R&D, Innovation, and Productivity :

Revisiting the "CDM model"

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OUTLINE

- List of some relevant studies
- Bird-eye view of the « CDM » model
- Revisiting "CDM" on French CIS3 1998-2000 [Mairesse, Mohnen, Kremp (2005)]
- To conclude: general issues and problems

Past and on-going work (1)

- Crépon, B., E. Duguet and J. Mairesse (1998), "Research and Development, Innovation and Productivity: An Econometric Analysis at the Firm Level", *Economics of Innovation and New Technology*, 7(2), 115-158.
- Mairesse, J. and P. Mohnen (2001), "To Be or Not to Be Innovative: An Exercise in Measurement", *STI Review. Special Issue on New Science and Technology Indicators*, OECD, 27, 103-129.
- Mairesse, J. and P. Mohnen (2002), "Accounting for Innovation and Measuring Innovativeness: An Illustrative Framework and an Application", *American Economic Review, Papers and Proceedings*, 92(2), 226-230.
- Mairesse, J. and P. Mohnen (2005), "The Importance of R&D for Innovation: A Reassessment Using French Survey Data", *The Journal of Technology Transfer,* special issue in memory of Edwin Mansfield, 30(1-2), 183-197.
- Hall, B.H. and J. Mairesse (2006),"Empirical Studies of Innovation in the Knowledge Driven Economy", Introduction to a special issue on: "Empirical studies of innovation in the knowledge driven economy", *Economics of Innovation and New Technology*, 15(4/5), 289-299.
- Mohnen, P., J. Mairesse and M. Dagenais (2006), "Innovativity: A Comparison across Seven European Countries", special issue on: "Empirical studies of innovation in the knowledge driven economy"*Economics of Innovation and New Technology*, 15(4/5), 391-413.

Past and on-going work (2)

- Kremp, E., and J. Mairesse (2003), “Knowledge Management, Innovation and Productivity: A Firm Level Exploration Based on the French CIS3 Data”, in D. Foray and F. Gault eds., “*Measuring Knowledge management in the Business Sector*”, OECD.
- Mairesse, J. and P. Mohnen (2004), “Intellectual Property in Services: What Do We Learn from Innovation Surveys ?”, in *Patents, Innovation, and Economic Performance*, OECD Conference Proceedings, OECD, Paris, 227-245.
- J. Mairesse and P. Mohnen, Kremp, E. (2005), “The Importance of R&D and Innovation for Productivity: A Reexamination in Light of the 2000 French Innovation Survey”, *Mimeo*
- Griffith R., E. Huergo, J. Mairesse and Bettina Peters (2006), "Innovation and Productivity across Four European Countries", *Oxford Review of Economic Policy*, 22(4), 483-498.
- Harrison, R., J. Jaumandreu, J. Mairesse and Bettina Peters (2008), "Does Innovation Stimulate Employment? A Firm-Level Analysis Using Comparable Micro Data from Four European Countries", NBER WP n°14216.
- Hall, B. H., F. Lotti and J. Mairesse (2008), "Employment, Innovation and Productivity: Evidence from Italian Micro Data", *Industrial and Corporate Change*, 17(4), 813-839. .
- Hall, B. H., F. Lotti and J. Mairesse (2008), "Innovation and Productivity in SME’s: Empirical Evidence for Italy", *Small Business Economics*, forthcoming.

Special issue on

Empirical studies of innovation in the knowledge driven economy

in Economics of Innovation and New Technology,

B. Hall and J. Mairesse, guest eds. (2006)

- Benavente, J-M., "The Role of Research and Innovation in Promoting Productivity in Chile".
- Heshmati, A. and H. Lööf, "Knowledge Capital and Heterogeneity in Firm Performance. A Sensitivity Analysis".
- Jefferson, G., B. Huamao, G. Xiaojing and Y. Xiaoyun, "R&D performance in Chinese industry".
- Van Leeuven G., and L. Klomp, "On the Contribution of Innovation to Multi-Factor Productivity".
- Duguet, E., "Innovation Height, Spillovers and TFP Growth at the Firm Level: Evidence from French Manufacturing for Company Performance".
- **....**

OTHER STUDIES (very very incomplete)

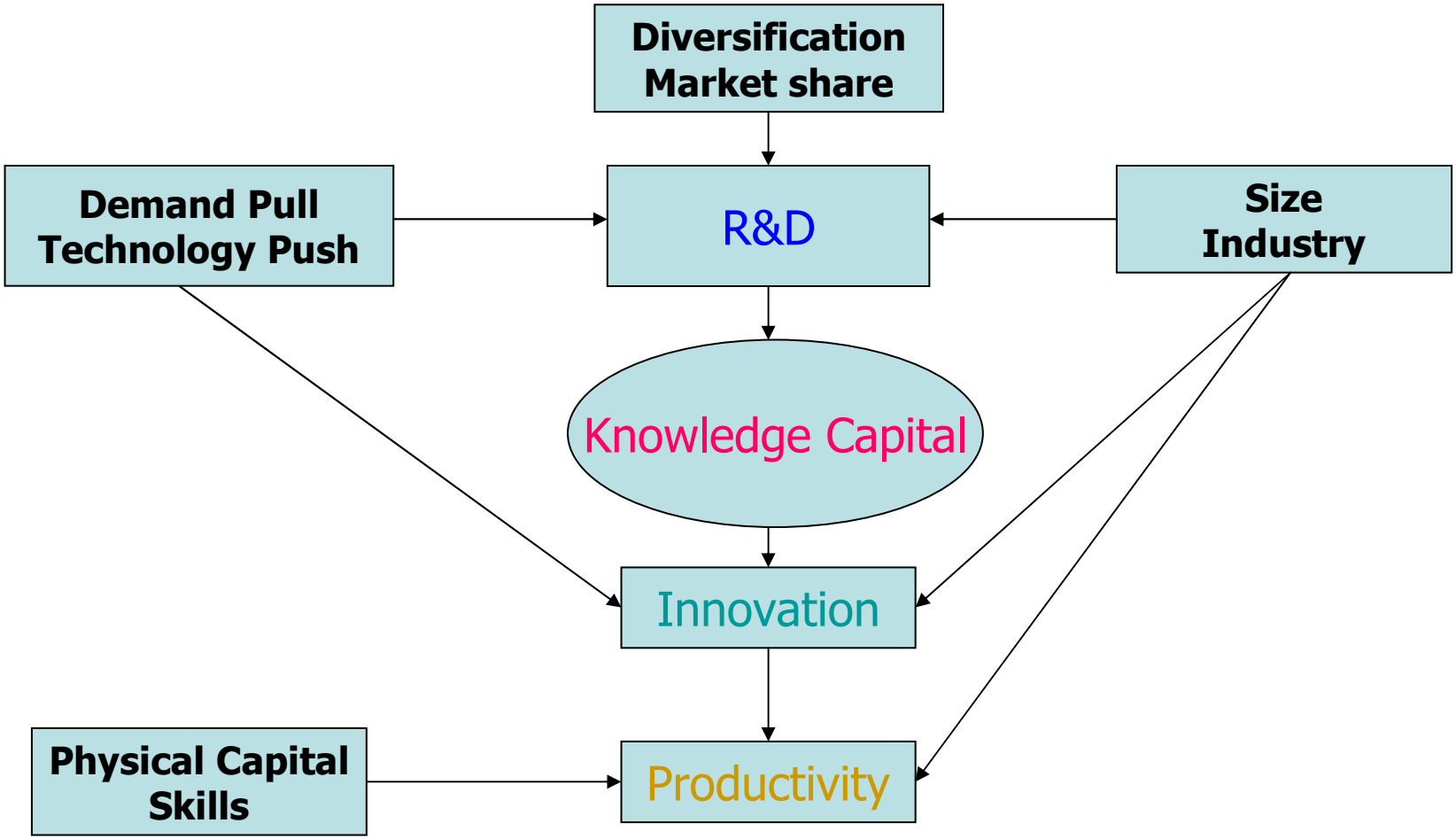
- Klomp, L. and G. Van Leeuwen G. (2001), "Linking Innovation and Firm Performance: A New Approach", *Journal of the Economics of Business*, 8(3), 343-364.
- Lööf, H. and A. Heshmati (2002), "Knowledge Capital and Performance Heterogeneity: A Firm-Level Innovation Study", *International Journal of Production Economics*, 76(1), 61-85.
- Lööf, H., A. Heshmati, R. Apslund and S.O. Nås (2002), "Innovation and Performance in Manufacturing Firms: A comparison of the Nordic Countries", mimeo.
- Criscuolo, C. and J. Haskel (2003), "Innovations and Productivity Growth in the UK: Evidence from CIS2 and CIS3", CeRiBa discussion paper.
- Galia, F. and D. Legros (2003), "Research and Development, Innovation, Training, Quality and Profitability: Econometric Evidence from France", mimeo.
- Janz, N., H. Lööf, and B. Peters (2004), "Firm level Innovation and Productivity: Is There a Common Story across Countries?", *Problems and Perspectives in Management*, 2, 184-204.
- Parisi, M., F. Schiantarelli and A. Sembenelli (2006), "Productivity, Innovation and R&D: Micro Evidence for Italy", *European Economic Review*, 50, 2037–2061.

The « CDM » model

with Bruno Crépon and Emmanuel Duguet

- Brings together the three main fields of investigation in the econometrics of research and innovation
- Proposes a "simple" framework articulating innovative and productive activities
- Takes advantage of the innovation survey information
- Uses estimation methods appropriate to the specification of the model and nature of data

The « CDM » model



Revisiting "CDM"
on French CIS3 1998-2000

with Elizabeth Kremp and Pierre Mohnen

- Basic idea from CDM model:

R&D ⇒ Knowledge

and Knowledge ⇒ Productivity

where instead of constructing knowledge capital from R&D, knowledge is "measured" by innovation output indicators

- Use of data from French CIS3 survey
- Extension of CDM model in various dimensions

R&D equations (1 and 2)

1. R&D indicator equation

$s_i = 0 \quad \text{if } s_i^* = x_{1i}b_1 + u_{1i} <= 0$

$= 1 \quad \text{if } s_i^* = x_{1i}b_1 + u_{1i} > 0$

2. R&D intensity equation (log "R&D" per employee)

$r_i = r_i^* = x_{2i}b_2 + u_{1i} \quad \text{if } s_i^* > 0$

$= 0 \quad \text{if } s_i^* <= 0$

where we assume that u_{1i} and u_{2i} follow a normal distributions

INNOVATION equations (3 and 4)

3. Product innovation indicator equation

$$pd_i = 0 \quad \text{if } pd_i^* = b^*_3 s_i^* + x_{3i}b_3 + u_{3i} <= 0$$

$$= 1 \quad \text{if } pd_i^* = b^*_3 s_i^* + x_{3i}b_3 + u_{3i} > 0$$

4. Product innovation intensity equation

(logit-share of innovative sales)

$$zinno_i = zinno_i^* = b^*_4 r_i^* + x_{4i}b_3 + u_{4i} \quad \text{if } pd_i^* > 0$$

$$= 0 \quad \text{if } pd_i^* <= 0$$

where u_{3i} and u_{4i} follow normal distributions

PRODUCTIVITY equation (5) and possibly other equations(6…)

5. Productivity equation (log "output" per employee)

$$prod_i = b^*_5 \, zinno^*_i + x_{5i} b_5 + u_{5i}$$

6. Employment equation …

Explanatory variables

- x_0 = {indicators for industry, size}
- x_1 = {x_0, market share, diversification, international market, domestic group, foreign group}
- x_2 = {x_1, technology push, demand pull, government support, cooperation, sources of information}
- x_3 = {x_0, international market, domestic group, foreign group, s*}
- x_4 = {x_0, international market, domestic group, foreign group, r*}
- x_5 = {x_0, capital per employee, materials per employee, zinno*}

One Possible Structure of CDM model

Variables: **Endogenous in blue** **Exogenous in black**	**R&D selection**	**R&D intensity**	**Product innovation occurrence**	**Product innovation intensity**	**Labor productivity**
Industry	x	x	x	x	x
Size	x	x	x	x	x
Market share	x	x			
Diversification	x	x			
Domestic Group	x	x	x	x	
Foreign group	x	x	x	x	
International market	x	x	x	x	
Technology push		x			
Demand pull		x			
Government support		x			
Cooperation		x			
Sources of information: **Internal (firm, group)**	x	x			
Basic (univers., public labs)	x	x			
Suppliers	x	x			
Customers	x	x			
Materials/employee					x
Capital/employee					x
Product innovation					x
R&D occurrence			x		
R&D intensity				x	((x))

Estimation by asymptotic least squares (ALS)

First step: estimate reduced form of the model

$$
\begin{aligned}
&\max \ln L = \\
&\Sigma_i \{ 0_{RDCON,i} \ln\Phi(-z_{0i}\pi_0) \\
&\quad + 1_{RDCON,i} \ [-\ln(\xi_1) + \ln\varphi((r_i - z_{1i}\pi_1)/\xi_1) \\
&\qquad\qquad + \ln\Phi([z_{0i}\pi_0 + \rho(r_i - z_{1i}\pi_1)/\xi_1]/(1-\rho_1^{\,2})^{0.5}] \\
&\quad + 0_{PC,i} \quad \ln\Phi(-z_{2i}\pi_2) + 1_{PC,i} \ \ln\Phi(z_{2i}\pi_2) \\
&\quad + 0_{PD,i} \quad \ln\Phi(-z_{3i}\pi_3) \\
&\quad + 1_{PD,i} \quad [-\ln(\xi_4) + \ln\varphi((zinno_i - z_{4i}\pi_4)/\xi_4) \\
&\qquad\qquad + \ln\Phi([z_{3i}\pi_3 + \rho(zinno_i - z_{4i}\pi_4)/\xi_4]/(1-\rho_4^{\,2})^{0.5}] \\
&\quad - \ln(\xi_5) + \ln\varphi((prod_i - z_{5i}\pi_5)/\xi_5)\}
\end{aligned}
$$

Relation between reduced form parameters and structural parameters

- The structural form parameters of interest are given by $b = [b_1, b_2, b_3, b_4, b_5]$.
- The reduced form parameters are given by

  $\pi=[\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \xi_2, \xi_4, \xi_5, \rho_{12}, \rho_{34}]$

  with covariance matrix Ω.
- There is a relationship between the reduced form and structural form parameters $g(b,\pi) = 0$, where

  g has the dimension of the number of reduced form parameters .

Second step: estimate structural parameters

- Choose b so as to minimize

$$g(b,\hat{\pi})'[\frac{\partial g(.)}{\partial \pi'}\hat{\Omega}\frac{\partial g'(.)}{\partial \pi}]^{-1} g(b,\hat{\pi})$$

where $\hat{\Omega}$ is the estimated covariance matrix of the estimated π.

- Test of the overidentifying restrictions can be performed by checking whether the quadratic form is significantly different from zero.

The French Innovation survey CIS3 (1)

- Launched in 2001 - 2002
- Over the period 1998-2000
- Coverage for the manufacturing industry
  5 100 firms over 20 employees are surveyed
- Sampling frame, using the business register
  - **all firms** over 500 employees
  - 1/2, to 1/8 for smaller 'size' firms
- Response The French Innovation Survey is **mandatory**
  - The response rate is over 85 %
- Part of the Third Community Innovation Survey (CIS3)

The French Innovation survey CIS3 (2)

- Based on the guidelines of the OSLO manual
- Provides information on innovation inputs and outputs
- Inputs : R&D expenditures …
- Outputs:
  - qualitative: binary indicators for being “innovative” in product and process, patenting …
  - quantitative: intensity of innovation : shares of innovative sales new for the firm or the market, of patented sales …
- Provides also information on the sources of innovation, cooperation, public funding

The French annual survey of enterprise

- The French annual survey of enterprise (EAE) is mandatory
- and covers all firms over 20 employees
- contains balance sheet data: gross book value …
- contains current account data: turnover, value added, gross output, materials, employees, share of sales in different industries at the NAF700 level …
- Here, we use the information on the 1996-2000 period for a balanced sample matched with the CIS3 innovation survey

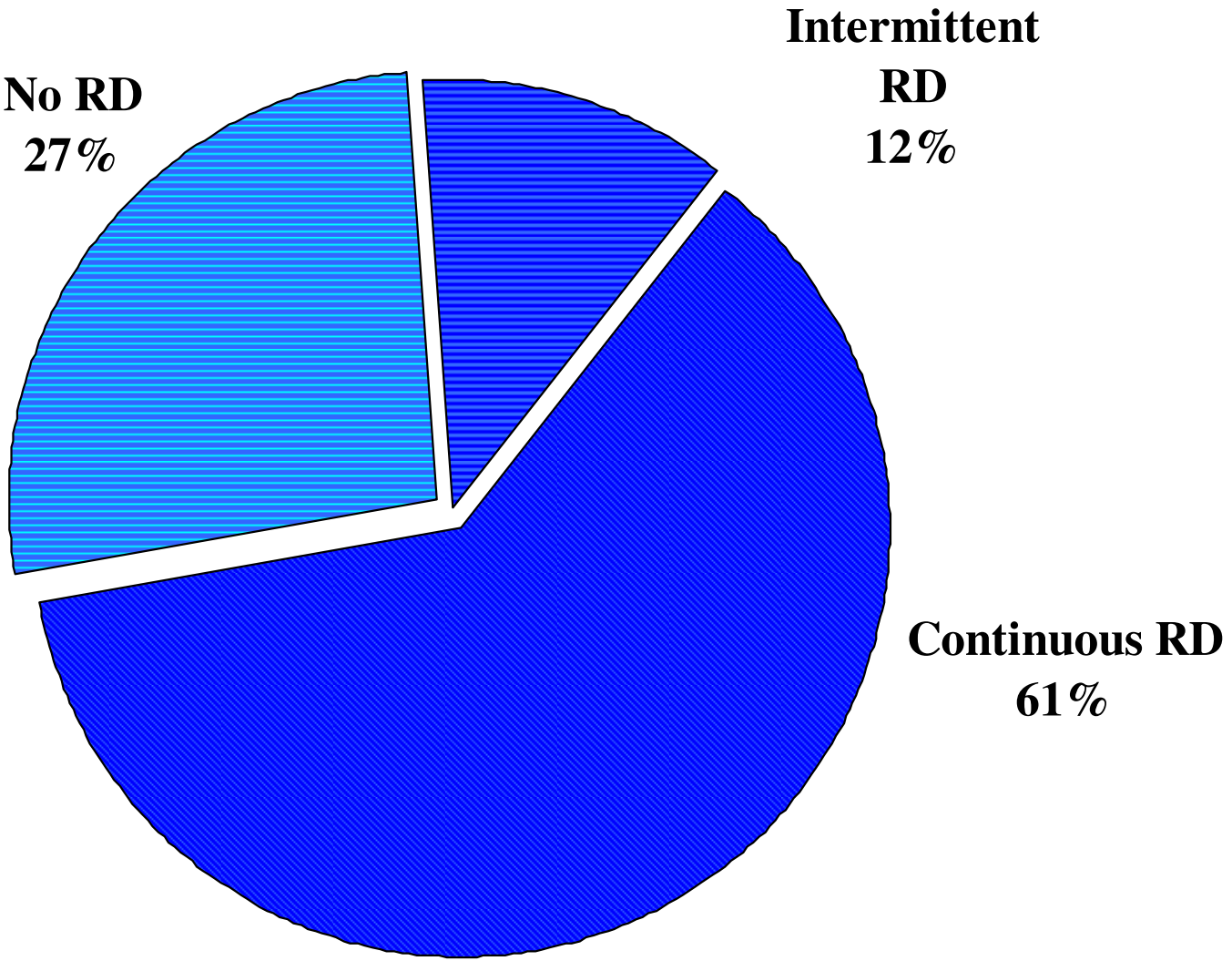
Table 1: Summary statistics: France, CIS 3, 1998-2000, Manufacturing Samples of all firms (TOTAL), innovative firms (INNO) and continuously R&D performing firms (R&D)

Variable	High-tech industries			Low-tech industries		
	TOTAL Sample	INNO Sub-sample	R&D Sub-sample	TOTAL Sample	INNO Sub-sample	R&D Sub-sample
Number of firms	899	678	488	1354	721	351
% firms performing R&D continuously in 1998-2000	54.3	72.0	100.0	25.9	48.7	100.0
R&D over sales in 2000 (in %)	n.r.	n.r.	5.4	n.r.	n.r.	2.1
R&D/Employee in 2000 (in 10^3 euros per person)	n.r.	n.r.	7.9	n.r.	n.r.	2.5
Sales/Employee: Mean/Median in 2000 (in 10^3 euros per person)	167/142	177/150	181/155	127/107	138/118	144/122

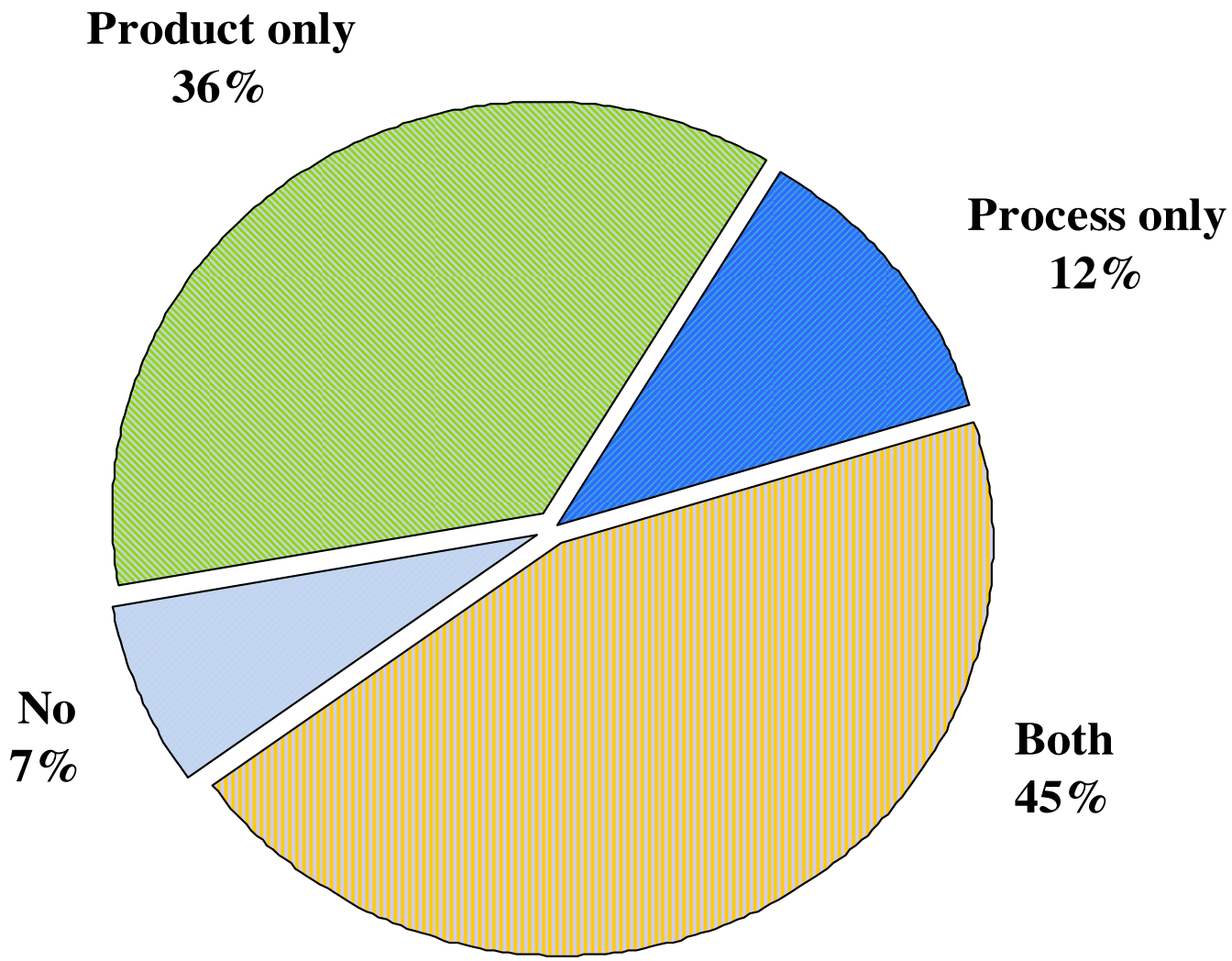
Having innovated with products new to the firm in 1998-2000*						
. % firms	**66.0**	**87.5**	**93.2**	**39.6**	**74.3**	**85.2**
. share of innovative sales in 2000	**n.r.**	**14.8**	**16.5**	**n.r.**	**9.4**	**11.6**
Having innovated with products new to the market in 1998-2000*						
. % firms	**41.4**	**54.9**	**64.3**	**19.6**	**36.8**	**50.1**
. share of innovative sales in 2000	**n.r.**	**8.1**	**9.6**	**n.r.**	**3.8**	**5.1**
Having innovated with processes in 1998-2000						
. % firms	**40.6**	**53.8**	**56.8**	**30.7**	**57.7**	**58.7**
Having applied for at least one patent in 1998-2000						
. % firms	**46.4**	**59.0**	**69.1**	**23.2**	**38.1**	**55.6**
Having at least one valid patent at the end of 2000*						
. % firms	**48.7**	**60.6**	**70.9**	**25.3**	**39.3**	**55.8**
. share of patent-protected sales in 2000	**15.2**	**18.2**	**20.9**	**6.0**	**8.2**	**10.8**

Number of employees: Mean/Median	561/185	680/266	819/361	309/114	409/166	586/297
% of firms for which the most significant market is international	57.2	67.8	74.4	31.5	39.1	50.1
% of firms belonging to a French group	45.9	46.0	49.0	47.3	50.6	53.8
% of firms belonging to a foreign group	35.2	39.5	39.8	21.7	28.4	31.6
% of firms with strong demand pull	n.r	63.7	70.3	n.r.	55.8	63.8
% of firms with strong cost push	n.r.	24.2	27.7	n.r.	17.3	20.2
Diversification index	1.18	1.20	1.23	1.16	1.18	1.24
Average market share (in %)	3.0	3.5	4.2	2.3	3.2	4.4
% of firms with government support for innovation	n.r.	33.9	38.3	n.r.	30.9	35.6
% of firms collaborating in innovation	n.r.	53.8	61.1	n.r.	37.7	49.9
% of firms with significant source of information for innovation from: . Within the firm or group	n.r.	78.3	85.2	n.r.	70.0	82.6
. Basic research institutions	n.r.	60.5	68.0	n.r.	40.6	54.7
. Suppliers	n.r.	47.8	48.6	n.r.	48.0	51.0
. Clients	n.r.	76.4	83.0	n.r.	67.5	76.1

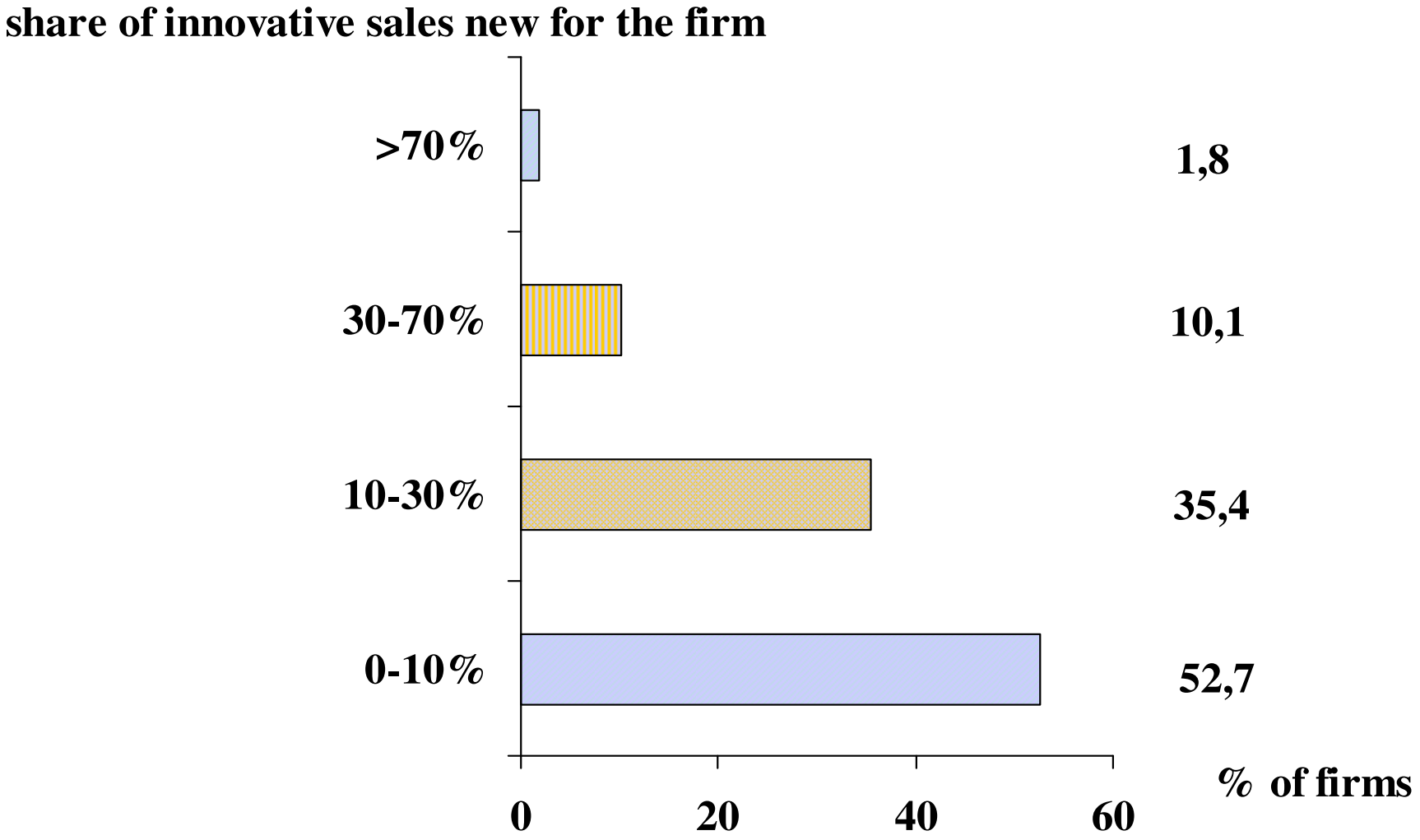
R&D Indicator for Innovative firms



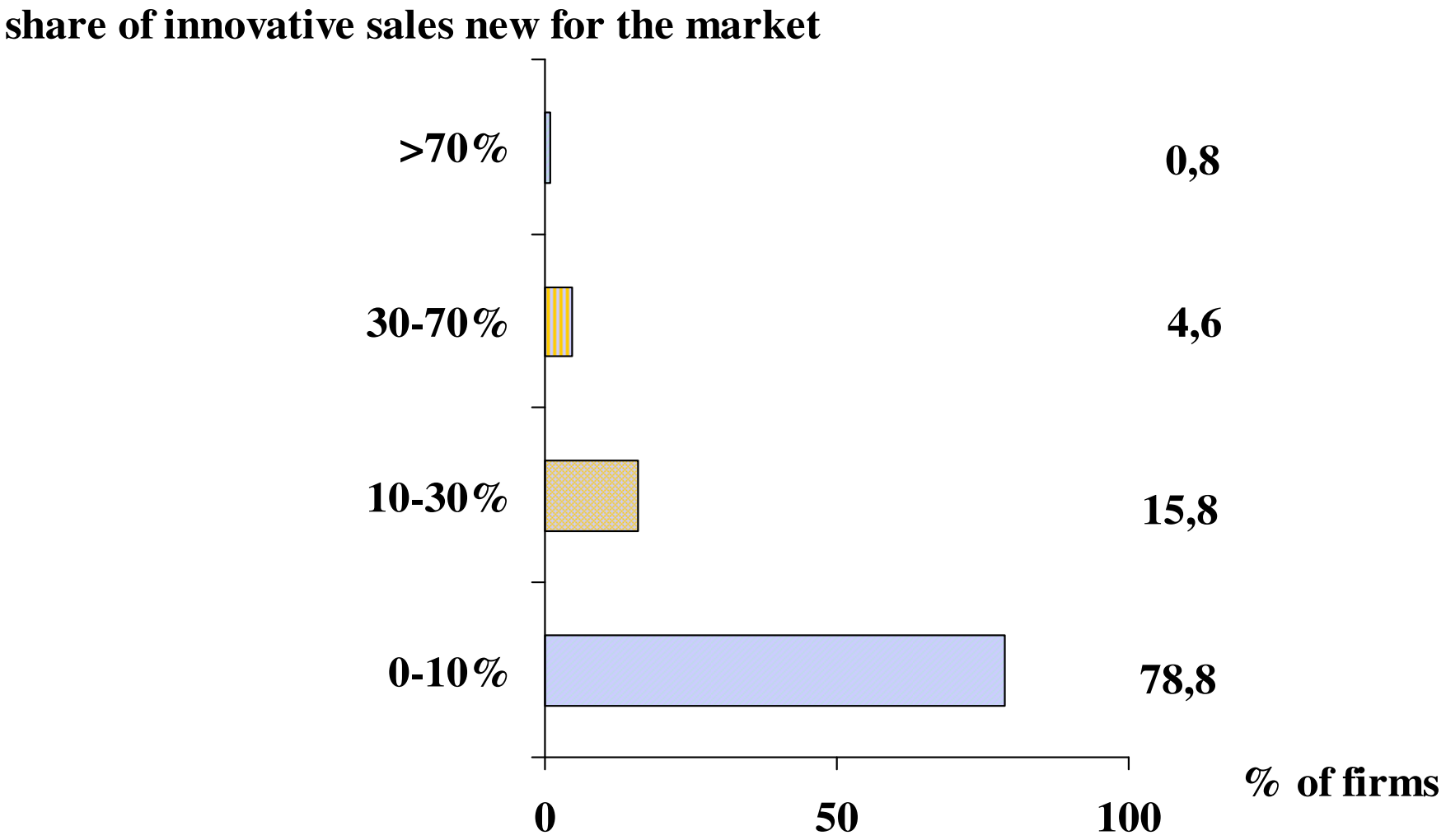
Process and Product Innovation Indicators



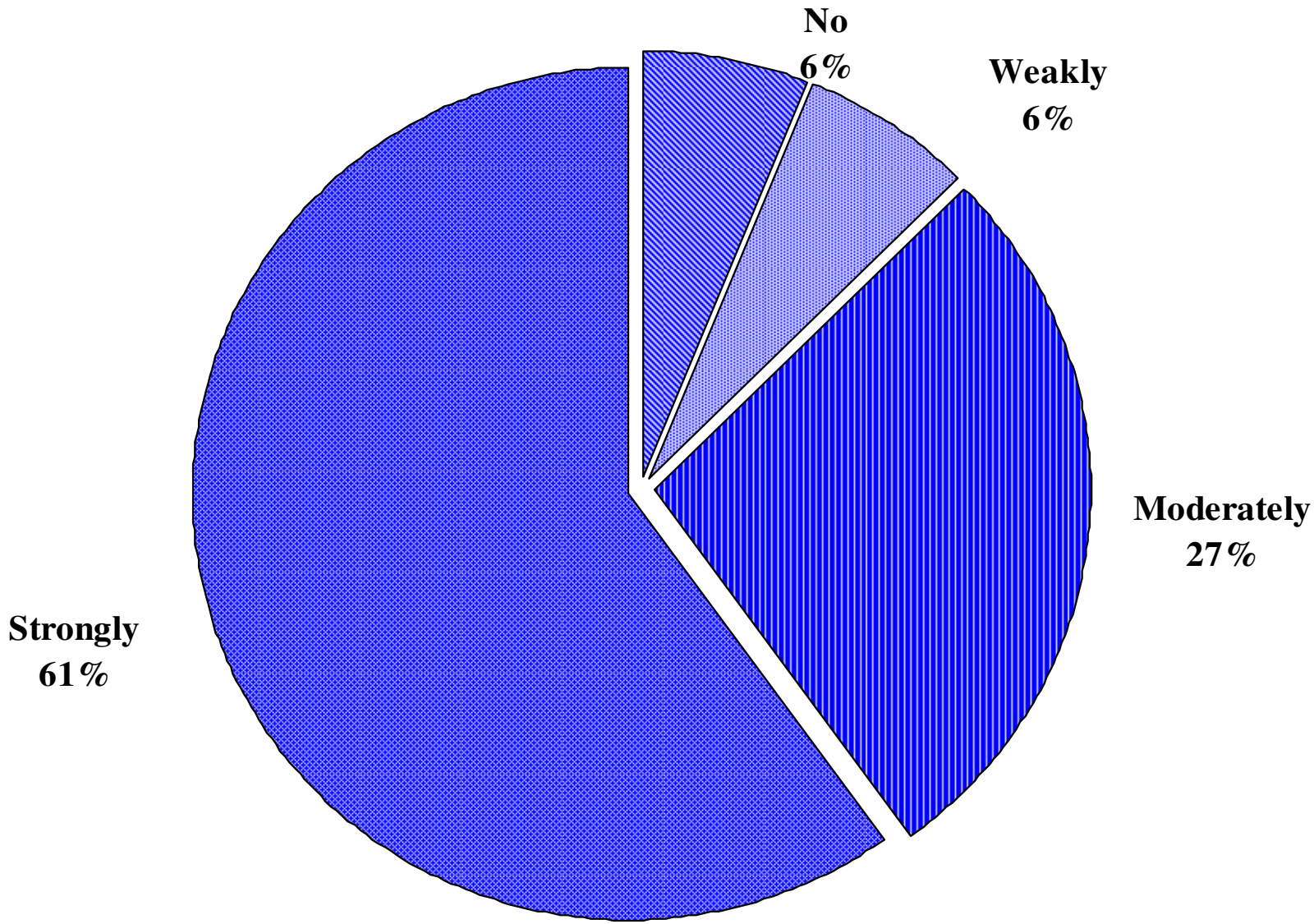
Share of innovative sales new for the firm



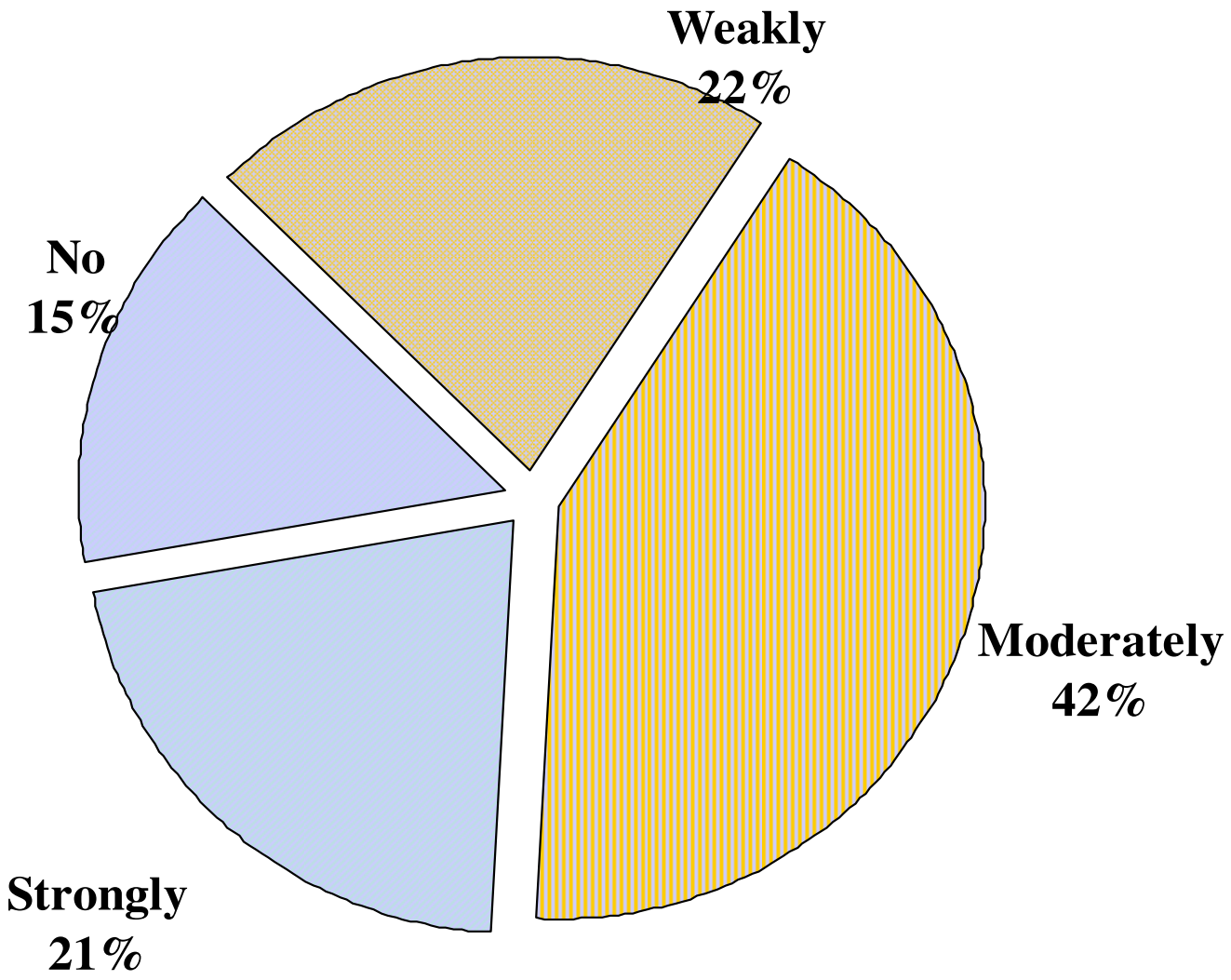
Share of innovative sales new for the market



Demand Pull indicator for Innovative firms



Technology Push indicator for Innovative firms



Experimenting with different specifications

- Complete versus partial model
- Correcting or not for selectivity and/or endogeneity
- Alternative measures of innovation
- Quantitative versus qualitative variables
- High-tech versus low-tech

Alternative measures of innovation

- R&D
  - Continuous R&D
  - Discrete R&D
- Discrete innovation output
  - Product new to firm
  - Product new to market
  - Patent application
  - Patent holding
- Continuous innovation output:
  - Share of innovative sales new to firm products
  - Share of innovative sales new to market products
  - Share of sales protected by a patent

Estimated parameters and average marginal effects (in %): complete model, with endogeneity and selectivity, and with new to the firm product innovation

High-Tech Industries	R&D occurrence	R&D/ Employee (log)	Innovation occurrence	Share of innovative sales (logit)	Labor productivity (log)
R&D occurrence			126.06*** [46.16***]		
R&D/employee (log)				**18.61 [2.07]**	
Share of innovative sales					**22.54 [2.03]**
Size (number of employees in log)	28.38*** [8.94***]	4.67	-7.48 [-2.74]	5.86 [0.65]	-3.03*
Market share (log)	4.95 [1.56]	9.24**			
Diversification (log)	4.14** [13.04**]	-7.11			
Domestic group	18.90 [5.95]	-3.03	-26.75** [-9.80**]	-9.74 [-1.08]	
Foreign group	0.28 [0.09]	-7.45	0.59 [0.21]	-5.68 [-0.63]	
International market	72.28*** [22.77***]	44.34***	-18.93 [-6.93]	2.35 [0.26]	
Technology push		56.38***			
Demand pull		5.71			
Government support		10.74			
Cooperation		21.50*			
Information from within firm or group		6.88			
Information from basic research		29.98**			
Information from suppliers		-18.61*			(C) 3.58***
Information from customers		6.27			(M) 71.28***

Explanation of different estimates of productivity elasticity for R&D and three innovation intensity indicators (1 and 2)

	Continuous R&D	**Products new to the firm, Products new to the market, and Patent holdings**
SINGLE EQUATION MODEL: One endogenous variable: Productivity		
No correction for selectivity and for endogeneity (OLS)	Regression (5) with observed R&D intensity i_R on R&D firms sub-sample	Regression (5) with observed innovation intensity i_I on innovating firms sub-samples
PARTIAL MODEL- Two or three endogenous variables: R&D occurrence or/and intensity, or Innovation occurrence or /and intensity, and Productivity		
Correcting only for selectivity (Maximum Likelihood)	Equations (1) and (5) with observed R&D intensity i_R on Full sample	Equations (3) and (5) with observed innovation intensity i_I, on full sample [with no R&D in equation (3) and the same exogenous *x*'s as in equation (1)]
Correcting only for endogeneity (ALS)	Equations (2) and (5) with predicted R&D intensity i_R^* on R&D firms sub-sample	Equations (4) and (5) with predicted innovation intensity i_I^*, on innovating firms sub-samples [with no R&D in equation (4) and same exogenous *x*'s as in equation (2)]
Correcting for selectivity and endogeneity (ALS)	Tobit equations (1) and (2), and Regression (5) with predicted R&D intensity i_R^* on Full sample	Tobit Equations (3) and (4), and regression (5) with predicted innovation intensity i_I^*, on full sample [with no R&D in equations (3) and (4) and the same exogenous *x*'s as in equations (1) and (2) respectively]

Explanation of different estimates of productivity elasticity for R&D and three innovation intensity indicators (3)

COMPLETE MODEL – Four or five endogenous variables: R&D occurrence and/or intensity, Innovation occurrence and intensity, and Productivity		
Correcting only for selectivity (Maximum Likelihood)	Not relevant.	Equation (3) with observed R&D occurrence s_R and regression (5) with observed innovation intensity i_I and fewer explanatory variables in equation (3) than in equation (1), on full sample.
Correcting only for endogeneity (ALS)	Not relevant.	Equation (2), Tobit equations (3) and (4) with respectively predicted R&D occurrence s_R^* and predicted intensity i_R^*, and regression (5) with predicted innovation intensity i_I^*, on R&D firms sub-sample
Correcting for selectivity and endogeneity (ALS)	Not relevant.	Tobit equations (1) and (2), Tobit equations (3) and (4) with respectively predicted R&D occurrence s_R^* and intensity i_R^*, and regression (5) with predicted innovation intensity i_I^*, on full sample

Different estimates of productivity elasticity (in %) with respect to R&D and three innovation intensity variables in High-Tech industries

Estimates of productivity elasticities with respect to:	R&D per employee	Products new to the firm	Products new to the market	Patent holdings
No correction for selectivity and for endogeneity (productivity equation alone - sub-samples)	3.46 (0.51)	0.32 (0.42)	-0.04 (0.51)	0.41 (0.27)
Correcting only for selectivity (partial model - full sample)	3.40 (0.52)	0.34 (0.39)	-0.01 (0.47)	0.52 (0.24)
Correcting only for endogeneity (partial model - sub-samples)	4.50 (1.44)	3.04 (1.82)	1.52 (1.65)	-2.27 (1.00)
Correcting for selectivity and endogeneity (partial model - full sample)	4.28 (0.93)	3.33 (1.26)	2.16 (0.88)	1.57 (0.84)
Correcting only for selectivity (complete model - full sample)	-	0.20 (0.40)	-0.10 (0.49)	0.48 (0.23)
Correcting only for endogeneity (complete model - sub-samples)	-	30.6 (30.1)	11.02 (6.06)	-86.00 (443.50)
Correcting for selectivity and endogeneity (complete model - full sample)	-	**22.54** **(14.50)**	7.00 (2.57)	16.97 (15.66)

Different direct and indirect estimates of productivity elasticities (in %) with respect to R&D in High-Tech industries

Estimates of productivity elasticities with respect to R&D*:	R&D per employee	Through Products new to the firm	Through Products new to the market	Through Patent holdings
No correction (productivity equation alone - sub-samples)	3.46 (0.51)	0.32 (0.42	-0.04 (0.51)	0.49 (0.25)
Correcting only for selectivity (complete model - full sample)	3.40 (0.52)	0.02 (0.56)	0.00 (0.21)	0.00 (0.36)
Correcting only for endogeneity (complete model – sub-samples)	4.50 (1.44)	3.70 (1.56)	3.01 (1.41)	3.63 (1.60)
Correcting for selectivity and endogeneity (complete model - full sample)	4.28 (0.93)	**4.20** **(1.15)**	2.86 (0.98)	4.39 (1.17)

Different estimates of the elasticity (in %) of three innovation intensity indicators with respect to R&D intensity

Estimates of innovation elasticities with respect to R&D:	Products new to the firm	Products new to the market	Patent holdings
No correction for selectivity and for endogeneity (innovation equation alone: innovation sub-samples)	9.31 (4.95)	5.24 (6.19)	14.20 (10.16)
Correcting only for selectivity (complete model - full sample)	8.94 (5.10)	2.95 (6.18)	0.00 (1.06)
Correcting only for endogeneity (complete model – continuous R&D sub-samples)	12.11 (11.90)	27.31 (15.13)	-4.22 (21.15)
Correcting for selectivity and endogeneity (complete model - full sample)	**18.61** **(11.20)**	40.80 (14.86)	25.87 (23.47)

Corresponding estimates of R&D gross rates of return (in %) for complete model specifications correcting for selectivity and endogeneity, and using or not the different intensity innovation indicators in High-Tech Industries

Variables	R&D per employee (log)	Products new to the firm (logit)	Products new to the market (logit)	Patent holdings (logit)
Elasticity of output w/t R&D	4.28 (0.93)	4.55 (1.13)	4.37 (0.99)	4.88 (1.14)
Rate of return of R&D				
First quartile	13.1	13.9	13.3	14.9
Median	24.7	26.3	25.2	28.2
Third quartile	56.7	60.3	57.9	64.7
Average	51.8	55.2	52.9	59.1

Explanation of different estimates of productivity elasticities for R&D binary indicator and five innovation binary indicators (1, 2 and 3)

	Continuous R&D	**Products new to the firm, Products new to the market, Process innovation, Patent applications and Patent holdings**
SINGLE EQUATION MODEL: One endogenous variable: Productivity		
No correction for endogeneity (OLS)	Regression (5) with observed R&D occurrence s_R, on full sample	Regression (5) with observed innovation occurrence s_R, on full sample
PARTIAL MODEL- Two endogenous variables: R&D or Innovation occurrence, and Productivity		
Correcting for endogeneity (ALS)	Probit Equation (1) and regression (5) with predicted R&D occurrence s_R^*, on full sample	Probit Equation (3) and regression (5) with predicted innovation occurrence s_I^*, on full sample [with no R&D in equation (3) and the same exogenous *x*'s as in equation (1)]
COMPLETE MODEL – Three endogenous variables: R&D occurrence, Innovation occurrence, and Productivity		
Correcting only for endogeneity (ALS)	Not relevant.	Probit Equation (1), Probit equation (3) with predicted R&D occurrence s_R^*, and regression (5) with predicted innovation occurrence s_I^*, on full sample

Different estimates of semi-elasticities of productivity (in %,) with respect to the binary R&D indicator and five binary innovation indicators in High-Tech industries

Estimates of semi-elasticities of productivity with respect to:	R&D Investment (yes/no)	Process innovation (yes/no)	Patent applications (yes/no)	Products new to the firm (yes/no)	Products new to the market (yes/no)	Patent holdings (yes/no)
No correction for endogeneity	3.32 (0.93)	0.81 (0.95)	1.24 (0.99)	1.11 (0.98)	2.12 (0.91)	0.83 (0.99)
Correcting for endogeneity (partial model - full sample)	2.27 (1.20)	5.20 (1.84)	2.75 (1.37)	2.81 (1.17)	4.24 (1.54)	2.91 (1.55)
Correcting for endogeneity (complete model - full sample)	-	6.26 (2.26)	3.28 (1.50)	3.12 (1.24)	4.67 (1.72)	3.76 (1.73)

Different direct and indirect estimates of semi-elasticities of productivity (in %,) with respect to the binary R&D indicator in High-Tech industries

Estimates of semi-elasticities of productivity with respect to R&D*:	R&D Investment (yes/no)	Through Process innovation (yes/no)	Through Patent applications (yes/no)	Through Products new to the firm (yes/no)	Through Products new to the market (yes/no)	Through Patent holdings (yes/no)
Correcting for endogeneity (complete model - full sample)	2.27 (1.20)	3.02 (2.31)	0.95 (1.41)	2.50 (1.66)	2.52 (1.90)	1.85 (1.69)

Different estimates of semi-elasticities (in %) of five binary innovation indicators with respect to the binary R&D indicator in High-Tech industries

Estimates of semi-elasticities of innovation with respect to R&D:	Products new to the firm (yes/no)	Products new to the market (yes/no)	Process innovation (yes/no)	Patent applications (yes/no)	Patent holdings (yes/no)
High-Tech Industries					
No correction for endogeneity	163.36	121.32	62.35	98.83	121.53
	(11.77)	(10.67)	(10.35)	(10.54)	(10.78)
Correcting for endogeneity	80.00	53.99	48.18	29.11	49.27
	(45.18)	(37.63)	(35.28)	(41.33)	(40.64)

SOME CONCLUSIONS

- Innovation indicators are noisy measures which needs to be instrumented. Taking into account selectivity also helps. [*Why?*]. Binary indicators seem somewhat less noisy than intensity indicators.
- R&D appears largely "exogenous" to productivity, not to innovation. If one is only interested in R&D productivity (i.e., rate of return), the extended production function does well.
- Innovation indicators are useful to go beyond a strict focus on R&D returns and to investigate the "black box" of innovative activities, for example in a framework à la "CDM".
- …