The rise and fall of factory discipline: Control *vs* incentives in the course of industrialization

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Introduction

- **industrialization process** $\Rightarrow$ growing labor productivity
- mechanisms at stake: technological improvements, physical capital accumulation, education...
- **one neglected aspect**: rise in the intensity of work effort [Clark 1994, Langlois 1999]
- new organizational forms based on **high degree of control** and discipline
- alternative way to extract more labor from workers $\Rightarrow$ **monetary incentives**
- since about the 1980s: new HRM practices $\Rightarrow$ more extensive use of monetary incentives [Ichniowski and co-authors 1996, 1997, 2003]

Introduction

Our focus:

1. how capitalists choose the labor extraction system?
   - incentives *vs.* control
   - evolution of this trade-off in the course of development
2. what are the feedback effects on the industrialization process?

Introduction

- existing literature [Demougin and Fluet 2001, Acemoglu and Newman 2002, Allgulin and Elligsen 2002 or Akerlof and Kranton 2008]:

1. trade-off between incentives and monitoring
2. remain at the firm level
3. static framework

- our definition of control $\Rightarrow$ allow to enforce a specific action to be performed by the agent
- benefits of control $\Rightarrow$ solve the moral hazard problem without income variability
- what are the costs of control?

Introduction

- **experimental findings** [Falk and Kosfeld 2006, Schnedler and Vadovic 2011, Riener and Wiederhold 2012, Fehr et al 2013, Bartling et al 2014]:
  - control = reduction of the choice set / minimum performance requirement
  - most individuals reduce their efforts when being controlled
- **interpretation**:
  - taste for autonomy / intrinsic value of decison rights [Falk and Kosfeld 2006, Fehr et al 2013, Bartling et al 2014]
  - control as a sign of distrust [Akerlof and Kranton 2008]
- up to direct costs of supervision there is some utility costs of control = **hidden costs of control**

What do we do?

- **at the firm level**:
  - firms face a moral hazard problem
  - alternative ways to solve it: control / incentives
  - disutility costs of control are taken seriously
- **market equilibrium** $\Rightarrow$ labor extraction system chosen by capitalist depends on market conditions
  - equilibrium wage $\Rightarrow$ reservation utility of agents
  - level of productivity $\Rightarrow$ benefits associated with the extraction of more efforts from workers
- **dynamic setting** $\Rightarrow$ labor extraction system chosen by capitalist shapes the incentives to innovate

Main results

- **rise and fall of the factory discipline** $\Rightarrow$ 3 stages of development:

1. low-powered monetary incentives [Clark 1994, Langlois 1999]
2. control [Clark 1994, Langlois 1999, Mokyr 2001]
3. high-powered monetary incentives [Ichniowski and co-authors 1996, 1997, 2003]

- two-way relationship between organizational changes and the development process $\Rightarrow$ multiple development paths
- role played by the autonomy in the industrialization process and in the diversity of organization observed among developed countries

Population structure and preferences

- at each date t, 3 types of agents coexist

1. a unit mass of inventors
2. a unit mass of capitalists
3. a continuum of workers of size N

- each kind of agent lives for one period and consumes only one good = the final good
- no occupational choice $\Rightarrow$ the class structure is exogenously given

Population structure and preferences

endowments:

1. each inventor is endowed with research-skill but no wealth and no labor-skill
2. each capitalist owns one firm, producing one intermediate good but no labor-skill and no research-skill
3. each worker is endowed with one unit of labor but no wealth and no research-skill

preferences:

- inventors and capitalists are risk-neutral
- workers are risk-averse
- work effort and research activity may incur utility losses

Production of the final good

- the final good (numéraire) is produced by perfectly competitive firms thanks to labor, technology and a continuum of intermediate products, indexed on the interval $[0, 1]$
- production function:

$$Y_t = (A_t L_t)^{1-\alpha} \int_0^1 x_{it}^{\alpha} di \qquad \text{with} \qquad \alpha \in (0, 1)$$

- x_{it} quantity of intermediate product i, A_t technological level, L_t quantity of labor

Production of intermediate goods (1)

- each intermediate good is produced by a unique firm, owned by a capitalist, using final good and one unit of labor
- intermediate producers may be either:
  - highly efficient $\Rightarrow$ one unit of final good $\rightarrow$ one unit of intermediate good
  - weakly efficient $\Rightarrow$ $\gamma > 1$ units of final good $\rightarrow$ one unit of intermediate good
- associated profits (net of salary costs):

$$\pi_{it}^{H} = p_{it}x_{it} - x_{it} \qquad \text{and} \qquad \pi_{it}^{L} = p_{it}x_{it} - \gamma x_{it}$$

- p_{it} price of the intermediate good i = marginal product:

$$p_{it} = \frac{\partial Y_t}{\partial x_{it}} = \alpha (A_t L_t)^{1-\alpha} x_{it}^{\alpha-1}$$

Production of intermediate goods (2)

- quantity produced by each monopolist:

$$x_{it}^H = \alpha^{\frac{2}{1-\alpha}} A_t L_t \qquad \text{and} \qquad x_{it}^L = \left(\frac{\alpha^2}{\gamma}\right)^{\frac{1}{1-\alpha}} A_t L_t$$

- labor market clearing condition: $L_t = N - 1 \Rightarrow$
- profits: $\pi_{it}^H = \pi A_t$ and $\pi_{it}^L = \mu \pi A_t$, with

$$\pi \equiv (N-1)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} \qquad \text{and} \qquad \mu \equiv \frac{1-\alpha/\gamma}{(1-\alpha)\gamma^{\frac{\alpha}{1-\alpha}}} \in (0,1)$$

Competitive wage

- wage in the final good sector = marginal product of labor:

$$w_t = \frac{\partial Y_t}{\partial L_t} = (1-\alpha) L_t^{-\alpha} A_t^{1-\alpha} \int_0^1 x_{it}^{\alpha} di$$

- denoting ρ_t the probability for a firm to be highly efficient we get

$$\int_0^1 x_{it}^{\alpha} di = \rho_t (x_{it}^H)^{\alpha} + (1-\rho_t)(x_{it}^L)^{\alpha}$$

- wage rate may be expressed as a function of A_t and ρ_t:

$$w_t = (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} \left[\rho_t + (1-\rho_t) \frac{1}{\gamma^{\frac{\alpha}{1-\alpha}}} \right] A_t$$

Innovation (1)

- technologies are developed in a perfectly competitive R&D sector using only labor (provided by inventors) and sold to final good producers
- technological level at date t = sum of these research efforts of inventors

$$A_t = \int_0^1 R_{jt} dj$$

- with R_{jt} the research effort of the inventor j
- wage of inventors by unit of effort = marginal product of the technology in the final good sector
- income of the inventor j

$$\frac{\partial Y_t}{\partial A_t} R_{jt} = \frac{\pi}{\alpha} \left[\rho_t + (1 - \rho_t) \frac{1}{\gamma^{\frac{\alpha}{1-\alpha}}} \right] R_{jt}$$

Innovation (2)

- utility cost of research efforts:

$$C(R_{jt}; A_{t-1}, \eta) = \begin{cases} \frac{\kappa(R_{jt}-\eta)^2}{2A_{t-1}} & \text{if} \quad A_t \geq \eta \\ 0 & \text{if} \quad A_t < \eta \end{cases} \qquad \text{with} \qquad \kappa, \eta > 0$$

- assumptions:

1. basic knowledge (η) are freely available for inventors
2. costs of efforts required to overcome the level η are decreasing in A_{t-1}

- marginal reward of effort = marginal cost of effort

$$A_t = \frac{\pi}{\kappa\alpha}\left[\rho_t + (1-\rho_t)\frac{1}{\gamma^{\frac{\alpha}{1-\alpha}}}\right] A_{t-1} + \eta = g(A_{t-1}, \rho_t)$$

Internal organization of the firm

- the level of efficiency of intermediate producers depends on work efforts provided by workers
- two levels of effort $\Rightarrow$ high ($e_a > 0$) and low ($e_b = 0$):
  - if e_a: π_t^H with probability $1/2$ and π_t^L with probability $1/2$
  - if e_b: π_t^L with probability 1
- organizational design:

1. **factory discipline** (f-firm) $\Rightarrow$ the principal observe the action of the agent $\Rightarrow$ the effort is contractible
2. no supervision $\Rightarrow$ the effort remains unobservable $\Rightarrow$ the principal may provide:
   - **low-powered monetary incentives** (b-firm)
   - **high-powered monetary incentives** (a-firm)

Internal organization of the firm

- organizational choice: $o_t \in \{a, b, f\}$
- worker's utility as a function of income y_t and effort e_t:

$$U(y_t, e_t; o_t) = y_t^{\sigma} - \Gamma(e_t; o_t) \quad \text{with} \quad \sigma \in (0, 1)$$

- utility cost of effort:

$$\Gamma(e_t; o_t) = \begin{cases} (1+\lambda)e_t & \text{if} \quad o_t = f \\ e_t & \text{if} \quad o_t = a, b \end{cases}$$

- $\lambda > 0 =$ degree of taste for the autonomy $\Rightarrow$ **hidden costs of control**
- reservation utility of workers at date t: u_t

Optimal wage contract - a-firms

- firm's objective:

$$\begin{array}{rl} \min \left\{ \frac{1}{2} w_{a,t}^H + \frac{1}{2} w_{a,t}^L \right\} & \\ \frac{1}{2}(w_{a,t}^H)^\sigma + \frac{1}{2}(w_{a,t}^L)^\sigma - e_a \geq u_t & \text{(PC)} \\ \frac{1}{2}(w_{a,t}^H)^\sigma + \frac{1}{2}(w_{a,t}^L)^\sigma - e_a \geq (w_{a,t}^L)^\sigma & \text{(ICC)} \end{array}$$

- optimal wage profile $\left\{ w_{a,t}^H, w_{a,t}^L \right\}$ inducing e_a:

$$w_{a,t}^L = u_t^{1/\sigma} \qquad \text{and} \qquad w_{a,t}^H = (u_t + 2e_a)^{1/\sigma}$$

- expected profits

$$\begin{aligned} V_a(A_t, u_t) &= \frac{\pi_t^H + \pi_t^L}{2} - \frac{w_{a,t}^H + w_{a,t}^L}{2} \\ &= \frac{(1+\mu)\pi}{2} A_t - \frac{(u_t + 2e_a)^{1/\sigma} + u_t^{1/\sigma}}{2} \end{aligned}$$

Optimal wage contract - b-firms

- optimal wage profile $\left\{w_{b,t}^H, w_{b,t}^L\right\}$ inducing e_b:

$$w_{b,t}^L = w_{b,t}^H = u_t^{1/\sigma}$$

- expected profits

$$\begin{aligned} V_b(A_t, u_t) &= \pi_t^L - w_{b,t}^L \\ &= \mu\pi A_t - u_t^{1/\sigma} \end{aligned}$$

Optimal wage contract - f-firms

- **factory discipline** $\Rightarrow$ the principal can impose e_a in the contract
- optimal wage profile $\left\{w_{f,t}^H, w_{f,t}^L\right\}$ implementing e_a:

$$w_{f,t}^L = w_{f,t}^H = (u_t + (1+\lambda)e_a)^{1/\sigma}$$

- expected profits

$$\begin{aligned} V_f(A_t, u_t) &= \frac{\pi_t^H + \pi_t^L}{2} - w_{f,t}^H \\ &= \frac{(1+\mu)\pi}{2} A_t - (u_t + (1+\lambda)e_a)^{1/\sigma} \end{aligned}$$

Organizational choices

The internal organization of one firm is related to two issues:

1. when should the principal induce the agent to work hard?
   - if incremental profit benefits associated to e_a overcome the cost of labor-extraction
   - it is the case when A_t is large enough
2. how to trigger e_a? through incentives or control?
   - it depends on the relative cost of incentives $\Rightarrow$ comparison between the *risk premium* and the *control premium*
   - *risk premium* $(\Pi_r) \Rightarrow$ accounts for the insurance effect of control

$$\Pi_r(u_t) = \frac{1}{2}\left[(u_t + 2e_a)^{1/\sigma} + u_t^{1/\sigma}\right] - (u_t + e_a)^{1/\sigma}$$

   - *control premium* $(\Pi_c) \Rightarrow$ accounts for the disutility effect of control

$$\Pi_c(u_t) = (u_t + (1+\lambda)e_a)^{1/\sigma} - (u_t + e_a)^{1/\sigma}$$

Organizational choices

- **assumption:** λ low enough $\Rightarrow \Pi_r(0) > \Pi_c(0)$

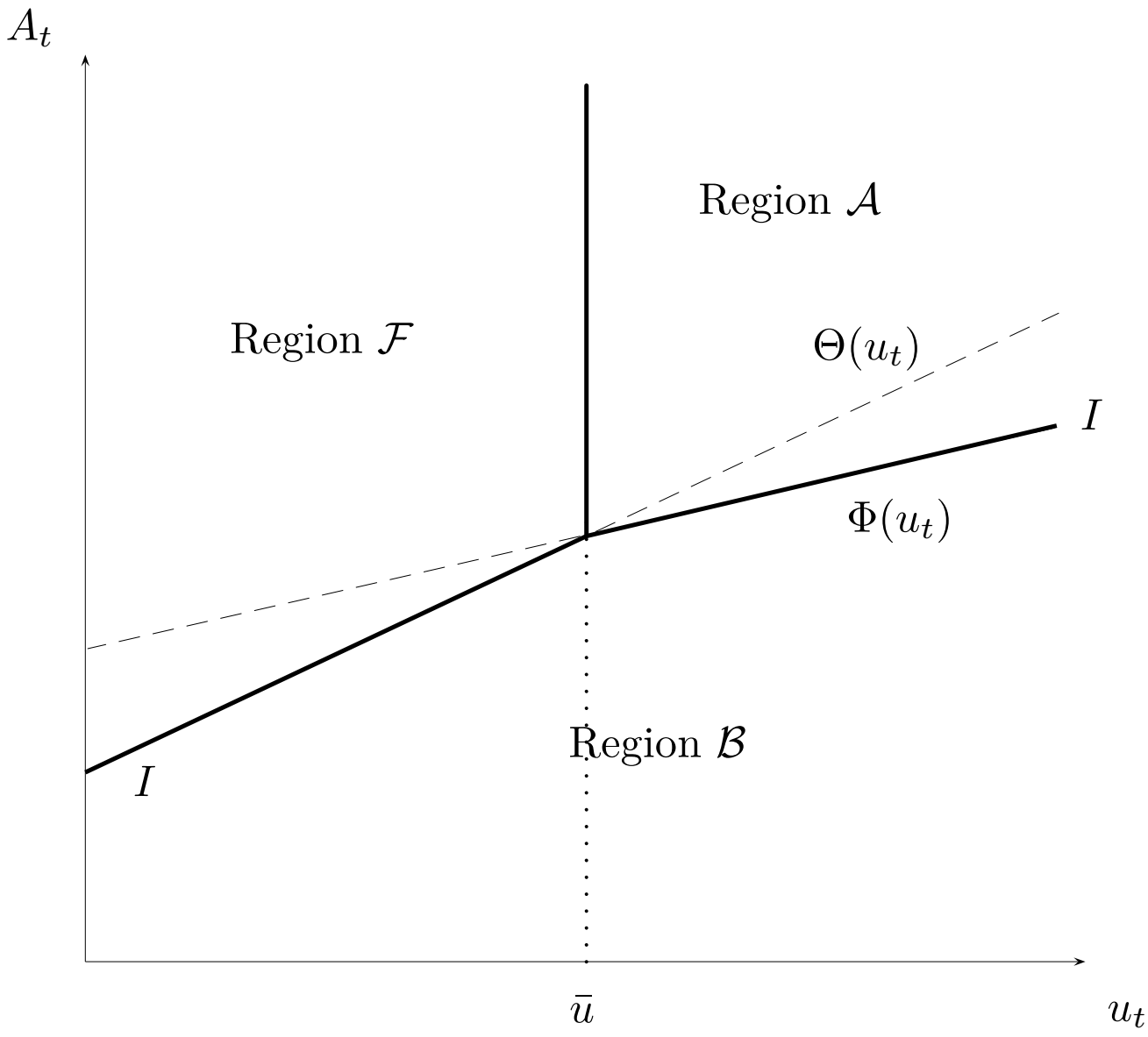
Lemma

There is a threshold value ($\bar{u} > 0$) of u_t such that:

$$\Pi_r(u_t) \left\{ \begin{array}{c} > \\ = \\ < \end{array} \right\} \Pi_c(u_t) \quad \text{when} \quad u_t \left\{ \begin{array}{c} < \\ = \\ > \end{array} \right\} \bar{u}$$

- crucial role played by the existence of hidden cost of control ($\lambda > 0$)

Organizational choices



Static equilibrium

timing of the game in each period:

1. technology is produced
2. capitalists are matched with workers
3. capitalists choose a labor extraction system and the associated wage contract $o_t \in \{a, b, f\}$:
   - if agent accepts $\Rightarrow$ next stage
   - otherwise $\Rightarrow$ he goes to the competitive labor market
4. effort choice made by workers
5. outcome is realized, wages are paid and production takes place in both sectors

Static equilibrium

- optimal research efforts of inventors $\Rightarrow A_t$ is a function of the expectation concerning ρ_t
- based on A_t and the expectations concerning $u_t \Rightarrow$ each firm in the intermediate sector chooses the optimal way to organize its production
- a worker who refuses the contract proposed by an intermediate producer finds a job in the final good sector:
  - we must have: $u_t = w_t^\sigma$
  - the expected wage rate depends on A_t and the expectation concerning ρ_t
- the proportion ρ_t of highly efficient firms must be consistent with these organizational choices:

$$\rho_t = \begin{cases} 0 & \text{if} \quad o_t = b \\ 1/2 & \text{if} \quad o_t = a, f \end{cases}$$

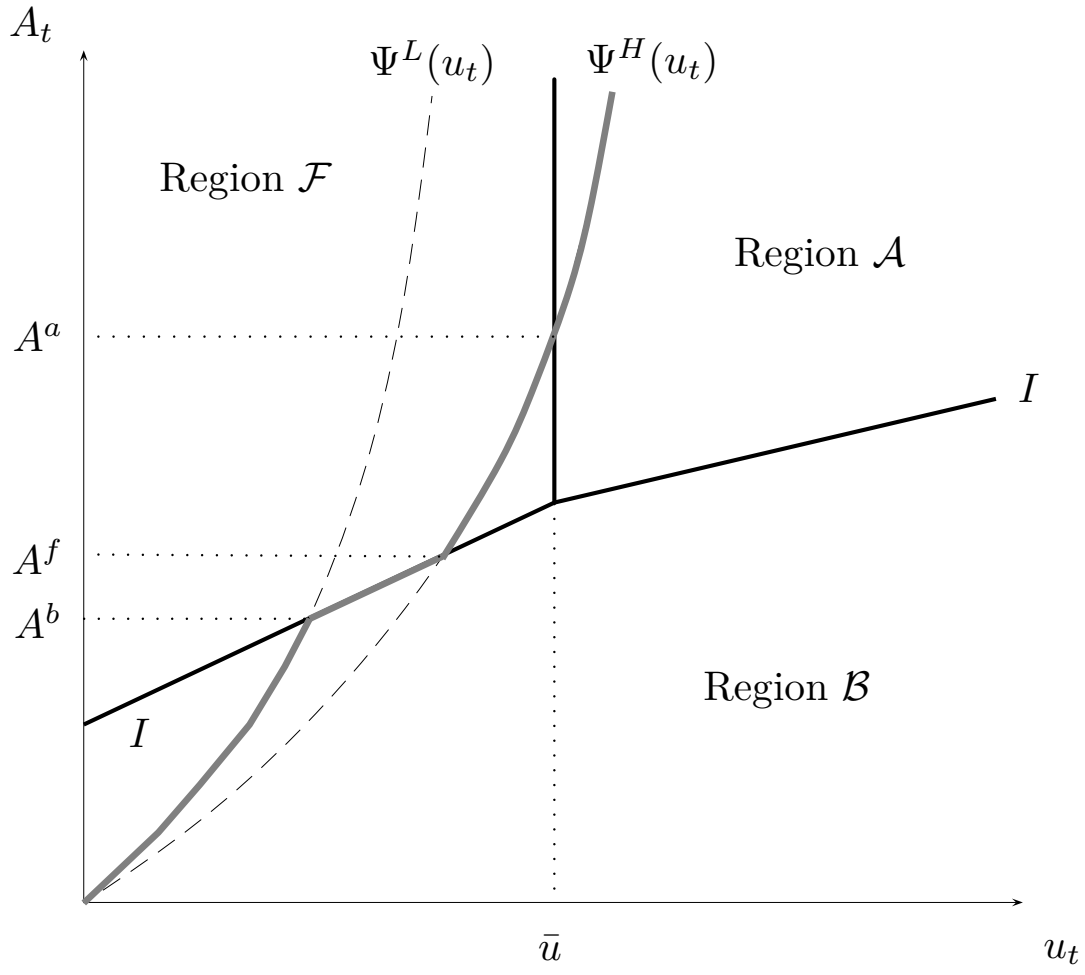
Static equilibrium

- the analysis of the equilibrium may be decomposed into two stages $\Rightarrow$ backward resolution:

1. equilibrium wage and organizational choices for a given level of A_t
2. equilibrium level of A_t derived from inventors' choices

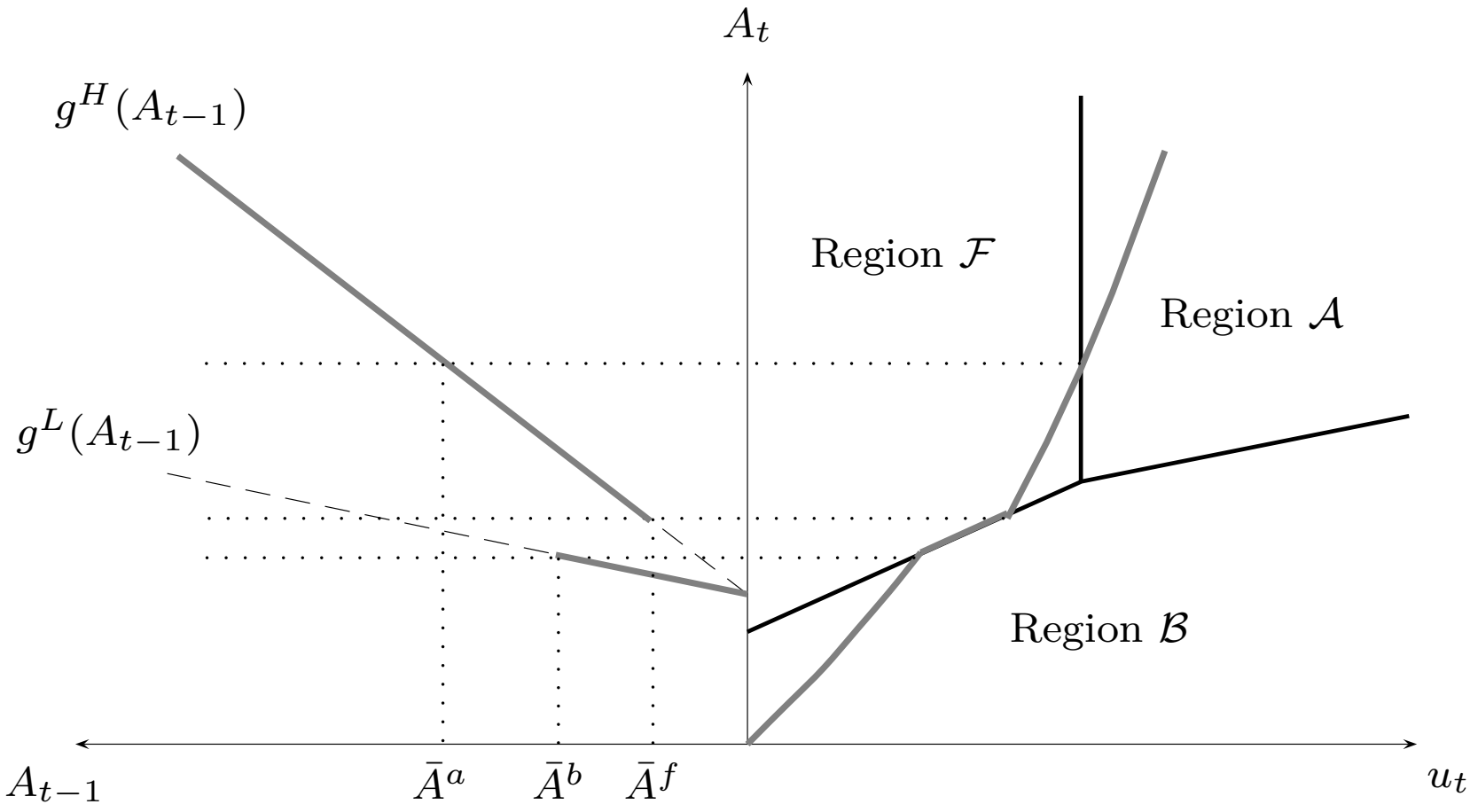
Static equilibrium - stage 1

equilibrium relationship between u_t and A_t (in grey):



Static equilibrium - stage 2

multiple perfect foresight equilibria:



Equilibrium dynamics

- the dynamics of the economy is driven by technological changes
- equilibrium inventors' behavior $\Rightarrow$ along the equilibrium path, we must have

$$A_t = \begin{cases} g(A_{t-1}, 0) & \text{if} \quad A_t \leq \bar{A}^f \\ g(A_{t-1}, 0) \text{ or } g(A_{t-1}, 1/2) & \text{if} \quad A_t \in (\bar{A}^f, \bar{A}^b) \\ g(A_{t-1}, 1/2) & \text{if} \quad A_t \geq \bar{A}^b \end{cases}$$

- with

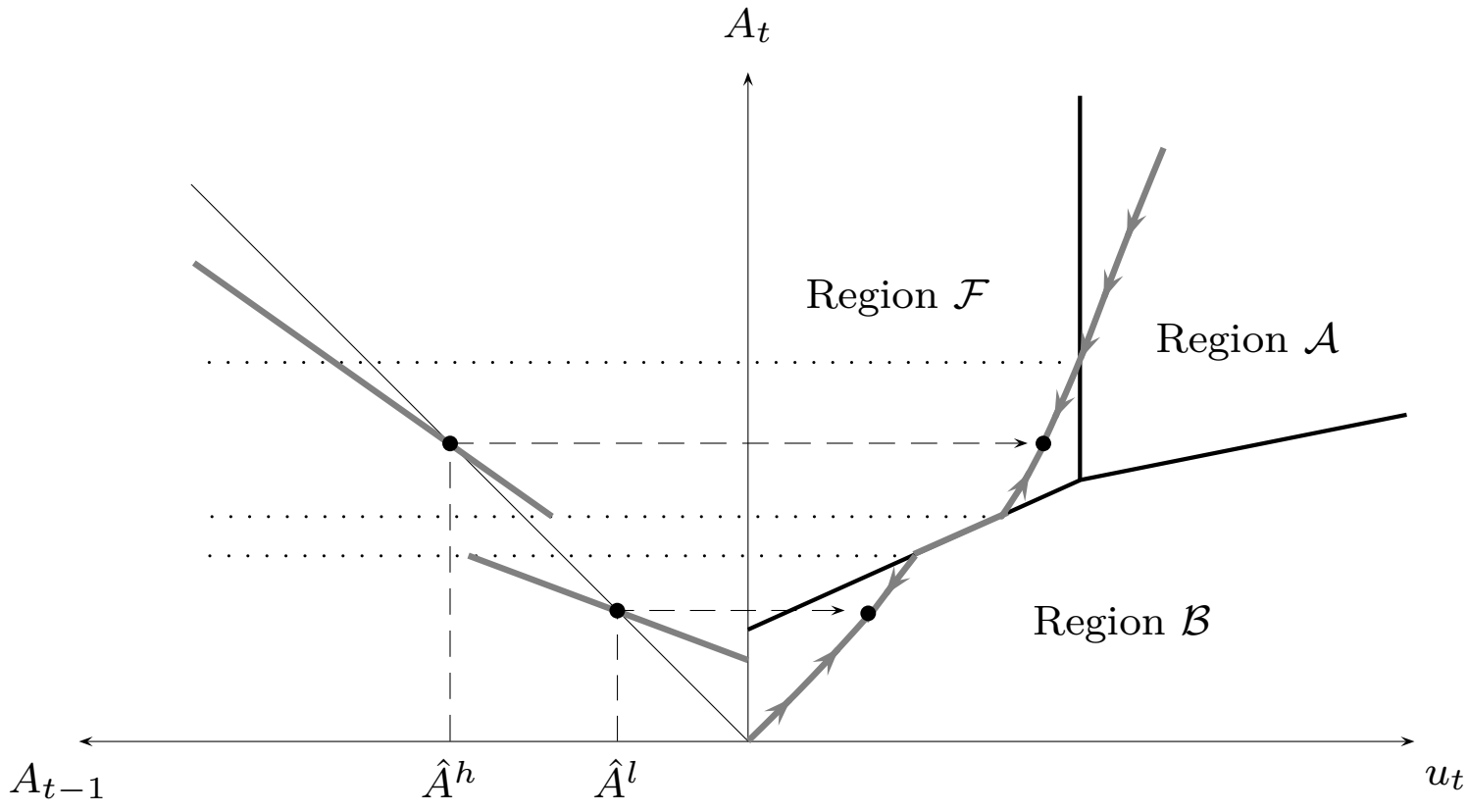
$$g(A_{t-1}, \rho_t) = \frac{\pi}{\kappa\alpha}\left[\rho_t + (1-\rho_t)\frac{1}{\gamma^{\frac{\alpha}{1-\alpha}}}\right] A_{t-1} + \eta$$

- according to the value of η several configurations may arise $\Rightarrow$ we focus on two specific cases

Multiple long-run equilibria

Proposition

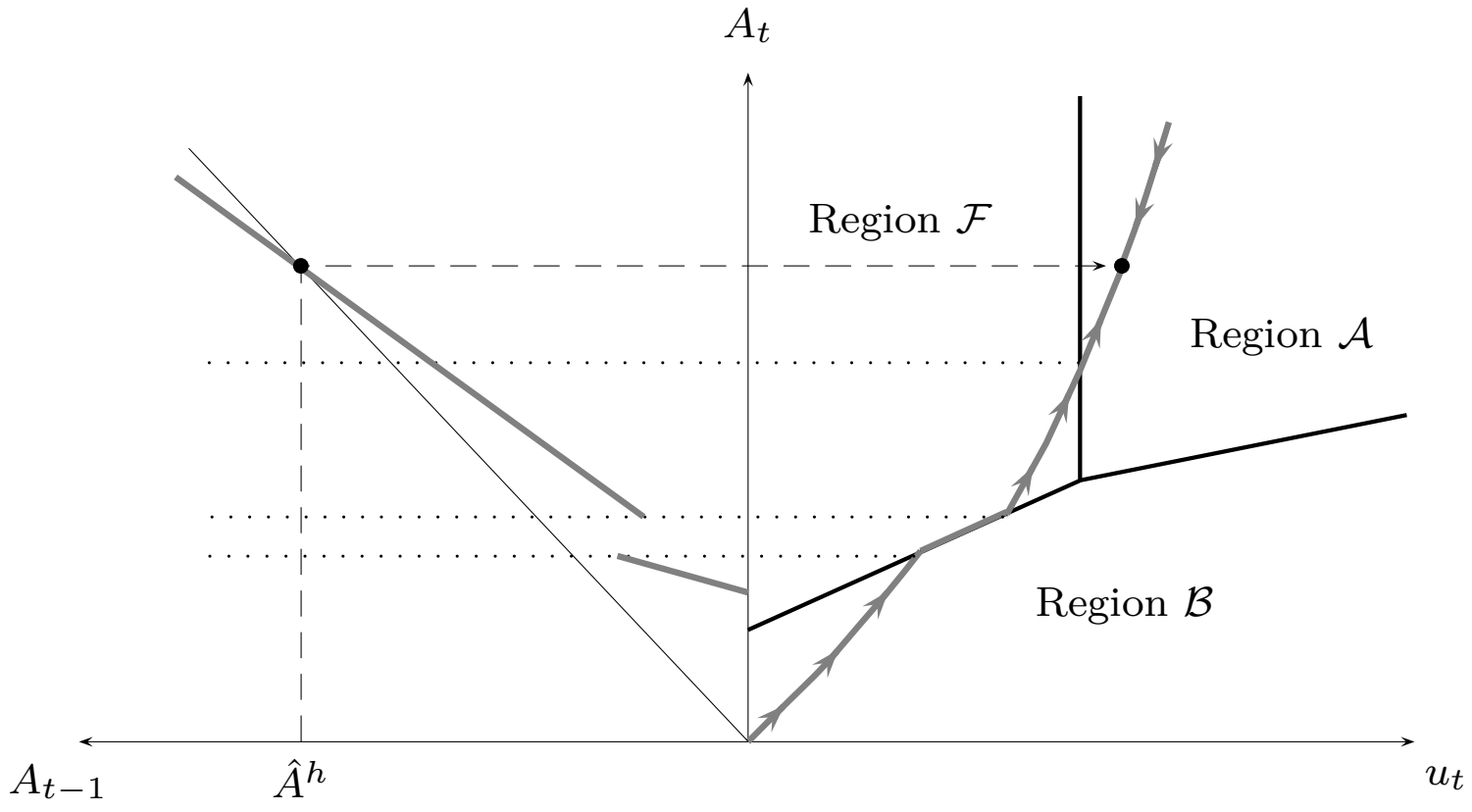
For intermediate values of η, there are two locally stable stationary equilibria: a *low equilibrium* that belongs to region $\mathcal{B}$ co-exists with a *high equilibrium* that belongs either to region $\mathcal{F}$ or to region $\mathcal{A}$.



The rise and fall of the factory discipline

Proposition

For large values of η, there is one unique globally stable stationary *high equilibrium* that belongs to region $\mathcal{A}$.



Comparative statics and discussion

- the role played by hidden costs of control in the diverse development of organizations is captured by the parameter λ

Proposition

rise in λ:

1. enlarges the basin of attraction of the low equilibrium
2. increases the likelihood that the high equilibrium belongs to region $\mathcal{A}$

Comparative statics and discussion

- result 1. $\Leftrightarrow$ researches in economic history about resistance movements against industrialization
- 2 main findings:

1. workers attached to the independence permitted by traditional mode of production $\Rightarrow$ resistance movements against the factory system [Berg 1985, Mokyr 2002]
2. these movements partly explain the delays in industrial take-off / technological backwardness experienced by some regions of Europe [Randall 1989, Mokyr 2002]

- captured in a stylized way by the impact of a change in λ on technological dynamics

Conclusion

- dynamic general equilibrium model where organizational choices are endogenous
- non-monotonic organizational changes along the development process
- multiple perfect foresight development paths
- central role played by the interactions between organizational changes and workers' preferences for the autonomy
- **extension:** efficiency losses associated to control $\Rightarrow$ non-monotonic (negative and then positive) effect of autonomy in the course of development