Endogenous growth with endogenous liquidity

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September 28th 2017 - CONCORDi Conference

An example of innovation policy mix

Figure 1 – Evolution of the structure of direct public aids in favor of innovation in France, per main objective category

Familles d'objectifs	Total (%)		Total hors incitations fiscales et sociales (%)	
	2000	2014	2000	2014
1) Augmenter les capacités privées en R & D	69	70,2	51	20
2) Accroître les retombées économiques de la recherche publique	1	2,6	2	10
3) Développer les projets de coopérations entre acteurs, les réseaux	8	7,2	13	28
4) Promouvoir l'entrepreneuriat innovant	2	3,6	3	9
5) Soutenir le développement des entreprises innovantes	19	16,4	31	33
Total	**100**	**100**	**100**	**100**

(1) hors soutiens au secteur de la défense.

Source: *Commission nationale d'évaluation des politiques d'innovation (CNEPI)*, France Stratégie (2016).

Could funding constraints largely weight on growth?

- Product innovation and equity availability are macroeconomic stakes
  1. In France between 2010 and 2012, the share of firms making product innovation is 24 percent, and notably 55 percent for firms with more than 250 employees (Insee, 2014).
  2. In France, there is a general lack of equity, especially for innovative SMEs, while investments "have to become more 'schumpeterian', and relatedly provided funds less guaranteed" (Villeroy de Galhau, 2015).
- A microfunded framework of firm dynamics for policy analysis including firms that...
  1. ... innovate and compete for products with destructive creation
  2. ... build liquidity (cash) reserves in relation with financial constraints
     - when entering: initial equity hindrances
     - when exiting: suboptimal liquidation value
     - when developing: asymmetric information about risky cash flows

This paper...

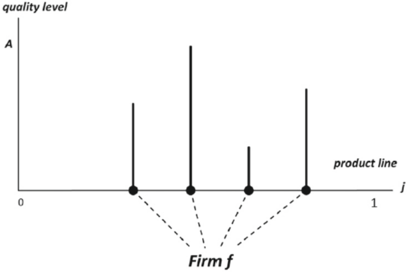
- ... theoretically gathers two modeling literatures
  1. Schumpeterian growth models
     Klette and Kortum (2004), Acemoglu, Akcigit, Bloom, and Kerr (2014), Aghion, Akcigit, and Howitt (2014), Acemoglu and Cao (2010)
  2. moral hazard related dynamic contracts
     DeMarzo, Fishman, He, and Wang (2012), Sannikov (2013), Chen (2014), Falato, Kadyrzhanova, and Sim (2013), Bolton, Chen, and Wang (2011)
     closest paper: Malamud and Zucchi (2016)
- ... maintains tractability allowing for policy experiments
  1. alleviating **hindrances to venture capital** seems far more efficient than improving corporate governance or reducing costs of liquidation
  2. **industrial features**, such as entry costs, cash flow volatility or mean returns, can have opposite effects on its overall liquidity
  3. a positive relation between liquidity and growth happens for **a stylized R&D intensive sector**

Outline

1. Model of the firm
   - Setup
   - Program
   - Optimal policy
2. General equilibrium

Production and innovation technology

Figure 2 – Structure of a firm



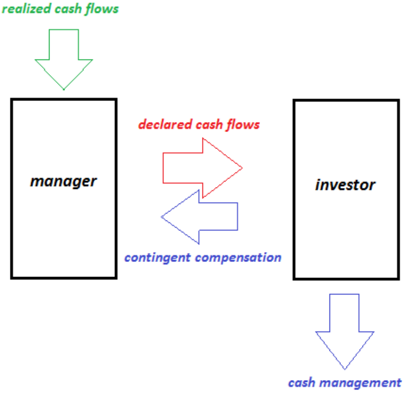
Source: Aghion et al. (2014).

- A firm has n_j product lines.
- Production is linear: $Y_j = A_j l_{0j}$.
- Evolution of productivity A_j :
  - competition is monopolistic
  - some firm innovates on product j
  - the "winner takes all"
  - $p_j =$ competitor marginal price
  - A_j increases by $\gamma > 1$
- Consumption is $\ln Y = \int_0^1 \ln Y_j dj$
- Cash flows are $\mu \equiv \frac{\gamma - 1}{\gamma}$
- Researchers (with wages w)

$$h(x) \equiv \theta^{-\alpha/(1-\alpha)} x^{1/(1-\alpha)}$$

Information between management and investors

Figure 3 – Moral hazard problem



- Realized cash flows (dS normal)

$$d\pi = \mu dt + \sigma dS$$

- Declared cash flows ($a \in [0, 1]$)

$$d\hat{\pi} = a\mu dt + \sigma dS$$

- Private benefit ($\lambda \in [0, 1]$)

$$b = \lambda(d\pi - d\hat{\pi})$$

- Investor determines
  - current compensation U
  - cash reserves for future ones
- Liquidation value $n_j \cdot l$

Contract and agents' values

- Contract over time Ψ specifying contingent investment x_t, compensation u_t and termination (at random time T)
- The managers' value is:

$$W(\Phi) = \max_{a_t} \mathbb{E} \left\{ \int_0^T e^{-\rho t} \Big[du_t + b_t(a_t) dt \Big] \right\}$$

- Starting with a single product line, under incentive compatibility ($a = 1$), the contract Ψ maximizes investor's value:

$$P_1(W_0) = \max_{\Phi} \mathbb{E} \left\{ \int_0^T e^{-rt} \Big[n_t(d\pi_t - w_t h_t dt) - du_t \Big] + e^{-rT} n_T l \right\}$$

Entry, exit and funding conditions

Figure 4 – Policy purposes (CNEPI)

4 – Promouvoir l'entrepreneuriat innovant	5 – Soutenir le développement des entreprises innovantes
Existence de barrières à l'entrée et/ou de barrières à la sortie liées à des coûts fixes irrécouvrables (*sunk costs*).	Rationnement du financement de l'innovation, en raison d'imperfections sur le marché des prêts bancaires : absence de collatéraux et incertitude sur les profits futurs, d'où une très forte asymétrie entre prêteurs et emprunteurs.
Degré de concurrence parfois inapproprié (insuffisant sur certains marchés, excessif sur d'autres).	
Obstacles administratifs à la mobilité des ressources humaines provenant des grandes entreprises et des laboratoires publics.	Développement insuffisant des marchés portant sur les investissements à haut risque : sous-dimensionnement du capital-investissement (notamment pour le *late stage*, en direction des entreprises à croissance rapide).

- Free entry condition (#4)

$$P_1(W_0) + W_0 = w\psi$$

- Termination value (#4)

$$I = (1 - \kappa) \times P_1(W_0)$$

- Initial liquidity (#5)

$$W_0^* = (1 - \zeta) \times \arg\max_{W_0 > 0} P_1(W_0)$$

Restated program in recursive form

- Compensated Poisson processes for the number of product lines

$$dJ^+ = dn^+ - xdt \text{ and } dJ^- = dn^- - \tau dt$$

- Cash motion law (using the martingale representation theorem)

$$dW = \rho W - du + \beta n\sigma dS + \beta^+ dJ^+ + \beta^- dJ^-$$

- Hamilton-Jacobi-Bellman equation (using Ito's lemma, $du = 0$)

$$rP_n(W) = \max \; n[\pi - wh(x)] + (\rho W - \beta^+ nx + \beta^- n\tau)P_n'(W) + \frac{1}{2}(\beta\sigma n)^2 P_n''(W)$$
$$+ nx[P_{n+1}(W + \beta^+) - P_n(W)] + n\tau[P_{n-1}(W - \beta^-) - P_n(W)]$$

Optimal policy, in per product line terms

$p = P/n$ and $\omega = W/n$

1. *Compensation are made only above a threshold $\bar{\omega}$*

$$du = \max\{\omega - \bar{\omega}, 0\}$$

2. *Compensation must provide an information rent*

$$\beta = \lambda$$

3. *Liquidity is injected or withdrawn each time n changes*

$$\beta^+ = \beta^- = \omega$$

4. *R&D intensity depends on the current cash level*

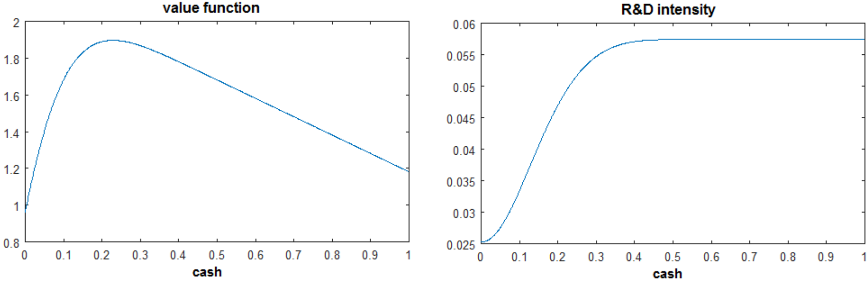
$$h'(x) = p(\omega) - \omega p'(\omega)$$

5. *The investor's value function can be solved exactly*

$$rp(\omega) = \max_x \ \pi - wh(x) + [\rho - (x - \tau)]\omega p'(\omega) + \frac{1}{2}(\lambda\sigma)^2 p''(\omega) + (x - \tau)p(\omega)$$

Optimal policy, illustrations

Figure 5 – Value function and R&D expenditures in equilibrium depending on cash



Note : Graphics are derived with standard calibration depicted in simulations below, which remains close to those used in DeMarzo et al. (2012) and appearing in the model *à la* Klette and Kortum (2004) used by Acemoglu et al. (2014). The innovation efficiency parameter is set at $\theta = 0.60$.

Outline

1. Model of the firm
2. General equilibrium
   - Setup and baseline
   - Experiments

Macroeconomic setting

Equilibrium values for τ, w, g and C

- Incumbents innovation intensity

$$z_i = \int_{n=1}^{+\infty} \int_{\omega=0}^{+\infty} nx(n,\omega) dM(n,\omega)$$

- Entrants innovation intensity z_e
- Number of products normalized to one (Klette and Kortum, 2004)
- Destructive creation τ and growth rates g

$$\tau = z_i + z_e \text{ and } g = \tau \ln \gamma$$

- Wages w adjust for labor market clearing: with production labor $(\gamma w)^{-1}$ and researchers for incumbents h_i and entrants $h_e = \psi z_e$
- Aggregate liquidity (cash) is denoted by C

Computational approach

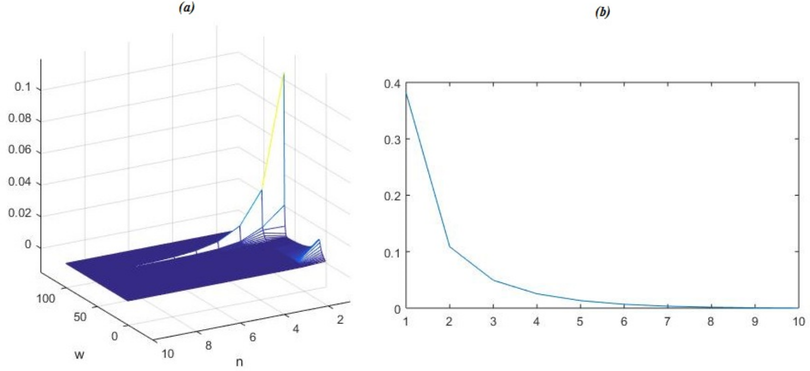
- Calibration (following notably DFHW and AABK)

param.	*description*	*value*
l_s	measure of workers	0.078
r	interest rate of investors	0.060
ρ	interest rate of managers	0.064
λ	agency problem stringency	0.20
κ	liquidation losses share	0.25
ζ	initial distance to optimal equity	0.25
μ	product line mean profit	0.20
σ	cash flow shocks volatility	0.13
γ	innovation step	0.223
θ	incumbent innovation capacity	0.40
ψ	entrants innovation capacity	0.15
α	innovation intensity w.r.t. knowledge stock	0.50

- Algorithm (following notably Atkeson and Burstein, 2010)
  1. solve firm program for optimal R&D and cash policies
  2. applies shocks on cash flows and transitions for product lines
  3. iterate until stability injecting a constant mass of entrants
  4. loop with respect to the destructive creation rate

Simulated distributional outcomes

Figure 6 – Example of firm distribution



Note: On panel (a), the overall distribution is represented on the (ω, n) grid. The number of points for cash values is 1000. On panel (b), the masses of firm are calculated for each level of product number n.

Alternative scenarios: moral hazard and liquidation

First-best and constrained economies: relatively close

Panel A - Baseline

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.10	1.78	6.77	11.52	1.25	21.0	7.3	2.95	3.82	0.40	15.5	1.51

Panel B - $\lambda = 0.05$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.03	1.74	6.99	11.51	1.28	5.80	2.5	2.80	4.19	0.13	2.8	1.56

Panel C - $\kappa = 0.03$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.09	1.79	6.73	11.58	1.64	18.8	4.3	2.95	3.79	0.74	8.2	1.50

Note: x_{fb} and q_{fb} indicate optimal R&D effort and Tobin's q in the first best case without financial frictions.

Proportional and level constraints: a radical difference

Alternative scenarios: initial funding

Panel A - Baseline

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.10	1.78	6.77	11.52	1.25	21.0	7.3	2.95	3.82	0.40	15.5	1.51

Panel B - $\zeta = 0.03$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.06	1.76	6.90	11.51	1.22	21.0	9.7	2.91	3.99	0.26	14.2	1.54

Panel C - $\omega_0 = 4.3$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.45	1.97	5.89	11.42	1.25	22.7	4.3	3.10	2.81	0.87	14.2	1.32

Note: x_{fb} and q_{fb} indicate optimal R&D effort and Tobin's q in the first best case without financial frictions.

Counterbalancing liquidity effects

Alternative scenarios: industrial features

Panel A - Baseline

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.10	1.78	6.77	11.52	1.25	21.0	7.3	2.95	3.82	0.40	15.5	1.51

Panel B - $\psi = 0.20$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
4.12	2.34	4.62	11.33	1.62	24.9	9.1	3.97	0.75	0.99	19.6	1.05

Panel C - $\mu = 0.266$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.08	1.77	10.57	11.50	1.26	18.7	6.5	2.89	7.68	0.37	11.7	3.27

Panel D - $\sigma = 0.173$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.13	1.80	6.67	11.52	1.24	27.6	9.1	2.95	3.73	0.51	19.5	1.49

Note: x_{fb} and q_{fb} indicate optimal R&D effort and Tobin's q in the first best case without financial frictions.

A case of R&D and cash intensive sector

Alternative scenarios: stylized high-tech firms (*à la* Klette and Kortum, 2004)

Panel A - Baseline

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.10	1.78	6.77	11.52	1.25	21.0	7.3	2.95	3.82	0.40	15.5	1.51

Panel B - $\theta = 0.30$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
2.32	1.78	6.41	11.50	1.25	20.8	7.3	2.21	4.20	0.29	14.9	1.43

Panel C - $\theta = 0.30$, $\psi = 0.20$, $\mu = 0.266$, $\sigma = 0.173$

x_{fb}	q_{fb}	τ	w_s	l	$\bar{\omega}$	ω_0	z_i	z_e	ν	C	g
3.09	2.29	7.14	11.12	1.59	27.7	9.7	2.94	4.21	0.43	19.6	2.21

Note: x_{fb} and q_{fb} indicate optimal R&D effort and Tobin's q in the first best case without financial frictions.

Conclusion

- Results
  1. A micro-funded model of firm innovation, growth and liquidity
  2. Initial funding among financial frictions as a major growth impediment
  3. Counterbalancing effects of industrial features on overall liquidity
- Further work
  - Interpret experiments as policy scenarios for cost estimations
  - Extensions: agency problem on the n uncertainty; financial sector

References

D. Acemoglu and D. Cao. Innovation by entrants and incumbents. *NBER Working Paper Series*, n°16411, 2010.

D. Acemoglu, U. Akcigit, N. Bloom, and W. Kerr. Innovation, reallocation and liquidity. *NBER Working Papers*, n°18993, 2014.

P. Aghion, U. Akcigit, and P. Howitt. What do we learn from schumpeterian growth theory? *Handbook of Economic Growth*, 2 (B):515–563, 2014.

A. Atkeson and A. Burstein. Innovation, firm dynamics and international trade. *Journal of Political Economy*, 118(3):53–63, 2010.

P. Bolton, H. Chen, and N. Wang. A unified theory of tobin's q, corporate investment, financing, and risk management. *Journal of Finance*, 66:1545–1578, 2011.

S. Chen. Financial constraints, intangible assets, and firm dynamics: theory and evidence. *IMF Working Papers*, n°14/88, 2014.

P. DeMarzo, M. Fishman, Z. He, and N. Wang. Dynamic agency and the q theory of investment. *Journal of Finance*, 68(6): 2295–2340, 2012.

A. Falato, D. Kadyrzhanova, and J. Sim. Rising intangible capital, shrinking debt capacity, and the U.S. corporate saving glut. *Federal Reserve Board Finance and Economics Discussion Series*, n°67, 2013.

France Stratégie. Quinze ans de politiques de l'innovation en france. *Report of the Commission nationale d'évaluation des politiques d'innovation*, 2016.

Insee. Les sociétés exportatrices sont plus innovantes que les autres. *Insee Première*, (1521), 2014.

T. Klette and S. Kortum. Innovating firms and aggregate innovation. *Journal of Political Economy*, 112(5):986–1018, 2004.

S. Malamud and F. Zucchi. Liquidity, innovation and endogenous growth. *ECB Working Paper Series*, n°1919, 2016.

Y. Sannikov. Dynamic security design and corporate financing. *Handbook of the Economics of Finance*, pages 71–122, 2013.

F. Villeroy de Galhau. Le financement de l'investissement des entreprises. *Rapport au Premier Ministre*, 2015.