Universität Bremen*
*EXZELLENT.

Determinants of foreign technological activity in Germany

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1. Relevance

FAZ (31.08.2005) – important German newspaper

„*More and more R&D becomes re-located abroad“*

… major goals are Eastern Europe and Asia.

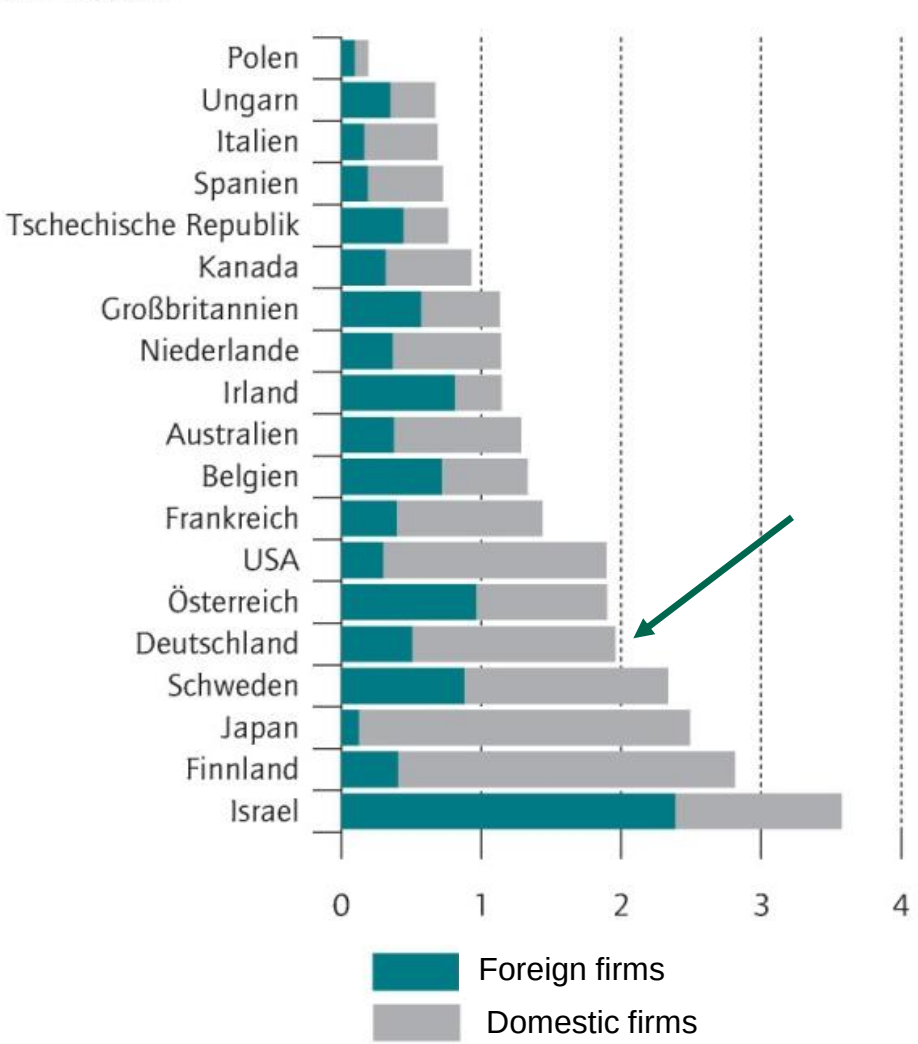
DIW Weekly News (No. 16/2004)

„*Foreign firms increase R&D spending in Germany*“

(…) Germany is an attractive location for research and development.

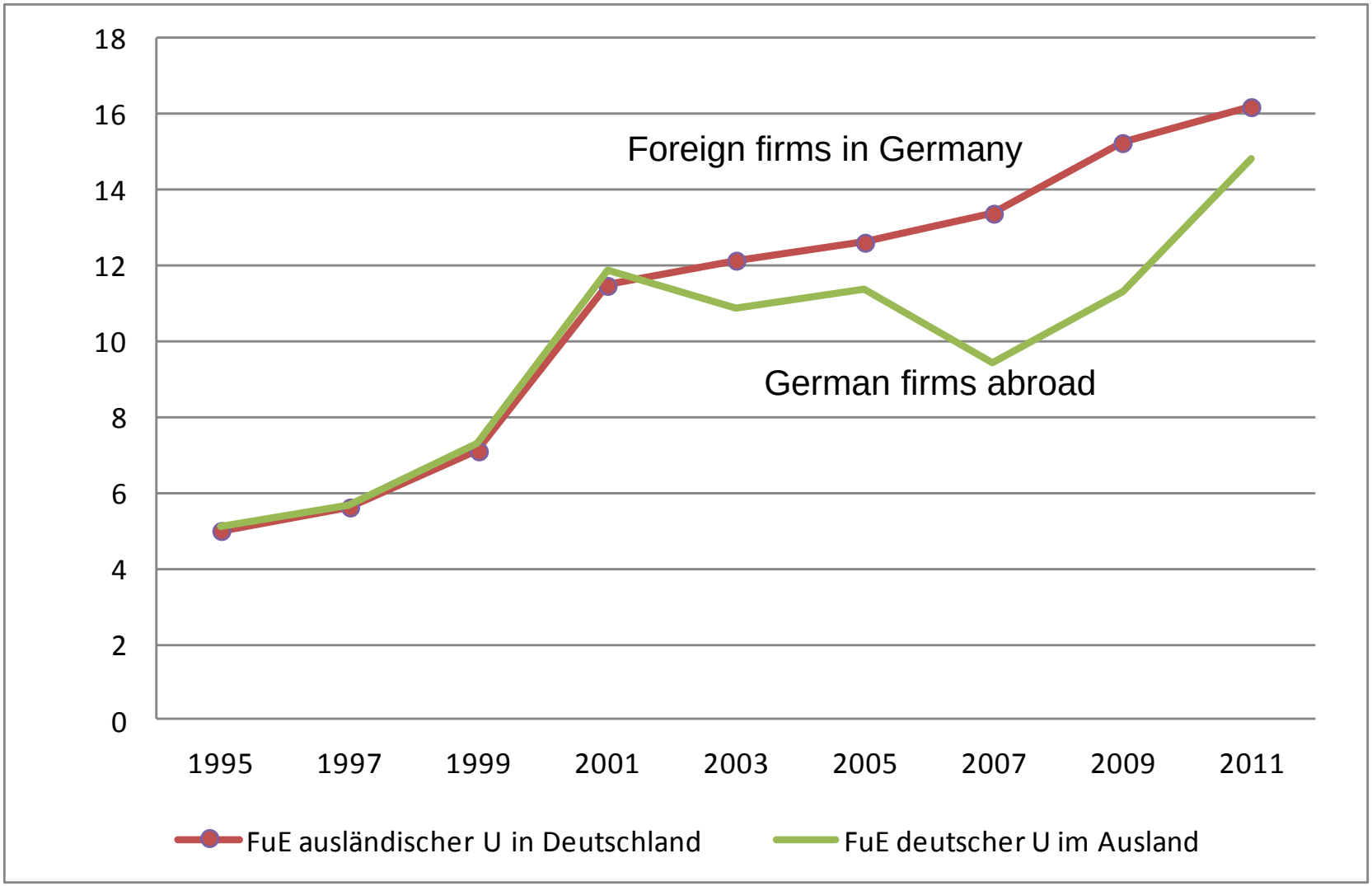
2. Empirical facts: R&D statistics

R&D expenditure in relation to GDP (%) 2009 (2010, 2011)



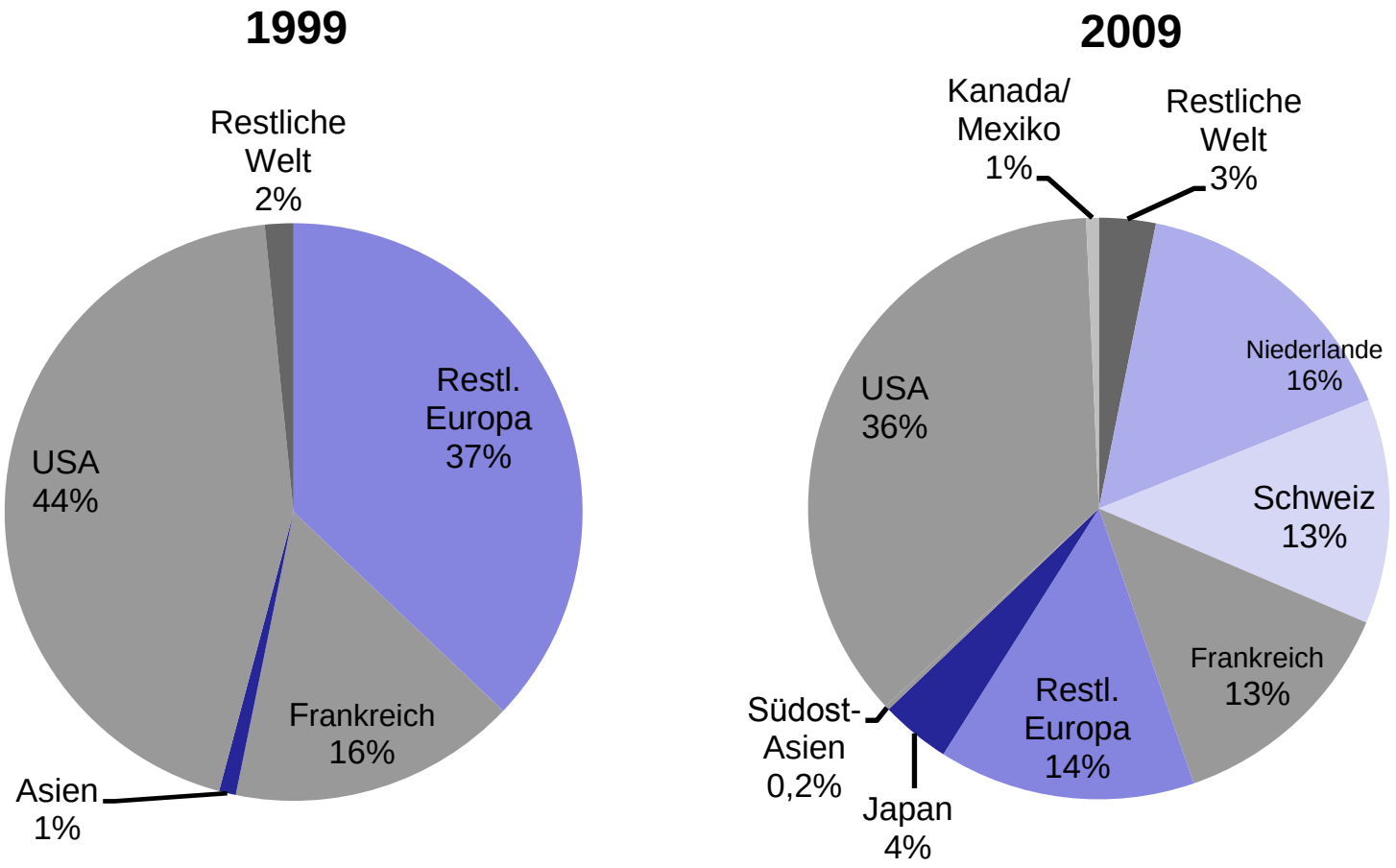
Source: Belitz (2014) mit Bezug auf OECD, [1] 2009: Polen, Ungarn, Spanien, Tschechien, Belgien, Österreich, Finnland, Israel; 2010: Australien, Japan; 2011: Italien, Kanada, GB, NL, Irland, Frankreich, USA, Deutschland, Schweden.

R&D expenditure in billion Euro, 1995 bis 2011



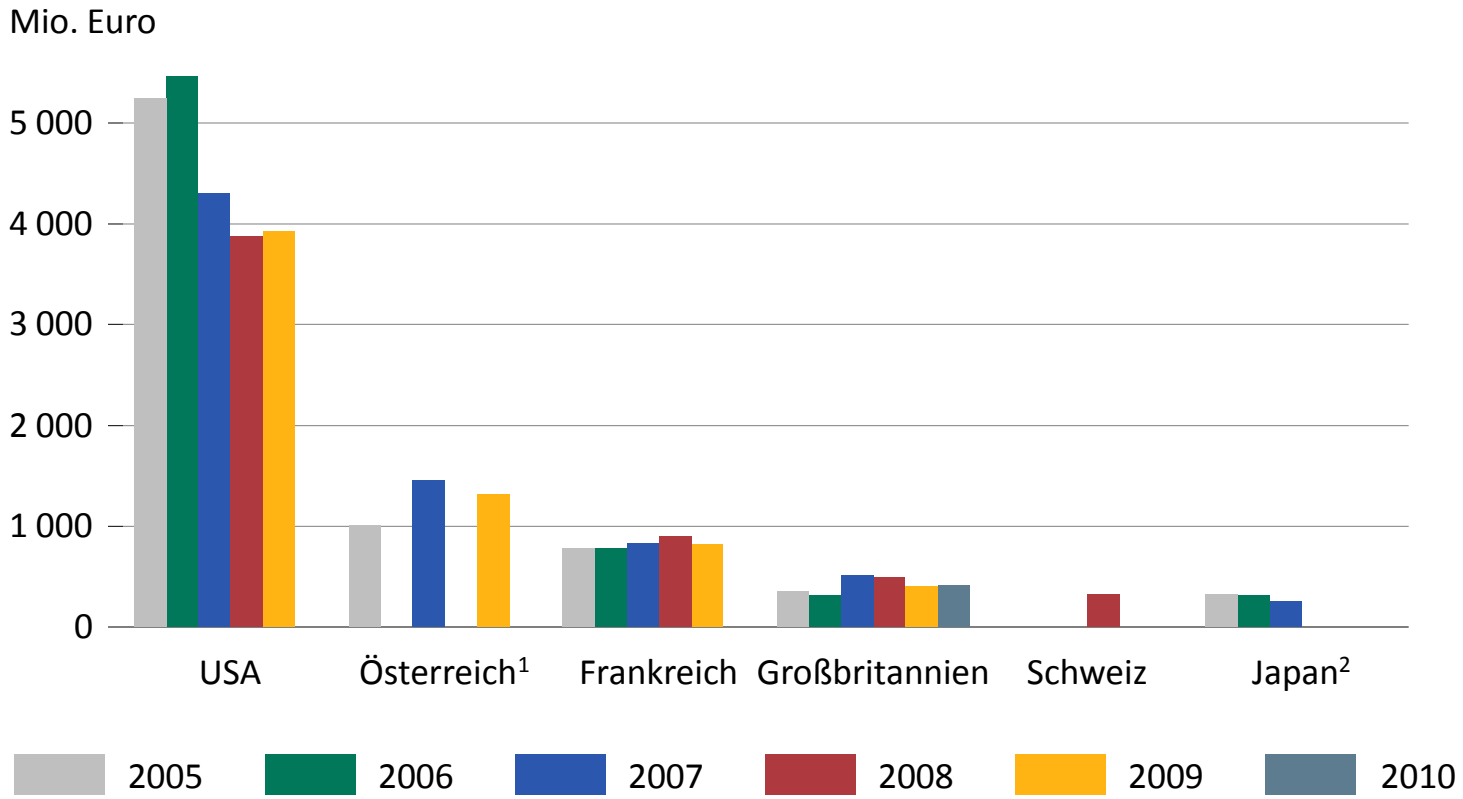
Quelle: Wissenschaftsstatistik im Stifterverband (SV), Schätzungen des DIW, Belitz (2014)

Countries of origin of foreign R&D in Germany



Quelle: Stifterverband, IWH et al. (2013).

R&D expenditure of German firms in selected host countries 2005 bis 2010



1) Österreich 2004 statt 2005. 2) Japan: Verarbeitendes Gewerbe.

Source: national statistical offices of the host countries, IWH et al. (2013), see also: Belitz (2014)

4. Empirical facts: patent indicators

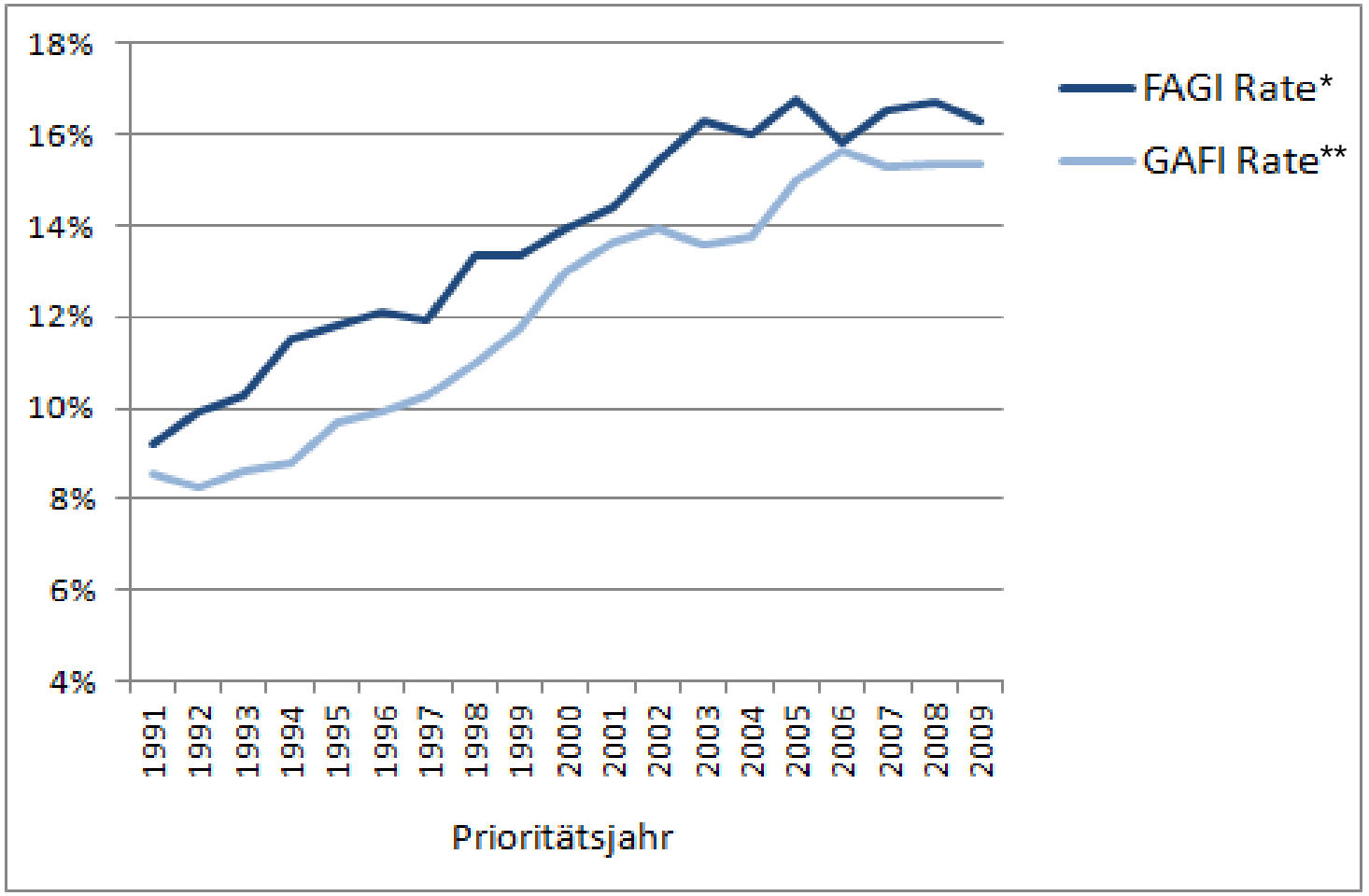
Data base

- Patent Cooperation Treaty (PCT) and European Patent Office (EPO) applications
- Priority years: 1991-2009
- OECD REGPAT data base (as of January 2012)
- Transnational patents!

Indicators (Guellec, van Pottelsberghe de la Potterie 2001)

- **GAFI**: German Applicant and Foreign Inventor
  - Applicant (owner) in Germany and inventor abroad, indicator for „outward R&D“ from Germany
- **FAGI:** Foreign Applicant and German Inventor
  - Applicant (owner) abroad and inventor in Germany, indicator for „inward R&D“ in Germany

Outward R&D (GAFI) and inward R&D (FAGI) in Germany 1991 – 2009

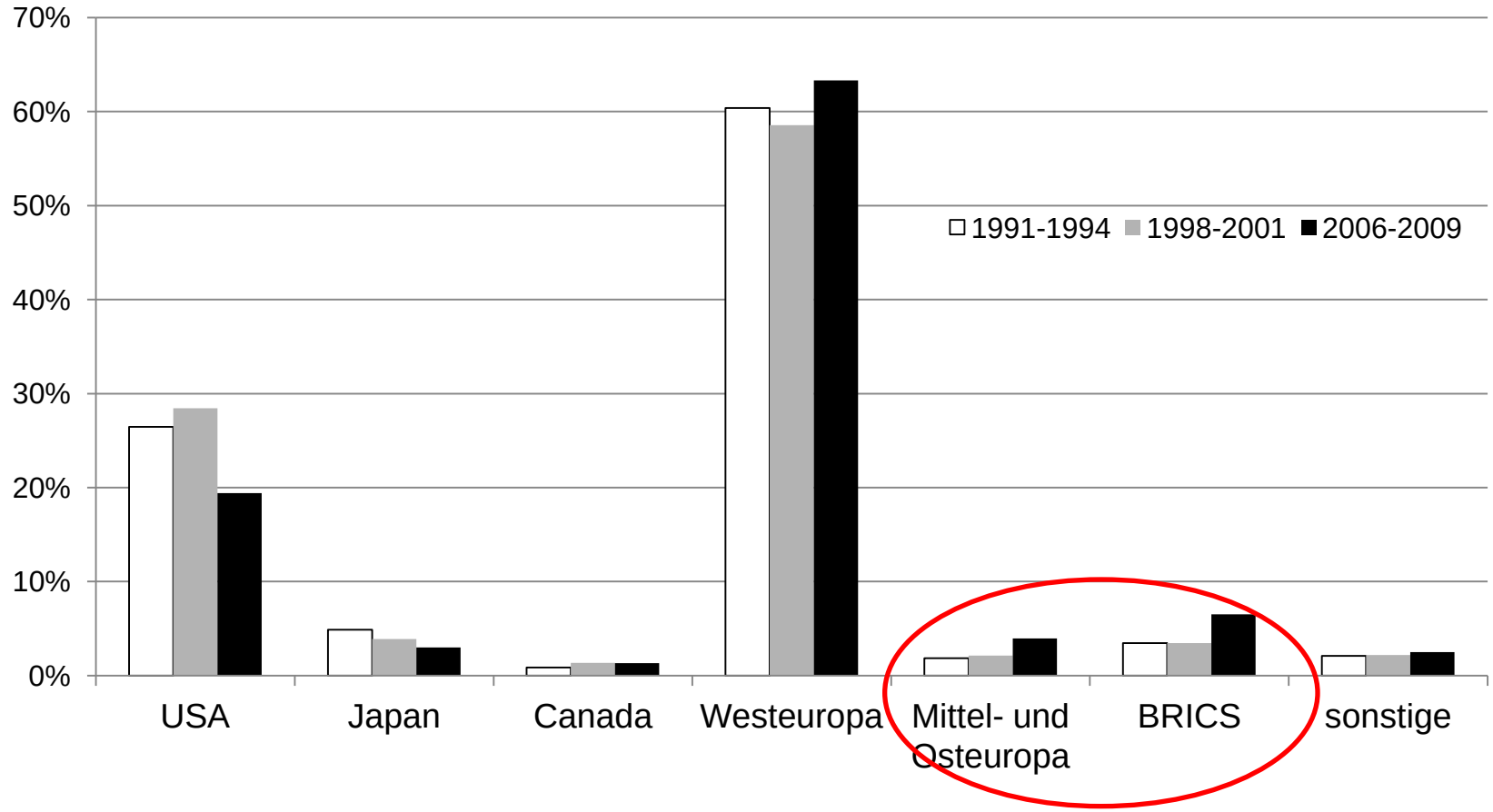


FAGI = **F**oreign **A**pplicant, **G**erman **I**nventor

GAFI = **G**erman **A**pplicant, **F**oreign **I**nventor

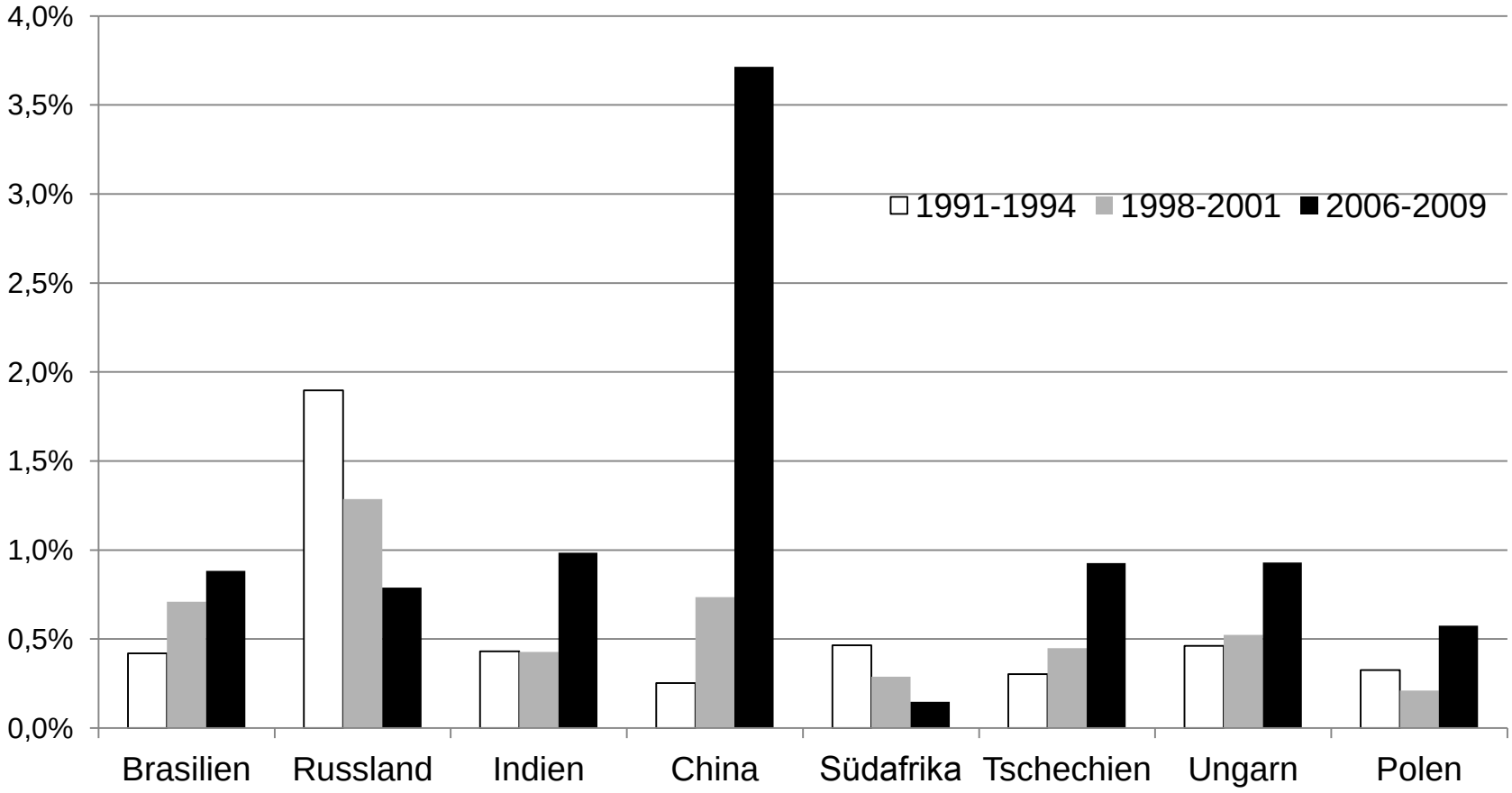
*FAGI Rate (%): Basis sind alle Patentanmeldungen mit mind. einem Erfinder in Deutschland; **GAFI Rate (%): Basis sind alle Patentanmeldungen mit mind. einem deutschen Anmelder
Source: IWH calculation, see: IWH et al. (2013).

Host countries of German outward R&D (GAFI)



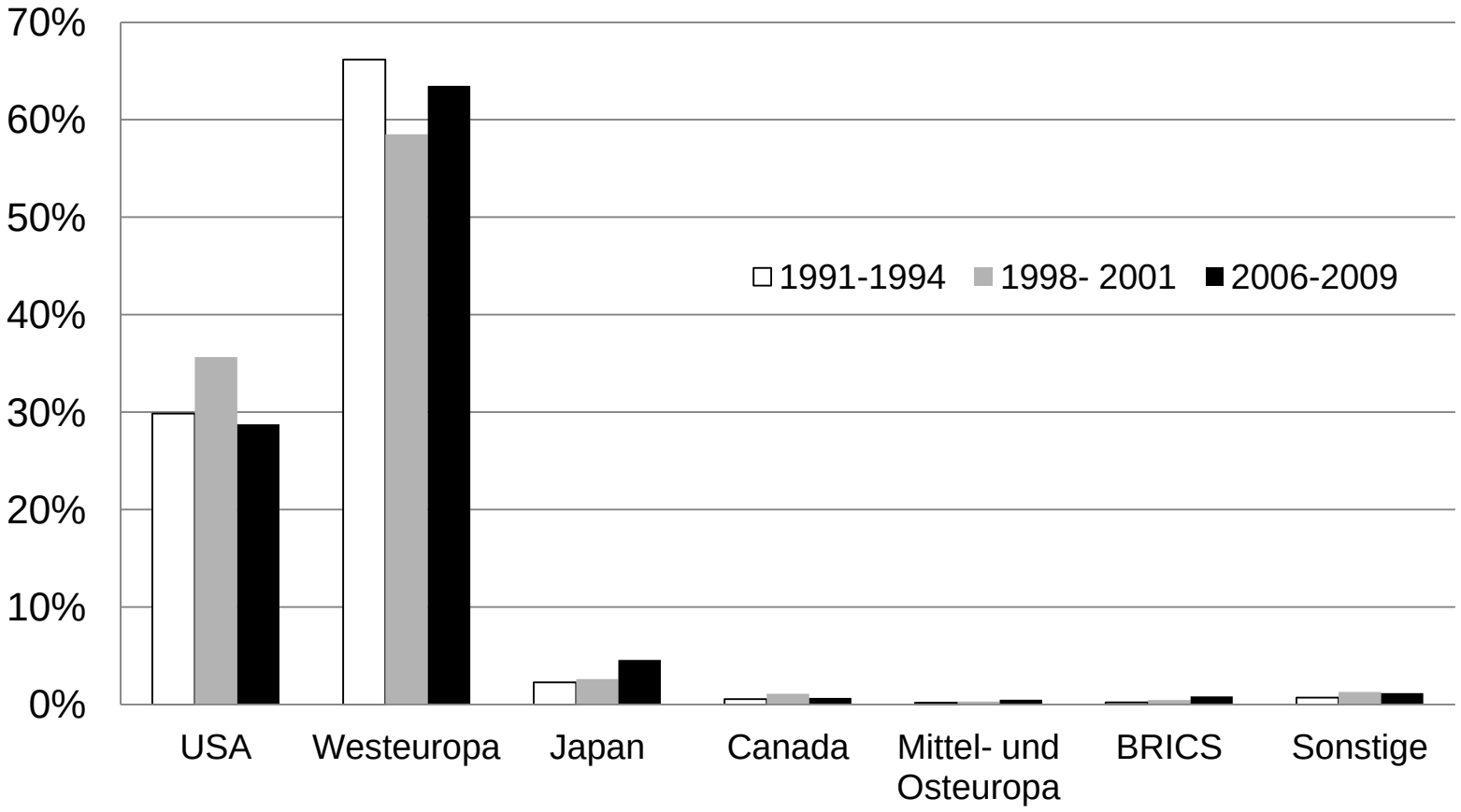
Source: OECD REGPAT database, January 2012; IWH (2013)

BRICS and CEEC as host of German outward R&D (GAFI)



Source: OECD REGPAT database, January 2012; IWH et al. (2013)

Countries of orign of foreign R&D in Germany (FAGI)



Source: OECD REGPAT database, January 2012; IWH et al. (2013)

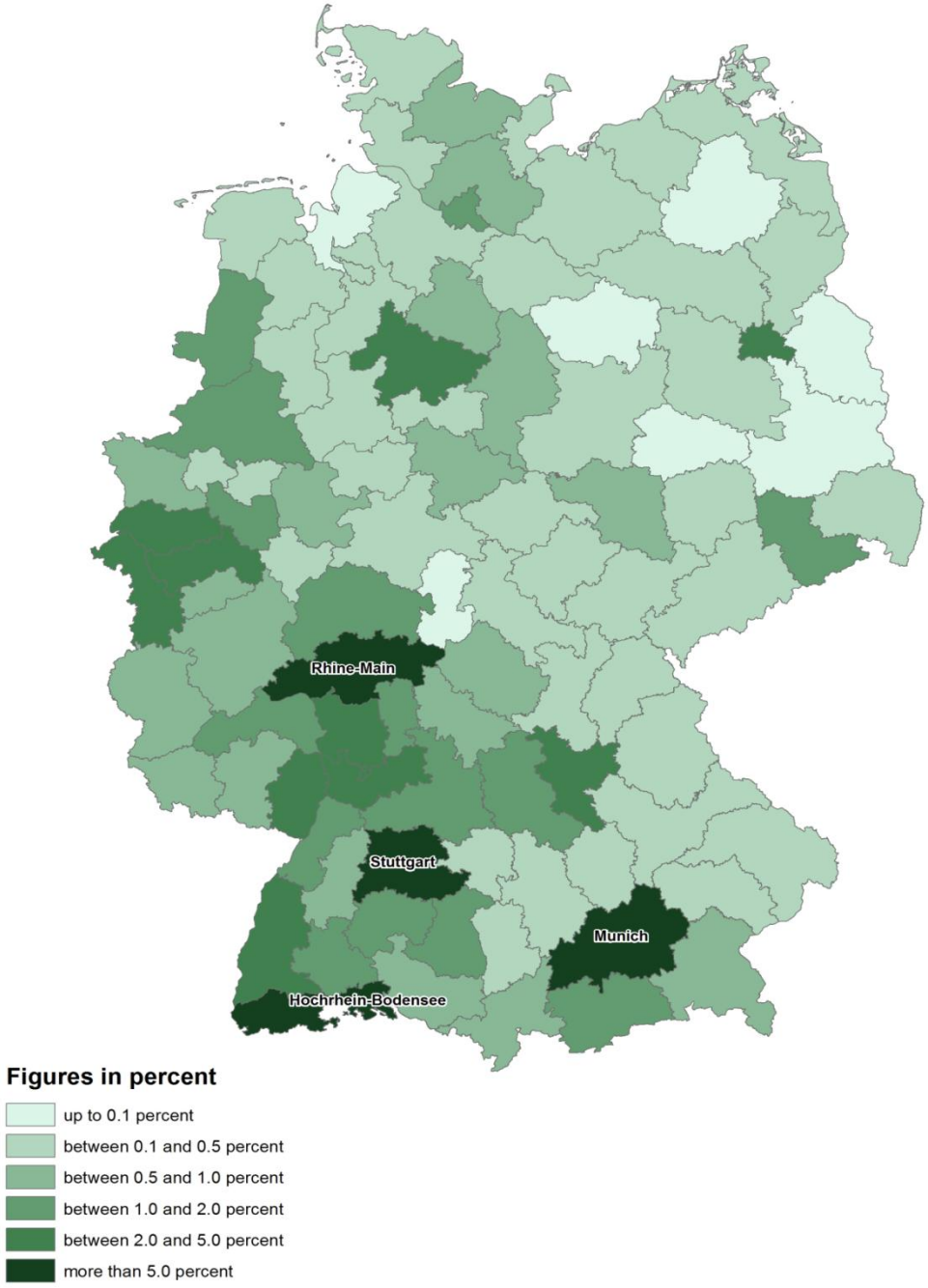
Intermediate conclusions

- Internationalization of R&D in Germany is mostly related to **Europe and USA**
- Inward R&D in Germany a **„signal“ for the attractiveness** of the business location

What are the determinants?
Do local externalities play a role (Cantwell 1989)?

4. Determinants of inward foreign R&D*

´*Dettmann, E.; Dominguez Lacasa, I.; Günther, J.; Jindra, B. : Determinants of Foreign Technological Activity in German Regions – A Count Model Analysis of Transnational Patents (1996-2009), IWH Diskussionspapier 12/2013



FAGI patent applications per region in Germany
(% of total) 2009

What are the determinants behind the (persistent) spatial distribution of inward foreign technological activity in Germany?

Source: OECD RegPat Database, IWH calculation

What is the analysis about?

Research objective

This paper investigates the **drivers of sub-national spatial dispersion** of foreign technological activity within Germany.

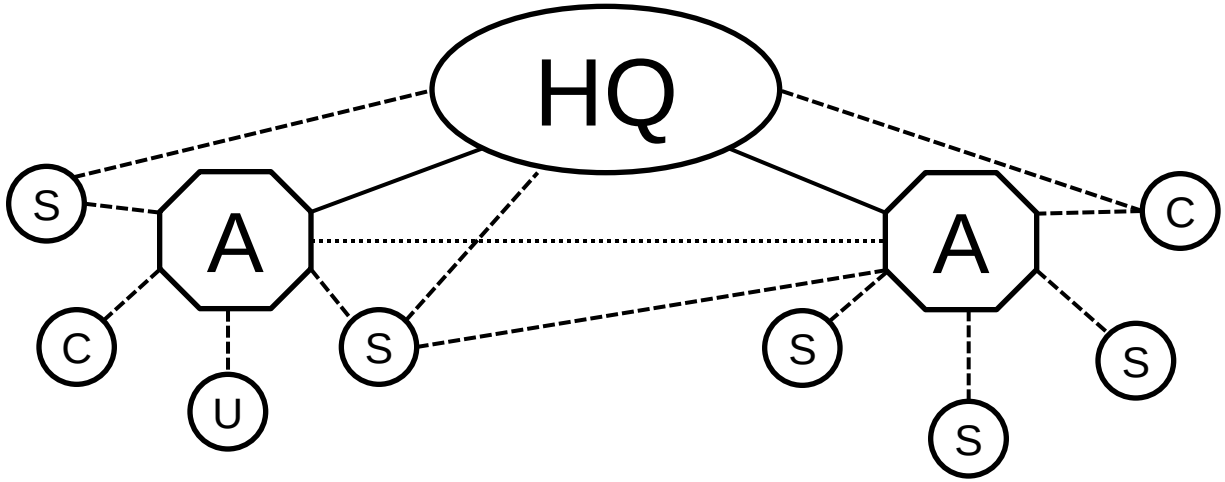
Contribution?

Different from **location choice analyses** (Crozet et al. 2004; Barrios et al. 2006; Basile et al. 2008; Guimarares et al. 2000) it adds to the few studies on the ***sub-national* determinants of foreign R&D** (Verspagen and Schoenmakers 2004; Cantwell and Piscitello 2005, 2007).

So far, our evidence questions earlier findings on the role of regional **diversification** and **domestic specialization** effects.

Theoretical framework
"Technological accumulation" (Cantwell 1989)

Agglomeration economies: intra- und inter-industry as well as science-industry **spillovers** in network structures of the MNE



HQ = headquarters, A = subsidiary, S = supplier, C = customer, U = university

Central hypotheses (I)

Marshallian knowledge externalities (Marshall 1962)

- (H1) **Technological specialization** in a given industrial sector of a region relative to other regions has a **positive effect** on foreign technological activity within this sector (Verspagen/Schoenmakers 2004; Cantwell/Piscitello 2005).
- (H1.1) If technological specialisation is concentrated in **few dominant domestic firms**, the effect on foreign technological activity within this sector can be **negative**.
  - Deterrence effects (Cantwell/Piscitello 2007).
  - Avoidance of knowledge loss
    (Chung/Alcacer 2007; McCann/Mudambi 2005; Mariotti et al. 2010).

Central hypothesis (II)

Jacobs type of urbanisation economies (1969)

- (H2) **Diversification** of a region in terms of a higher number of sectors with technological specialization compared to other regions has a **positive effect** on foreign technological activity (Cantwell/Piscitello 2005).

Science-Industry-Spillovers (Cooke 1992, 1998; Asheim et al. 1997)

- (H3) The potential for **science-industry spillover** within a region of a host country has a **positive effect** on foreign technological activity within the region (Cantwell/Piscitello 2005, Görg/Strobl 2003).

Data and measurement

Dependent Variable

- **FAGI** – Patent applications with at least one Foreign Applicant and at least one German Inventor
- Source: PCT and EPO patent applications from **OECD RegPat Database** 2012
- **'Cross-border-ownership'** approach
  (Guellec und van Pottelsberghe de la Potterie 2001; OECD 2009)
- 1996 to 2009: **54,512 FAGI** patents
- Assigned to **96 regions** (ROR) and **22 industries** (2 digit-level)

Explanatory variables

Central explanatory variables

- Specialisation (RTA index)
  - *Foreign specialisation (RTA index with basis FAGI)*
  - *Domestic specialisation (RTA index with basis GAGI)*
- Diversification (*MLQ index*)
- Science-industry spillover (*no. students per 1.000 inhabitants*$_{j,t}$)

Control variables

Human capital, taxation, infrastructure, size of region, capital, prior cumulative technological activity

Dummies: federal states, year, industry, spatial lags, interaction term RTA*hightech sector

[1] GAGI = Patents with only German applicant, at least one German inventor

Agglomeration measures

Specialisation – Revealed Technological Advantage

(Cantwell/Piscitello 2005)

$$RTA_{ijt} = \frac{P_{ijt}/\sum_i P_{ijt}}{\sum_j P_{ijt}/\sum_{ij} P_{ijt}}$$

Intra-industry externalities

The RTA indicated a specialisation of a region in a respective sector in comparision to all other region. Values of *RTA*>1 suggest that a region is comparatively advantaged in sector i, whereas *RTA<1* points to a comparative disadvantage.

Diversification – Median Location Quotient/Specialisation Index

(Basile et al. 2012)

$$MLQ_{it} = \frac{S_{it,J/2} + S_{it,J/2+1}}{2} \text{ with } S_{ijt} = \frac{P_{ijt}/\sum_j P_{ijt}}{\sum_j P_{ijt}/\sum_{ij} P_{ijt}}$$

Inter-industry externalities

The median location quotient measure of the numbers of sectors in which a region shows a revealed comparative technological advantage: A high median indicates that a region has a comparative advantage in a large number of sectors.
→ *high specialisation and diversification can coexist in the same region*

where P- number of patent applications; S – location quotient; i=1, …m 96 region; j=1, …, 22 manufacturing sectors; t=1, …, 14 years (1996-2009)

Econometric model

Pooled negative binominal regression model

$$FAGI_{ijt} = \exp(X_{ij,t-1}\beta + \varepsilon_{ijt})$$

where FAGI – Number of patent applications with at least one Foreign Applicant and at least German Inventor

X – explanatory variables with time lag

β – coefficients of explanatory variables

ε – Error term (unobserved region specific effects)

i=1, …, 96 regions

j=1, …, 22 manufacturing industries

t=1,…, 14 years (1996-2009)

Econometric issues

Endogeneity

Inclusion lagged explanatory variables (t-1; t-5)

Inclusion of prior cumulative number of patents in region i

Spatial correlations

Use of functional rather than purely administrative regions
Inclusion of spatial lags in all regressions of the key variables

Dependent variable no whole number

Fractional counting → transformation to next integer → increases the mean → possible overestimation of coefficients' size → use sign of coefficients

Overdispersion

Variance (43.42) of transformed dep. variable exceeds the mean (2.54) – negative binominal model to account for unobserved effects of overdispersion

Excess zeros

Voung test shows that no zero inflation model is required

Regression results

	(1)	(2)	(3)
Specialisation (RTA)	0.3716***	-	-
	(0.0087)		
- Foreign specialisation	-	0.5819***	0.6067***
		(0.0090)	(0.0090)
- Domestic specialisation	-	0.1000***	0.1105***
		(0.0067)	(0.0068)
Diversification (MLQ)	-1.5079***	-1.6261***	-1.6907***
	(0.0331)	(0.0316)	(0.0316)
Science-industry spillovers	0.0015***	0.0012***	0.0008***
	(0.0005)	(0.0005)	(0.0005)
Human Capital	0.8906***	0.6922***	0.9631***
	(0.0725)	(0.0692)	(0.0681)
No. of observations	29,269	29,269	29,269
Loglikelihood	-43,716	-42,328	-42,734
Chi-square	35,919	38,695	37,883
P-value Chi	0.0000	0.0000	0.0000
PseudoR2	0.291	0.314	0.307

Standard errors in parentheses; ***p<0.01; **p<0.05; *p<0.1

Determinants of foreign R&D in German regions

✓ **Specialisation – i**ntra-industry spillovers (Marshall)
(Verspagen/ Schoenmakers 2004; Cantwell/Piscitello 2005).

Plus: independent from foreign / domestic specialisation

? **Diversification** – inter-industry spillovers (Jacobs)

Alternative (?): Related Variety (Frenken et al. 2007) – *further research!*

✓ **Science-industry spillovers**
(Cantwell/Piscitello 2005, Görg/Strobl 2003)

✓ **Human capital**
(Hall 2011, Kumar 2001)

5. Discussion

Message for policy (and beyond)

- R&D internationalisation so far strongest between Europe and USA
- BRICS and CEEC gain importance!
- Germany is not loosing at the moment (inward and ourtward R&D), but challenge for the future

- Clusters matter!
- Science infrastructre!
- Human capital!

Thank you for your attention!

Appendix

Grenzen der internationalen FuE-Statistik in Deutschland (Stifterverband)

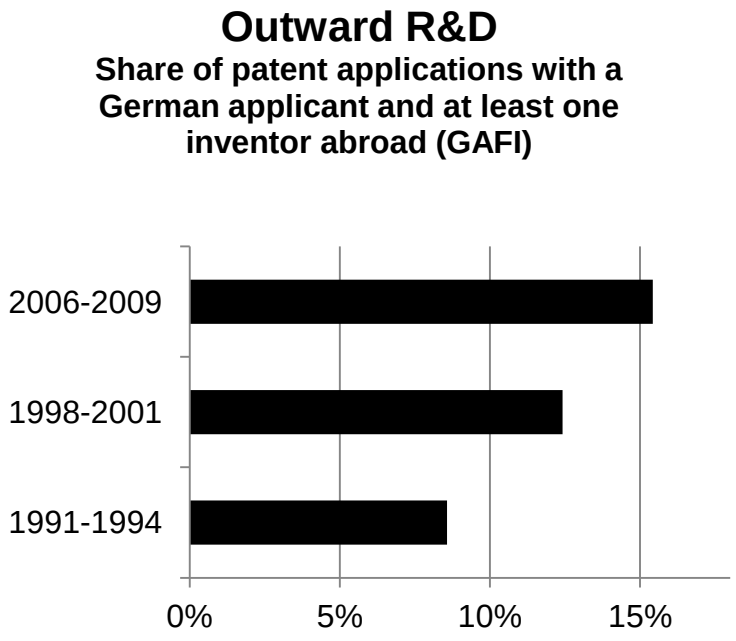
Ausländische U. in Deutschland (Inward R&D)

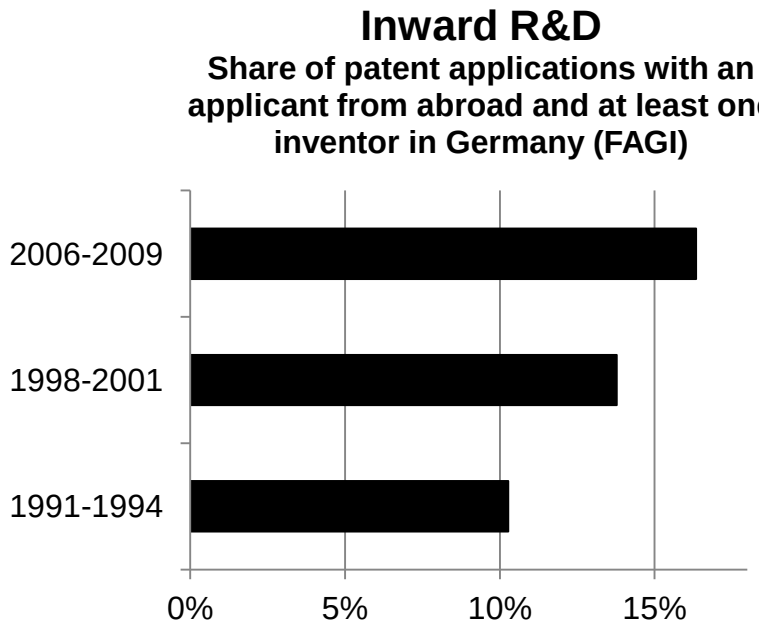
- Nationale Befragung + Informationen zu Eigentümerstrukturen
- **Branchen und Herkunftsländer wie Mehrheitseigentümer**

Deutsche U. im Ausland (Outward R&D)

- seit 2001 als “Restgröße” berechnet: Globale FuE der ca. 100 größten Unternehmen (Geschäftsberichte) – FuE im Inland = FuE im Ausland
- **Branchenzuweisung lt. Muttergesellschaft**
- **keine Zielländer**

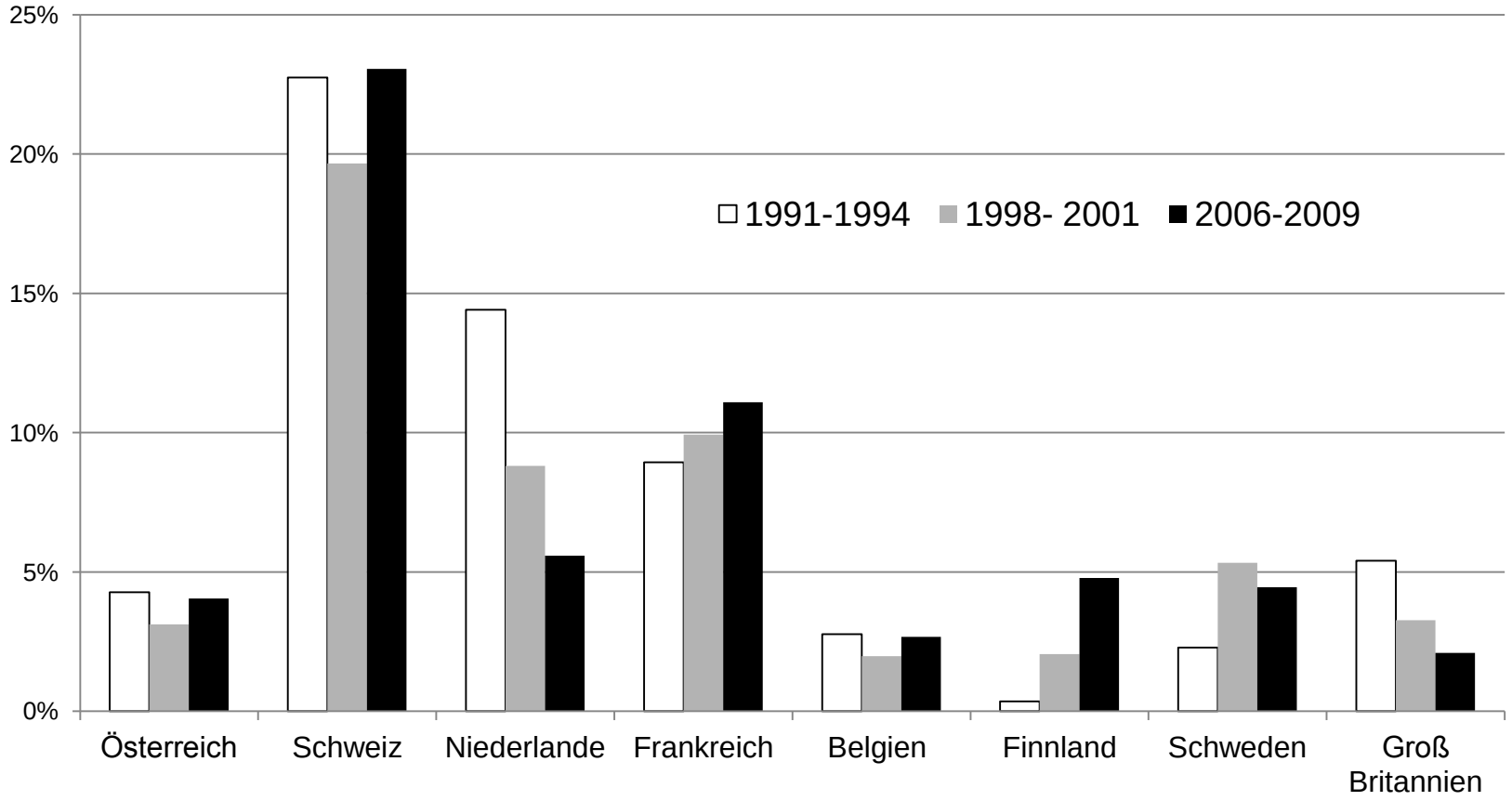
Erfindertätigkeiten deutscher U. im Ausland (GAFI) und ausländischer U. in Deutschland (FAGI), Teil II





Datenquelle: OECD REGPAT Datenbank, Januar 2012.

Ausgewählte europäische Herkunftsländer der Unternehmen mit technologischen Aktivitäten in Deutschland (FAGI)



Source: OECD REGPAT database, January 2012; IWH et al. (2013)

Operationalization I

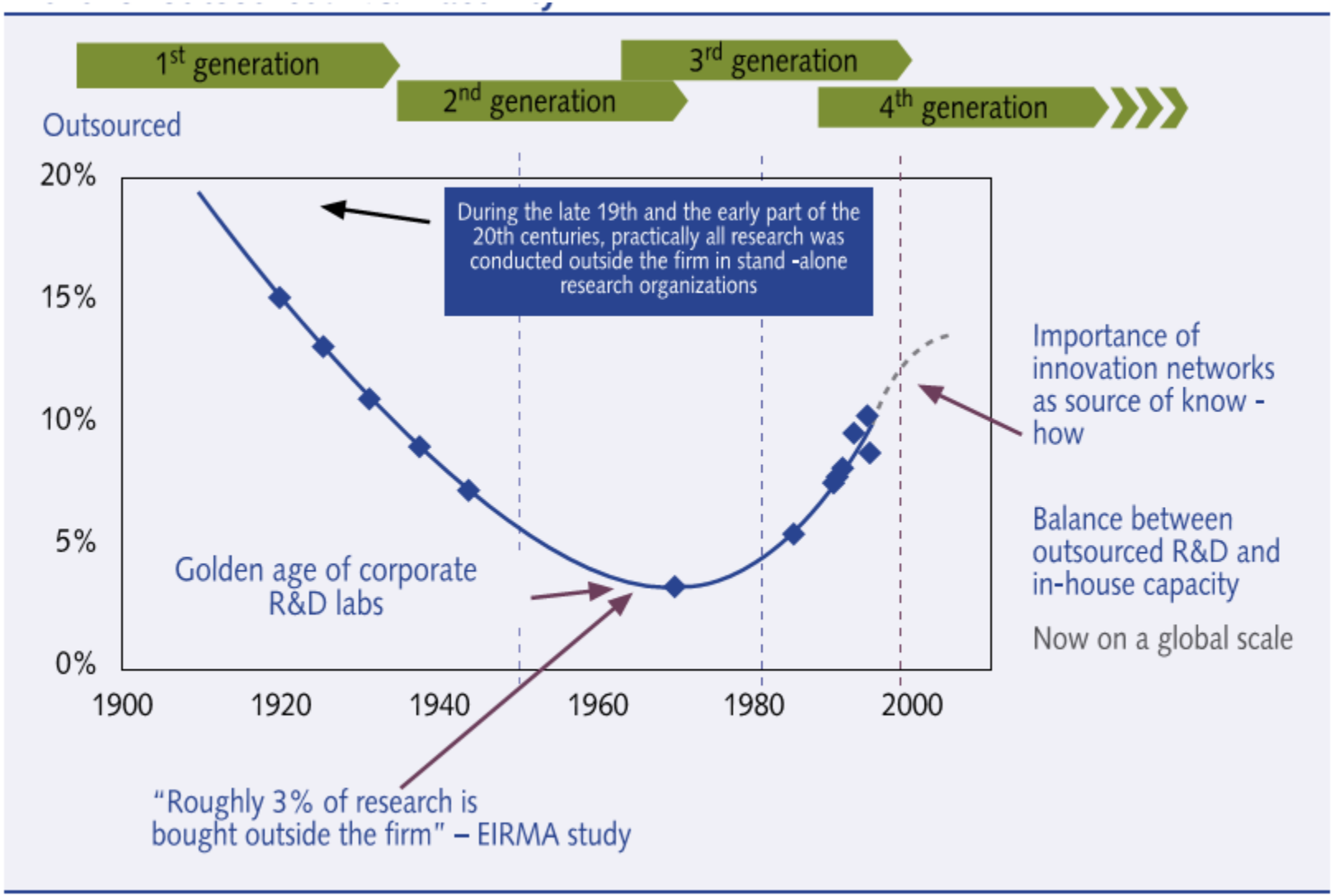
Dependent Variable	
Inward foreign techn. activity	FANI, patent applications with at least one foreign applicant and at least one German inventor in the region (i) and industrial sector (j) and year (t)
Explanatory Variables	
Tech. specialization	RTA index (i, j, t); P (basis) = all patents with at least one German Inventor
Foreign tech. spec.	RTA index (i, j, t); with P (basis) = all patents with at least one foreign applicant and at least one Germ. inventor (FAGI)
Domestic tech. spec.	RTA index (i, j, t); with P (basis) = all patents with only one German applicant and at least one German inventor (GAGI)
Domestic dominance	Difference between cumulative GAGI and cumulative FAGI in the region (i) and industrial sector (j) and year (t)
Diversification	MLQ index (i, t); P (basis) = all patents with at least one German Inventor
HOR (Higher Order Region)*RTA/MLQ	HOR (0/1) takes value of 1 if the number of all patent applications (with at least one German inventor) > mean of patent applivations over all 96 regions

Operationalization II

Continuation, Explanatory variables	
Science-Education infrastructure (SEI)	Number of students in higher education per 1000 inhabitants of the region
Control variables	
Cumulative causation	Cumulative number of all patent applications (with at least one German inventor)
Human capital endowment (HCE)	Share of high qual. employees in the total number of employees with sector specific qualification in the region
Business tax	Business tax rate of the region
Transport infrastructure	Journey time to the next motorway by car
Health care index	Number of doctors and hospital beds/inhabitant in the region
Size	log. size of region in square kilometres
Capital	Dummy for the capital (federal state) in the region

Operationalization III

Continuation, Control variables	
SEI neighbour	Average SEI of neighbouring regions
HCE neighbour	Average HCE of neighbouring regions
Diversification neighbour	Average MLQ of neighbouring regions
High tech*RTA index	Interaction term of RTA index with a dummy for high tech sector / medium-high tech sector
Secotor	Dummies for industrial sectors (NACE Rev. 1.1 2, 15-35) with NACE 36 as reference
Federal states	Dummies for 16 federal states with Mecklenburg-Vorpommern as reference
Year	Annual dummies for 1997 to 2009 with 1996 as reference


1st generation
2nd generation
3rd generation
4th generation
Outsourced
20%
15%
10%
5%
0%
1900
1920
1940
1960
1980
2000
During the late 19th and the early part of the 20th centuries, practically all research was conducted outside the firm in stand -alone research organizations
Golden age of corporate R&D labs
"Roughly 3% of research is bought outside the firm" – EIRMA study
Importance of innovation networks as source of know - how
Balance between outsourced R&D and in-house capacity
Now on a global scale