p}_{\theta^L}(\rho)}\frac{\left(\theta^L R-l\left(\theta^L\right)\right)\int\int_{\bar{p}_{\theta^L}(\rho)}^{\infty} d\Phi_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)}{1-l\left(\theta^L\right)+\int\int_{\bar{p}_{\theta^L}(\rho)}^{\infty}\left(\rho-\theta^L\rho_0+l\left(\theta^L\right)\right)d\Phi_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)} \qquad \text{RbcS}$$

RbcS Y

V χ_{θ^L} pYz V

ρ_L^*

$$\chi_{\theta^L}(\rho)=\begin{cases}1 & \rho\leq\rho_L^*\\ 0 & \end{cases}$$

u V_L^* RbcS $\chi_{\theta^L}(\rho)$

R??S R Sk

$$V^*=\max_{\bar{p}_{\theta^H}(\rho)} A\frac{\tilde{S}\left(\bar{p}_{\theta^H}(\rho),\rho_L^*\right)}{\tilde{D}\left(\bar{p}_{\theta^H}(\rho),\rho_L^*\right)} \qquad \text{RbdS}$$

t k

$$\int\int_{\bar{p}_\theta(\rho)}^{\infty} d\Phi_P\left(p|\theta,\rho\right)dF_\theta(\rho)$$
$$=\int\int_{R\theta+\bar{p}_{\theta^H}(\rho)-l(\theta)}^{\infty}\phi_u\left(R\theta-p\right)f_\theta(\rho)\,dpd\rho+\int\int_{\bar{p}_{\theta^H}(\rho)}^{R\theta+\bar{p}_{\theta^H}(\rho)-l(\theta)}\gamma\phi_u\left(R\theta-p\right)f_\theta(\rho)\,dpd\rho$$

z $\Phi_P(p|\theta,\rho)$Y

YYY$\bar{p}_{\theta^H}(\rho)$ k

$$-\gamma\phi_u\left(R\theta-\bar{p}_{\theta^H}(\rho)\right)f_\theta(\rho)-(1-\gamma)\,\phi_u\left(l(\theta)-\bar{p}_{\theta^H}(\rho)\right)f_\theta(\rho)\equiv-g_P^\theta\left(\bar{p}_{\theta^H}(\rho)\right)f_\theta(\rho)$$

w– t RbdS k

$$\begin{aligned}&-\alpha\left(\theta^H R-l\left(\theta^H\right)\right)g_P^H\left(\bar{p}_{\theta^H}(\rho)\right)f_{\theta^H}(\rho)-(1-\alpha)\left(\theta^L R-l\left(\theta^L\right)\right)g_P^L\left(\bar{p}_{\theta^H}(\rho)\right)f_{\theta^L}(\rho)\\+\quad&V^*\left(\alpha\left(\rho-\theta^H\rho_0+l\left(\theta^H\right)\right)g_P^H\left(\bar{p}_{\theta^H}(\rho)\right)f_{\theta^H}(\rho)+(1-\alpha)\frac{\theta^L R-l\left(\theta^L\right)}{V_L^*}g_P^L\left(\bar{p}_{\theta^H}(\rho)\right)f_{\theta^L}(\rho)\right)=0\end{aligned}$$

V $\bar{p}^*(\rho)$V

$$\frac{g_P^L\left(\bar{p}_{\theta^H}(\rho)\right)f_{\theta^L}(\rho)}{g_P^H\left(\bar{p}_{\theta^H}(\rho)\right)f_{\theta^H}(\rho)}=\frac{\alpha}{1-\alpha}\frac{\theta^H R-l\left(\theta^H\right)-V^*\left(\rho-\theta^H\rho_0+l\left(\theta^H\right)\right)}{\left(\theta^L R-l\left(\theta^L\right)\right)\left(\frac{V^*}{V_L^*}-1\right)}$$

RgS Y"

V^* V_L^*Y

w V_L^* V^* $\bar{p}_{\theta^H}(\rho;V^*,V_L^*)$ R z

V^* V_L^*S

$$\frac{g_P^L\left(\bar{p}_{\theta^H}\left(\rho;V^*,V_L^*\right)\right)f_{\theta^L}(\rho)}{g_P^H\left(\bar{p}_{\theta^H}\left(\rho;V^*,V_L^*\right)\right)f_{\theta^H}(\rho)}=\frac{\alpha}{1-\alpha}\frac{\theta^H R-l\left(\theta^H\right)-V^*\left(\rho-\theta^H\rho_0+l\left(\theta^H\right)\right)}{\left(\theta^L R-l\left(\theta^L\right)\right)\left(\frac{V^*}{V_L^*}-1\right)}\qquad\text{RbeS}$$

w V_L^* RbcS

$\bar{p}_{\theta^H}(\rho;V^*,V_L^*)$Y r V V_L^*V V^* RbeS

$\bar{p}_{\theta^H}(\rho;V^*,V_L^*)$ $\chi_{\theta^H}(p,\rho;V^*,V_L^*)$Y

,

$$\Gamma\left(V^*,V_L^*\right)=A\frac{\tilde{S}\left(\bar{p}_{\theta^H}\left(\rho;V^*,V_L^*\right),\rho_L^*\right)}{\tilde{D}\left(\bar{p}_{\theta^H}\left(\rho;V^*,V_L^*\right),\rho_L^*\right)}$$

bd $\bar{p}_{\theta^H}(\rho;V^*,V_L^*)V\rho_L^*$V V_L^*Y

V^* bd

$$V^*=\Gamma\left(V^*,V_L^*\right)$$

z Y

w W zt

k

$$I_{\theta^H} = \frac{A}{\tilde{D}\left(\chi_{\theta^H}, \chi_{\theta^L}\right)} \quad \text{RbfS}$$

$$I_{\theta^L} = \frac{\int\int \chi_{\theta^H}(p,\rho)\, d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho)}{\int\int \chi_{\theta^L}(p,\rho)\, d\Phi_P\left(p|\theta^L,\rho\right) dF_{\theta^L}(\rho)} \frac{A}{\tilde{D}\left(\chi_{\theta^H}, \chi_{\theta^L}\right)} \quad \text{RbgS}$$

w V $\chi_\theta(p,\rho)$ ReS

Yz R, θ^H, θ^L, $l\left(\theta^H\right)$, $l\left(\theta^L\right)$

$$\frac{d}{dp}\left(\frac{g_P^L(p)}{g_P^H(p)}\right)\Bigg|_{p=\left(R\theta^L + l\left(\theta^H\right)\right)/2} < 0$$

$g_P^L\left(\bar{p}_{\theta^H}(\rho)\right)/g_P^H\left(\bar{p}_{\theta^H}(\rho)\right)$ RgS

R S $\bar{p}_{\theta^H}(\rho)$Y

A1.3 Proof of Proposition 4

w RfSV ρV

$$\Pr\left(p \geq \bar{p}_{\theta^H}(\rho)\,|\rho\right) = \gamma \int_{\bar{p}_{\theta^H}(\rho)}^{R\theta + \bar{p}_{\theta^H}(\rho) - l(\theta)} \phi_u(R\theta - p)\, dp + \int_{R\theta + \bar{p}_{\theta^H}(\rho) - l(\theta)}^{\infty} \phi_u(R\theta - p)\, dp$$

, $u = R\theta^H - p$V

$$\begin{aligned} &= \gamma \int_{l\left(\theta^H\right) - \bar{p}_{\theta^H}(\rho)}^{R\theta - \bar{p}_{\theta^H}(\rho)} \phi_u(u)\, du + \int_{-\infty}^{l(\theta) - \bar{p}_{\theta^H}(\rho)} \phi_u(u)\, dp \\ &= \gamma \Phi\left(R\theta^H - \bar{p}_{\theta^H}(\rho)\right) + (1-\gamma)\,\Phi\left(l\left(\theta^H\right) - \bar{p}_{\theta^H}(\rho)\right) \end{aligned}$$

YYYσ_u^2 $\bar{p}_\theta(\rho)$ k

$$\begin{aligned} &-\frac{1}{2}\frac{1}{\sigma_u^2}\left(\gamma \int_{l\left(\theta^H\right) - \bar{p}_{\theta^H}(\rho)}^{R\theta - \bar{p}_{\theta^H}(\rho)} \frac{1}{\sqrt{2\pi\sigma_u^2}} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} du + \int_{-\infty}^{l(\theta) - \bar{p}_{\theta^H}(\rho)} \frac{1}{\sqrt{2\pi\sigma_u^2}} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} dp\right) \\ &+ \left(\gamma \int_{l\left(\theta^H\right) - \bar{p}_{\theta^H}(\rho)}^{R\theta - \bar{p}_{\theta^H}(\rho)} \frac{u^2}{2\left(\sigma_u^2\right)^2\sqrt{2\pi\sigma_u^2}} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} du + \int_{-\infty}^{l(\theta) - \bar{p}_{\theta^H}(\rho)} \frac{u^2}{2\left(\sigma_u^2\right)^2\sqrt{2\pi\sigma_u^2}} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} dp\right) \end{aligned}$$

$$= \frac{1}{2\left(\sigma_u^2\right)^2}\left(\gamma \int_{l\left(\theta^H\right) - \bar{p}_{\theta^H}(\rho)}^{R\theta - \bar{p}_{\theta^H}(\rho)} \frac{u^2 - \sigma_u^2}{\sqrt{2\pi\sigma_u^2}} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} du + \int_{-\infty}^{l(\theta) - \bar{p}_{\theta^H}(\rho)} \frac{u^2 - \sigma_u^2}{\sqrt{2\pi\sigma_u^2}} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} dp\right)$$

$$= \frac{1}{2\left(\sigma_u^2\right)^2}\left(\gamma \int_{-\infty}^{R\theta - \bar{p}_\theta(\rho)} \frac{u^2 - \sigma_u^2}{\sqrt{2\pi\sigma_u^2}} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} du + (1-\gamma)\int_{-\infty}^{l(\theta) - \bar{p}_{\theta^H}(\rho)} \frac{u^2 - \sigma_u^2}{\sqrt{2\pi\sigma_u^2}} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} dp\right)$$

$$R\theta - \bar{p}_\theta(\rho) < 0$$

$$l(\theta) - \bar{p}_\theta(\rho) > 0$$

$$R\theta - \bar{p}_\theta(\rho) > 0 > l(\theta) - \bar{p}_\theta(\rho)$$ γ

A1.4 Proof of Proposition 5

RbS RcS —

bVcV dY

w W —e

k

$$I_\theta^{AS} = \frac{A}{1 - l(\theta) + \int\int (\rho - \theta\rho_0 + l(\theta))\,\chi_\theta^{AS}(p,\rho)\,d\Phi_P^{AS}(p|\theta,\rho)\,dF_\theta(\rho)}$$

RdSY

k

$$\max_{\left\{\chi_{\theta^H}^{AS},\,\chi_{\theta^L}^{AS}\right\}} \left(R\theta^H \int\int \chi_{\theta^H}^{AS}(p,\rho)\,d\Phi_P^{AS}\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho) - 1 - \int\int \rho\chi_{\theta^H}^{AS}(p,\rho)\,d\Phi_P^{AS}\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)\right) I_{\theta^H}^{AS}$$

zt k

$$\begin{aligned} & \left(R\theta^L \int\int \chi_{\theta^L}^{AS}(p,\rho)\,d\Phi_P^{AS}\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho) - 1 - \int\int \rho\chi_{\theta^L}^{AS}(p,\rho)\,d\Phi_P^{AS}\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)\right) I_{\theta^L}^{AS} \\ \geq & \left(R\theta^L \int\int \chi_{\theta^H}^{AS}(p,\rho)\,d\Phi_P^{AS}\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho) - 1 - \int\int \rho\chi_{\theta^H}^{AS}(p,\rho)\,d\Phi_P^{AS}\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)\right) I_{\theta^H}^{AS} \end{aligned}$$

r Vz $\chi_\theta^{AS}(p,\rho)$

$$\chi_\theta^{AS}(p,\rho) = \begin{cases} 1 & p \geq \bar{p}_\theta^{AS}(\rho) \\ 0 & \end{cases}$$

$\bar{p}_\theta^{AS}(\rho)$Y z V

RfS k

$$\phi_P^{AS}(p|\theta,\rho) = \begin{cases} \phi_u(R\theta - p) & p \geq R\theta + \bar{p}_\theta^{AS}(\rho) - l(\theta) \\ \gamma\phi_u\left(R\theta^L - p\right) & \bar{p}_\theta^{AS}(\rho) \leq p < R\theta + \bar{p}_\theta^{AS}(\rho) - l(\theta) \\ (1-\gamma)\,\phi_u(l(\theta) - p) & \bar{p}_\theta^{AS}(\rho) - R\theta + l(\theta) \leq p < \bar{p}_\theta^{AS}(\rho) \\ \phi_u(l(\theta) - p) & p < \bar{p}_\theta^{AS}(\rho) - R\theta + l(\theta) \end{cases}$$ RhS

z k

$$\max_{\left\{\bar{p}^{AS}_{\theta^H},\,\bar{p}^{AS}_{\theta^L}\right\}}\left(R\theta^H\int_0^\infty\int_{\bar{p}^{AS}_{\theta^H}(\rho)}^\infty d\Phi^{AS}_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)-1-\int_0^\infty\int_{\bar{p}^{AS}_{\theta^H}(\rho)}^\infty\rho d\Phi^{AS}_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)\right)I^{AS}_{\theta^H}$$

zt k

$$\begin{aligned}&\left(R\theta^L\int_0^\infty\int_{\bar{p}^{AS}_{\theta^L}(\rho)}^\infty d\Phi^{AS}_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)-1-\int_0^\infty\int_{\bar{p}^{AS}_{\theta^L}(\rho)}^\infty\rho d\Phi^{AS}_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)\right)I^{AS}_{\theta^L}\\ \geq\ &\left(R\theta^L\int_0^\infty\int_{\bar{p}^{AS}_{\theta^H}(\rho)}^\infty d\Phi^{AS}_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)-1-\int_0^\infty\int_{\bar{p}^{AS}_{\theta^H}(\rho)}^\infty\rho d\Phi^{AS}_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)\right)I^{AS}_{\theta^H}\end{aligned}$$

x zt V

$I^{AS}_{\theta^H}$ Y

, V^{AS}_H V^{AS}_L V

Y Y z V

YYY $\bar{p}^{AS}_{\theta^L}(\rho)$ k

$$\left(1+V^{AS}_L\right)\rho-R\theta^L-V^{AS}_L\left(\theta\rho_0+l(\theta)\right)\geq 0 \qquad \text{Rbi S}$$

$\bar{p}^{AS}_{\theta^L}(\rho)$ Yr V V

k

$$\chi_{\theta^L}(\rho)=\begin{cases}1 & \rho\leq\bar{\rho}^{AS}_L\\ 0 & \end{cases}$$

$\bar{\rho}^{AS}_L$ bi Y ReSY

V zt

$I^{AS}_{\theta^H}$ k

$$\max_{\left\{\chi^{AS}_{\theta^H},\,\chi^{AS}_{\theta^L}\right\}}\left(R\theta^H\int\int\chi^{AS}_{\theta^H}(p,\rho)\,d\Phi^{AS}_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)-1-\int\int\rho\chi^{AS}_{\theta^H}(p,\rho)\,d\Phi^{AS}_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)\right)I^{AS}_{\theta^H}$$

$$V^{AS}_H\equiv\max_{\bar{p}^{AS}_{\theta^H}(\rho)}\frac{R\theta^H\int_0^\infty\int_{\bar{p}^{AS}_{\theta^H}(\rho)}^\infty d\Phi^{AS}_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)-1-\int_0^\infty\int_{\bar{p}^{AS}_{\theta^H}(\rho)}^\infty\rho d\Phi^{AS}_P\left(p|\theta^H,\rho\right)dF_{\theta^H}(\rho)}{R\theta^L\int_0^\infty\int_{\bar{p}^{AS}_{\theta^H}(\rho)}^\infty d\Phi^{AS}_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)-1-\int_0^\infty\int_{\bar{p}^{AS}_{\theta^H}(\rho)}^\infty\rho d\Phi^{AS}_P\left(p|\theta^L,\rho\right)dF_{\theta^L}(\rho)}V^{AS}_L$$

z zt R

V^{AS}_L SY YYY $\bar{p}^{AS}_{\theta^H}(\rho)$ k

$$\frac{g^{AS}_P\left(\bar{p}^{AS}_{\theta^H}(\rho)\,|\theta^L,\rho\right)}{g^{AS}_P\left(\bar{p}^{AS}_{\theta^H}(\rho)\,|\theta^H,\rho\right)}\frac{f_{\theta^L}(\rho)}{f_{\theta^H}(\rho)}=\frac{V^{AS}_L\left(\rho-R\theta^H\right)}{V^{AS}_H\left(R\theta^L-\rho\right)} \qquad \text{Rbj S}$$

$$g_P^{AS}\left(\bar{p}_{\theta^H}^{AS}(\rho)\,|\theta,\rho\right)=\gamma\phi_u\left(R\theta-\bar{p}_{\theta^H}^{AS}(\rho)\right)+(1-\gamma)\,\phi_u\left(l\,(\theta)-\bar{p}_{\theta^H}^{AS}(\rho)\right)$$

bj $\bar{p}_{\theta^H}^{AS}(\rho)$Y– V — dV bj

V_H^{AS} V_H^{AS} Y z VV_H^{AS}

— dY

RfS

v k r

z z

Y z V

Y z c z

Y

z V z

Y

Y w V z

V

Y – V V z

Y –

V z V W

Y z V

Y – V V

Y

r ff á R oj hg S V W

V

L L W Y V V

W Y

Y z V W V *ex-ante* V

Y

– V *ex-post*

Y

u

V Y

t V V ff á R oj hg S Y

”

Y V V

Y “ V V

W Y

Y

–

Y ff R oj hj S V ? V ?

Y ff á
Rbj hgSV Y?
ff á Rbj hgS
Y
— Rbj i eS
Y W V W
W V
W Y— Y
R
SY z
Y — Rbj i eS
V V
Yz V ff Wá V
”
ff á Rbj hgS Y
z Vs x RcaagS
— Rbj i eS
Yr V
ff Wá
W Y
Y s x RcaagS
’ Y V
V
ff Wá Yy V ff á Rcaai S
V s x RcaagS V
’ Y
x Vz
ff á Rbj hgSYz
W Y
r V W
Y– V W
ff á Rbj hgSV V —
Rbj i eSV V R S Y V

V W
Y
W
Y
Yy Vz W
ex-ante R V S
V Y– V
ex-post
z Y
V W
Y” V
Yw V
V
Y L L p z
W Y V
Y” V
Y
W V
Y V

Yy V
Y
W
Yz Vt á Rbj i gS V Vff Rcabb S
W
Yz Vff Rcabb S
Yy V W W
V W Y
– V W V
[d] Y
ex-ante V V W

[d] ff Rbj hj V S L L R
ff WW SV Rbj hh S “ Rbj hh SW
Rbj hh SW Rbj hi S L L Y

ex-post

$$\max_{\mathcal{C}\subseteq\mathbb{C}^{MH}} U\left(C_{\theta^H};\theta^H,\Phi_p\left(\cdot|\theta^H,\rho\right)\right)$$

$$\pi\left(C_\theta;\theta,\Phi_p\left(\cdot|\theta,\rho\right)\right)=0 \quad \forall\theta\in\Theta$$

$$U\left(C_{\theta^i};\theta^i,\Phi_p\left(\cdot|\theta^i,\rho\right)\right)\geq U\left(C_{\theta^j};\theta^i,\Phi_p\left(\cdot|\theta^i,\rho\right)\right) \quad i,j=L,H$$

Proposition 5. *The solution to P4 (which coincides with the equilibrium of the game when the latter exists) is given by a menu of contracts $\mathcal{C}^{AS}$ with the following properties:*

1. *The entrepreneur consumes the minimum share of output if the project is successful and nothing otherwise:*

$$\bar{c}_\theta^{e,AS}(p,\rho)=(R-\rho_0)\,I_\theta^{AS},\ \ \underline{c}_\theta^{e,AS}(p,\rho)=0,\ \ c_{\theta,L}^{e,AS}(p,\rho)=0$$

2. *The investor receives all the pleadgeble income if the project is successful and the liquidation value if the project is liquidated:*

$$\bar{c}_{\theta}^{i,AS}(p,\rho)=\rho_0 I_{\theta}^{AS},\ \underline{c}_{\theta}^{i,AS}(p,\rho)=0,\ c_{\theta,L}^{i,AS}(p,\rho)=l(\theta)\,I_{\theta}^{AS}$$

3. *The low type obtains the same liquidity insurance as in the symmetric information benchmark:*

$$\chi_{\theta^L}^{AS}(\rho)=\begin{cases}1 & \text{if } \rho\leq\bar{\rho}_L^{AS}\\ 0 & \text{otherwise}\end{cases}$$

where $\bar{\rho}_L^{AS}$ is the solution to 18 in the appendix.

4. *The continuation rule for the high type $\chi_{\theta^H}^{AS}(p,\rho)$ depends on the asset price. Formally, for each ρ there exists a threshold $\bar{p}_{\theta^H}^{AS}(\rho)$ such that*

$$\chi_{\theta^H}^{AS}(p,\rho)=\begin{cases}1 & \text{if } p\geq\bar{p}_{\theta^H}^{AS}(\rho)\\ 0 & \text{otherwise}\end{cases}$$

where $\bar{p}_{\theta^H}^{AS}(\rho)$ is the solution to 19 in the appendix.

5. *Investment is given by:*

$$I_{\theta}^{AS}=\frac{A}{1-l(\theta)+\int\int(\rho-\theta\rho_0+l(\theta))\,\chi_{\theta}^{AS}(p,\rho)\,d\Phi_P^{AS}(p|\theta,\rho)\,dF_{\theta}(\rho)}$$

6. *The optimal contract determines an equilibrium distribution for the asset price $\Phi_P^{AS}(p|\theta,\rho)$ given by (17) in the appendix.*