# Inputs and outputs of innovative activities.
## The importance of firm- and sector-specific factors

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*IPTS Steering Workshop on*

*"Industrial Research and Innovation"*

*Seville, 14-15 June 2012*

# Role of business R&D and innovation investments on firms' performance: science-based sectors

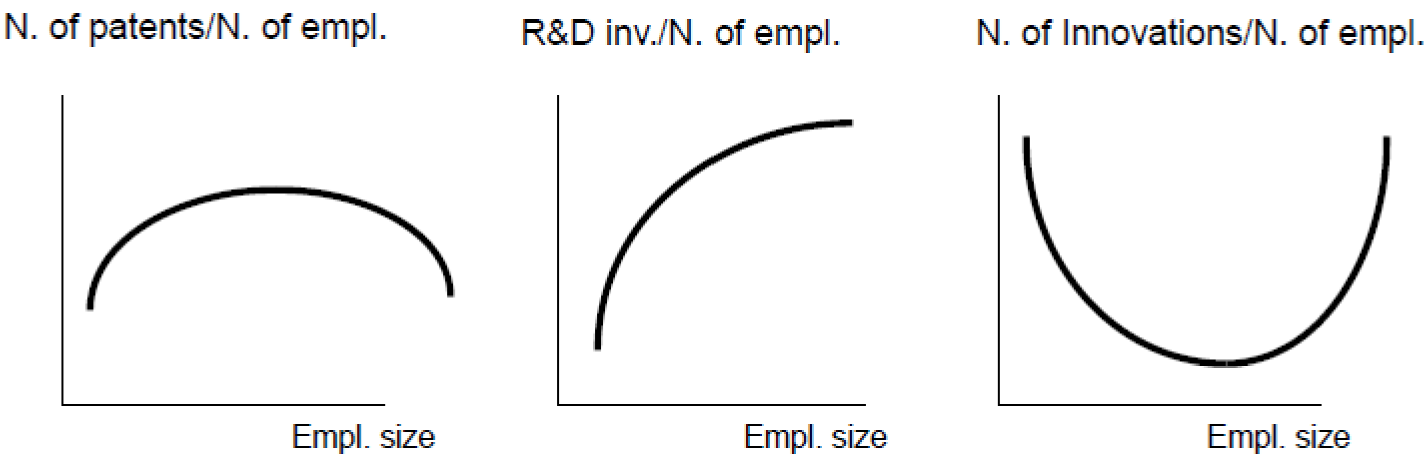
- **R&D** is the main determinant of the innovative output of firms in the science-based sectors:
  - R&D investment is a good proxy for the autonomous innovative capability of firms and sectors which produce internally the technology they use:
    - Either at the sector or firm level, it is in general positively correlated (although not necessarily in a linear fashion) with indicators of economic performance (productivity growth, market power, export shares, and profits);

# Role of business R&D and innovation investments on firms' performance: science-based sectors

- **External technological acquisition**, both through '*embodied technical change*' acquired by means of investment in new machinery and equipment (Salter, 1960) and through the *purchasing of external technology* incorporated in licenses, consultancies, and know-how is also important.

# Firm size and innovativeness: a controversial relationship

- **Firm size** matters: Large firms are more likely to have an innovative output (Schumpeter “Mark I”);
- But empirical evidence inconclusive:



# R&D and Innovation Investments: Science-based sectors

Dependent variable: N. of patents; Negative binomial regression

| | USPTO | EPO | WIPO |
|---|---|---|---|
| ln(R&D) | 0.355 | -0.222 | 0.239 |
| | (1.00) | (0.45) | (0.66) |
| $\ln(R\&D)_{t-1}$ | 0.602** | 0.282 | -0.009 |
| | (2.08) | (0.64) | (0.03) |
| $\ln(R\&D)_{t-2}$ | 0.430** | 0.771** | 0.681*** |
| | (2.11) | (2.47) | (3.28) |
| $\ln(R\&D)^2$ | -0.072** | -0.031 | -0.009 |
| | (2.14) | (0.65) | (0.25) |
| ln(CapExp) | 0.404*** | 0.620** | 0.191 |
| | (2.62) | (2.51) | (1.29) |
| $\ln(CapExp)_{t-1}$ | -0.050 | -0.026 | -0.052 |
| | (0.83) | (0.25) | (0.83) |
| $\ln(CapExp)_{t-2}$ | -0.032 | -0.298** | -0.144* |
| | (0.41) | (2.23) | (1.72) |
| $\ln(CapExp)^2$ | -0.052** | -0.088* | -0.036 |
| | (2.02) | (1.91) | (1.32) |
| ln(Employees) | 0.168** | 0.468*** | 0.232*** |
| | (2.10) | (3.43) | (2.61) |
| $z_{i,t}$ (time_trend) | -0.090 | -0.508*** | -0.103 |
| | (1.57) | (5.10) | (1.63) |
| $a_{i,t}$ (dummy_eu) | 0.121 | 2.941*** | 0.407** |
| | (0.74) | (11.47) | (2.33) |
| Constant | -3.252*** | -4.057*** | -2.055*** |
| | (4.14) | (3.97) | (2.70) |
| No. of observations | 241 | 235 | 237 |
| Pseudo $R^2$ | 0.11 | 0.137 | 0.08 |
| Deviance/df | 0.91 | 1.15 | 0.98 |
| Pearson/df | 0.73 | 1.28 | 0.96 |
| Log-likelihood | -756.94 | -455.36 | -795.39 |
| LR $chi^2(11)$ | 181.01 | 145.07 | 144.80 |
| Prob>$chi^2$ | 0.0000 | 0.0000 | 0.0000 |

Absolute value of t statistics in parentheses. The superscripts mean: *significant at 10%; **significant at 5%; ***significant at 1%

Source: Piergiovanni – Santarelli (2012)

# Role of business R&D and innovation investments on firms' performance: other sectors

- The **innovation outputs** of other types of firms:
  - YICs ($\rightarrow$), SMEs, entrepreneurial firms, etc.
- And sectors:
  - consumer goods, mechanical engineering, etc.
- Can be seen as the outcomes of **several innovation inputs** and not only as the consequence of R&D investment, technological acquisition, and ability to exploit economies of scale.

# Effects of various types of capital on innovative output

- In fact, presence, availability and characteristics of other types of capital may exert a positive effect on innovative output. These include:
  - Entrepreneurship capital;
  - Financial capital;
  - Human capital;
  - Social capital.

# Effects of various types of capital on innovative output

- *Entrepreneurship capital*: Provided that radical innovations often come from new start-ups (Acs at al., 2009), the larger presence of individuals that are willing to create new firms may lead to higher innovative output:
  - Nurturing entrepreneurship capital?
- *Financial capital*: Given that R&D and other innovative activities require substantial financial investments, a lack of financial means could hinder innovation (Hyytinen and Toivanen, 2005). “Type 1” credit rationing and “Redlining” more likely to affect SMEs and YICs:
  - Changing the attitudes of financial institutions intrinsically risk-averse when they have to cope with SMEs and YICs pursuing aggressive innovation strategies?

# Effects of various types of capital on innovative output

- *Human capital*: Developing new technologies within firms requires sufficient access to relevant human capital. The literature on 'absorptive capacity' (Cohen and Levinthal, 1989) suggests that firms should invest in their knowledge base by hiring educated workers or provide training programs to keep their human resources up-to-date:
  - Universities as suppliers of knowledge-intensive outputs (perhaps more graduates than research)?
- *Social capital*: As a form of mutual recognition which, by promoting social cohesion and mutual obligations (Putnam, 1993), may contribute to create a seedbed for many driving forces, including *innovation*, of economic growth and prosperity:
  - Promoting participation in weak-tie networks (e.g. formal business associations)?

# Effects of various types of capital on innovative output: All sectors

Dependent variable: No. of patents and N. of trademarks; OLS estimates

| Variable | Patents | | Trademarks | |
|---|---|---|---|---|
| d1999 | -0.2068 | (4.99)*** | -0.4212 | (3.62)*** |
| d2000 | -0.2076 | (5.05)*** | -0.3483 | (3.02)*** |
| d2001 | -0.2131 | (5.13)*** | -0.3854 | (3.30)*** |
| d2002 | -0.2182 | (5.05)*** | -0.4211 | (3.47)*** |
| d2003 | -0.2185 | (5.03)*** | -0.4193 | (3.43)*** |
| d2004 | -0.2171 | (4.98)*** | -0.3699 | (3.02)*** |
| d2005 | -0.2252 | (5.02)*** | -0.4042 | (3.20)*** |
| d2006 | -0.2012 | (4.44)*** | -0.4110 | (3.22)*** |
| d2007 | -0.1226 | (2.30)** | -0.6031 | (4.02)*** |
| Entrepreneurship capital$_{t-1}$ | 0.8394 | (2.71)** | 2.9481 | (3.39) *** |
| Financial capital$_{t-1}$ | 6.4365 | (2.56)** | 12.7362 | (1.80)** |
| Financial capital$^2_{t-1}$ | -339.3173 | (2.90)*** | -577.9521 | (1.76)** |
| Human capital $_{t-1}$ | 1.9047 | (6.30)*** | 10.3273 | (12.76)*** |
| Social capital$_{t-1}$ | 5.1213 | (7.95)*** | 11.5291 | (6.37)*** |
| Firm size $_{t-1}$ | 0.0596 | (10.56)*** | 0.1078 | (6.79) *** |
| Population density $_{t-1}$ | 0.0000 | (2.51)** | 0.0003 | (9.26)*** |
| Value added pc$_{t-1}$ | 0.0020 | (2.63)** | 0.0105 | (4.81)*** |
| Commerce$_{t-1}$ | -0.7174 | (8.73)*** | -3.3126 | (14.33) *** |
| $R^2$adjusted | 0.7606 | | 0.8712 | |
| N | 927 | | 927 | |

Absolute Student's t in brackets; *** refers to 99% confidence level; ** refers to 95% confidence level.
Source: Carree – Piergiovanni – Santarelli – Verheul (2012)

# Degree of vertical integration as a crucial sectoral characteristic

- In-house R&D is weak in non-high-tech SMEs and in the supplier dominated sectors(Pavitt, 1984), which nevertheless may be involved in the introduction of entirely new products. In fact, they display a much greater intensity of "used" R&D than of "performed" R&D (Santarelli and Sterlacchini, 1994):
  - Exchange of semi-manufactured products, intermediary commodities and capital goods facilitates **R&D investment spillovers** on other sectors.

# External and Internal R&D: Various sectors

Ratios of external R&D to internal R&D (Sectoral level)

| | R&D via patents United States | R&D via capital goods Italy | R&D via innovations United Kingdom |
|---|---|---|---|
| Chemicals | 0.5 | 0.13 | 0.24 |
| Metal products | 1.37 | 0.51 | 0.80 |
| Mechanical machinery | 0.24 | 0.36 | 0.74 |
| Instruments | 0.14 | 0.02 | 0.81 |
| Electrical & Electronics | | 0.02 | |
| Electrical | 0.32 | | 0.39 |
| Electronics | 0.26 | | 0.47 |
| Motor vehicles | 0.21 | 0.07 | 1.12 |
| Textile, Clothing & Footwear | 1.38 | 13.00 | 4.14 |
| Food, Beverages & Tobacco | 1.18 | 2.22 | 0.67 |
| Paper & Printing | 1.31 | 3.80 | 4.25 |
| Rubber & Plastics | 1.12 | 0.25 | 1.17 |

Source: Santarelli – Sterlacchini (1994)

# Labour productivity impact of innovation output

- Questions to be addressed:
- 1) Is innovativeness associated to accelerated labour productivity growth?
- 2) Are sectoral specificities important when it comes to explain the differentiated impact that innovative activities have on labour productivity?
- 3) Is smaller/larger firm size resulting in accelerated labour productivity growth?

# Labour productivity impact of innovation output: Science-based firms

| Dependent variable: Labour Productivity Growth; OLS estimates | |
|---|---|
| Stock pat EPO | .158*** |
| | (0.062) |
| Stock pat USPTO | -.316*** |
| | (0.099) |
| Pat bio EPO (t-1) | 0.409* |
| | (0.289) |
| Pat bio USPTO (t-1) | -0.818* |
| | (0.578) |
| log SIZE (t-1) | -1.637** |
| | (0.925) |
| log $SIZE^2$ (t-1) | .108** |
| | (0.065) |
| Constant | 0.945 |
| | (1.296) |
| N. of observations | 425 |
| $R^2$ | 0.059 |

OLS estimates on the pooled sample, including year effects.
Robust and clustered standard errors in brackets.
***, **, * mean stat. signif. at 0.01%, 0.05% and 0.10%.
Source: Santarelli – Lotti (2008)

# R&D investment, capital investment, and the economic value of different types of innovation

- The economic value of innovation may vary according to the type of innovation;
- Different types of R&D and other innovation inputs may exert a different impact on different types of innovation;
- Sterlacchini (2008) finds that:
  - Sales of improved products and products that are new to the firm are particularly affected by expenditure on product R&D;
  - Sales due to process innovations are significantly associated with purchases of innovative capital goods;
  - Expenditures for design, engineering and pre-production developments are closely associated with the sales of products new to the domestic market and entirely new.
  - Joint employment of different innovation inputs raises the sales of the most innovative products.

# Determinants of the value of different types of innovation

Dependent variable: Value of different types of innovation; OLS Regressions

| Dependent variables: | | FIrmSales | | IntrSales | | ProdSales | |
|---|---|---|---|---|---|---|---|
| *Type of regression:* | | *unrestricted* | *restricted* $\alpha_1, \beta = 0$ | *unrestricted* | *restricted* $\alpha_2, \gamma = 0$ | *unrestricted* | *restricted* $\alpha_2, \gamma, \delta = 0$ |
| Independent variables | Coeff. | | | | | | |
| Constant | $A$ | 6.63 | 7.72 | 1.48 | 2.41 | 2.62 | 0.12 |
| | | (5.09)^ | (11.1)^ | (0.94) | (2.26) | (1.20) | (0.08) |
| *ProdR&DExp* | $\alpha_2$ | 0.54 | 0.59 | 0.05 | | 0.11 | |
| | | (3.91)^ | (5.95)^ | (0.27) | | (0.43) | |
| *Des_EngExp* | $\beta$ | 0.08 | | 0.59 | 0.64 | 0.90 | 1.10 |
| | | (0.27)^ | | (2.19) | (3.60) | (2.42) | (5.29) |
| *InnCapExp* | $\gamma$ | 0.16 | | 0.18 | | -0.37 | |
| | | (1.14)^ | | (0.93) | | (-1.39) | |
| *logSIZE* | $\delta$ | -0.68 | -0.60 | 0.26 | 0.37 | 0.24 | |
| | | (-3.50) | (-3.26)^ | (1.28) | (2.59) | (0.84) | |
| Std.Dev. of residuals | | 0.61 | 0.60 | 0.62 | 0.65 | 0.92 | 0.92 |
| Adjusted R-squared | | 0.42 | 0.44 | 0.56 | 0.58 | 0.47 | 0.47 |
| F-test for the restriction | | | 1.042 [0.367] | | 0.432 [0.654] | | 0.981 [0.417] |

(*) t-ratios are in round brackets; probability levels of the F-tests for the restrictions are in squared brackets.

^= t-ratio corrected for heteroskedasticity [White's (1980) procedure].

Dependent variables (logs of industry sales per employee for interviewed firms):

*FirmSales* = sales related to the introduction of products new to the firm;

*IntrSales* = sales related to the introduction of products new to the Italian market;

*ProdSales* = sales related to the introduction of entirely new products.

Source: Sterlacchini (2008)

# Young and small firms as drivers of innovation?

- Whereas in the US they played an essential role in the implementation of new technologies, in Europe young and small firms have revealed capacity to innovate not higher than that of established firms (Criscuolo et al., 2012) and a high rate of early failure, resulting more into churning rather than into innovative sectoral dynamics (Santarelli and Vivarelli, 2007);
- Nevertheless, among the various types of young and small firms, YICs have been shown to exhibit a greater potential for sales and **employment** growth (Czarnitzki and Delanote, 2012).

# The innovativeness of young and established firms (UK)

Differences in innovative performance between **new ventures** (firms aged <5 years and with >10 employees) and established firms: manufacturing (UK)

| SIC code | Sector | Established firms | | New ventures | | z-Tes.. | *p-V•lue* |
|---|---|---|---|---|---|---|---|
| | | Number | Proportion of product innovators | Number | Proportion of product innoators | | |
| 15 | Food & Drink | 381 | 0.470 | 32 | 0.375 | 1.033 | 0.302 |
| 17 | Textiles | 106 | 0.368 | 14 | 0.500 | -0.955 | 0.339 |
| 18 | Wearing Apparel | 67 | 0.343 | 12 | 0.167 | 1.211 | 0.226 |
| 20 | Wood & Products of Wood | 126 | 0.262 | 14 | 0.357 | -0.760 | 0.447 |
| 21 | Pulp, Paper & Paper Products | 113 | 0.407 | 9 | 0.333 | 0.434 | 0.664 |
| 22 | Publishing & Printing | 335 | 0.343 | 39 | 0.359 | -0.195 | 0.845 |
| 24 | Chemicals & Chemical Products | 163 | 0.663 | 9 | 0.889 | -1.410 | 0.158 |
| 25 | Rubber & Plastic Products | 282 | 0.479 | 24 | 0.542 | -0.592 | 0.554 |
| 1 b | Non-Metallic Mineral Products | 149 | 0.416 | 8 | 0.500 | -0.468 | 0.640 |
| 27 | Basic Metals | 74 | 0.311 | 9 | 0.333 | -0.1 38 | 0.891 |
| 28 | Fabricated Metal Products | 526 | 0.310 | 42 | 0.381 | -0.954 | 0.340 |
| 29 | Machinery & Equipment | 356 | 0.500 | 26 | 0.346 | 1.515 | 0.130 |
| 30 | Office Machinery & Computers | 35 | 0.686 | 3 | 0.333 | 1.235 | 0.217 |
| 31 | Electrical Machinery & Apparatus | 214 | 0.435 | 14 | 0.429 | 0.044 | 0.965 |
| 32 | Radio, TV & Communication Equipment | 114 | 0.754 | 12 | 0.583 | 1.282 | 0.200 |
| 33 | Medical, Precision & Optical Instruments | 186 | 0.677 | 16 | 0.563 | 0.937 | 0.349 |
| 34 | Motor Vehicles | 216 | 0.454 | 27 | 0.481 | -0.273 | 0.785 |
| 35 | Other Transport Equipment | 92 | 0.435 | 15 | 0.600 | -1.191 | 0.234 |
| 36 | Furniture | 341 | 0.463 | 60 | 0.383 | 1.148 | 0.251 |
| 37 | Recycling | 13 | 0.186 | 10 | 0.600 | 2.67'1 | 0.008 |
| Total manufacturing | | 3919 | 0.443 | 395 | 0.430 | 0.490 | 0.624 |

Two-sample z-test on the equaliry of proportions.
Source: Criscuolo – Nicolau – Salter (2012).

# The innovativeness of young and established firms (UK)

Differences in innovative performance between **new ventures** (firms aged <5 years and with >10 employees) and established firms: services (UK)

| SIC code | Sector | Established firms | | New ventures | | z-Test[a] | p-Value |
|---|---|---|---|---|---|---|---|
| | | Number | Proportion of product innovators | Number | Proportion of product innovators | | |
| 50 | Sale, Maintenance & Repair of Motor Vehicles & Motorcycles | 343 | 0.207 | 40 | 0.150 | 0.851 | 0.395 |
| 51 | Wholesale Trade & Commission Trade, exc. Motor Vehicles & Motorcycles | 721 | 0.300 | 59 | 0.475 | −2.787 | 0.005 |
| 52 | Retail Trade, exc. Motor Vehicles & Motorcycles; Repair of Personal & Household Goods | 1096 | 0.173 | 125 | 0.184 | −0.297 | 0.766 |
| 55 | Hotels & Restaurants | 544 | 0.176 | 136 | 0.228 | −1.378 | 0.168 |
| 60 | Inland Transport | 451 | 0.186 | 51 | 0.294 | −1.835 | 0.067 |
| 61 | Water Transport | 19 | 0.211 | 1 | 1.000 | −1.777 | 0.076 |
| 62 | Air Transport | 18 | 0.500 | 4 | 0.250 | 0.908 | 0.364 |
| 63 | Supporting & Auxiliary Transport Activities; Activities of Travel Agencies | 274 | 0.292 | 26 | 0.192 | 1.078 | 0.281 |
| 64 | Post & Telecommunications | 197 | 0.406 | 68 | 0.426 | −0.294 | 0.768 |
| 65 | Financial Intermediation | 120 | 0.508 | 14 | 0.429 | 0.565 | 0.572 |
| 66 | Insurance & Pension Funding | 59 | 0.508 | 7 | 0.000 | 2.554 | 0.011 |
| 67 | Activities Auxiliary to Financial Intermediation | 312 | 0.340 | 49 | 0.286 | 0.746 | 0.455 |
| 70 | Real Estate Activities | 267 | 0.243 | 37 | 0.324 | −1.060 | 0.289 |
| 71 | Renting of Machinery & Equipment | 219 | 0.265 | 30 | 0.300 | −0.407 | 0.684 |
| 72 | Computer & Related Activities | 314 | 0.650 | 62 | 0.661 | −0.175 | 0.861 |
| 73 | Research & Development | 157 | 0.554 | 25 | 0.560 | −0.055 | 0.956 |
| 74 | Other Business Activities | 1596 | 0.291 | 282 | 0.397 | −3.573 | 0.000 |
| Total services | | 6609 | 0.286 | 1006 | 0.344 | −3.800 | 0.000 |

[a] Two-sample z-test on the equality of proportions.

# Definitions of young and small firms

- **NTBFs**: (A.D. Little Consulting Group, 1977): an independently owned business established for not more than 25 years and based on the exploitation of an invention or technological innovation which implies substantial technological risks;
- **YICs**: (EC, General Block Exemption Regulation, 2008): firms having less than 250 employees, being less than 6 years old and spending at least 15% of their operating expenses on R&D;
- **SY**: (Czarnitzki and Delanote, 2012): firms displaying the same features of YICs but not having any R&D requirements.

# The growth of YICs, NTBFs, and SYs

Dependent variable: firm growth; Pooled OLS

| Variables | (1) Sales Growth | | (2) Sales Growth | | (3) Emp Growth | | (4) Emp Growth | |
|---|---|---|---|---|---|---|---|---|
| YIC | 10.774 | *** | 10.083 | *** | 4.703 | ** | 4.661 | ** |
| | (3.651) | | (3.655) | | (2.030) | | (2.061) | |
| NTBF | | | -1.525 | | | | 1.052 | |
| | | | (1.647) | | | | (1.064) | |
| SY | | | -3.391 | | | | -1.672 | |
| | | | (2.939) | | | | (1.431) | |
| ln(EMP)[a] | -1.026 | *** | -1.031 | *** | -0.315 | * | -0.328 | * |
| | (0.291) | | (0.290) | | (0.186) | | (0.185) | |
| ln(AGE) | -1.300 | *** | -1.717 | *** | -0.640 | ** | -0.682 | ** |
| | (0.444) | | (0.534) | | (0.259) | | (0.304) | |
| RDint | 0.098 | | 0.091 | | 0.055 | | 0.049 | |
| | (0.090) | | (0.091) | | (0.051) | | (0.051) | |
| $RDint^2$ | -0.002 | * | -0.002 | * | -0.001 | | -0.001 | |
| | (0.001) | | (0.001) | | (0.001) | | (0.001) | |
| FOREIGN | 0.741 | | 0.743 | | 0.737 | | 0.762 | |
| | (0.901) | | (0.900) | | (0.561) | | (0.561) | |
| EXPORT | -2.023 | ** | -2.025 | ** | -2.692 | *** | -2.728 | *** |
| | (0.876) | | (0.875) | | (0.490) | | (0.489) | |
| GP | -0.837 | | -0.834 | | 0.675 | | 0.635 | |
| | (0.842) | | (0.842) | | (0.508) | | (0.510) | |
| Constant | 4.286 | ** | 5.858 | ** | -2.979 | ** | -2.739 | * |
| | (2.010) | | (2.328) | | (1.303) | | (1.435) | |
| R2 | 0.09 | | 0.09 | | 0.06 | | 0.06 | |
| N | 6110 | | 6110 | | 7888 | | 7888 | |
| F statistic | 17.138 | *** | 16.026 | *** | 17.299 | *** | 16.432 | *** |
| F-test on joint significance of industry dummies | 7.82 | *** | 7.81 | *** | 4.35 | *** | 4.40 | *** |
| F-test on joint significance of time dummies | 49.72 | *** | 49.33 | *** | 29.18 | *** | 28.61 | *** |
| F-test on joint significance of region dummies | 0.67 | | 0.79 | | 1.95 | * | 2.01 | * |

* p<0.10, ** p<0.05, *** p<0.01

Note: Cluster-robust standard errors are given in parentheses.
[a]: The results hold when we include the logarithm of turnover as a size measure, instead of the logarithm of employment in the regressions on sales growth.

Source: Czarnitzki – Delanote (2012)

# Main obstacles to the emergence of YICs: Evidence-based hints for policy action

- Liquidity constraints:
  - Entry subsidies; R&D incentives; public procurement addressed to innovative products.
    - For public procurement to be effective it is important that it does not pick winners (national champions) but rather identifies and purchases emerging technologies and advanced technology products;
- Lack of complementary assets:
  - Support technology transfer from research centers and universities; subsidize recruitment of Science, Technology, Engineering, and Mathematics graduates:
    - The availability of advanced skills and the provision of incentive schemes aimed to support hiring of university graduates can compensate for lack of experience and limited absorptive capacity of YICs;

# Entrepreneurship and the emergence of YICs: Evidence-based hints for policy action

- Shortcomings of the mechanism of IPR protection:
  - Given that trade secret is most widely used than patenting, setting in motion a process of homogeneization of the national legislations in relation to trade secrets in the EU (according to the general standards referred to in Art. 39 of the TRIPS Agreement) may allow YICs to take full advantage of this IPR protection mechanism;
- Institutional framework:
  - For YICs relying on a mix of R&D investment and external technological acquisition, policies addressed to create a regulatory and institutional framework favorable to RJVs and innovative cooperation between YICs and well established incumbents might also be desirable (Cassiman and Veugelers, 2000; Piga and Vivarelli, 2004).

# Policy action for the next technological revolution: A somewhat provocative conclusion

- Target high R&D intensive sectors expected to produce **new technologies** of potentially high pervasiveness?
- Or target sectors with high potential for **product innovation**?
- Don’t forget the effects of the “dotcoms” bubble;
- Consider the possibility of the next bubble being brought about by the sectors of the “green economy”.

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