Screening for breakthroughs

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paper: arXiv.org/abs/2011.10090

Progress: finding & implementing better ways of doing things.

Requires

(1) discovery

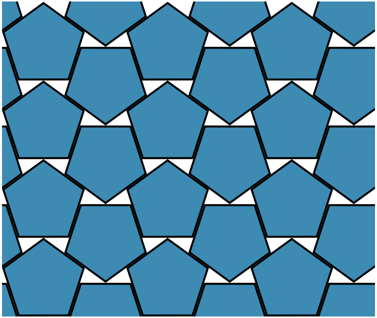
(2) disclosure.

$\Longrightarrow$ progress requires incentivising disclosure.

Vignette: footballs

Atkin, Chaudhry, Chaudry, Khandelwal & Verhoogen, *QJE* 2017

- materials-saving production method
- very few firms adopted
- reason: workers did not disclose.

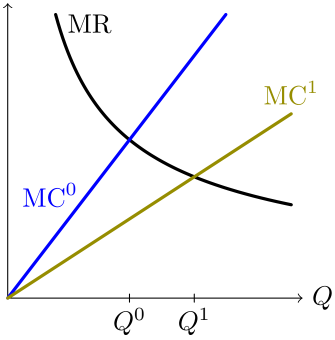


Example: skilling up production

A firm produces output using labour: $Q = Y(L)$.

(Simplest) rigidity: fixed salary.

Worker acquires a *skill* at random time $\tau \sim G$.



Privately observed;
can be verifiably disclosed.

Skilled production has lower MC.

- cheaper $\implies$ better.
- incentive to produce more $\implies$ more toil for worker.

Model

Breakthrough occurs at uncertain time.

- privately observed by agent
- expands utility possibilities
- causes conflict of interest

Agent (verifiably) discloses breakthrough at time of her choosing.

Principal controls physical allocation over time
$\Longrightarrow$ controls agent's utility.

Principal has commitment.

Applications

Talent-hoarding

Manager observes whether & when subordinate acquires skill.

Conflict: HQ wants to assign talent optimally,
manager wants to keep worker.

Unemployment insurance

Unemployed worker receives job offer at uncertain time.

State observes employment status, not job offers.

Conflict: state wants employed to work hard & pay tax.

Results

Question: how best to incentivise disclosure of privately-observed breakthrough?

Answer: mechanisms with deadline structure.

- affine case: simple deadline mechanism.
- in general: graduated deadline mechanism.

Related literature

Dynamic mechanism design

- *difference:* agent cannot secretly enjoy breakthrough.

  $\hookrightarrow$ suitable when principal observes what tech used.

- *closest paper:* Bird & Frug (2019).
  - *difference:* agent can delay disclosure.

Verifiable disclosure

- *difference:* agent can delay, principal has commitment.

Contribution

(1) identify pervasive agency problem:
the need to incentive *prompt* disclosure.

(2) isolate & study the problem:
characterise optimal mechanisms.

(3) develop techniques for this problem.

Plan

Model

The principal's problem

Keeping the agent indifferent

Deadline mechanisms

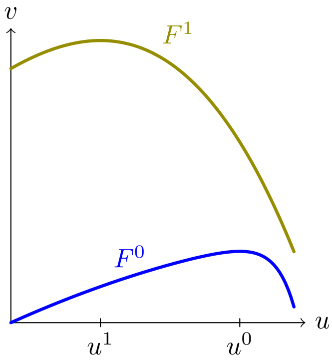
Optimal mechanisms in general

Unemployment insurance

Model

Agent & principal. Utilities $u \in [0, \infty)$ and $v \in [-\infty, \infty)$.

Time $t \in [0, \infty)$. Common discount rate $r > 0$.



Utility possibility frontiers $F^0 \leq F^1$

– unique peaks u^0, u^1.

– concave and upper semi-continuous

– $F^1 - F^0$ has strict local max on $\left[0, u^0\right]$.

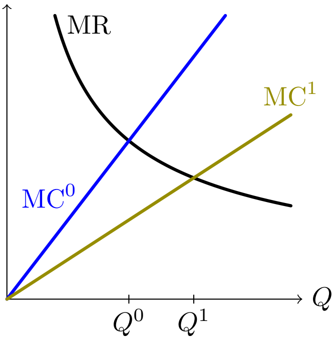
Conflict of interest:
peaks satisfy $u^1 < u^0$.

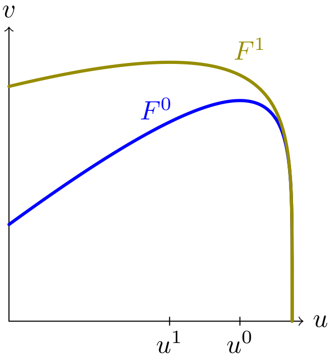
F^1 arrives at $\tau \sim G$. $G(0) = 0$.

Agent observes breakthrough, can disclose availability of F^1.

Principal controls flow u, has commitment. (discussion: slide 42)

Example: skilling up production





$$\text{As } Q \nearrow, \quad \text{worker suffers} \;\; \& \;\; \text{profit} \begin{cases} \nearrow & \text{while } Q \leq Q^j \\ \searrow & \text{while } Q > Q^j. \end{cases}$$

Mechanisms

A mechanism is (x^0, X^1)

– x_t^0: flow utility at time t if agent has not disclosed,

– X_t^1: continuation utility from disclosing at time t

$$= r\int_t^\infty e^{-r(s-t)} x_s^{1,t} \mathrm{d}s \quad \text{for some flow } \left(x_s^{1,t}\right)_{s\geq t}.$$

Incentive-compatibility

Mechanism (x^0, X^1) is *incentive-compatible ('IC')* iff agent prefers to disclose promptly:

(a) does not prefer to delay disclosure by some $d > 0$

(b) does not prefer to *never* disclose.

Revelation principle: suffices to consider IC mechanisms.

Wlog for IC to use F^1 when available. (Clearly optimal.)

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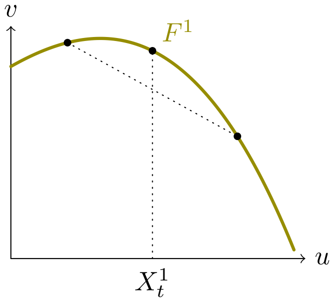
The principal's problem after disclosure

Fix a mechanism (x^0, X^1).

Recall: for each t, continuation X^1_t provided by a flow $\left(x^{1,t}_s\right)_{s \geq t}$



$$\text{s.t.} \quad r \int_t^\infty e^{-r(s-t)} x^{1,t}_s \mathrm{d}s = X^1_t.$$

Principal's flow payoff: $F^1\left(x^{1,t}_s\right)$.

Option 1: constant flow
$x^{1,t}_s = X^1_t \quad \forall s \geq t$.

Option 2: non-constant flow.

F^1 concave $\implies$ constant better.

The principal's problem

Fix a mechanism (x^0, X^1).

Principal's flow payoff:

– before breakthrough: $F^0(x^0_t)$

– after breakthrough: $F^1(X^1_\tau)$ forever

Principal's problem:

$$\max_{(x^0, X^1)} \mathbf{E}_{\tau \sim G}\left(r \int_0^\tau e^{-rt} F^0\left(x^0_t\right) \mathrm{d}t + e^{-r\tau} F^1\left(X^1_\tau\right)\right) \quad \text{s.t. IC.}$$

Undominated and optimal mechanisms

Principal's problem:

$$\max_{(x^0,X^1)} \mathbf{E}_{\tau\sim G}\left(r\int_0^\tau e^{-rt}F^0\left(x_t^0\right)\mathrm{d}t + e^{-r\tau}F^1\left(X_\tau^1\right)\right) \quad \text{s.t. IC.}$$

An IC mechanism *dominates* another iff

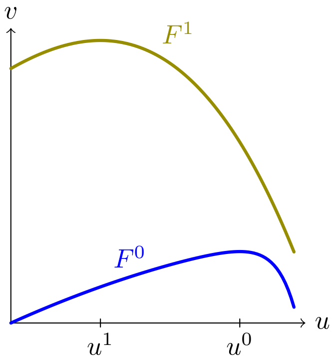
- former is better for every G,
- strictly for some G.

Undominated: not dominated by any IC mechanism.

An IC mechanism is *optimal* for G iff undominated
& maximises principal's payoff under G.

Undominated mechanisms have $x^0 \leq u^0$

Lemma. If (x^0, X^1) is undominated, then $x^0_t \leq u^0$ for a.e. t.



If $x^0_t > u^0$, lower it:

– better for principal

– delay *less* attractive
$\implies$ still IC.

(proof: slide 43)

Plan

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Keeping the agent indifferent

Fix a mechanism (x^0, X^1).

Let X_t^0 denote time-t continuation utility from *never* disclosing:

$$X_t^0 := r \int_t^\infty e^{-r(s-t)} x_s^0 \mathrm{d}s.$$

Agent chooses between

– disclosing promptly: payoff X_t^1

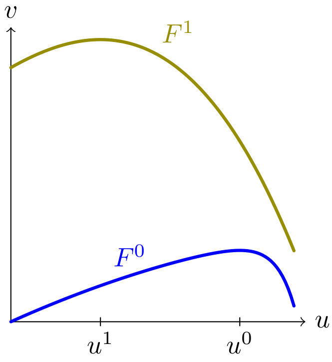
– never disclosing: payoff X_t^0

– delaying by $d > 0$: payoff $X_t^0 + e^{-rd} \left(X_{t+d}^1 - X_{t+d}^0 \right)$

Theorem 1. If (x^0, X^1) is undominated,
then agent always indifferent: $X_t^1 = X_t^0$ for every t.

Keeping the agent indifferent

Theorem 1. If (x^0, X^1) is undominated,
then agent always indifferent: $X_t^1 = X_t^0$ for every t.



Naïve intuition:
when incentive strict,
lower disclosure reward X_t^1.

Problem: need not benefit principal.

Hurts her if $X_t^1 \in [0, u^1]$.
And will spend time here!

(sketch proof: slide 44)

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Dropping superscripts

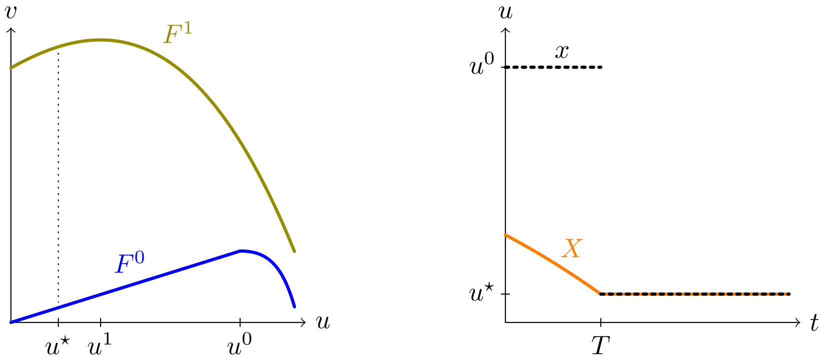
A mechanism is (x^0, X^1).

An *undominated* mechanism is pinned down by x^0 since X^1 must make agent indifferent (Theorem 1):

$$X_t^1 = X_t^0 = r \int_t^\infty e^{-r(s-t)} x_s^0 \mathrm{d}s.$$

Drop superscripts: a mechanism is (x, X). (Automatically IC.)

Deadline mechanisms

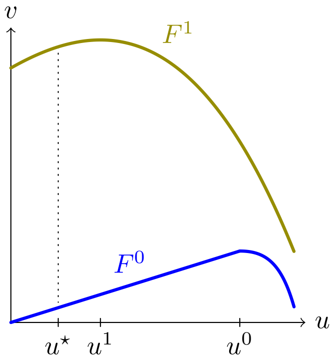


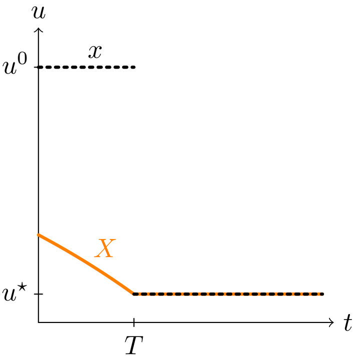
Suppose F^0 is affine on $[0, u^0]$.

Write $u^\star$ for max of $F^1 - F^0$ on $[0, u^0]$.

Deadline mechanism (x, X): $\quad x_t = \begin{cases} u^0 & t < T \\ u^\star & t \geq T \end{cases}$ $\quad$ for $T \in [0, \infty]$.

Deadline mechanisms



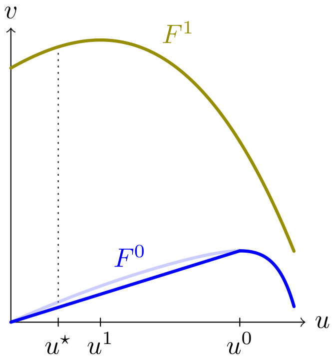


Theorem 2. If F^0 is affine on $[0, u^0]$,
then all undominated mechanisms are deadline mechanisms.

– undistorted early: $x_t = u^0$

– inefficient late: $x_t < u^0$

The role of affineness

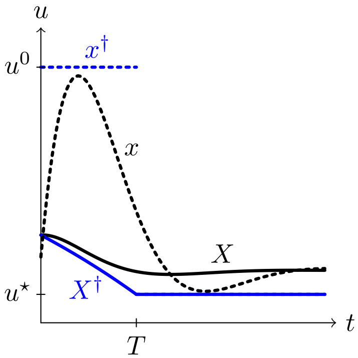


Countervailing force:

if F^0 strictly concave,
then intermediate flows x^0
better than extreme ones.

This force is absent if F^0 is affine.

Front-loading



Fix a mechanism (x, X)

with $\quad u^\star \leq x \leq u^0$.

Deadline mechanism:

$$x_t^\dagger = \begin{cases} u^0 & \text{for } t < T \\ u^\star & \text{for } t \geq T \end{cases}$$

with T s.t. $\quad X_0^\dagger = X_0$.

A *front-loading:* flow has same present value,
but is higher early and lower late.

(better: slide 49)

Optimal deadline

Optimal deadline depends on breakthrough distribution G:
given by a first-order condition. (undom. DLs: slide 55) (FOC: slide 56)

Later breakthrough ($G \nearrow$ in FOSD) $\implies$ later deadline.

Summary: if F^0 affine,

– qualitative prediction: deadline mechanism.
distribution-free.

– quantitative prediction: deadline given by FOC.
distribution-dependent.

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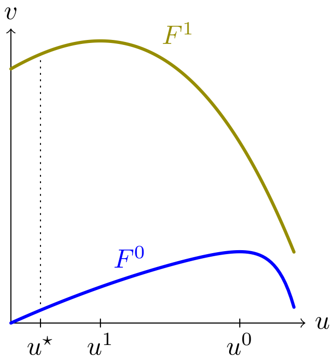
Optimal mechanisms in general

Let $u^\star$ be the rightmost $u \in [0, u^0]$ at which F^0, F^1 have equal slopes.

Theorem 3. Any mechanism (x, X) optimal for a distribution G with unbounded support has $x_t \searrow$ from $\lim_{t\to 0} x_t = u^0$ to $\lim_{t\to\infty} x_t = u^\star$.



Current pf assumes: F^0 strictly concave, F^0, F^1 possess bounded derivatives.

Only difference from deadline mech: may want *gradual* transition to exploit concavity of F^0.

(undominated mechanisms: slide 59)

Optimal path

Distribution-free qualitative prediction: $x_t \searrow$ from u^0 to $u^\star$.

Optimal path depends on breakthrough distribution G:
described by an Euler equation. (Euler: slide 60)

Later breakthrough ($G \nearrow$ in MLRP)

$\Longrightarrow$ more lenient: $X_t \nearrow$ in every period t.

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Unemployment insurance

Purpose of UI: support the *involuntarily* unemployed.

– want those with job offers to accept.

Difficulty: job offers privately observed.

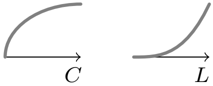
$\Longrightarrow$ cannot be too generous
lest workers turn down offers.

Model

Unemployed worker receives job offer at uncertain time,
chooses whether & when to accept.

State observes employment status, not job offers.

Worker values consumption & leisure: $u = \phi(C) - \kappa(L)$



Social welfare: $$v = \underbrace{u}_{\text{worker}} + \lambda \times \underbrace{(wL - C)}_{\text{net tax revenue}}$$

State controls C, L using fiscal powers.

Optimal UI: literature

Private job offers esp. Atkeson and Lucas (1995)

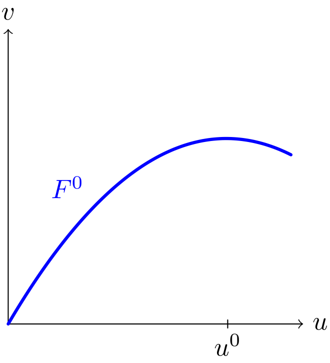
– *assumption:* offers expire instantly.

Private search effort esp. Shavell and Weiss (1979), Hopenhayn and Nicolini (1997)

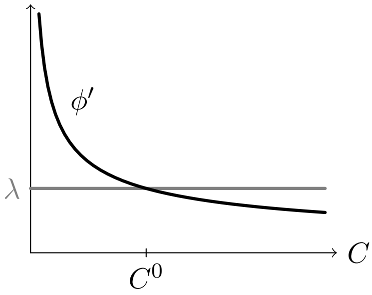
– moral hazard rather than adverse selection

Utility possibilities

$$u \;=\; \phi(C) \qquad\qquad v \;=\; u \;+\; \lambda \times (\qquad - C)$$

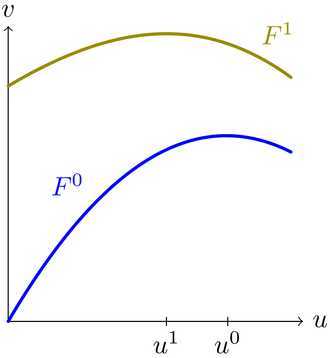


Unemployed: $L = 0.$



Utility possibilities

$$u = \phi(C) - \kappa(L) \qquad v = u + \lambda \times (wL - C)$$



Unemployed: $L = 0$.

Employed: vary both C & L.

Conflict $u^1 < u^0$:
state wants $L > 0$, worker doesn't.

($u^\star$: slide 61)

Deadline benefits

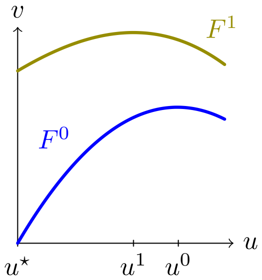
Deadline mechanism: e.g. Germany, France, Sweden, …

– before deadline: high benefit / efficient consumption

Germany: 60% of previous net salary.

– after deadline: low benefit.

Germany: €446 per month.



Approx optimal iff F^0 approx affine.

either (a) ϕ close to affine

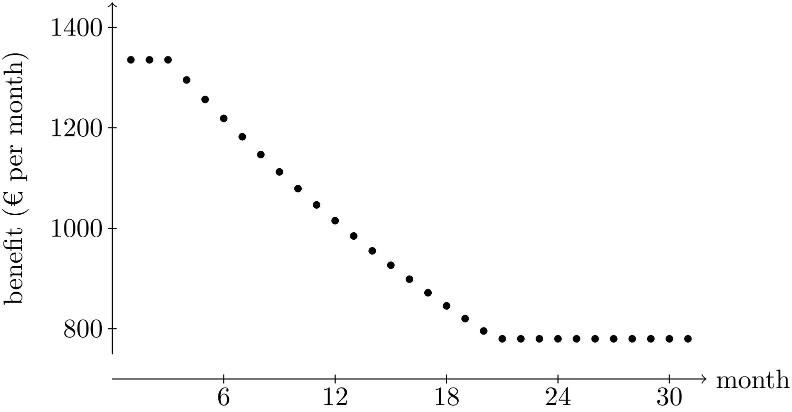
or (b) λ small.

(other countries: slide 62)

Gradual tapering

Exactly optimal benefit: ↘ from generous to low.

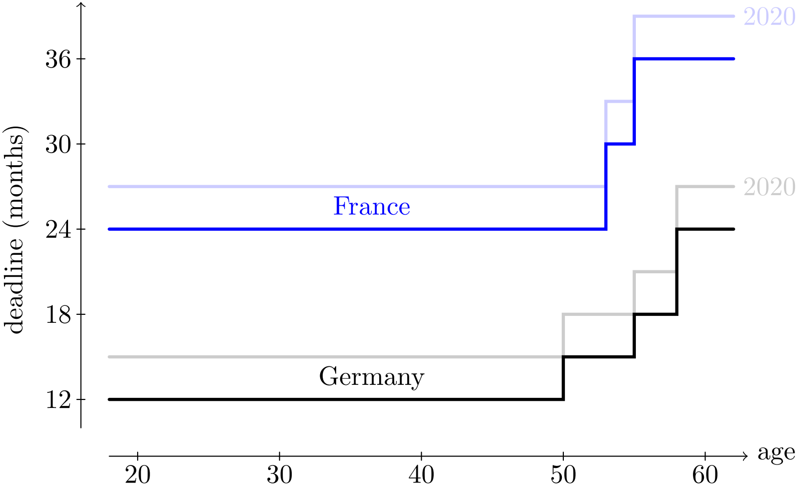
Italy:



Choice of deadline

Optimal deadline: later for workers with worse prospects.

$\Longrightarrow$ later (1) for older workers. (2) during recessions.



Deadlines were extended during the 2020 recession.

Conclusion

Problem: agent privately observes technological breakthrough.

Solution: a deadline structure to incentivise disclosure.

– affine case: simple deadline mechanism.

– in general: graduated deadline mechanism.

Method: new techniques, e.g. front-loading argument.

Conclusion

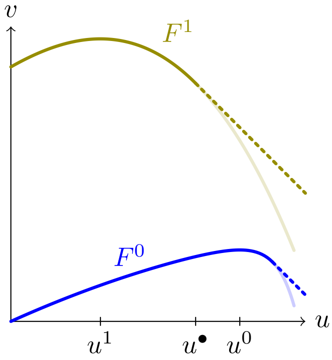
Problem: agent privately observes technological breakthrough.

Future work: embed our problem in richer environments, utilising our techniques. E.g.

– costly & unobservable effort to hasten breakthrough

– repeated breakthroughs over time.

The limited role of transfers



Suppose can pay agent $w \geq 0$.

$\implies$ payoffs resp. $u + w$ & $v - w$.

Expands utility possibility frontiers when slope < -1.

Transfers used only where expanded frontier $>$ original.

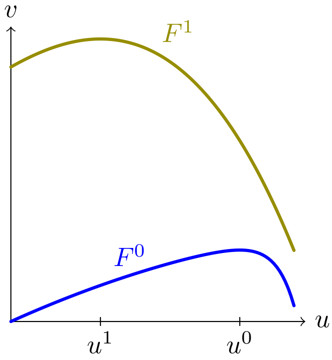
Proposition. Undominated mechanisms (x, X) use transfers

– only after disclosure

– only when $X > u^\bullet$.

Robustness

Weak assumptions on frontiers F^0, F^1 & distribution G.



Without loss:

- F^0, F^1 concave, usc
- disclosures verifiable (if principal observes her payoff)

Nothing changes:

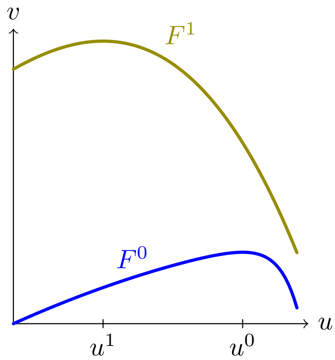
- participation instead of $u \geq 0$
- random F^1, provided agent doesn't observe realisation.

Little changes: noisy monitoring.

(back to slide 11)

Undominated mechanisms have $x^0 \leq u^0$: proof

Lemma. If (x^0, X^1) is undominated, then $x^0_t \leq u^0$ for a.e. t.



Proof: Fix an IC (x^0, X^1).

Alternative mechanism:
$(\min\{x^0, u^0\}, X^1)$.

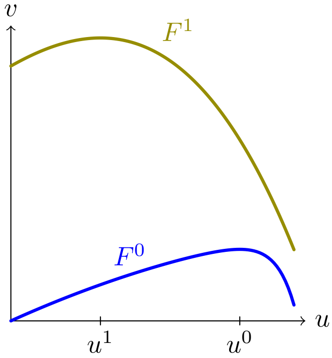
Better, strictly unless $x^0 \leq u^0$ a.e.

and IC: in every period,

- disclosure equally attractive
- non-disclosure
  (weakly) less attractive. ■

(back to slide 19)

Sketch proof of Theorem 1



Discrete time. Write $\beta := e^{-r}$.

IC requires

$$X^1_s \geq (1-\beta)x^0_s + \beta X^1_{s+1} \quad \forall s.$$

Suppose IC slack at time t:

$$\underbrace{X^1_t}_{> u^1} \; > \; (1-\beta) \underbrace{x^0_t}_{\geq u^1} + \beta \underbrace{X^1_{t+1}}_{\geq u^1}.$$

If both RHS terms are $\geq u^1$, then the LHS is $> u^1$

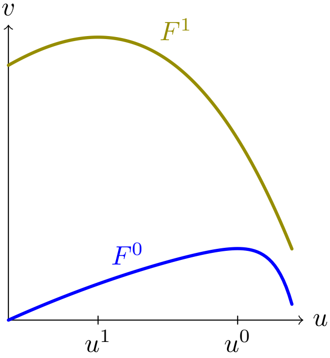
$\iff$ either (i) $X^1_t > u^1$, (ii) $x^0_t < u^1$, or (iii) $X^1_{t+1} < u^1$.

Sketch proof of Theorem 1

slack IC: $X_t^1 \quad > \quad (1-\beta)x_t^0 \quad + \quad \beta X_{t+1}^1$

$\implies$ either (i) $X_t^1 > u^1$, (ii) $x_t^0 < u^1$, or (iii) $X_{t+1}^1 < u^1$

There's an IC-preserving improvement in each case:



Case (i): lower X_t^1
(Preserves time-t IC,
slackens time-$(t-1)$ IC.)

Case (ii): raise x_t^0
(Preserves time-t IC.)

Case (iii): raise X_{t+1}^1
(Preserves time-t IC,
slackens time-$(t+1)$ IC.)

(back to slide 22)

Sketch proof of Theorem 1: remaining pieces

(1) We showed: agent is indifferent about *delaying* disclosure.

Final piece: agent indifferent about *never* disclosing.

(proof: slide 47)

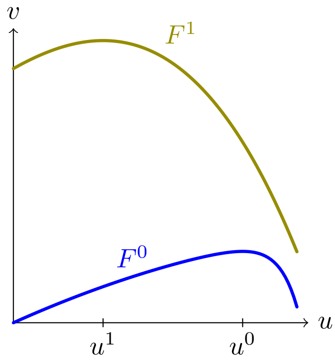
(2) Proof in continuous time: delicate, but same economics.

– case (ii): insufficient to modify x^0 in single period: must increase it on *non-null* set of times.

– cases (i) & (iii): cannot modify X^1 in single period while preserving IC.

(back to slide 22)

Final piece in proof of Theorem 1



We showed: agent is indifferent about *delaying* disclosure:

$$X_t^1 = (1-\beta)x_t^0 + \beta X_{t+1}^1$$
$$= \underbrace{(1-\beta)\sum_{s=t}^{T-1} \beta^{s-t} x_s^0}_{\to X_t^0 \text{ as } T\to\infty} + \beta^{T-t} X_T^1.$$

Must show:
indifferent about *never* disclosing:

$$X_t^1 = X_t^0 \iff \lim_{T\to\infty} \beta^{T-t} X_T^1 = 0.$$

If not, then X_t^1 blows up as $t \to \infty$.
Fairly clear that this is not optimal.

(back to slide 46)

Final piece in proof of Theorem 1: formal

Since $X^1_t \to \infty$, there is a time T after which $X^1_t > u^0 + u^1$.

Consider $(x^0, X^{1\dagger})$, where $X^{1\dagger}_t := \begin{cases} X^1_t & \text{for } t \leq T \\ X^0_t + u^1 & \text{for } t > T. \end{cases}$

Better since $u^1 \leq X^{1\dagger}_t \leq X^1_t$, strictly after T.

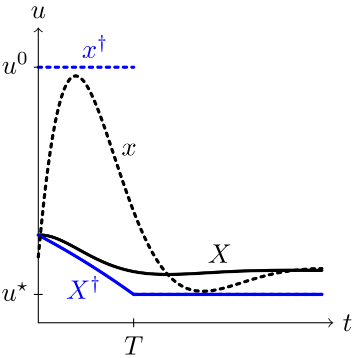
To verify IC, check deviations:

– never disclosing is unprofitable: $X^{1\dagger} \geq X^0$

– before T, delay is unprofitable:
  – delaying to $t' \leq T$: same as in original mechanism
  – delaying to $t' > T$: worse than in original mechanism

– after T, delay is unprofitable:
earn u^1 upon disclosure, so sooner is better. (back to slide 46)

Sketch proof of Theorem 2



Fix a mechanism (x, X)

with $\quad u^\star \leq x \leq u^0.$

Deadline mechanism:

$$x_t^\dagger = \begin{cases} u^0 & \text{for } t < T \\ u^\star & \text{for } t \geq T \end{cases}$$

with T s.t. $\quad X_0^\dagger = X_0.$

Front-loading x makes X decrease faster (before T):

$$X_t^\dagger \leq X_t \quad \text{with equality at } t = 0.$$

(proof: slide 52)

Sketch proof of Theorem 2

Write
$$Y_t := r \int_t^\infty e^{-rs} F^0(x_s) \mathrm{d}s$$
$$= F^0\left(r \int_t^\infty e^{-rs} x_s \mathrm{d}s \right) = F^0(X_t) \quad \text{since } F^0 \text{ affine.}$$

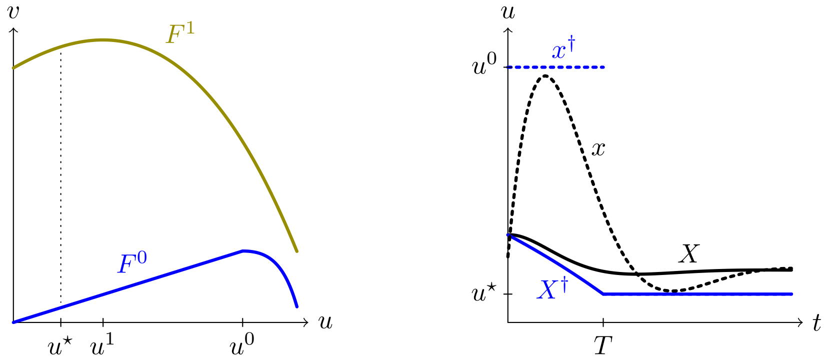
Principal's payoff:
$$Y_0 + e^{-r\tau}\Big[F^1(X_\tau) - Y_\tau \Big]$$
$$= F^0(X_0) + e^{-r\tau}\Big[F^1(X_\tau) - F^0(X_\tau) \Big].$$

Front-loading...

– increases pre-disclosure payoff $Y_0 - e^{-r\tau} Y_\tau$.

– changes post-disclosure payoff $F^1(X_\tau)$.

Sketch proof of Theorem 2



Principal's payoff: $F^0(X_0) + e^{-r\tau}\Big[F^1(X_\tau) - F^0(X_\tau)\Big].$

Since $X \geq u^\star$, F^0 steeper than $F^1 \implies$ lower X is better.

Slight elaboration to drop assumption $x \geq u^\star$. (full proof: slide 53)

(back to slide 27)

Proof of Theorem 2: front-loading lowers $\boldsymbol{X}$

Mechanism (x, X). Deadline mechanism:

$$x_t^\dagger = \begin{cases} u^0 & \text{for } t < T \\ u^\star & \text{for } t \geq T \end{cases} \quad \text{with } T \text{ s.t. } X_0^\dagger = X_0.$$

Claim. $X^\dagger \leq X$. (With equality at $t = 0$.)

Proof:

- For $t < T$, since $x^\dagger = u^0 \geq x$ on $[0, t] \subseteq [0, T]$,

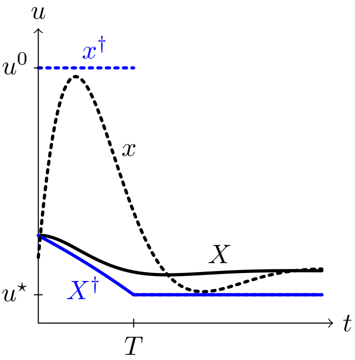
$$\begin{aligned} e^{-rt} X_t^\dagger &= X_0^\dagger - r \int_0^t e^{-rs} x_s^\dagger \mathrm{d}s \\ &\leq X_0 - r \int_0^t e^{-rs} x_s \mathrm{d}s = e^{-rt} X_t. \end{aligned}$$

- for $t \geq T$, $X_t^\dagger = u^\star \leq X_t$.
  (Recall: assumed $u^\star \leq X_t$ for simplicity.) ■

(back to slide 49)

Proof of Theorem 2: dropping $x \geq u^\star$

$$\text{Principal's payoff} \;=\; F^0(X_0) + e^{-r\tau}\left[F^1 - F^0\right](X_\tau)$$



Fix any mechanism (x, X).

Alternative deadline mechanism:

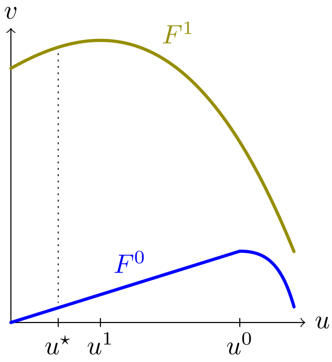
$$x_t^\dagger = \begin{cases} u^0 & \text{for } t < T \\ u^\star & \text{for } t \geq T, \end{cases}$$

with T s.t. $\quad X_0^\dagger = \underline{\underline{X_0 \vee u^\star}}$.

Idea: still a front-loading, but now possibly *increase* X_0. (Good.)

Proof of Theorem 2: dropping $x \geq u^\star$

$$\text{Principal's payoff} \;=\; F^0(X_0) + e^{-r\tau}\Big[F^1 - F^0\Big](X_\tau)$$



By the front-loading logic,
$X^\dagger \;\leq\; X \vee u^\star$.

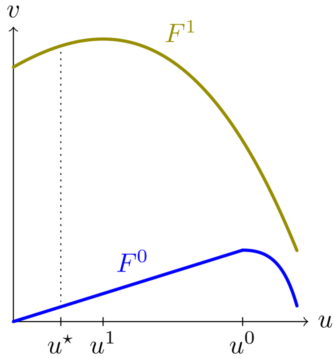
$X^\dagger$ better since
both are $\geq u^\star$,
and $F^1 - F^0 \searrow$ on $[u^\star, u^0]$.

Clearly $X \vee u^\star \;\geq\; X$.

$X \vee u^\star$ better since
they differ only when in $[0, u^\star]$,
and $F^1 - F^0 \nearrow$ on $[0, u^\star]$.

(back to slide 27)

Undominated deadlines



Recall: X decreases before T.

If T so early that $X_0 < u^1$, better to increase until $X_0 = u^1$.

- x high for longer
- X higher $\implies$ closer to peak u^1.

$\implies$ undominated mechs have DL late enough that $X_0 \geq u^1$.

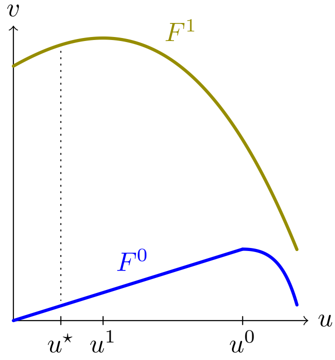
Proposition. If F^0 is affine on $[0, u^0]$, then undominated mechs are exactly the deadline mechanisms with deadline late enough that $X_0 \geq u^1$.

(back to slide 28)

First-order condition

Trade-off: want

- late deadline if late breakthrough
- early deadline if early breakthrough.

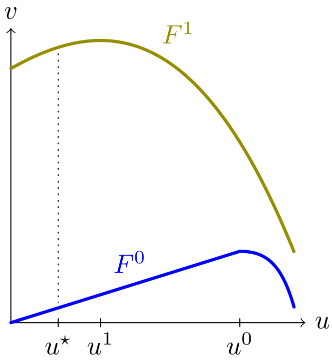


First-order condition

Assume $u^\star > 0$ & F^1 diff'able on $(0, u^0)$. (And F^0 affine.)

Proposition. Mechanism (x, X) is optimal for G iff it is a deadline mechanism with $\mathbf{E}_G\left(F^{1\prime}(X_\tau)\right) = 0$.

(derivation: next slide)



Use new technology optimally *on average.*

Pins down deadline T since $X_t =$

$$\begin{cases} u^0 - e^{-r(T-t)}\left(u^0 - u^\star\right) & \text{for } t < T \\ u^\star & \text{for } t \geq T. \end{cases}$$

(back to slide 28)

Derivation of first-order condition

$$\text{principal's payoff:} \quad \mathbf{E}_G\Big(r\int_0^\tau e^{-rs}F^0(x_s)\mathrm{d}s + e^{-r\tau}F^1(X_\tau)\Big).$$

Increasing T has two effects:

– if $\tau > T$ (benefit):

$$\underbrace{\Big[F^0(u^0) - F^0(u^\star)\Big]}_{=F^{0\prime}(u^\star)\times(u^0-u^\star)}\mathrm{d}T \times \text{discounting.}$$

– if $\tau \leq T$ (cost):

$$\begin{aligned} &F^{1\prime}(X_\tau) \times \mathrm{d}X_\tau \times \text{discounting.} \\ = &F^{1\prime}(X_\tau) \times \Big(u^0 - u^\star\Big)\mathrm{d}T \times \text{discounting.} \end{aligned}$$

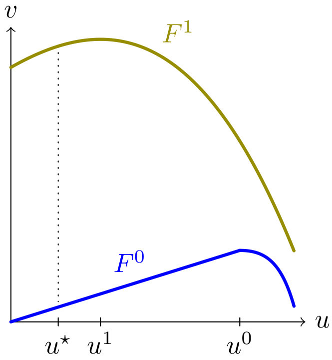
First-order condition:

$$[1 - G(T^\star)]F^{0\prime}(u^\star) + G(T^\star)\mathbf{E}_G\Big(F^{1\prime}(X_\tau)\Big|\tau \leq T^\star\Big) = 0.$$

Derivation of first-order condition

First-order condition:

$$[1 - G(T^\star)]F^{0\prime}(u^\star) + G(T^\star)\mathbf{E}_G\Big(F^{1\prime}(X_\tau)\Big|\tau \le T^\star\Big) = 0.$$



$F^{0\prime}(u^\star) = F^{1\prime}(u^\star)$
since $u^\star$ is interior max of $F^1 - F^0$.

$X_\tau = u^\star$ for $\tau > T^\star$.

$\implies$ first FOC term
$= [1 - G(T^\star)]F^{1\prime}(X_\tau)$

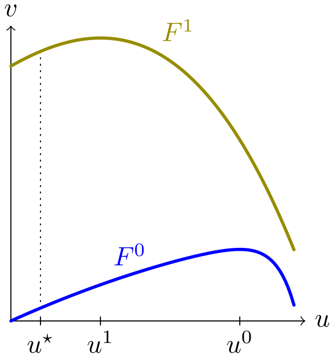
$\implies$ FOC reads $\mathbf{E}_G\big(F^{1\prime}(X_\tau)\big) = 0$.

(back to slide 28)

Undominated & optimal mechanisms in general

Theorem 3(a). Any undominated mechanism (x, X) has
$x_t \searrow$, $\quad X_0 \geq u^1 \quad$ and $\quad X \geq u^\star$.

Theorem 3(b). Any mechanism (x, X) optimal
for some distribution G (with unbounded support)
has $\lim_{t\to 0} x_t = u^0$ (and $\lim_{t\to\infty} x_t = u^\star$).



Current pf assumes F^0 strictly concave,
F^0, F^1 possess bounded derivatives.

(back to slide 30)

Optimal path: Euler equation

Proposition. Assume $u^\star > 0$
and F^0, F^1 possess bounded derivatives.
If (x, X) is optimal for G, then it satisfies

- initial condition $\quad \mathbf{E}_G\big(F^{1\prime}(X_\tau)\big) = 0$
- Euler equation $\quad F^{0\prime}(x_t) \geq \mathbf{E}_G\big(F^{1\prime}(X_\tau)\big|\tau > t\big)$
  for every t at which $G(t) < 1$, with equality if $x_t < u^0$.

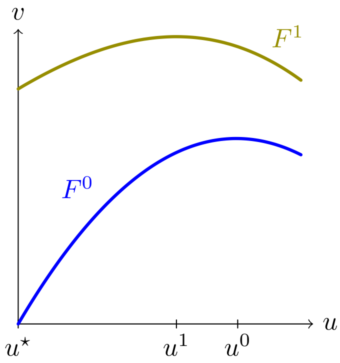
If G has density g & F^0 twice diff'able,
differentiated (& rearranged) Euler reads

$$\dot{x}_t = -\underbrace{\frac{g(t)}{1 - G(t)}}_{\text{hazard rate}} \underbrace{\frac{F^{0\prime}(x_t) - F^{1\prime}(X_t)}{-F^{0\prime\prime}(x_t)}}_{\text{curvature}}.$$

(back to slide 31)

Utility possibilities: $u^\star$

$$u \;=\; \phi(C) \;-\; \kappa(L) \qquad\qquad v \;=\; u \;+\; \lambda \times \big(wL - C\big)$$



$$F^{0\prime} > F^{1\prime} \implies u^\star = 0.$$

Reason: interests less aligned
when worker employed.

(back to slide 36: utility poss)
(back to slide 37: DL UI mechs)

Some deadline UI systems

	before DL	after DL (€/mo.)
Germany	60% of net salary	446
Sweden	80% of net salary	415
Netherlands	70% of net salary	1059
France	€368/mo. $+ 0.404 \times$ SJR*	515

*SJR: an industry-specific reference salary.

Note: this excludes additional funds for particular expenses, such as rent or utilities. These are large in e.g. Sweden.

(back to slide 37)

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