Good Rents versus Bad Rents: R&D Misallocation and Growth

Philippe Aghion (LSE) Antonin Bergeaud (HEC Paris) Timo Boppart (IIES)

Peter J. Klenow (Stanford) Huiyu Li (Fed SF)

Minneaplis Fed Bag Lunch

June 2023

Question and motivation

A much-studied topic is whether the economy devotes sufficient resources to R&D overall

Less studied is whether R&D is efficiently allocated across firms

We investigate one potentially important source of R&D misallocation, namely heterogeneity in knowledge spillovers

What we do

Develop a model of endogenous growth where markup dispersion arises from **two sources**: differences in process efficiency and in the step size of quality innovations

A key assumption is that quality innovations build upon previous quality levels

We compare the decentralized equilibrium with the planner's solution

Then we quantify the sources of markup dispersion among French manufacturing firms and the resulting implications for growth and welfare

What we find

Compared to the decentralized equilibrium, the social planner wants to reallocate research effort toward firms with big quality steps (and hence big spillovers)

We infer modest differences in firm-level process efficiencies and larger differences in their quality step sizes from price and revenue productivity data in French manufacturing

$\sim$ 50 basis points lower growth in the decentralized equilibrium than socially optimal

Planner also wishes to undo the static misallocation, but this has a small level effect

Some papers *featuring* R&D misallocation

- Akcigit, Celik, and Greenwood (2016 ECMA)
- Acemoglu, Akcigit, Alp, Bloom and Kerr (2018 AER)
- Akcigit and Kerr (2018 JPE)
- Chen, Liu, Suarez Serrato, and Xu (2021 AER)
- Lehr (2022 working paper)
- Cavenaile, Celik, Roldan-Blanco, and Tian (2022 working paper)
- Williams (2023)

Some papers *analyzing* R&D misallocation

- Akcigit, Hanley, and Serrano-Velarde (2021 REStud)
- Hopenhayn and Squintani (2021 JPE)
- Akcigit, Hanley and Stantcheva (2022 ECMA)
- Liu and Ma (2022 working paper)
- Ayerst (2023 working paper)
- Acemoglu (2023 working paper)

Roadmap

$\boxed{\text{Motivating evidence}}$

Model

Decentralized equilibrium

Planner's solution

Calibration and quantitative results

Datasets

- A representative sample of French manufacturing firms over 2012–2019
  - Firm-level value added, wage bill, and assets (FARE)
  - Firm-level hours worked (DADS)
  - Product-level prices and quantities (EAP)
  - Firm-level R&D expenditures (GECIR)
- 128,485 firm-year observations and 32,641 firms

Key variables we construct at the firm-year level

Revenue productivity:

$$\text{TFPR}_{j,t} = \frac{VA_{j,t}}{K_{j,t}^{\alpha_{s(j,t),t}} W_{j,t}^{1-\alpha_{s(j,t),t}}}$$

Physical productivity:

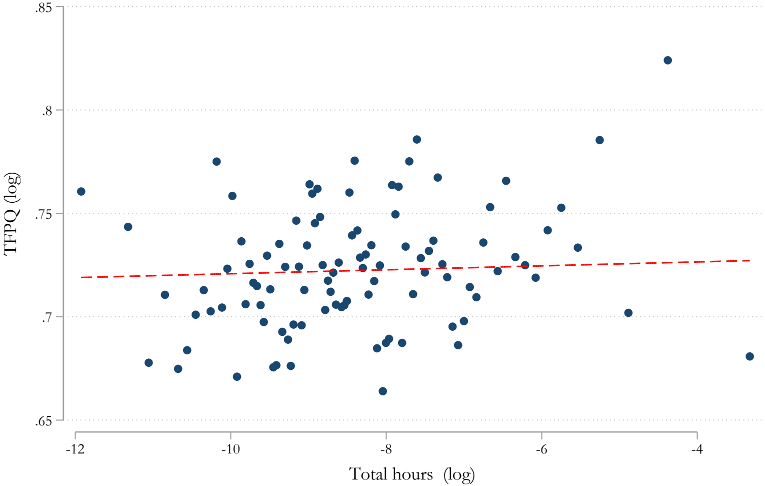
$$\text{TFPQ}_{j,t} = \frac{\text{TFPR}_{j,t}}{P_{j,t}}$$

Price (not quality adjusted):

$$P_{j,t} = \prod_{i=1}^{N_{j,t}} \quad p_t(i,j)^{\omega_{i,j,t}}$$

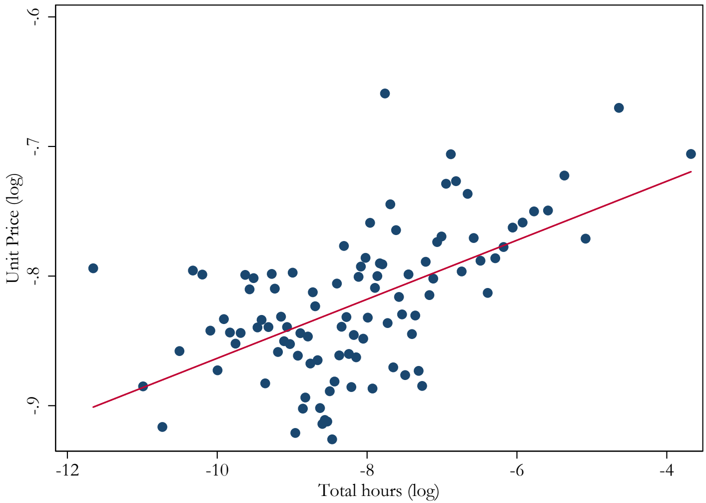
$p_t(i,j)$ is a standardized unit price and $\omega_{i,j,t}$ is product i's share of firm sales

Larger firms tend to have lower TFPQ



Source: Underlying data is French manufacturing firm-year observations from 2012–2019. TFPQ is constructed from the FARE dataset, and hours worked are from DADS. Industry-year fixed effects are removed from each variable before 100 bin-scatter points. Each bin contains about 1200 firm-years.

Larger firms tend to have higher prices



Source: Underlying data is French manufacturing firm-year observations from 2012–2019. TFPQ is constructed from the FARE dataset, and hours worked are from DADS. Industry-year fixed effects are removed from each variable before 100 bin-scatter points. Each bin contains about 1200 firm-years.

Robustness checks for TFPQ and hours relationship

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
-0.070**	-0.062***	-0.151***	-0.070**	-0.066**	-0.067**	-0.098***	-0.118***	-0.049*
(0.025)	(0.021)	(0.027)	(0.025)	(0.024)	(0.025)	(0.026)	(0.023)	(0.027)

1. Baseline
2. Adding a control for age interacted with a sector FE
3. Using TFPQ measured with hours in the denominator (same variable as the dependent variable) but lagged
4. Using TFPQ measured with hours instrumented with TFPQ measured with wagebill
5. Using 5 digits sector FE instead of 2 digit sector FE
6. Measuring the dependent variable using only production workers
7. Using gross output TFPQ
8. Using fixed cost shares (0.3 and 0.7) for K and W when computing TFPQ
9. Including intangibles in the measure of K

Robustness checks for the price and hours relationship

(1)	(2)	(3)	(4)
0.078***	0.066***	0.070***	0.075***
(0.025)	(0.021)	(0.022)	(0.026)

1. Baseline
2. Adding a control for age interacted with a sector FE
3. Using 5 digits sector FE instead of 2 digit sector
4. Measuring the dependent variable using only production workers

Roadmap

Motivating evidence

$\boxed{\text{Model}}$

Decentralized equilibrium

Planner's solution

Calibration and quantitative results

Household

Representative household with preferences

$$U_0 = \sum_{t=0}^{\infty} \beta^t \log C_t$$

Final output is produced using a Cobb-Douglas aggregator of intermediate goods

$$Y = \exp\left(\int_0^1 \log\left[q(i)y(i)\right] di \right)$$

where $q(i)$ denotes the quality of good i and $y(i)$ its quantity.

Intermediate goods production

Fixed number J of intermediate good producers

Each firm j has the knowledge to produce at quality $q(i, j)$ in line $i \in [0, 1]$

Firms differ in two primitive dimensions

- process efficiency a_j
- step size of quality improvements γ_j

Process efficiency

Firm j can produce variety i at quality $q(i,j)$ using production labor

$$y(i,j) = a_j \cdot l(i,j)$$

Binary process efficiency types: high a_H and low a_L

High/Low process efficiency ratio: $\Delta \equiv \mathrm{a}_H / a_L > 1$

Quality step sizes

ψ_z units of research labor increases the best quality of a randomly drawn line by $\gamma_j > 1$

E.g. when firm j innovates on line i where the best quality is $q(i,j')$

$$q(i,j) = \gamma_j \cdot q(i,j')$$

Binary step size types: big γ_B and small γ_S

Big/Small quality step-size ratio: $\Gamma \equiv \gamma_B/\gamma_S > 1$

Firm types and market shares

With the two dimensions of binary heterogeneity — high (H) vs. low (L) process efficiency and big (B) vs. small (S) step sizes — we have 4 firm types $k \in \{HB, HS, LB, LS\}$

Let $\phi_k \equiv$ the exogenous fraction of firms of type k

Let $S_k \equiv$ the endogenous share of lines operated by firms of type k

Boundary of the firm

Per-period overhead cost for firm j “active” in $n(j)$ product lines (expressed in final goods)

$$\psi_o \cdot n(j)^\eta \cdot Y$$

Convexity ($\eta > 1$) yields both a well-defined boundary of the firm in the decentralized equilibrium and a non-trivial planner’s solution

Aggregate resources used for overhead

$$O = \sum_j \psi_o \cdot n(j)^\eta \cdot Y$$

Resource constraints

Final output can be used for consumption or to cover production overhead:

$$Y = C + O$$

Fixed Z units of R&D labor

Fixed L units of production labor

Our focus is on the allocation of Z (and to a lesser extent L) across firms

The growth rate on the BGP

We analyze the Balanced Growth Path (BGP) along which the size distribution of firms is stationary and aggregate quality grows at a constant rate

The growth rate is the product-weighted geometric mean of the step sizes raised to Z/ψ_z

$$1 + \overline{g} = \left(\prod_k \gamma_k^{\overline{S}_k} \right)^{Z/\psi_z}$$

We will compare the planner's $\overline{S}_k$ values with the decentralized equilibrium values

Source of growth along the BGP

Growth comes from quality innovations building on previous quality levels

Process efficiency a_j is given and fixed

Matches French manufacturing from 2012 to 2019:

- TFP growth of 2.3% per year
- Average TFPQ growth within firms of only 0.1% per year
- Suggests measured growth comes from quality innovation
- Variety growth may not show up in measured TFP growth (Aghion et al., 2019)

Roadmap

Motivating evidence

Model

Decentralized equilibrium

Planner’s solution

Calibration and quantitative results

Production costs

Quality-adjusted marginal cost for firm j to produce variety i is

$$\frac{w}{q(i,j) \cdot a(j)}$$

In each line i, $j(i)$ denotes the lowest cost firm and $j'(i)$ the second lowest cost firm

Assume $\gamma_S > \Delta$ so that $j(i)$ is the producer with the highest quality in line i

- Even for low a and small γ firms, their quality advantage γ_S overcomes their process efficiency disadvantage *vis a vis* a high productivity follower

Price setting

Bertrand competition within each product line $i \in [0, 1]$

The leading firm sets its *quality-adjusted* price equal to the *quality-adjusted* marginal cost of the second-best producer

$$\frac{p(i, j(i), j'(i))}{q(i, j(i))} = \frac{w}{q(i, j'(i)) \cdot a(j'(i))}$$

Markups

In line i the leading firm $j(i)$'s choice of price implies markup

$$\mu(i,j(i),j'(i)) \equiv \frac{p(i,j(i),j'(i))}{w/a(j)} = \frac{a(j(i))}{a(j'(i))} \cdot \frac{q(i,j(i))}{q(i,j'(i))}$$

Markups are endogenously determined by the relative process efficiency and relative quality of the best firm relative to the second-best firm

The markup in line i increases with the gaps in quality and process efficiency

Markup across lines under the four types of firms

$$\mu(i, j(i), j'(i)) \;=\; \begin{cases} \gamma(j(i)) \cdot \Delta & \text{if } a(j(i)) = a_H \text{ and } a(j'(i)) = a_L \\ \gamma(j(i)) & \text{if } a(j(i)) = a(j'(i)) \\ \gamma(j(i))/\Delta & \text{if } a(j(i)) = a_L \text{ and } a(j'(i)) = a_H \end{cases}$$

The four types of firms imply six different markup levels across product lines

A firm's average markup across lines increases with its step size and process efficiency

Line profits in each period

Due to the Cobb-Douglas aggregation of intermediates into final output, sales in each product line are given by Y and are independent of quality and price levels

$$p(i) \cdot y(i) = Y \ \ \forall \, i$$

Profit in a line is

$$Y\left(1 - \frac{1}{\mu(i, j(i), j'(i))}\right)$$

Firm profits in each period

A firm of type k that is active in n lines and faces high productivity firms in $n \cdot h$ lines has the following per-period profit after overhead costs (relative to Y):

$$\pi_k(n,h) = n \cdot h \cdot \left(1 - \frac{a_H}{a_k \cdot \gamma_k}\right) + n \cdot (1-h) \cdot \left(1 - \frac{a_L}{a_k \cdot \gamma_k}\right) - \psi_o \cdot n^\eta$$

$\left(1 - \frac{a_H}{a_k \cdot \gamma_k}\right)$ = the line profit share when facing a high process efficiency competitor

$\left(1 - \frac{a_L}{a_k \cdot \gamma_k}\right)$ = the line profit share when facing a low process efficiency competitor

Firm innovation and value

Each period a firm loses $(Z/\psi_z) \cdot n$ of its n products to creative destruction

A firm hires $\psi_z x$ units of R&D labor in a given period to take over x new lines

$$V_{k,0} = \max_{\{x_t, n_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} Y_t \left[\pi_k(n_t, h_t) - x_t \cdot \psi_z \cdot \frac{w_{z,t}}{Y_t} \right] \prod_{s=0}^{t} \left(\frac{1}{1+r_s} \right)$$

subject to

$$n_{t+1} = n_t \cdot (1 - Z/\psi_z) + x_t$$

The BGP of the decentralized equilibrium

Along the BGP we have $\bar{x}_k = (Z/\psi_z) \cdot \bar{n}_k$ and $h = \overline{S}_{HB} + \overline{S}_{HS} \equiv \overline{S}$

From the firm's FOC for R&D, any two $\bar{n}_k$ and $\bar{n}_{k'}$ satisfy

$$\bar{n}_k^{\eta-1} - \bar{n}_{k'}^{\eta-1} = \frac{1}{\psi_o \eta} \left[\overline{S} \cdot a_H \cdot \left(\frac{1}{a_{k'} \cdot \gamma_{k'}} - \frac{1}{a_k \cdot \gamma_k} \right) + (1 - \overline{S}) \cdot a_L \cdot \left(\frac{1}{a_{k'} \cdot \gamma_{k'}} - \frac{1}{a_k \cdot \gamma_k} \right) \right]$$

- A firm's size depends **only** on its average markup across its products: $\mu_k \propto a_k \cdot \gamma_k$
- Firms with higher markups are larger (more products, sales, and labor)

French R&D subsidy program

Business income tax rate: $\tau = 33\%$

R&D subsidy rate: $\underline{\tau}_{RD} = 30\%$ for R&D expenditures below 100 million Euros and $\overline{\tau}_{RD} = 5\%$ for R&D expenditures in excess of 100 million Euros

Post-tax period profit relative to Y is

$$
\begin{aligned}
& (1-\tau)\left(\pi_k(n,h) - \frac{\psi_z w_z}{Y} x\right) && \text{post-tax income} \\
+ \quad & \underline{\tau}_{RD} \min\left\{\frac{\psi_z w_z}{Y} x,\ \underline{RD}\right\} && \text{subsidy for R\&D below threshold} \\
+ \quad & \overline{\tau}_{RD} \max\left\{\frac{\psi_z w_z}{Y} x - \underline{RD},\ 0\right\} && \text{subsidy for R\&D in excess of threshold}
\end{aligned}
$$

$\underline{RD}$ = 11.69 from average ratio of 100 million Euros to sales per firm in an industry

BGP with R&D subsidy program

Marginal R&D subsidy rate:

$$\tau_{RD}(x) = \begin{cases} \underline{\tau}_{RD} & \text{if } \frac{\psi_z w_z}{Y} x < \underline{RD} \\ \overline{\tau}_{RD} & \text{if } \frac{\psi_z w_z}{Y} x > \underline{RD} \end{cases}$$

FOC for firm's R&D choice implies:

$$\begin{aligned} \bar{n}_k^{\eta-1} - \bar{n}_{k'}^{\eta-1} &= \frac{\bar{S}\, a_H + (1-\bar{S})\, a_L}{\psi_o\, \eta} \cdot \left(\frac{1}{\gamma_{k'}\, a_{k'}} - \frac{1}{\gamma_k\, a_k} \right) && \text{markup difference} \\ &+ \frac{\psi_z w_z}{Y} \cdot \frac{1/\beta - 1 + Z/\psi_z}{1-\tau} \cdot \left[\tau_{RD}\left(\frac{Z}{\psi_z} \bar{n}_k \right) - \tau_{RD}\left(\frac{Z}{\psi_z} \bar{n}_{k'} \right) \right] && \text{R\&D subsidy} \end{aligned}$$

Roadmap

Motivating evidence

Model

Decentralized equilibrium

$\boxed{\text{Planner's solution}}$

Calibration and quantitative results

Planner's problem

The social planner maximizes household utility

$$\max_{\left\{C_t, Q_{t+1}, \left\{n_{k,t+1}, x_{k,t}\right\}_{\forall k}\right\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \log(C_t)$$

subject to the resource constraints and the laws of motion

The planner allocates research labor across firms to raise quality levels on randomly drawn product lines and to (dynamically) distribute products across firms

Features of the BGP of the planner's solution

The planner equalizes production labor across product lines: $L = l(i)$

Any two n_k and $n_{k'}$ satisfy

$$n_k^{\eta-1} - n_{k'}^{\eta-1} = \frac{1-\bar{o}}{\psi_o \eta}\left[\log\left(\frac{a_k}{a_{k'}}\right) + \left(1 + \frac{Z/\psi_z}{1/\beta - 1}\right)\log\left(\frac{\gamma_k}{\gamma_{k'}}\right)\right]$$

where $\bar{o}$ is the steady state fraction of output devoted to overhead

The planner puts greater weight on the γ differences because of spillovers

Welfare along the BGP

$$\frac{1}{1-\beta}\left(\log(C_0) + \frac{\beta}{1-\beta}\cdot\log(1+\overline{g})\right)$$

- $C_0 \equiv C_t(1+\overline{g})^{-t}$ is the consumption level along the BGP
- Fixed L and Z imply no trade-off between consumption and R&D
- Our focus is on the (mis)allocation of Z and L across firms

Levels and growth

$$C/L = (1 - o) \cdot Q \cdot \Phi \cdot \mathcal{M}$$

- $o = O/Y$ is the fraction of output used for overhead
- $Q = \exp\left(\int_0^1 \log\left(q(i)\right) di\right)$ is the geometric mean quality level
- $\Phi = \exp\left(\sum_k S_k \log\left(a_k\right)\right) = a_L \Delta^S$ is the geometric average of process efficiency
- $\mathcal{M}$ captures misallocation of labor across lines due to markup dispersion

$$1 + \bar{g} = \left(\prod_k {\gamma_k}^{\overline{S}_k}\right)^{Z/\psi_z}$$

Illustrative example: no markup heterogeneity across firms

Two types of firms: LB and HS and $\Delta = \Gamma$

Decentralized equilibrium: $\mu_{LB} = \mu_{HS}$ and hence all firms are of the same size

Social planner (SP) vs decentralized equilibrium (DE):

- LB firms are bigger in the SP
- faster growth rate in the SP
- lower average process efficiency in the SP
- higher overhead and lower consumption share of output
- higher allocative efficiency (same production labor in all product lines)

Roadmap

Motivating evidence

Model

Decentralized equilibrium

Planner's solution

$\boxed{\text{Calibration and quantitative results}}$

Calibration

7 parameters governing firm heterogeneity: ϕ_{HB}, ϕ_{HS}, ϕ_{LB}, Γ, Δ, ψ_o/J and η

3 "common" parameters: γ_S, ψ_z/Z, and β

Allow for measurement error in firm-level TFPR, prices and hours

The growth rate of TFP, the real interest rate, and the average level of markups discipline the "common" parameters

The dispersion of prices, TFPR, TFPQ, and size acoss firms (and their correlation with each other) are informative about the firm heterogeneity parameters

Properties of the BGP in the decentralized equilibrium

- High a_j and big γ_j firms have higher markups and higher TFPR levels

$$\text{TFPR}_j \equiv \frac{\text{Revenue}_j}{\text{Inputs}_j} \propto \gamma_j \cdot a_j$$

- Big γ_j firms have higher sales-weighted average prices

$$P_j \propto \gamma_j$$

- High a_j firms have lower marginal cost and higher TFPQ levels

$$\text{TFPQ}_j \equiv \frac{\text{TFPR}_j}{P_j} \propto a_j$$

Intuition behind calibration

- The largest employers are both high TFPQ and big step size firms
- The smallest employers are both low TFPQ and small step size firms
- To generate a negative correlation between TFPQ and employment we need:
  - Many firms in the middle $\iff$ $\phi_{HS} \cdot \phi_{LB} > \phi_{HB} \cdot \phi_{LS}$
  - Step size gap $\Gamma >$ process efficiency gap Δ

Measurement error

In the absence of measurement error, model elasticities of employment wrt to TFPQ and price are much higher than those in the data

Choose the variance of measurement error in TFPQ and prices to fit the elasticities

Lower signal-to-noise ratios push the elasticities toward zero

“Measurement error” may include factors outside of our model

Calibration results

Targets	Data	Model
1. Dispersion in firm-level prices, $Var_j(\log \hat{p})$	0.546	0.546
2. Dispersion in firm-level TFPQ, $Var_j(\log \widehat{\text{TFPQ}})$	0.627	0.629
3. Dispersion in firm-level TFPR, $Var_j(\log \widehat{\text{TFPR}})$	0.103	0.103
4. Dispersion in firm hours	2.546	1.532
5. Semi-elasticity of firm employment share wrt firm price, $\hat{\beta}_{l,p}$	0.074	0.154
6. Semi-elasticity of firm employment share wrt firm TFPQ, $\hat{\beta}_{l,\text{TFPQ}}$	0.004	-0.001
7. Semi-elasticity of firm price wrt firm employment share, $\hat{\beta}_{p,l}$	0.018	0.055
8. Semi-elasticity of firm TFPQ wrt firm employment share, $\hat{\beta}_{\text{TFPQ},l}$	-0.001	-0.000
9. Aggregate price-cost markup ratio	1.50	1.397
10. Productivity growth rate (ppt year)	2.3	2.3
11. Interest rate (ppt/year)	5.2	5.2
12. R&D share of output (percent)	10.6	10.8
13. Semi-elasticity of firm employment share wrt firm price, control TFPQ	0.483	0.941
14. Semi-elasticity of firm employment share wrt firm TFPQ, control price	0.411	0.801

Parameter values

ϕ_{HB}	Share of firms with high process efficiency and big step size	0.04
ϕ_{HS}	Share of firms with high process efficiency and small step size	0.45
ϕ_{LB}	Share of firms with low process efficiency and big step size	0.45
ϕ_{LS}	Share of firms with low process efficiency and small step size	0.06
γ_S	Small step size	1.160
$\Gamma \equiv \gamma_B/\gamma_S$	Step size gap	1.3
$\Delta \equiv \varphi_H/\varphi_L$	Process efficiency gap	1.15
ψ_o/J	Scale of overhead cost	0.105
η	Curvature of overhead cost	1.65
β	Discount factor	0.973
ψ_Z/Z	R&D cost relative to R&D labor	14.7
	Implied share of measurement error in price	96.9%
	Implied share of measurement error in TFPR	92.8%

Planner reallocates R&D toward big step size firms

Recall growth is given by

$$1+\overline{g} \quad = \quad \left(\prod_k \gamma_k^{\overline{S}_k}\right)^{Z/\psi_z}$$

Product shares (in ppt)

	$\overline{S}_{HB}$	$\overline{S}_{HS}$	$\overline{S}_{LB}$	$\overline{S}_{LS}$	high proc. eff.	big step size
Decentralized	9.7	27.1	63.2	0.0	36.8	72.9
Planner	13.4	0.0	86.6	0.0	13.4	100.0
Difference	$+3.7$	-27.1	$+23.4$	-0.0	-23.4	$+27.1$

Growth effect comes from reallocation of R&D towards firms with big γ

Growth and level effects along the BGP

Growth effects:

- Planner has 0.50 bps higher growth rate: $\overline{g}^P = 2.84\%$ vs. $\overline{g}^D = 2.34\%$
- Permanent consumption equivalent of +19.0%

Level effects:

$$\frac{C_0^P}{C_0^D} = \underbrace{\overbrace{\frac{1-o^P}{1-o^D}}^{\text{Overhead}}}_{0.944} \bullet \underbrace{\overbrace{\frac{\Phi^P}{\Phi^D}}^{\text{Process efficiency}}}_{0.968} \bullet \underbrace{\overbrace{\frac{\mathcal{M}^P}{\mathcal{M}^D}}^{\text{Allocative efficiency}}}_{1.005} = 0.919$$

- Permanent consumption equivalent of −8.1% (so net gain is +10.9%)

Concluding remarks

We studied R&D allocation in an economy where markup heterogeneity arose from differences in the step size of quality innovations and process efficiency across firms

- Calibrated the model using data on French manufacturing firms
- Planner tilted innovation toward big quality step firms to enhance growth

Next steps:

- Incorporate the impact of transition dynamics on welfare gains for SP vs. DE
- Calculate the optimal size-dependent R&D subsidy

Discount factor

	Lower	Benchmark	Higher
	$\beta = 0.95$	$\beta = 0.972$	$\beta = 0.99$
$g^P - g$ (bps)	17	17	17
Growth gain (CE ppt)	3.2	5.7	17.7
Level gain (CE ppt)	- 2.5	- 2.3	- 2.3
Overall gain (CE ppt)	0.7	3.4	15.4