

# Intangible Assets and Firm-Level Productivity

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Table Ronde Franco-Allemande sur les Actifs Immatériels,  
Paris, November 22, 2013

# Motivation

- Major challenge for Europe: reap benefits from knowledge economy
  - Lisbon strategy 2000-2010 (3 % target), Europe 2020
- Knowledge capital is more than R&D
- Challenging task: Measuring knowledge capital and its impact on economic performance
- Conceptual framework for measuring intangibles (Corrado et al. 2009):
  - Computerized information: *software and computerized databases*
  - Innovative property: *R&D, license costs, expenses for design*
  - Economic competencies: *brand equity, human capital and organizational cap.*
- At the macro level:
  - Important level of investment in intangible assets (US: 11.7% of GDP, DE: 7.5%, FR: 9.2% - 2004)
  - Positive contribution of intangible assets to labour productivity growth [US: 0.85, DE: 0.45, FR: 0.55 1995-2003]

# Motivation & Research Questions

## ■ At the micro level:

- Much evidence on productivity enhancing effects of R&D and IT, less so on firm-specific training, organizational capital, brand equity or other types of intangibles
- Only few take them simultaneously into account or look at complementary effects between intangible investments

## ■ Research questions:

- Do all types of investments in intangible assets enhance productivity at the firm-level?
- Which types of intangibles are particularly productivity enhancing?
- To which extent do complementarity effects exist between intangibles?

# Previous Evidence

- Impact of capitalized intangibles (Marrocu, Paci and Pontis 2010)
  - Significant productivity-enhancing effect of intangibles for 6 European countries: FR, IT, NL, ES, SWE, UK
  - Impact of intangible capital, however, is roughly half as large as that of physical capital (elasticity: 0.04-0.06)
  - Variation across countries relatively large: impact three times larger in UK than in Spain (reflection of differences in accounting standards?)
  - Flaw: rely on balance sheet data → only capitalized intangible assets
  
- Impact of capitalized vs expensed and intellectual (R&D+patents) vs customer (advertising + trademarks) capital (Bontempi and Mairesse 2008)
  - Strong positive relation between intangible capital and productivity levels, much weaker link for productivity growth
  - Intangible capital is at least as productive as tangible capital.
  - Productivity effects are higher for intellectual and capitalized intangible cap.
  - Limitation: No further distinction between different components or complementarities

# Simultaneous Analysis of Different Intangible Assets

- Effect of training and R&D (Ballot et al. 2006)
  - Productivity effect of *training larger* than that of R&D in France and Sweden
  - Significant *complementarity* between training and R&D:  
Training (R&D) has a larger positive impact on productivity if the firm accumulates R&D capital (human capital).
  
- Effect of R&D, training, advertising and firm-specific organizational capital (Ramirez and Hachiya 2008)
  - Contribution of intangibles to productivity growth in Japanese firms
  - *Advertising* is one of the *most productive* inputs
  - Organizational capital crucial factor for productivity → Drawback: no information on organizational capital, proxied by fixed effect
  - Did not investigate complementarities

# Econometric framework

- Extended Cobb-Douglas production function approach:

$$Q_{it} = A e^{\lambda_t} L_{it}^{\alpha} K_{it}^{\beta} M_{it}^{\delta} IC_{it}^{\gamma_1} HC_{it}^{\gamma_2} BC_{it}^{\gamma_3} OC_{it}^{\gamma_4} e^{u_{it}}$$

Q: output, L: labour, K: physical capital, M: material

$\lambda$ : exogenous technological change,

u: error term

IC: innovative capital

HC: firm-specific human capital

BC: brand (reputation) capital

OC: organizational capital

- As log specification:

$$q_{it} - l_{it} = a + \mu l_{it} + \beta(k_{it} - l_{it}) + \delta(m_{it} - l_{it}) + \gamma_1(ic_{it} - l_{it}) + \gamma_2(hc_{it} - l_{it}) \\ + \gamma_3(bc_{it} - l_{it}) + \gamma_4(oc_{it} - l_{it}) + \lambda_t + u_{it}$$

with

$$\mu = \alpha + \beta + \delta + \gamma_1 + \gamma_2 + \gamma_3 + \gamma_4 - 1$$

# Data: Mannheim Innovation Panel

- Mannheim Innovation Panel (MIP):
  - Official annual innovation survey in the German manufacturing, mining, energy and water supply industry and most business services
  - Conducted by ZEW on behalf of German ministry on education and research
  - German contribution to the European-wide harmonized Community Innovation Surveys CIS (every two years).
  - Representative for German firms with 5 and more employees
- Merged with EPO patent data and German and European trademark data
- Sample period: surveys 2007-2011 (time period: 2006-2010)
- Unbalanced panel:
  - 11,022 observations and 6,235 firms (average participation of 1.78)

Number of participation	1	2	3	4	5
<b>Firms</b>	3634	1241	761	370	229
<b>Observations</b>	3634	2482	2283	1480	1145

# Variables

## Dependent variable:

- **Labour productivity:**  $\log(\text{sales}/\text{employee})$

## Explanatory variables I:

- **Labour :**  $\log(\# \text{ employees})$ 
  - To avoid double counting: correct total # of employees for R&D employees
- **Physical capital:**  $\log(\text{tangible assets} / \text{employee})$
- **Material:**  $\log(\text{material expenses} / \text{employees})$
- **Controls:**
  - East Germany, export intensity, group, time and industry dummies

All expenditure are deflated using appropriate industry price indices



# Knowledge-related Intangible Input Factors

## ■ Basic model: 3 types

– *Innovative Capital, Human Capital and Brand Capital*

## ■ Innovative Capital: R&D, Design&Licenses, Patent stock

- **R&D:**  $\log(\text{R\&D expenditure} / \text{employee})$ 
  - Deflated using R&D deflator: weighted sum of deflators on labour costs, investments and intermediate inputs at NACE 2 digit level
- **Design& licenses:**  $\log(\text{expenses for design, licenses, product preparation related to innovation} / \text{employee})$ 
  - Captures innovative capital that is not related to R&D activities
  - Deflated using R&D deflator
- **Patent stock:**  $\log(\text{patent stock}/\text{employee})$ 
  - output oriented indicator of a firm's knowledge capital
  - number of EPO patent applications

# Knowledge-related Intangible Input Factors

## ■ Brand Capital:

- **Marketing expenditure:**  $\log(\text{marketing expenditure} / \text{employee})$ 
  - Deflated using price deflator of industry 731 (advertising)
- **Trademark stock:**  $\log(\text{accum. number of trademarks} / \text{employee})$

## ■ Human Capital:

- **Training expenditure:**  $\log(\text{training expenditure} / \text{employee})$ 
  - Deflated using deflator on labour costs
- **Share of high skilled employees:** share of employees with university or college degree

# Knowledge-related Intangible Input Factors

## ■ Extended model: Accounting for Organizational Capital

- No comparable quantitative measure available for organizational capital
- Introduction of an organizational innovation (0/1) as proxy for some kind of organizational investment
- Information is only available for the 2006, 2008 and 2010 cross-section (sample size: 7,538).
- 3 dummies whether firm has introduced within the previous three years

### ● **New business processes**

(e.g. quality management systems, supply chain management systems, lean production, matrix organization, knowledge management systems)

### ● **New workplace organization**

(e.g. decentralization or centralization of decision making, job rotation, team work, basic realignment of departments)

### ● **New external relationships**

(e.g. alliances, coop. agreements, outsourcing, customer relationship, supplier integration)

# Proportion of Firms Investing in Intangible Assets

	Full sample	2006	2007	2008	2009	2010
<b>Innovative Capital</b>						
R&D	0.42	0.41	0.42	0.40	0.43	0.44
Design & Licenses	0.36	0.42	0.40	0.34	0.31	0.33
Patent Stock	0.15	0.14	0.15	0.13	0.18	0.16
<b>Human Capital</b>						
Firm-specific Training	0.88	0.91	0.88	0.87	0.85	0.86
High Skilled Labour	0.88	0.90	0.89	0.87	0.89	0.89
<b>Branding Capital</b>						
Marketing	0.82	0.79	0.86	0.86	0.79	0.82
Trademark Stock	0.37	0.36	0.37	0.34	0.37	0.39
<b>Organizational Capital</b>						
Business Process	0.39	0.49		0.35		0.36
Labour Organization	0.36	0.42		0.32		0.34
Relationmanagement	0.25	0.31		0.20		0.24
<b>Controls</b>						
East Germany	0.34	0.33	0.34	0.33	0.37	0.33
Group	0.36	0.36	0.38	0.34	0.38	0.38
Export	0.55	0.57	0.55	0.52	0.55	0.55

# Expenditure on Intangible Assets

	Median	Mean	SD	Min	Max
<b>Productivity</b>					
Level	133.81	218.60	375.18	1.67	16448.67
Growth	0.01	0.01	0.33	-5.56	3.98
<b>Traditional Inputs</b>					
Capital	28.08	135.49	465.80	0.05	14693.95
Labour	50.52	825.02	6029.28	1.00	175000.00
Material	49.19	109.04	277.18	0.05	16448.67
<b>Innovative Capital</b>					
R&D	0.00	5.22	29.47	0.00	1000.00
Design & Licenses	0.00	1.52	11.37	0.00	921.60
Patent Stock	0.00	0.00	0.04	0.00	1.99
<b>Human Capital</b>					
Firm-specific Training	0.26	0.58	1.28	0.00	60.00
High Skilled Labour	0.10	0.20	0.23	0.00	1.00
<b>Branding Capital</b>					
Marketing	0.34	2.11	8.53	0.00	500.00
Trademark Stock	0.00	0.04	0.15	0.00	4.00

Measured in thousand € per employee (except patent stock and trademark stock)

# Labour Productivity Differences Between Firms Investing and Not Investing in Intangible Capital

	Non-Investors	Investors	High investing firms
<b>Innovative Capital</b>			
R&D	196.6	249.3	310.7
Design & Licenses	199.6	252.7	291.1
Patent Stock	204.7	298.2	293.3
<b>Human Capital</b>			
Firm-specific Training	151.0	228.1	283.1
High Skilled Labour	143.0	228.6	258.6
<b>Branding Capital</b>			
Marketing	188.4	225.1	282.4
Trademark Stock	176.8	291.1	286.3
<b>Organizational Capital</b>			
Business Process	199.2	230.9	
Labour Organization	199.5	233.4	
Relationmanagement	197.6	253.4	

Measured in thousand € per employee (except patent stock and trademark stock)



# Impact of Intangibles on Firm-Level Productivity

	(1)	(2)	(3)	(4)	(5)	(6)
Capital	0.215***	0.191***	0.181***	0.179***	0.163***	0.164***
Labour	0.041***	0.006	-0.004	0.002	0.008	0.003
Material	0.401***	0.387***	0.381***	0.374***	0.372***	0.364***
East Germany Group		-0.151***	-0.160***	-0.165***	-0.134***	-0.156***
Export Intensity		0.146***	0.139***	0.126***	0.136***	0.121***
		0.168***	0.097***	0.134***	0.133***	0.087***
<b>Innovative Capital</b>						
R&D			0.056***			0.033***
Design & Licenses			0.008***			0.005*
Patent Stock			0.018***			0.011*
<b>Human Capital</b>						
Training				0.068***		0.047***
High Skilled Labour				0.337***		0.250***
<b>Branding Capital</b>						
Marketing					0.048***	0.034***
Trademark Stock					0.038***	0.027***
Adjusted $R^2$	0.684	0.697	0.706	0.712	0.709	0.720
W_Time	0.003	0.014	0.007	0.026	0.000	0.000
W_Industry	0.000	0.000	0.000	0.000	0.000	0.000
Observations	11,022	11,022	11,022	11,022	11,022	11,022

Estimation method: Olley-Pakes estimation

# Exploring the Role of Organizational Capital on Productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Capital	0.196***	0.181***	0.152***	0.177***	0.152***	0.151***	0.173***	0.169***
Labour	0.052***	0.017**	0.012*	0.019***	0.019**	0.019**	-0.005	0.009
Material	0.404***	0.390***	0.384***	0.378***	0.372***	0.366***	0.381***	0.373***
East Germany		-0.157***	-0.167***	-0.168***	-0.137***	-0.158***	-0.166***	-0.166***
Belonging to a Group		0.143***	0.138***	0.122***	0.133***	0.119***	0.135***	0.124***
Export Intensity		0.148***	0.087***	0.115***	0.111***	0.071***	0.109***	0.095***
<b>Organizational Capital</b>								
Business Process	0.047***	0.049***	0.031**	0.021	0.035***	0.015	0.028**	0.024*
Labour Organization	-0.015	-0.018	-0.021	-0.023*	-0.018	-0.021	-0.023*	-0.027**
Relationmanagement	0.028**	0.021	-0.002	-0.001	-0.004	-0.020	0.003	-0.014
<b>Innovative Capital</b>								
R&D			0.060***			0.035***	0.064***	0.051***
Design & Licenses			0.013***			0.009***	0.002	0.045***
Patent Stock			0.015*			0.010	0.040**	0.047**
<b>Human Capital</b>								
Firm-specific Training				0.066***		0.042***	0.092***	0.106***
High Skilled Labour				0.337***		0.241***	0.140***	0.121***
<b>Branding Capital</b>								
Marketing					0.072***	0.053***	0.014	0.110***
Trademark Stock					0.025***	0.016**	0.085***	0.068***
Adjusted $R^2$	0.677	0.690	0.699	0.704	0.704	0.714	0.698	0.707
W_Time	0.144	0.103	0.085	0.062	0.010	0.006	0.094	0.046
W_Industry	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	7,538	7,538	7,538	7,538	7,538	7,538	7,538	7,538

(7) Dummies for R&D, OIC, HC, BC; (8) dummies for RD, OIC, HC, BC being 1 for above industry median



# Complementarity Between Intangibles

## ■ Definition:

- Complementarity (substitutability) between two intangibles is defined as an increase (decrease) in productivity effect of one intangible asset through the investment in another intangible.

## ■ Methodology

- Carree et al. (2011): approach to test for complementarity for quantitative variables
- Having seven intangible assets, 21 complementarity relationships are feasible
- Approach implies simultaneous of test 32 ( $= 2n^2$ ) constraints in the multiple-restrictions test
- Following table provides results only for those combinations that turn out to be significant.
- Because of multiple restrictions, significance level of the combined hypotheses is adjusted by the Bonferroni procedure.

# Complementarity Between Intangibles

Test	(1) RDxP	(2) DLxSL	(3) DLxTM	(4) TxSL	(5) TxTM	(6) SLxTM	(7) MxTM
H1	.	.	.	(--)	.	.	.
H2	.	.	.	.	.	.	.
H3	(+)	.	.	(--)	.	.	.
H4	.	.	.	(--)	.	.	.
H5	.	.	.	(--)	.	.	.
H6	.	.	.	.	.	.	.
H7	.	.	.	(--)	.	.	.
H8	.	.	.	.	.	.	.
H9	.	.	.	.	.	.	.
H10	.	.	.	.	.	.	.
H11	.	.	.	(---)	(--)	.	.
H12	(++)	.	.	(--)	.	.	.
H13	(+)	.	.	.	.	.	.
H14	.	.	.	(--)	.	.	.
H15	.	.	.	.	(-)	.	.
H16	.	.	.	.	.	.	(+)
H17	.	(--)	(-)	(---)	.	.	.
H18	.	.	.	(--)	.	.	.
H19	.	.	.	.	.	.	.
H20	.	.	.	.	.	.	.
H21	.	.	.	.	.	.	.
H22	.	.	.	.	.	.	.
H23	(+)	.	.	(---)	(-)	.	.
H24	.	.	.	.	(--)	(-)	.
H25	(++)	.	.	.	.	.	.
H26	.	.	.	.	.	.	.
H27	.	(-)	.	(--)	.	.	.
H28	.	(-)	.	(--)	.	.	.
H29	.	.	.	.	.	.	.
H30	.	.	.	.	.	.	.
H31	(+)	.	.	.	.	.	.
H32	.	.	.	.	.	.	.

## Complementarity:

if the coefficient for at least one of the 32 hypotheses is positive and significant while none of the coefficients of the other hypotheses is significantly negative

RD & patents (1)

Marketing & trademarks (7)

## Substitutability: vice versa

Training & high skilled labour (4)

High skilled & exp. Design/licenses (2)

A bit puzzling is (weak) finding of substitutability:

Trademark & design/licenses (3)

Trademark & human capital (5,6)

# Conclusions

- Estimate productivity effects of different kinds of intangible assets at the firm level.
- Strong positive and similar productivity effects for expenses on R&D, marketing and training
  - Effects are smaller when simultaneously controlling for other intangibles
  - Short-run productivity effect of an increase in training expenditure is stronger than for R&D expenditure or marketing expenditure which are of similar size
- Positive *long-term* productivity effects for firms investing in innovative capital and brand capital (indicated by stocks)
- Firms' increasing their expenditure for design & licenses experienced on average an increase in productivity though the effect is rather small

# Conclusions

- Results for organizational capital turn out to be mixed.
  - productivity enhancing effect for firms changing business processes
  - Negative effect when firms introduce new workplace organizations.
- Interesting relationships between different kind of intangible assets:
  - R&D & patents and marketing exp & trademarks are complements
  - Training expenditure and skilled labour are substitutes
  - Same finding holds for skilled labour and expenditures for design and licences.
- Effects have to be found much stronger for firms investing heavily in intangibles (above median)
  - Split samples based on intensity of intangible investments
  - Studying existence of heterogenous effects along the productivity distributions, e.g. do most productive firms benefit more from intangible investments than low productive firms?

# **Additional Slides: Industry Heterogeneity**

# Proportion of Firms Investing in Intangible Assets, by Industry

	Full sample	O-M	LT-M	MT-M	HT-M	KI-S	LKI-S
<b>Innovative Capital</b>							
R&D	0.42	0.12	0.35	0.59	0.81	0.36	0.16
Design & Licenses	0.36	0.20	0.33	0.46	0.48	0.33	0.23
Patent Stock	0.15	0.05	0.08	0.30	0.36	0.04	0.03
<b>Human Capital</b>							
Firm-specific Training	0.88	0.89	0.78	0.90	0.93	0.89	0.89
High Skilled Labour	0.88	0.83	0.82	0.92	0.95	0.90	0.83
<b>Branding Capital</b>							
Marketing	0.82	0.72	0.82	0.83	0.91	0.83	0.80
Trademark Stock	0.37	0.24	0.40	0.44	0.60	0.30	0.23
<b>Organizational Capital</b>							
Business Process	0.39	0.26	0.31	0.44	0.53	0.41	0.34
Labour Organization	0.36	0.29	0.33	0.38	0.42	0.38	0.31
Relationmanagement	0.25	0.21	0.18	0.25	0.36	0.28	0.20
<b>Controls</b>							
East Germany	0.34	0.33	0.30	0.31	0.35	0.37	0.37
Group	0.36	0.31	0.34	0.45	0.42	0.29	0.35
Export	0.55	0.08	0.64	0.84	0.87	0.28	0.30

# Impact of Intangibles on Productivity – Industry Heterogeneity

	(1) Manuf.	(2) Serv.	(3) LTM	(4) MTM	(5) HTM	(6) KIS	(7) LKIS
Labour	0.002	0.020*	-0.010	0.001	0.025	0.041***	-0.008
Capital	0.104***	0.189***	0.134*	0.108***	0.095**	0.256***	0.070
Material	0.468***	0.282***	0.456***	0.460***	0.402***	0.265***	0.277***
East Germany	-0.122***	-0.201***	-0.134***	-0.145***	-0.165***	-0.193***	-0.226***
Group	0.094***	0.136***	0.159***	0.092***	0.036	0.136***	0.122***
Export Intensity	0.081***	0.033	0.190***	0.078***	0.045	-0.008	0.119
<b>Innovative Capital</b>							
R&D Capital	0.024***	0.043***	0.035***	0.026***	0.027**	0.041***	0.050
Design & Licenses	-0.000	0.025***	0.008	-0.001	0.003	0.032***	-0.010
Patent Stock	0.013**	0.046***	-0.029	0.018***	0.038**	0.033**	0.095***
<b>Human Capital</b>							
Training	0.029***	0.070***	0.023**	0.024***	0.038***	0.065***	0.081***
High Skilled Labour	0.281***	0.240***	0.266***	0.174***	0.251***	0.239***	0.353***
<b>Branding Capital</b>							
Marketing	0.027***	0.046***	0.052***	0.007*	0.037***	0.048***	0.053***
Trademark Stock	0.020***	0.043***	0.032**	0.005	0.029**	0.030**	0.062*
Adjusted $R^2$	0.771	0.690	0.761	0.788	0.734	0.721	0.578
W_Time	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W_Industry	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	6,614	4,408	1,715	3,196	938	2,934	1,474