The Value of Innovation for VC Backed Startups

Setting the scene

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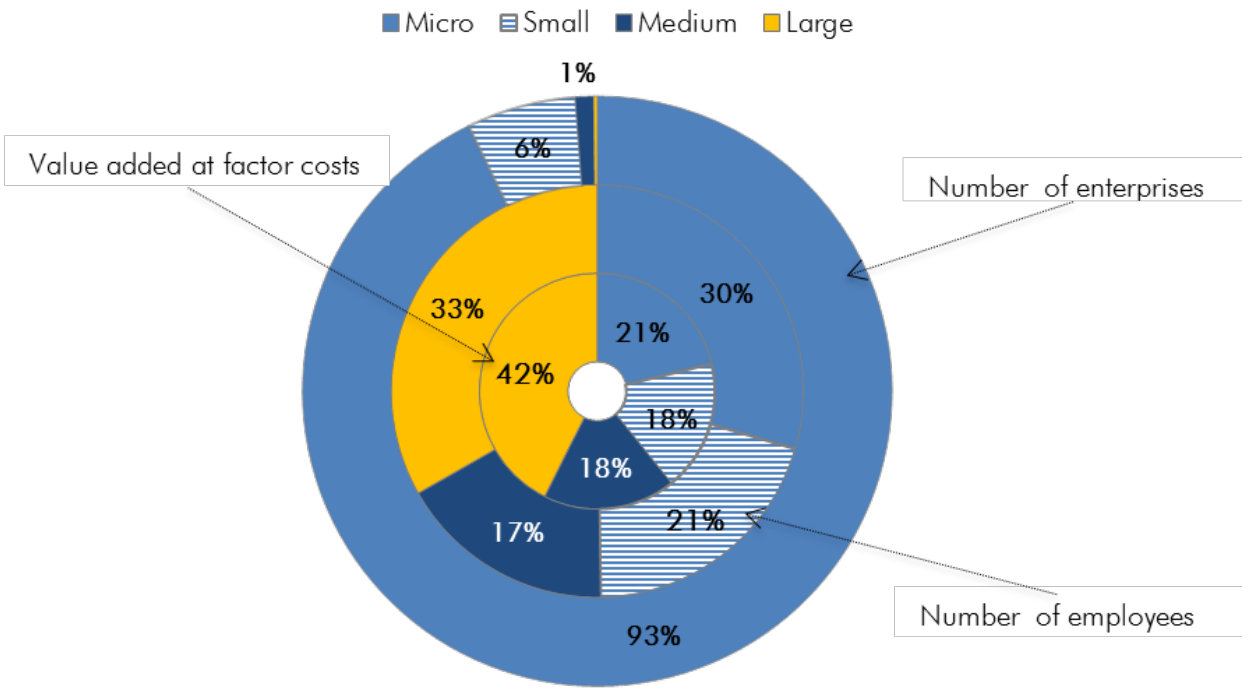
Importance of SMEs

An essential part of the EU economy

EU definition (EC)	Employees	Annual turnover or Balance sheet total	
Micro	<10	≤ EUR 2m	≤ EUR 2m
Small	<50	≤ EUR 10m	≤ EUR 10m
Medium-sized	<250	≤ EUR 50m	≤ EUR 43m



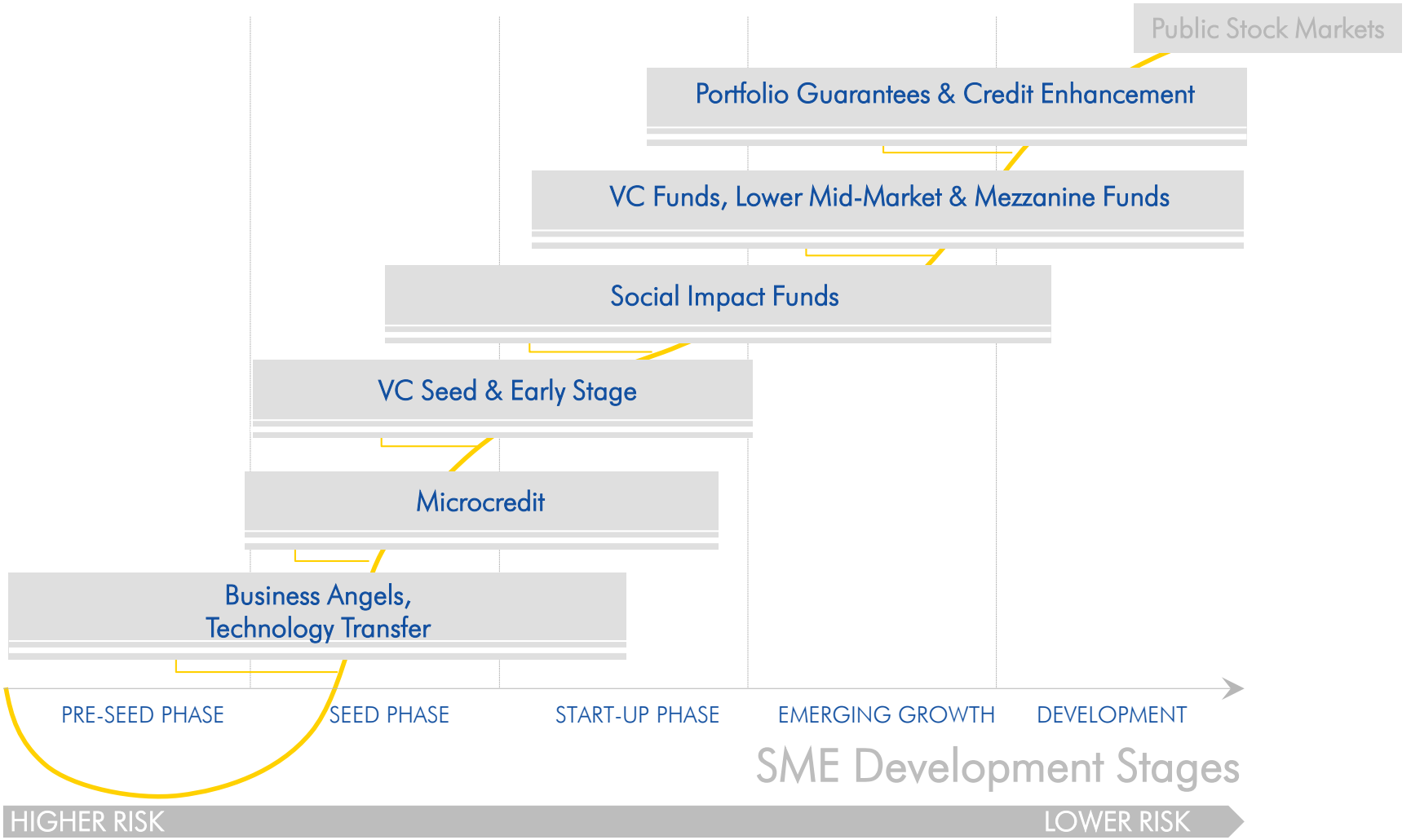
SMEs:

- 99.8% of all companies (approx. 23m)
- 90m employees (68% of total employment)
- A heterogenous group with a range of different financing needs

Source: ESBFO June 2017, based on European Commission (2016)

EIF

Support for different development stages



Impact assessment

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“Recent progress”

- 3 years in the making, the (ex-post) impact assessment project has brought five working papers, covering a significant share of EIF’s policy toolbox (guarantees, microfinance, VC).
- The current strand of work is focused on Venture Capital. It features a pipeline of five publications, some currently in the making, all based on EIF proprietary data.
- The series of working paper is titled **“The European venture capital landscape: an EIF perspective”**, and was started June ‘16.
- Our aim is that the series becomes a classical reference for anyone interested in government support for VC. For this reason, we imposed ourselves high academic standards.

A taste of our recent publications…

EIF's impact on the VC ecosystem

"Since 2007, 1% additional EIF financing caused a1.4% increase in activity from other market players"

Financial growth and cluster analysis

"Four types of growth trajectories, identified by speed and bias towards sales/innovation"

Exits, returns and IPOs backed by EIF

"EIF-backed first time teams do not underperform wrt experienced teams*"*

EIF-supported innovation

⇨

The Value of Innovation for EIF-backed startups

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CREDIT 2017 – 28-29 September 2017, Venice

Outline

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Introduction

- Patents are valuable tools for innovative start-ups.
- They can be used *strategically*:
  1. as a *signalling* tool to seek external financing (Hoenen *et al.*, 2014).
  2. to *maximise* profits from R&D expenditure (Cornelli and Schankerman, 1999).
- In addition, patents affect the *economic value* of start-ups as well as their growth potential (Helmers and Rogers, 2011).

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This paper

- Provides stylised facts on the use of patents by new ventures, looking at start-ups backed by EIF over the last two decades.
- Estimates the aggregate economic value of their patented innovations by means of renewal data models.

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Data

- Following the literature, we use INPADOC (INternational PAtent DOCumentation) families of patents as proxies to innovations (Hall, 2014).
- We identify 16,148 innovations from 2,951 EIF-backed start-ups in the 1996–2014 period. Innovations are matched to firm identities following Thoma *et al.* (2010). Data is sourced from the Orbis-PATSTAT database.
- Data coverage drops after 2012, so we focus on innovations up until that year and reduce the sample to 14,436 innovations.
- Most patents come from Life sciences and ICT companies, then Manufacturing, Services and Green-Tech.
- For about 14.5% of total innovations the application was submitted prior to the EIF-backed VC investment (the rate is 60% for first innovations only). About 9% were further acquired by start-ups, while 16% were sold.

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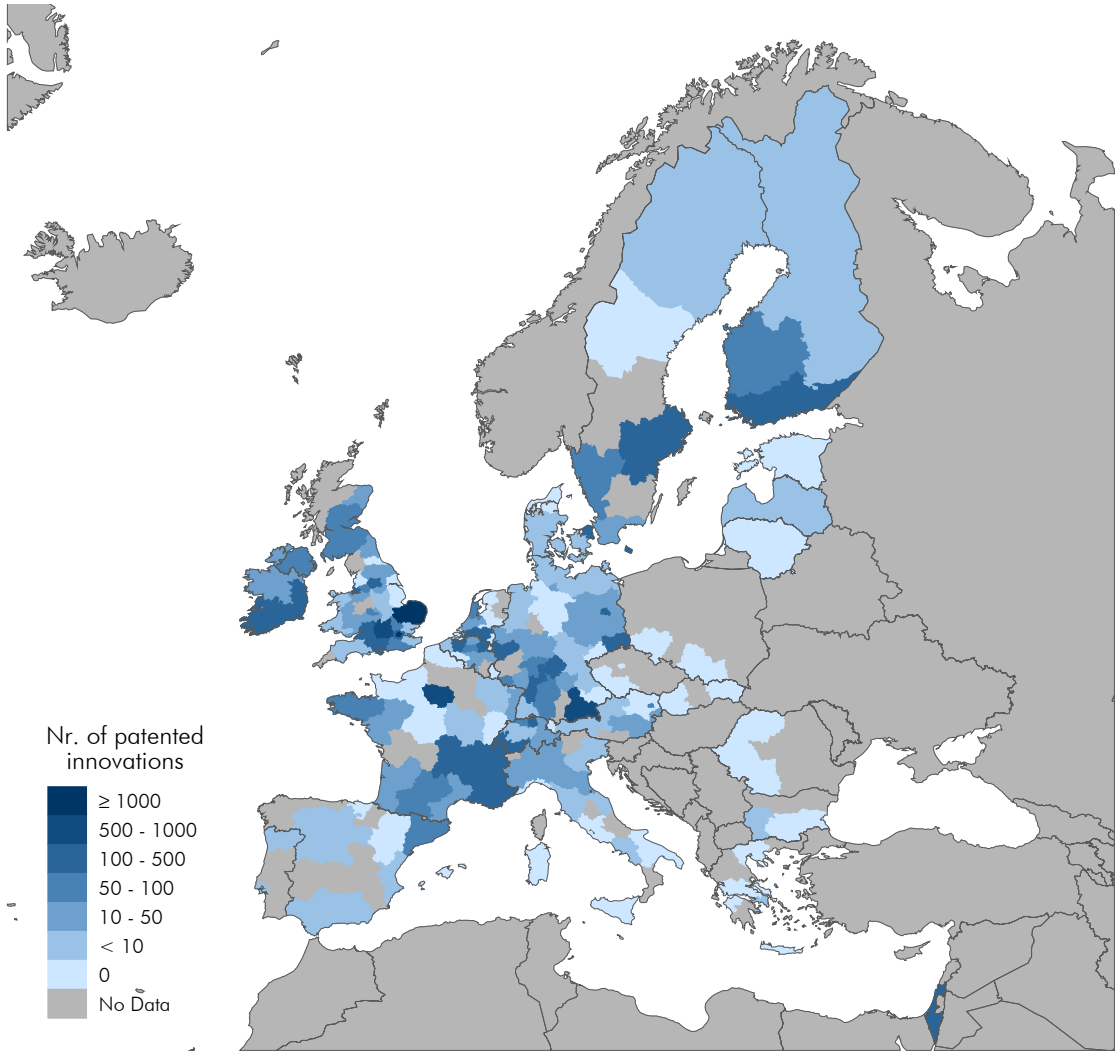
Geographical distribution

Figure 1: Number of patented innovations by NUTS-2 region



Note: based on a sample of 12,266 innovations from 2,491 European start-ups supported by EIF with available location data.

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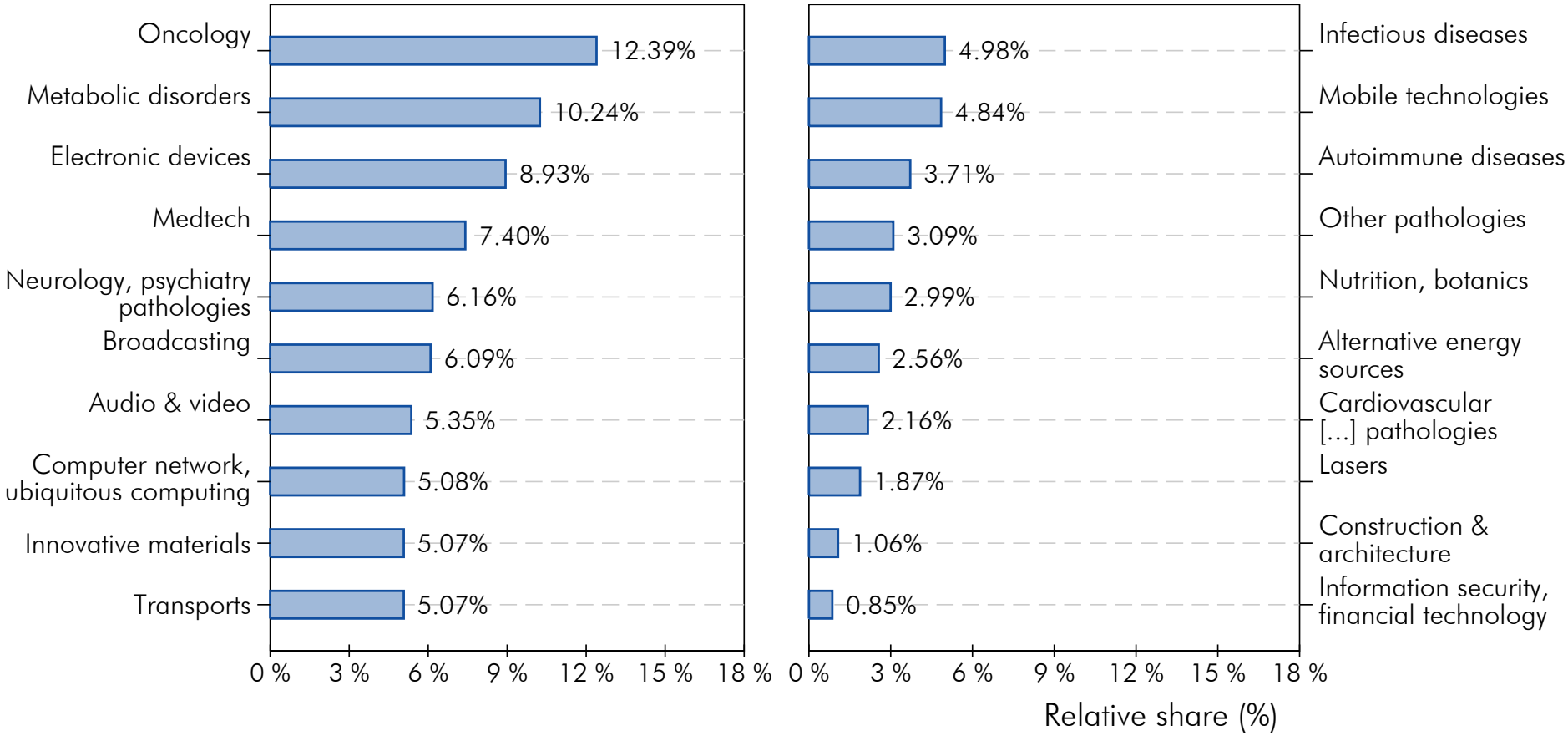
Innovation fields

Figure 2: Relative share of innovation fields



Note: based on a sample of 8,044 innovations associated to 829 EIF-backed startups with complete innovation field data.

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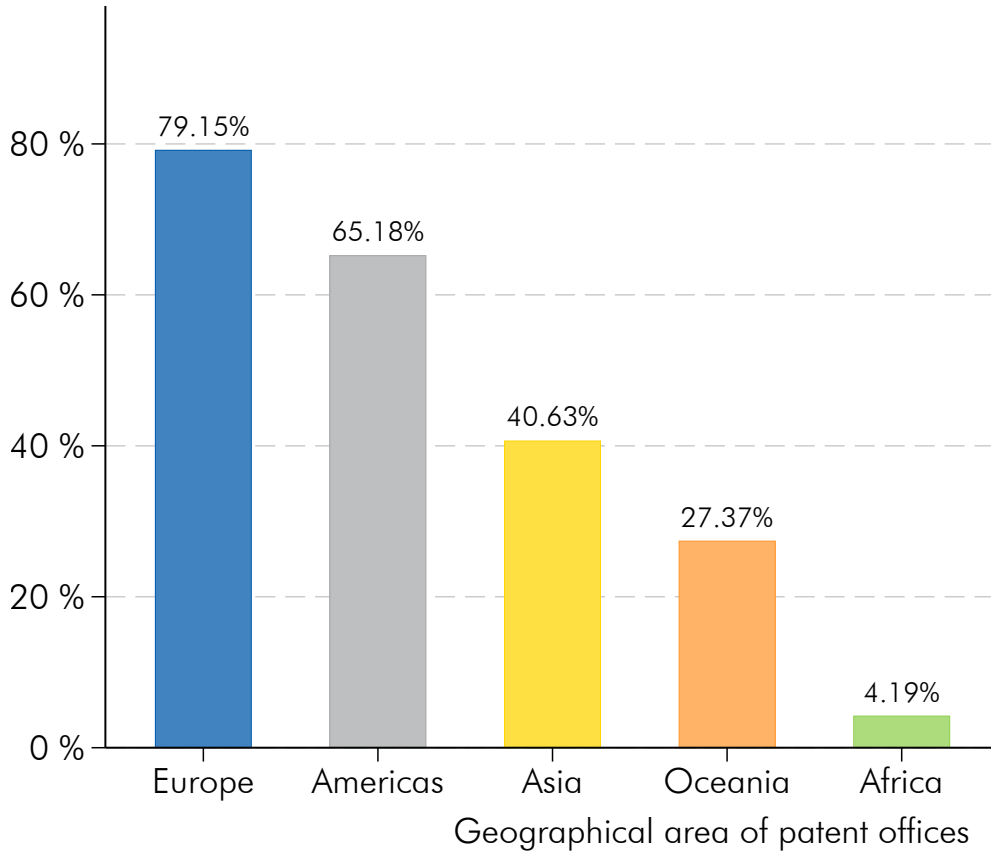
Geographical coverage

- About 80% of innovations are enforced in Europe.
- The American (US) market is very relevant for most European start-ups.
- Other markets are less appealing, (though JP and KR are well represented).
- Charts by start-up location underline the *home bias* of IP coverage.

Figure 3: Patent enforcement rates by geographical area



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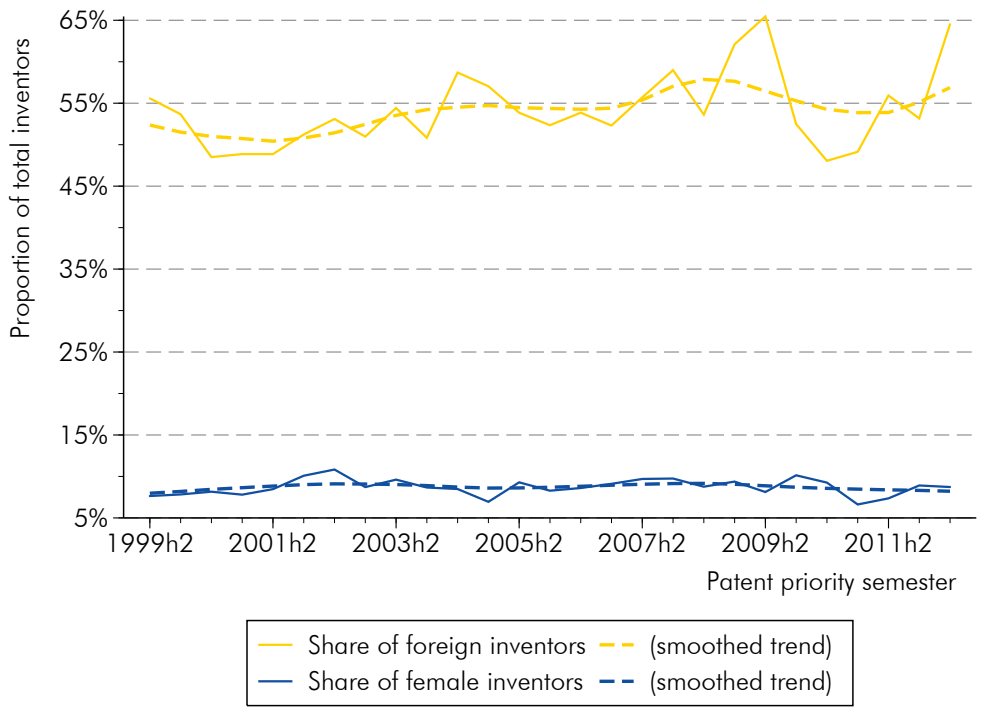
Inventor team composition

- Increasing internationalisation of inventor teams.
- Share of teams with at least one female researcher increase, but not female participation in general.
- Aggregate trends hide large differences across country and/or technology field.

Figure 4: Share of foreign inventors in start-up teams



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The economic value of start-ups' innovations

- Unit counts of patent families implicitly assume that patented innovations are homogeneous in value. This is unrealistic.
- In most countries patent holders must pay a periodical renewal fee in order to preserve their Intellectual Property (IP) rights.
- Assuming renewal decisions are rational, patentors will only maintain their IP rights as long as their value is higher than the renewal fee.
- Patent renewal patterns thus contain information on patents' *private* value.
- We implement a renewal data model based on the seminal work of Pakes and Schankerman (1984) and, more recently, Bessen (2008) and Gupeng and Xiangdong (2012).

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A model of IP protection renewal and value

Assumption 1: innovation value

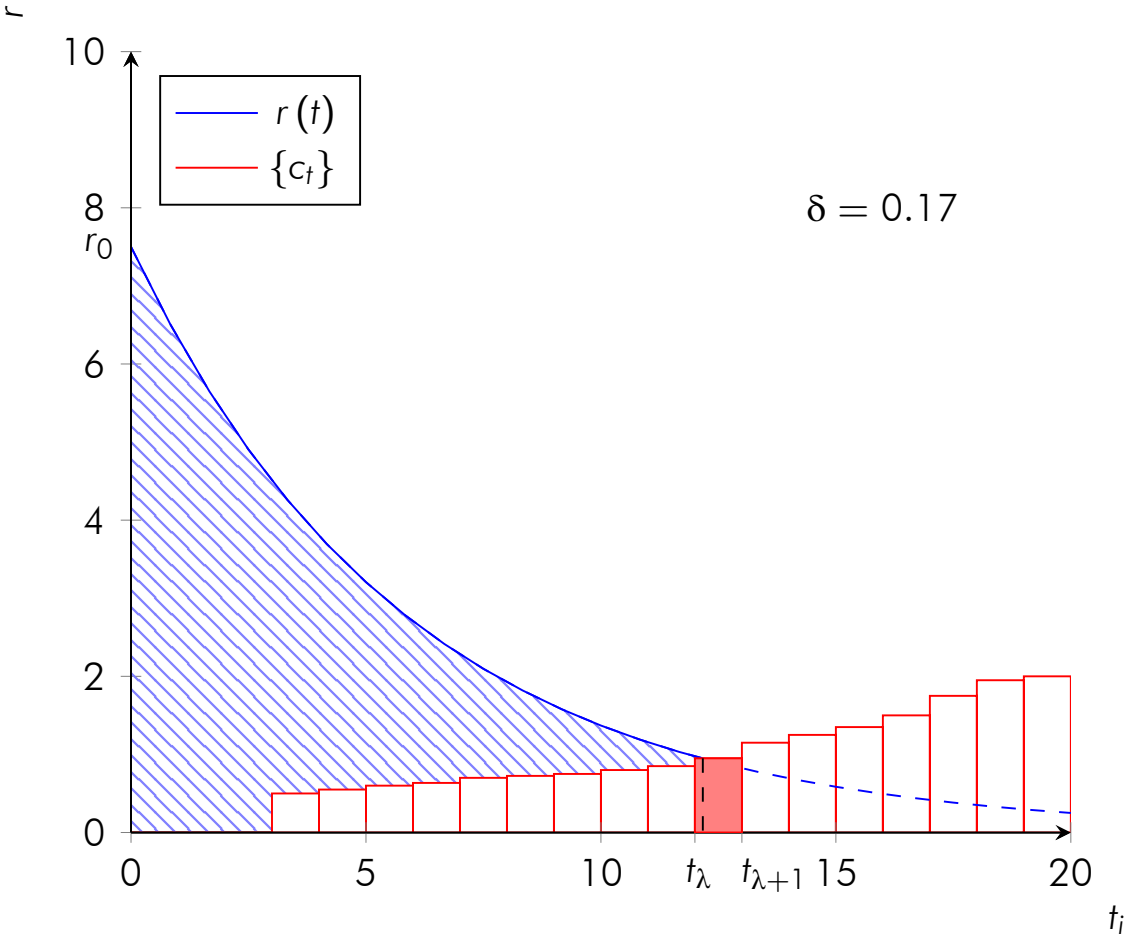
- Similarly to innovations counts, the value of innovation k shall be equivalent, by assumption, to the value of the respective INPADOC family. As in Deng (2007), we associate this to the total value of patents $j = 1, \ldots, J$ in family k:

$$IV_k = \sum_{j=1}^{J} PV_j \tag{1}$$

where PV_j, $j = 1, 2, \ldots, J$ represents all returns $PR_j \in \Re$ accruing to the holder of patent j, minus its enforcement costs.

A model of IP protection renewal and value

Assumption 2: Pakes and Schankerman's functional form for patent returns



- Costs: $c(t) = \{c_t\}$, $c'(t) \geq 0$
- Revenues: $r(t) = r_0 e^{-\delta t}$
- Profit maximisation:

$$\begin{cases} r_0 \int_{t_\lambda}^{t_{\lambda+1}} e^{-(s+\delta)\tau} d\tau \geq c_{t_\lambda} \\ r_0 \int_{t_{\lambda+1}}^{t_{\lambda+2}} e^{-(s+\delta)\tau} d\tau < c_{t_{\lambda+1}} \end{cases} \quad (2)$$

$\Rightarrow$ $z_{t_\lambda} c_{t_\lambda} \leq PR < z_{t_{\lambda+1}} c_{t_{\lambda+1}}$ where $z_{t_{\lambda+m}} = z\left(\delta, s, t_{\lambda+m}, t_{\lambda+(m+1)}\right)$.
As in Bessen (2008), we assume s at 10% p.a.

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A model of IP protection renewal and value

Assumption 3: return distribution

- As in Bessen (2008), Gupeng and Xiangdong (2012) and several other works in the literature we assume PR_i to be log-normally distributed. Our model is:

$$\ln(PR_i) = \mathbf{x}_i\beta + \varepsilon_i, \quad \varepsilon_i|\mathbf{x} \sim N(0, \sigma_\varepsilon) \tag{3}$$

- On the basis of (3), we can estimate $\lambda_i \in \{0, 1, 2, \ldots, T\}$ using a *censored ordered probit* model.
- *Why censored?* To account for active patents whose last renewal period is not (yet) observed. We follow Gupeng and Xiangdong (2012) approach and apply a Tobin-like correction to the ordered probit likelihood function.
- MLE estimates of β, σ_ε and δ are used to obtain expected values of PR_i, PV_i and, via (1), IV_k.

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Regression set-up

- We shift our focus to patent applications, for which owners pay renewal fees. Fee data is retrieved for 14 EU28 patent offices, plus the USPTO (93% coverage rate).
- We narrow our analysis to applications submitted in 1986–2012. We estimate patent value for 3 subgroups:
  1. USPTO applications
  2. EP/EP-PCT appl.s (+ national phase)
  3. National (EU28) applications
- For patents submitted to the USPTO, we estimate an extremely high decay rate. A similar outcome is obtained in Bessen (2008), where the author argues that this result indicates the failure of the assumption of constant technological decay.

Figure 5: Renewal rates by estimation group

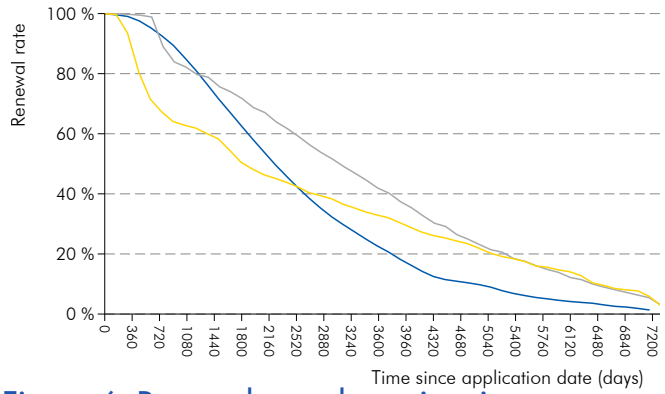
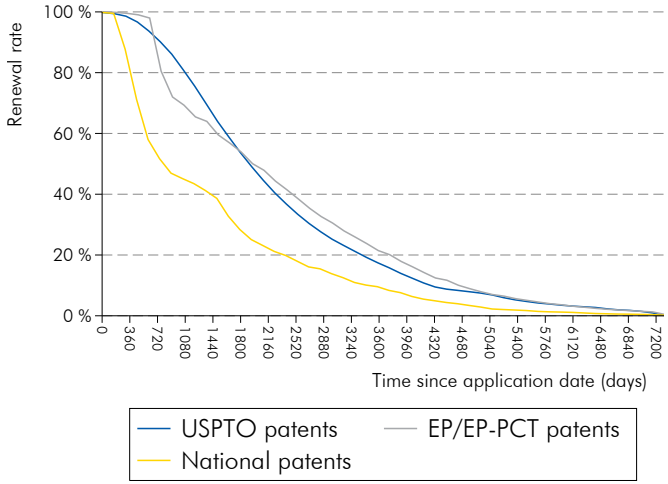


Figure 6: Renewal rates by estimation group (lapsed patents only)



Regression results

	EPO & national phase patents	National patents	USPTO patents	USPTO patents with $\delta = 0.25$
	(1)	(2)	(3)	(4)
	MLE	MLE	MLE	MLE
ln (Patent stock)	-0.2963***			
	(0.030)			
ln (Patent family size)		0.8609***	0.9449***	0.5867***
		(0.145)	(0.127)	(0.069)
ln (Number of inventors)	0.3966***			
	(0.045)			
ln (Citations made)	1.5079***	0.8687***	0.7478***	0.4833***
	(0.108)	(0.133)	(0.105)	(0.057)
ln (Citations received)	0.6141***			
	(0.045)			
ln (Non-patent citations made)	-0.5637***			
	(0.107)			
ln (Number of claims)	-0.2228***		-0.4232***	-0.2604***
	(0.051)		(0.131)	(0.080)
Median claim length-to-words ratio	-0.1349**	0.6516***	-0.7224***	-0.4589***
	(0.065)	(0.235)	(0.163)	(0.097)
Patent made no citation†	1.9742***		-2.9199***	-1.7791***
	(0.199)		(0.540)	(0.321)
Patent received no citation†	0.9685***		-2.7299***	-1.6504***
	(0.113)		(0.346)	(0.184)
Patent made no non-patent citation†	0.9281***			
	(0.163)			
Part of PCT application†		-2.7934***		
		(0.311)		
Constant	8.6020***	3.8553***	14.0280***	11.0482***
	(0.520)	(1.473)	(1.298)	(0.734)
Application period[a]	Yes	Yes	Yes	Yes
Technology field[b]	Yes	Yes	Yes	Yes
Start-up macro-region[c]	Yes	Yes	Yes	Yes
δ	0.251	0.033	0.583	0.251
σ_ε	3.07	3.71	6.24	3.92
Median expected revenue (2005 EUR)	107,044	901	35,930	6,311
Mean expected revenue (2005 EUR)	1,079,053	58,707	36,068,101	228,440
Log-likelihood	-35402	-4285	-8725	-8745
N° of observations	21,303	3,202	9,400	9,400

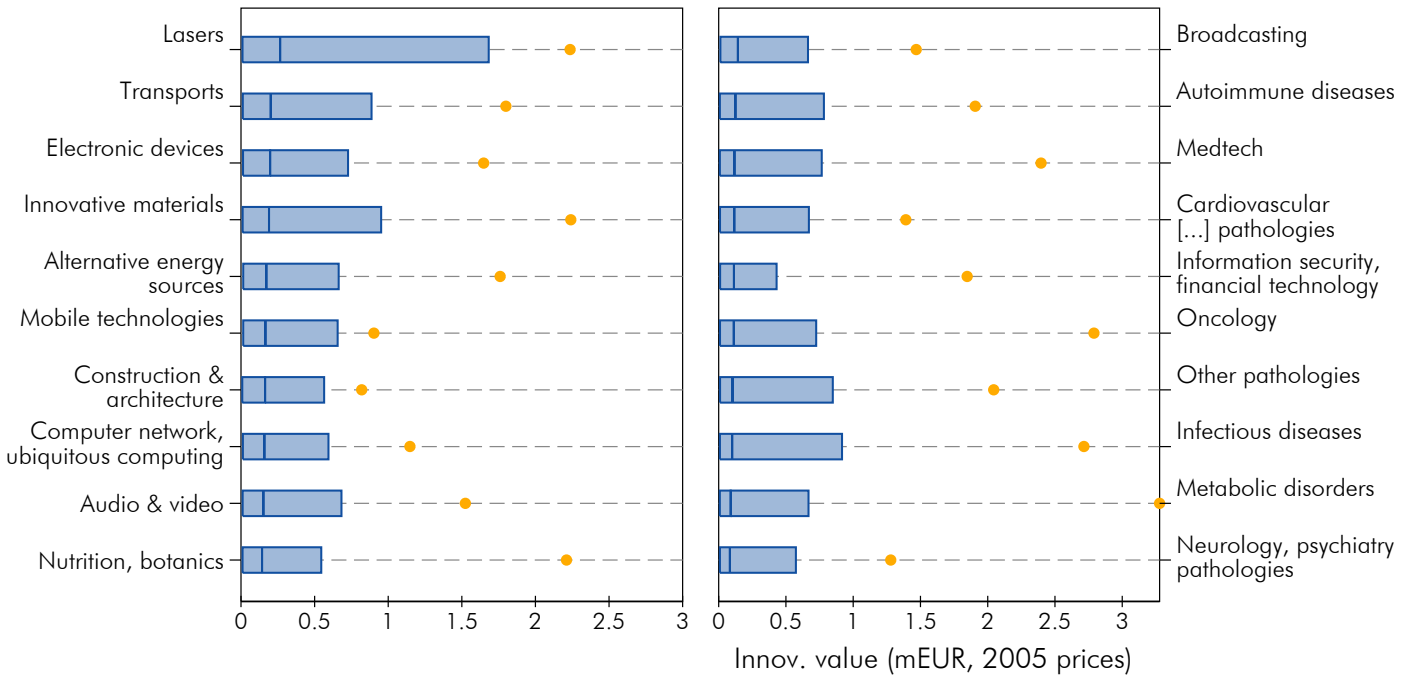
* p<0.05, ** p<0.01, *** p<0.001; † dichotomic variable; [a] Application periods: *1987-2001* (baseline), *2002-2007*, *2008-2012*. For columns (3) to (5), dummy "post-2008" used instead; [b] Technology fields: *ICT* (baseline), *electronics*, *life sciences*, *others*; [c] DACH (baseline), FR&BENELUX, BI, NORDICS, SOUTH/CESEE, ROW; INPADOC family cluster-robust standard errors in brackets.

- **Patent stock:** coefficient supports the hypothesis of diminishing returns of innovation (Evenson, 1991).
- **Inventor team size:** positively correlated with value (only for EP/EP-PCT sample).
- **Female and nationality shares in inventor team:** not significant when controlling for technology field and/or regions.
- Coefficients on claims point to start-ups creating more value with *narrowly-defined* and not *overly technical* patents. The role of citations is ambiguous.

Innovation values I

- Innovation values range from a few hundred Euro to more than EUR 400m ('05 prices), with median EUR 140k and mean EUR 2.2m.
- Differences are observed across regions and sectors, providing evidence of different incentives, as well as *barriers*, to patenting (Sànchez *et al.*, 2015).

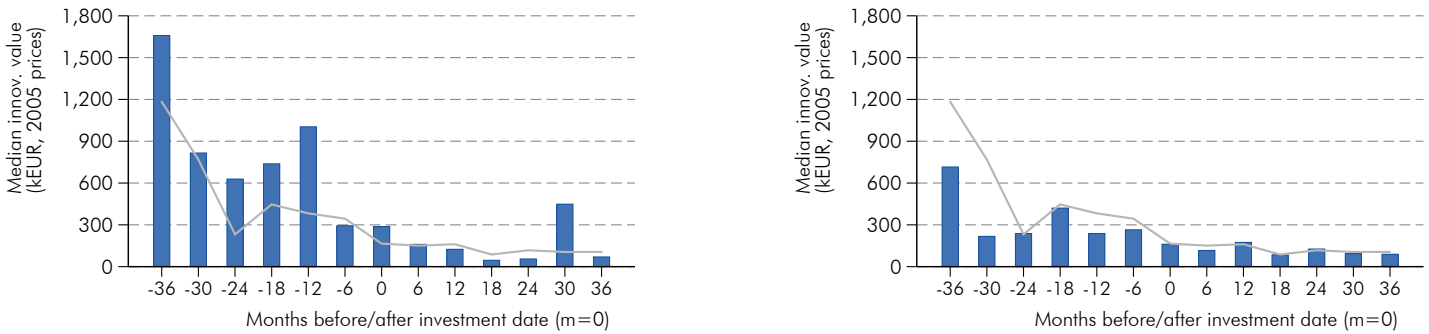
Figure 7: Box plots of patent family values by innovation field



Note: based on a sample of 8,657 innovations associated to 894 EIF-backed startups. Blue boxes represent the interquartile range. The vertical blue line intersecting each box represents the median, while the orange dot represents the mean.

Innovation values II

Figure 8: Median innovation value prior/following first EIF-backed investment



(a) Initial innovations only

(b) Follow-on innovations only

Note: based on 11,597 innovations from 985 EIF-backed startups. The grey line represents the 6-months rolling median.

- Why? Two hypotheses:
  1. *Selection effect*: VCs "pick", not "make", innovative start-ups (predicts results of Peneder, 2010 and Bronzini *et al.*, 2015).
  2. *Raising of incentives/lowering of barriers*: start-ups that are capital-relieved have lower barrier to patenting; more importantly, start-ups have lower barriers to protect their innovation. Consistent with the *commercialisation acceleration* argument in Hellmann and Puri (2000).
- Was a possibly significant channel for VC's impact on innovation overlooked?

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VC financing and the innovation multiplier

- We compare aggregate patented innovation values to EIF-supported VC investments. All monetary values are converted to EUR 2005 prices via the GDP deflator of each start-up's nation.
- We obtain that for every EUR of EIF-backed investments start-ups generated, on average, EUR 2.74 of value in patented innovations. The distribution is very skewed (median multiplier = EUR 0.09, mainly driven by non-patentors).
- Sectors such as life sciences and manufacturing (with a mean multiplier of 5.63 and 3.71 respectively) are more efficient in turning venture capital into patented value than ICT (1.18) and other sectors (below parity).
- Geographic differences also arise, in line with the geographical spread of patenting propensity (*e.g.* see Figure 1).

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Conclusions

- Patenting decisions for start-ups typically show *home bias*, and are affected by incentives (or *barriers*) to innovation (sectoral and/or institutional).
- In particular, we observe that low patenting activity is associated to innovation fields with higher median innovation values (*selection bias*).
- VC financing **may** positively affect existing innovations, not exclusively following innovations.
- Overall, technology-driven start-ups supported by EIF succeeded in generating significant volumes of innovation value.

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References I

Bessen, J. (2008). The value of U.S. patents by owner and patent characteristics. *Research Policy*, vol. 37, no. 5, pp. 932 – 945. URL **http://www.sciencedirect.com/science/article/pii/S0048733308000474**.

Bronzini, R., Caramellino, G. and Magri, S. (2015). Venture Capitalists at Work: What Are the Effects on the Firms They Finance? Working paper, Bank of Italy, Rome.

Cornelli, F. and Schankerman, M. (1999). Patent Renewals and R&D Incentives. *The RAND Journal of Economics*, vol. 30, no. 2, pp. 197–213. URL **http://www.jstor.org/stable/2556077**.

Deng, Y. (2007). Private value of European patents. *European Economic Review*, vol. 51, no. 7, pp. 1785 – 1812. URL **http://www.sciencedirect.com/science/article/pii/S0014292106001231**.

Evenson, R.E. (1991). Patent data by industry: evidence for invention potential exhaustion? In *Technology and productivity: the challenge for economic policy*, pp. 233–48. OECD Publishing, Paris.

Gupeng, Z. and Xiangdong, C. (2012). The value of invention patents in China: Country origin and technology field differences. *China Economic Review*, vol. 23, no. 2, pp. 357 – 370.

Hall, B.H. (2014). Using Patent Data as Indicators. 11^{e} Séminaire SciScI – Observatoire des Sciences et des Techniques, Paris. URL **http://www.obs-ost.fr/sites/default/files/BronwynHall_2014_Diaporama.pdf**.

Hellmann, T. and Puri, M. (2000). The interaction between product market and financing strategy: The role of venture capital. *The Review of Financial Studies*, vol. 13, no. 4, pp. 959–984. URL **http://dx.doi.org/10.1093/rfs/13.4.959**.

Helmers, C. and Rogers, M. (2011). Does patenting help high-tech start-ups? *Research Policy*, vol. 40, no. 7, pp. 1016–1027.

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References II

Hoenen, S., Kolympiris, C., Schoenmakers, W. and Kalaitzandonakes, N. (2014). The diminishing signaling value of patents between early rounds of venture capital financing. *Research Policy*, vol. 43, no. 6, pp. 956 – 989. URL **http://www.sciencedirect.com/science/article/pii/S004873331400016X**.

Pakes, A. and Schankerman, M. (1984). The rate of obsolescence of patents, research gestation lags, and the private rate of return to research resources. In Z. Griliches, editor, *R&D, Patents and Productivity*, chap. 4, pp. 73–88. University of Chicago Press for the NBER, Chicago.

Peneder, M. (2010). Technological regimes and the variety of innovation behaviour: Creating integrated taxonomies of firms and sectors. *Research Policy*, vol. 39, no. 3, pp. 323 – 334. URL **http://www.sciencedirect.com/science/article/pii/S0048733310000247**.

Sànchez, A., Hortal, P. and Cuesta, D. (2015). Patent Costs and Impact on Innovation: International Comparison and Analysis of the Impact on the Exploitation of R&D Results by SMEs, Universities and Public Research Organizations. Tender No. SI2.624064, European Commission, DG Research and Innovation. URL **http://ec.europa.eu/research/innovation-union/pdf/patent_cost_impact_2015.pdf**.

Thoma, G., Torrisi, S., Gambardella, A., Guellec, D., Hall, B.H. and Harhoff, D. (2010). Harmonizing and Combining Large Datasets - An Application to Firm-Level Patent and Accounting Data. Working Paper 15851, National Bureau of Economic Research. URL **http://dx.doi.org/10.3386/w15851**.

Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica*, vol. 26, no. 1, pp. 24–36.

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