LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Fakultät für Betriebswirtschaft
Munich School of Management

Inside the Digital Economy: Digitization and Firm Organization

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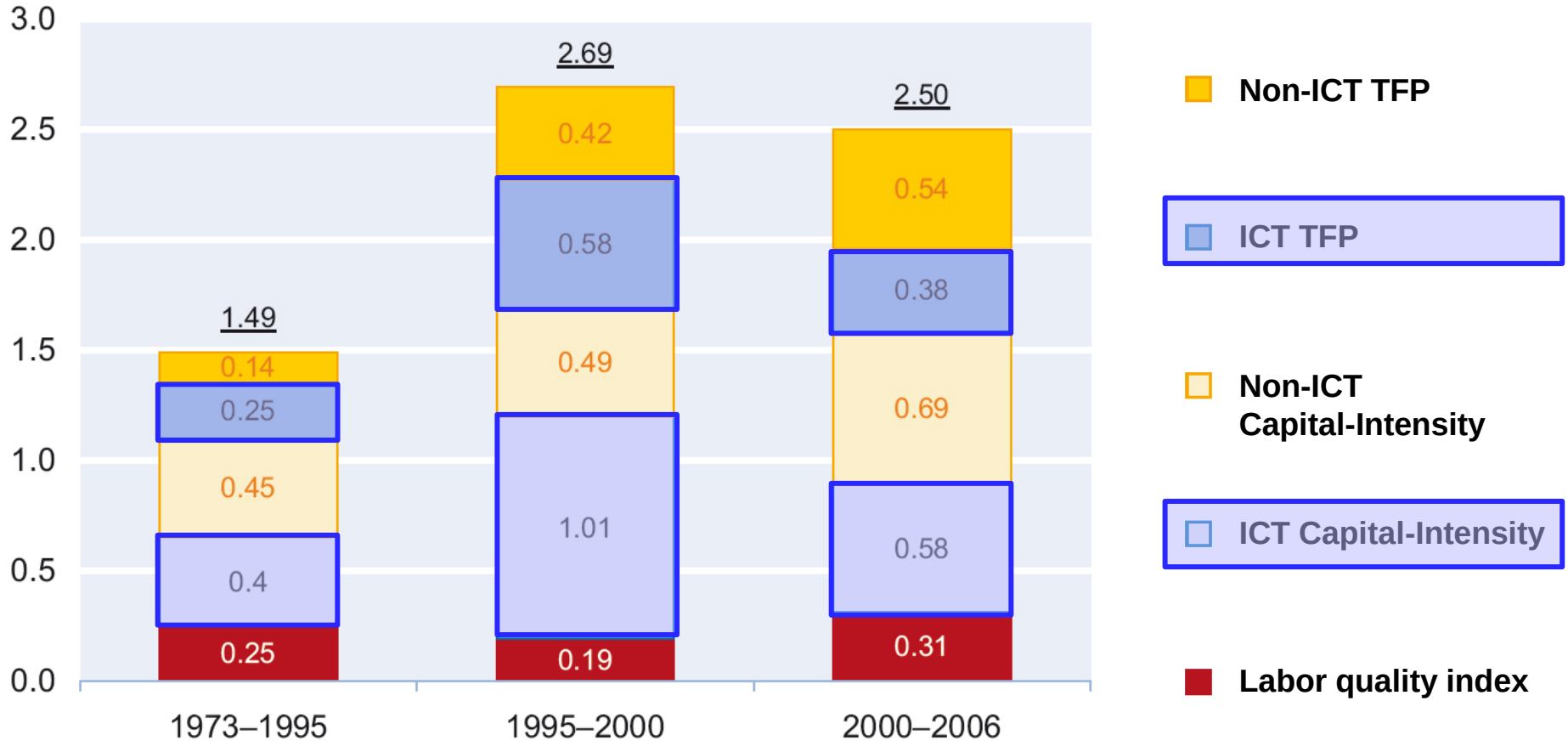
Overcoming the Crisis: How to Foster Innovation and Entrepreneurship in a Diverging European Economy?

ZEW Mannheim, 09/10/15

1. **Information and communication technologies and economic growth**
2. How can ICT affect organization(s)?
3. Some evidence on the interaction of ICT and organization
   - Cloud readiness across industries
   - Competitive pressure and the adoption of complementary innovations
4. Ongoing work on ICT and organization
5. Summary and a research agenda

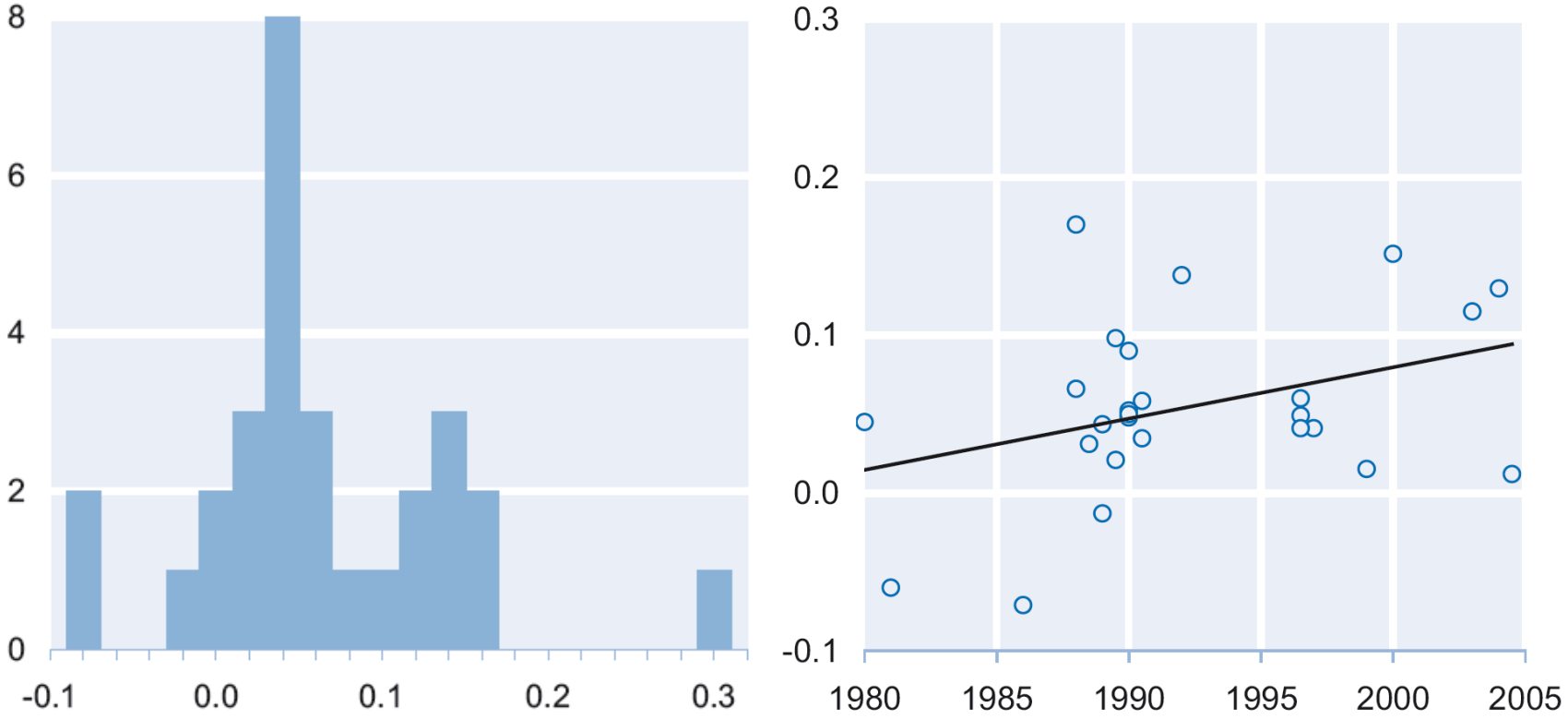
ICT accounts for a large share of US productivity growth



Source: Jorgenson (2008)

ICT output elasticities are around .06 and rising over time

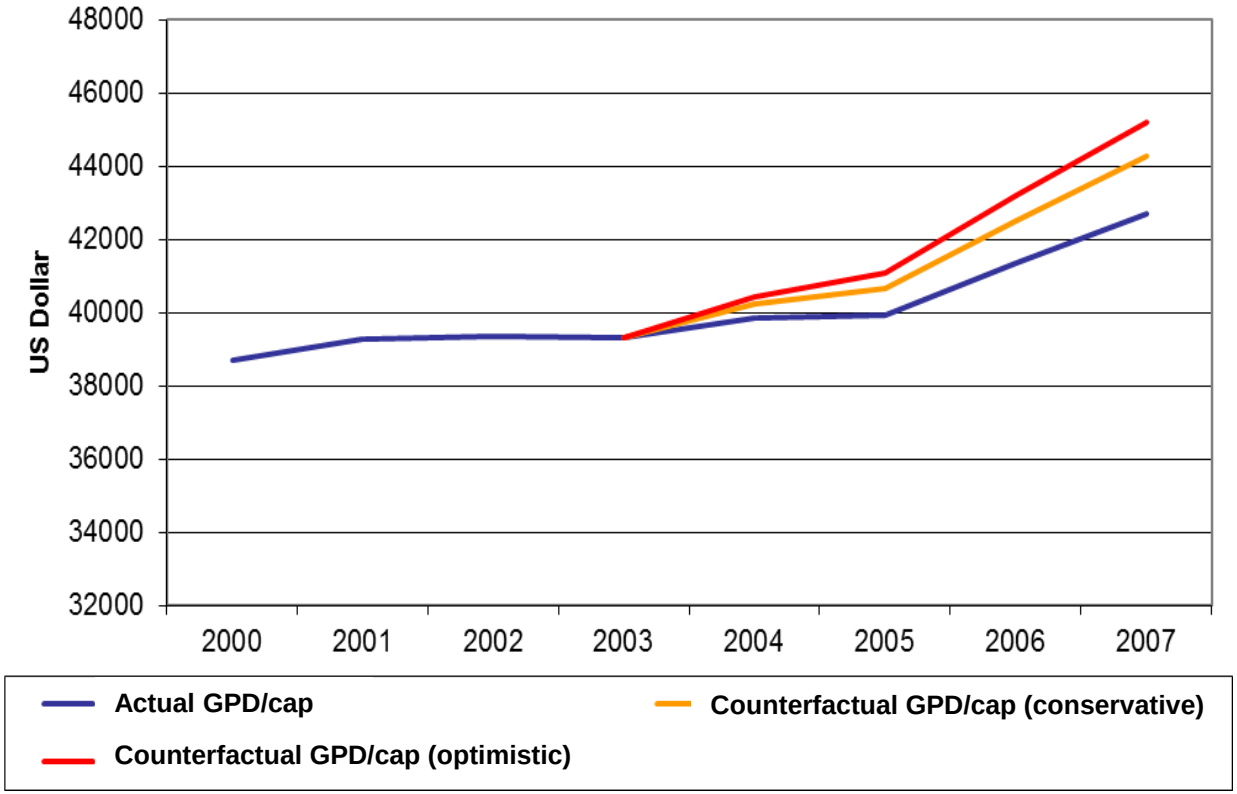
$$lnY_{it} = \alpha ln\mathrm{K}_{nICT,it} + \beta ln\mathrm{K}_{ICT,it} + \gamma ln\mathrm{L}_{it} + controls_{it} + \epsilon_{it}$$



Source: Cardona/Kretschmer/Strobel (2013). Observations from 28 papers weighted by within-study variance.

Specific technologies (e.g. Broadband) contribute massively to economic growth

Counterfactual GDP/capita in Germany
(if Germany had had a 10% higher BB penetration in 2003)



Source: Czernich/Falck/Kretschmer/Wößmann (2011). Counterfactual analysis of cross-country growth regressions

ICT as a General Purpose Technology

- ICT is efficiency enhancing in many production processes (**diffuses widely**).
- ICT triggers **complementary changes and innovations**.
- ICT improves over time, while the **cost of usage declines**.

Source: Adapted from Bresnahan and Trajtenberg (1995)

1. Information and Communication Technologies and Economic Growth

- ICT credited with contributing significantly to recent growth periods.
  - ICT-producing and ICT-using industries benefit from spread and improvement of ICT.
- Increase in output through ICT investment increases over time.
  - A 10% increase in ICT investment leads to .6% increase in growth.
- Some technologies may have an even bigger impact.
  - E.g. 10% higher broadband penetration leads to .9-1.5% higher GDP growth.
- So why do some technologies have such a large impact?
  - Have some General Purpose Technology (GPT) characteristics.

➔ Could firm organization be a complementary factor to fully „unlock“ ICT?

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2. How can ICT affect organizations?

- Reduce marginal cost of existing processes (process innovation)
- Enable new, previously not viable processes (drastic process innovation)
- Facilitate better match of consumer preferences (product innovation)
- Create opportunities through linking information across independent actors

2. How can ICT affect organizations?

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  - HR processes – cost per employee decreases, esp. in commission-based professions
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  - Configurator websites – allow customers to configure their ideal product
  - „Freemium“ business models – second-degree price discrimination & network effects
- Create opportunities through linking information across independent actors

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  - Digital health – creates web of previously separate information to improve care and reduce cost
  - „Sharing economy“ – Uber, AirBnB, Kickstarter etc. link many independent agents on both sides

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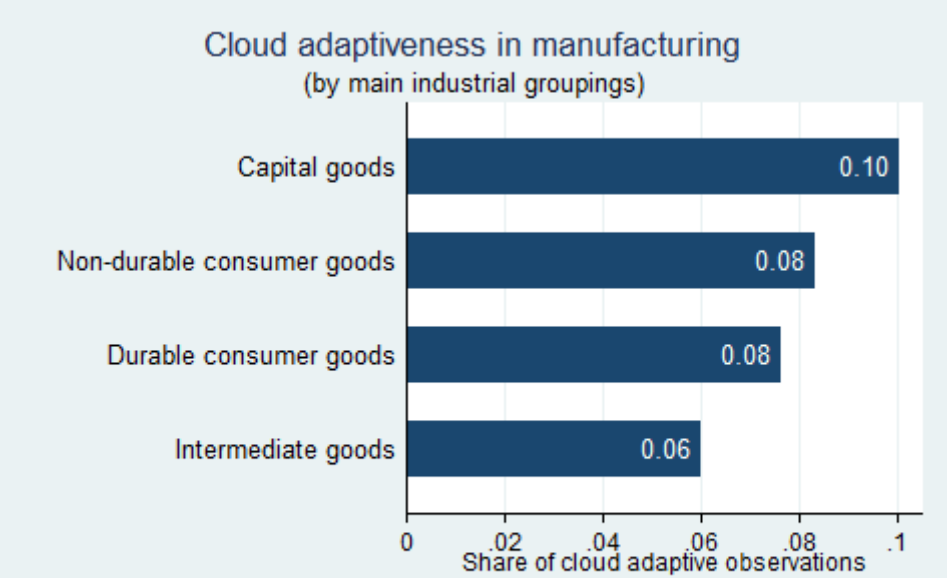
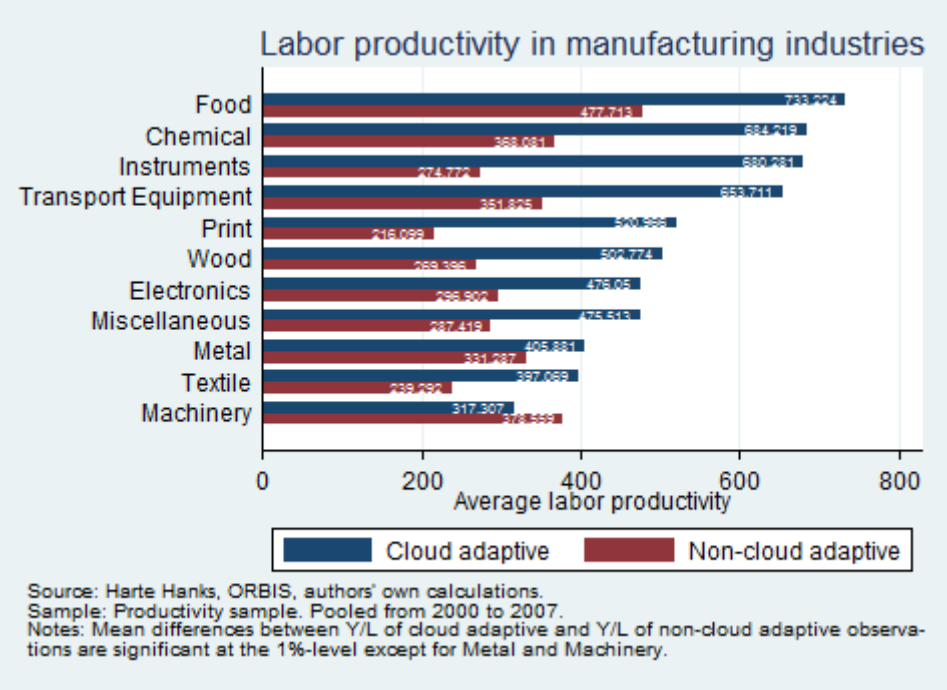
- Cloud readiness across industries (Candel Haug/Kretschmer/Strobel, forthcoming, Telecoms Policy)
  - Firm adoption of cloud-like infrastructure differs widely across industries



Source: Harte Hanks, ORBIS, authors' own calculations.
Sample: Adoption sample. Pooled from 2000 to 2007.
Note: The pairwise mean differences between the groupings are significant at the 1%-level, except for the consumer goods groupings.

3. Some evidence on the interaction of ICT and firm organization

- Cloud readiness across industries (Candel Haug/Kretschmer/Strobel, forthcoming, Telecoms Policy)
  - Firm adoption of cloud-like infrastructure differs widely across industries
  - Cloud-ready firms are more productive than their industry peers



Source: Harte Hanks, ORBIS, authors' own calculations.
Sample: Productivity sample. Pooled from 2000 to 2007.
Notes: Mean differences between Y/L of cloud adaptive and Y/L of non-cloud adaptive observations are significant at the 1%-level except for Metal and Machinery.

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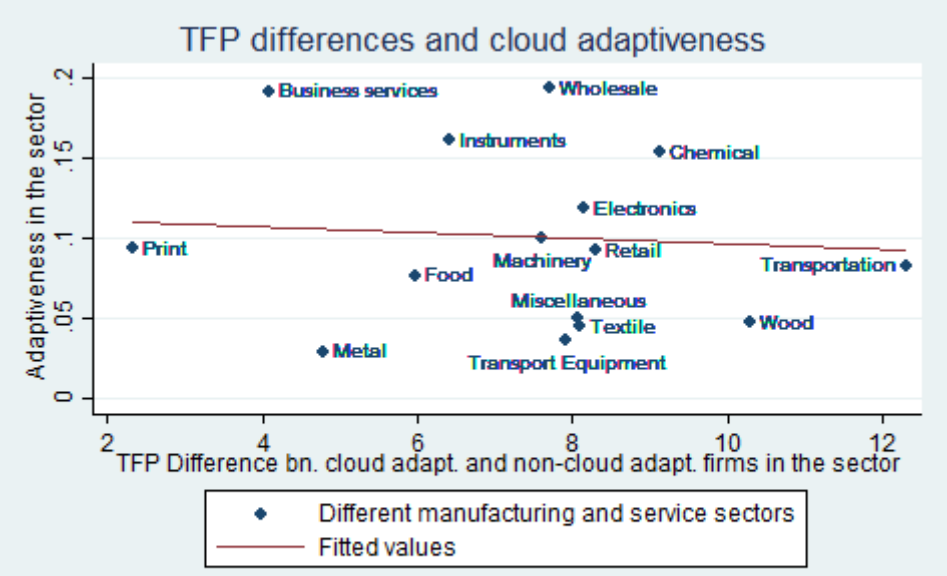
  - However, adoption is not fastest in industries where the productivity gap is largest



Source: Harte Hanks, ORBIS, authors' own calculations.
Sample: Productivity sample. Pooled from 2000 to 2007.
Notes: The Financial sector, Other services and Health/Education/Social are not represented as their mean differences are insignificant.

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  ➔ Organizational factors could faciliate or hinder the adoption of cloud-like infrastructures

  ➔ ICT alone is not a driver of growth, it has to be faciliated by the „right“ organizational form

3. Some evidence on the interaction of ICT and firm organization

- Competitive Pressure and the Adoption of Complementary Innovations (Kretschmer/Miravete/Pernias, AER 2012)
  - Considers a single country-industry (French car dealers)
  - Utilizes a change in regulation for car manufacturers to intensify competition among dealers across territories
  - Tracks adoption of two enterprise software packages: HR and Applications development software
  - Finds that firms grow (i.e. increase scale of operations) upon liberalization and
    - …increasingly adopt more App development software,
    - …which in turn triggers less HR adoption

  ➔ Scale and some types of enterprise software go together, while different types of software are often substitutes

  ➔ Supports the view that ICT is an integral part of the firm‘s organizational structure

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4. Ongoing work on ICT and Organization

- Organizational Observatory @LMU Munich
- Telephone survey with the aim of capturing the Organization Design of German firms
  - Not simply surveying „standard“ structural variables (hierarchy, org chart etc.), but get a theoretically grounded picture of how the firm „works“
  - Five elements of organization design, two dimensions:
    - Task allocation
    - Planning and controlling
    - Compensation and incentives
    - Information flows
    - Personnel management
    - ➔ Centralization and Formalization for each dimension
  - For information flows, also ask use of ERP and production software (CAD/CAM)
  - Future surveys of ICT decisionmakers within the firm to get detailed view on ICT

4. Ongoing work on ICT and Organization

- Potential questions that can be addressed:
  - Can ICT support certain types of information flow (centralized, formalized)?
  - Are there „ambidextrous“ ICT systems that can support different types of information exchange or are they substitutes?
  - Does ICT use lead or lag the type of information flow?

- Future plans:
  - Annual survey on org design and ICT use
  - Matching into other datasets, e.g. innovativeness, linked employer-employee data etc.
  - Making use of shocks over time for identification

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ICT can offer a way out of this crisis (and future ones)

- The aggregate growth contribution of ICT is (very) high, suggesting that ICT may be a General Purpose Technology.
- GPT differ from conventional technologies in their complementarities and ability to affect many economic activities.
- The impact of ICT innovations is often determined by users. Much of the action happens there. To be classified as a GPT, ICT has to reach „unlikely“ users.

5. Summary and a research agenda

Opening the black box of enterprise ICT

- We know quite a lot about ICT (and there is a good deal of data around, including here at ZEW!), but much less about organization design – and both have to „fit“ to generate most value.

- Industry- or firm-specific studies aimed at uncovering precise mechanisms and interdependencies have most potential for real insights.

- Longitudinal studies can shed light on the „driving“ versus „facilitating“ role of ICT.

THANK YOU!

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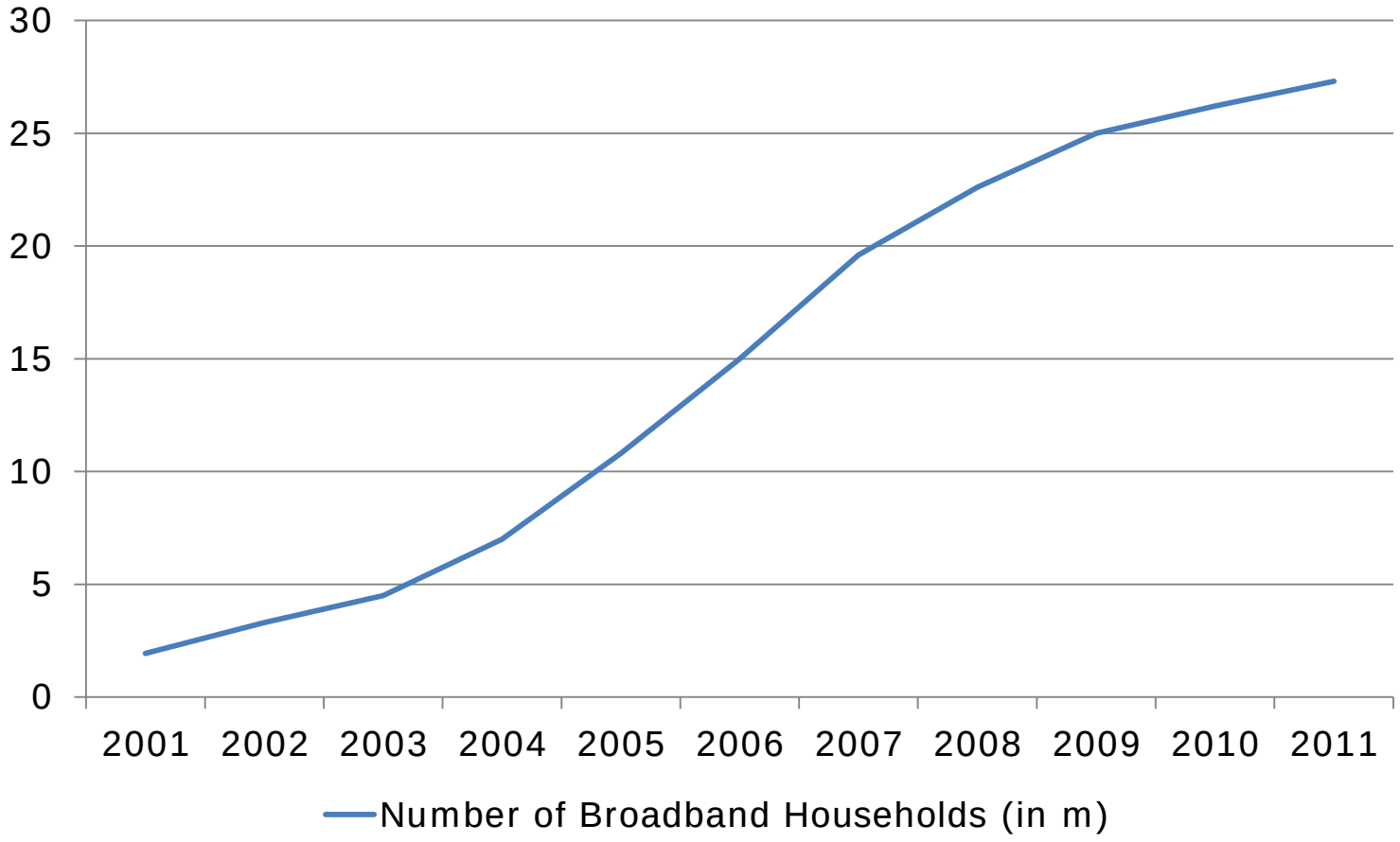
Broadband and Economic Growth: Motivation

- During the recent economic crisis, many governments initiated stimulus packages that emphasize investment in high speed internet and promote the roll-out of broadband networks.
- Possible channels through which high-speed internet may facilitate macroeconomic growth:
  - accelerate the distribution of ideas and information
  - foster competition for and development of new products and processes
  - facilitate the introduction of new working practices, entrepreneurship or job matching
- Counterfactual study looks at growth contributions in different countries

Extensive Diffusion of Broadband in Germany



Quelle: Bundesnetzagentur, 2012

Communication Infrastructure and Economic Development

- Röller and Waverman (AER 2001)
  - Analysis of the roll-out of the traditional telephone network
  - Positive effect of rate of telephone lines on GDP per head OECD average: 1/3 of annual growth attributed to telephone infrastructure
- Crandall, Lehr and Litan (2007); Gillett, Lehr, Osorio and Sirbu (2006)
  - Analyse the broadband development across U.S. states
  - Positive associations between broadband penetration and different economic outcome variables such as employment, wages, and housing prices.

Broadband Infrastructure and Economic Growth

- Aim: Isolate supply side effects from demand side effects and endogenous regulation
  - Reverse causality: Broadband infrastructure can be built in economically successful countries, so there might be correlation, but not causation
- Instrumental variable approach:
  - Roll-out of broadband networks takes place along the already existing voice-telephony and cable TV networks.
  - Geographic extent of the broadband network is bounded by the extent of the traditional communication networks.
  - Both networks were built for other purposes and finished before broadband diffusion started.

Country Sample

- Complete data available for panel of 20 OECD countries
  - Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, UK, USA
  - 5 additional countries in models without controls for investment and education:

    Czech Republic, Italy, Portugal, South Korea, Spain
- 12 years: 1996-2007
- Sources:
  - OECD
  - ITU (International Telecommunication Union)

Variables

- Broadband rate
  - Broadband connections (>256 kbit/s) per 100 inhabitants
- GDP per working-age population (2000 PPP)
- Capital accumulation
  - Real private non-residential fixed capital formation / real private GDP
- Human-capital accumulation
  - Years of schooling population aged 15-64
- Population aged 15-64 years
- Fixed-telephone lines per 100 inhabitants
- Cable TV subscribers per 100 inhabitants

Logistic Diffusion and Nonlinear First Stage

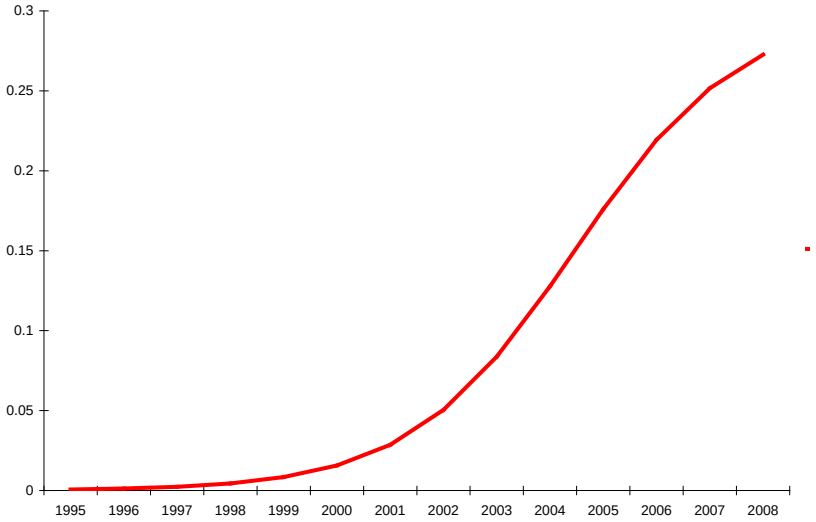
- Instruments:

  Fixed telephone lines and cable TV subscribers in 1996

- Spread of new technologies typically follows S-shaped diffusion curve (Griliches 1957)

$$B_{it} = \frac{\gamma_i}{1+\exp(-\beta(t-\tau))} + \varepsilon_{it}$$

  - γ: maximum broadband rate
  - β: diffusion speed
  - τ: inflexion point



- Existing networks determine maximum broadband rate γ_i

$$\gamma_i = \gamma_0 + \gamma_1 telephone + \gamma_2 cableTV$$

Logistic Diffusion and Nonlinear First Stage

- Non-linear first stage: Crucial to choose correct functional form (Angrist/Krueger 2001)
- Vast empirical literature following Griliches (1957) on logistic diffusion curves (Comin, Hobijn and Rovito 2006)

Predicted values from first stage used to determine growth effect of broadband:

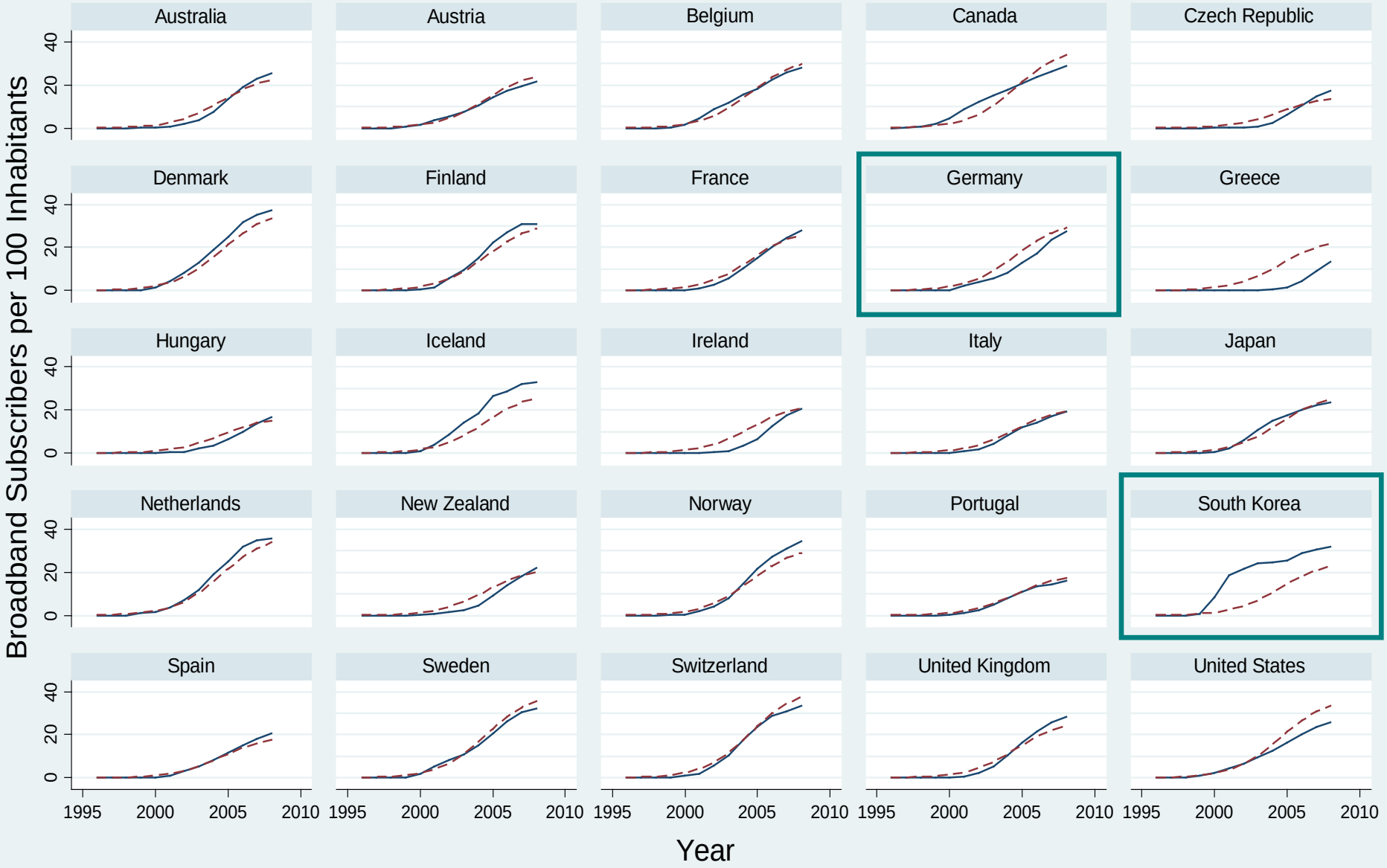
- Predicted values
  - Time-varying predicted values for broadband rate
  - Predicted value for year of introduction of broadband ($B_{it} \geq 1\%$)
- Bootstrapped standard errors in second stage

The Diffusion Curve: First Stage of IV Model

Dependent variable: Broadband penetration rate	**Model 1**	**Model 2**
Voice-telephony penetration rate (γ_1)	0.585***	0.487***
	(6.16)	*(4.59)*
Cable-TV penetration rate (γ_2)	0.279**	0.301**
	(2.11)	*(2.54)*
Diffusion speed (β)	0.647***	0.623***
	(15.60)	*(13.36)*
Inflexion point (τ)	2.004.5***	2.004.5***
	(10423.8)	*(10508.9)*
Constant (γ_0)	-0.057	0.002
	(1.25)	*(0.04)*
R^2	0.96	0.93
F-test (voice PR = cable PR = 0)	26.69	32.18
Observations	260	325
Countries	20	25

- Estimated by non-linear least squares
- Same results when 2nd-stage control variables are included

Actual and Predicted Broadband Penetration Rates



Effect of Broadband Diffusion: IV Results

$$\log y_{it} = \alpha_i + \alpha_t + \alpha_1 D_{it} + \beta_1 \log s_{it} + \beta_2 \log h_{it} + \beta_3 n_{it} + \varepsilon_{it}$$

Dependent variable: Log of GDP per capita	**Model 1**	**Model 2**	**Model 3**
Predicted broadband introduction	0.027***	0.031***	0.039***
	(2.84)	*(3.18)*	*(4.56)*
Log of capital formation/GDP	0.107**		
	(2.11)		
Log of years of education	0.088		
	(0.61)		
Growth of working-age population	0.043		
	(0.06)		
Country dummies	yes	yes	yes
Year dummies	yes	yes	yes
Constant	3.627***	3.563***	3.492***
	(12.10)	*(65.67)*	*(61.41)*
R^2 (within)	0.86	0.85	0.84
Observations	240	240	300
Countries	20	20	25

Effect of Broadband Diffusion: IV Results

$$\Delta \log y_{it} = \alpha + \alpha_1 B_{it} + \beta_1 \Delta \log s_{it} + \beta_2 \Delta \log h_{it} + \beta_3 \Delta n_{it} + \beta_4 \log y_{i0} + \beta_5 T_{it}^{B} + \varepsilon_{it}$$

Dependent variable: Growth of GDP per capita	**Model 1**	**Model 2**	**Model 3**
Predicted broadband penetration rate	0.092***	0.135***	0.145***
	(3.57)	*(5.27)*	*(4.10)*
Years since predicted broadband introduction	-0.003***	-0.005***	-0.005***
	(3.92)	*(5.40)*	*(4.03)*
Growth of capital formation/GDP	0.069***		
	(5.73)		
Growth of years of education	-0.004		
	(0.19)		
Δ Growth of working-age population	-0.18		
	(0.77)		
GDP per capita in 1996	-0.001***	-0.001***	-0.001***
	(6.06)	*(6.57)*	*(4.38)*
Constant	0.052***	0.056***	0.049***
	(10.29)	*(11.59)*	*(8.36)*
R^2	0.29	0.19	0.12
Observations	240	240	300
Countries	20	20	25

Additional IV Specifications

- Results are robust in specifications that add
  - Full set of country fixed effects
    - Estimated effects slightly larger
  - Dummies for four time intervals

- Critical-mass specification
  - Network effects: non-linear effect of broadband infrastructure?
  - Include interaction terms of predicted broadband penetration and step dummies for having reached at least 10% and 20%
  - Clearest effect when 10% threshold is passed; linear beyond

- Results about the same with lagged broadband penetration
  - Nearly whole effect occurs contemporaneously

- Results are robust when we use broadband per household

Is our Instrument an accurate predictor of BB and not other ICTs?

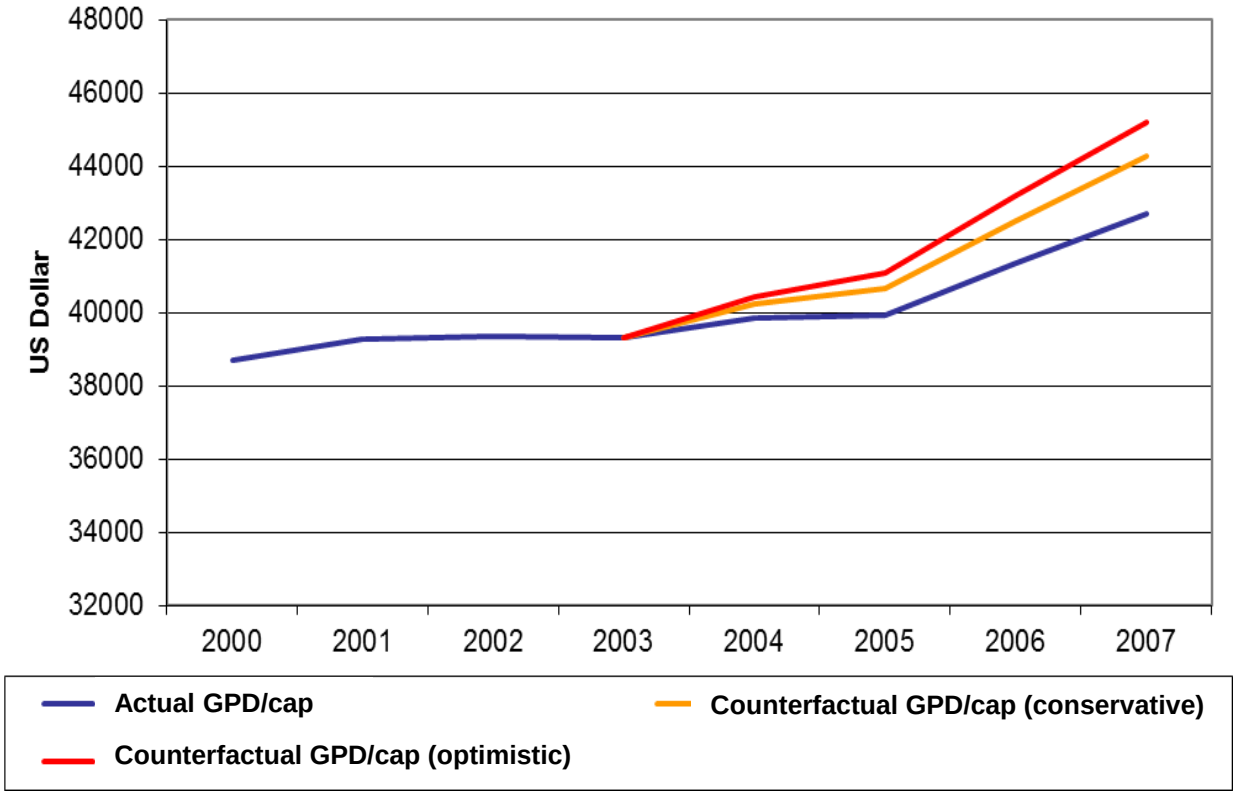
- Indirect effect of voice-telephony and cable TV networks?
  - Through non-broadband channels – e.g., use of other technologies
  - Estimated diffusion curves for mobile telephony and computers

  →No significant effects of penetration of traditional networks on diffusion of mobile telephony and computers
- Independent direct effect of traditional networks?
  - Likely to have subsided; per-capita GDP in 1996 included
  - Non-linear 1st stage allows us to test for any 2nd-stage effects!

  →No significant effects of penetration of traditional networks on growth; predicted broadband penetration keeps significant positive effect

Broadband Diffusion and Growth

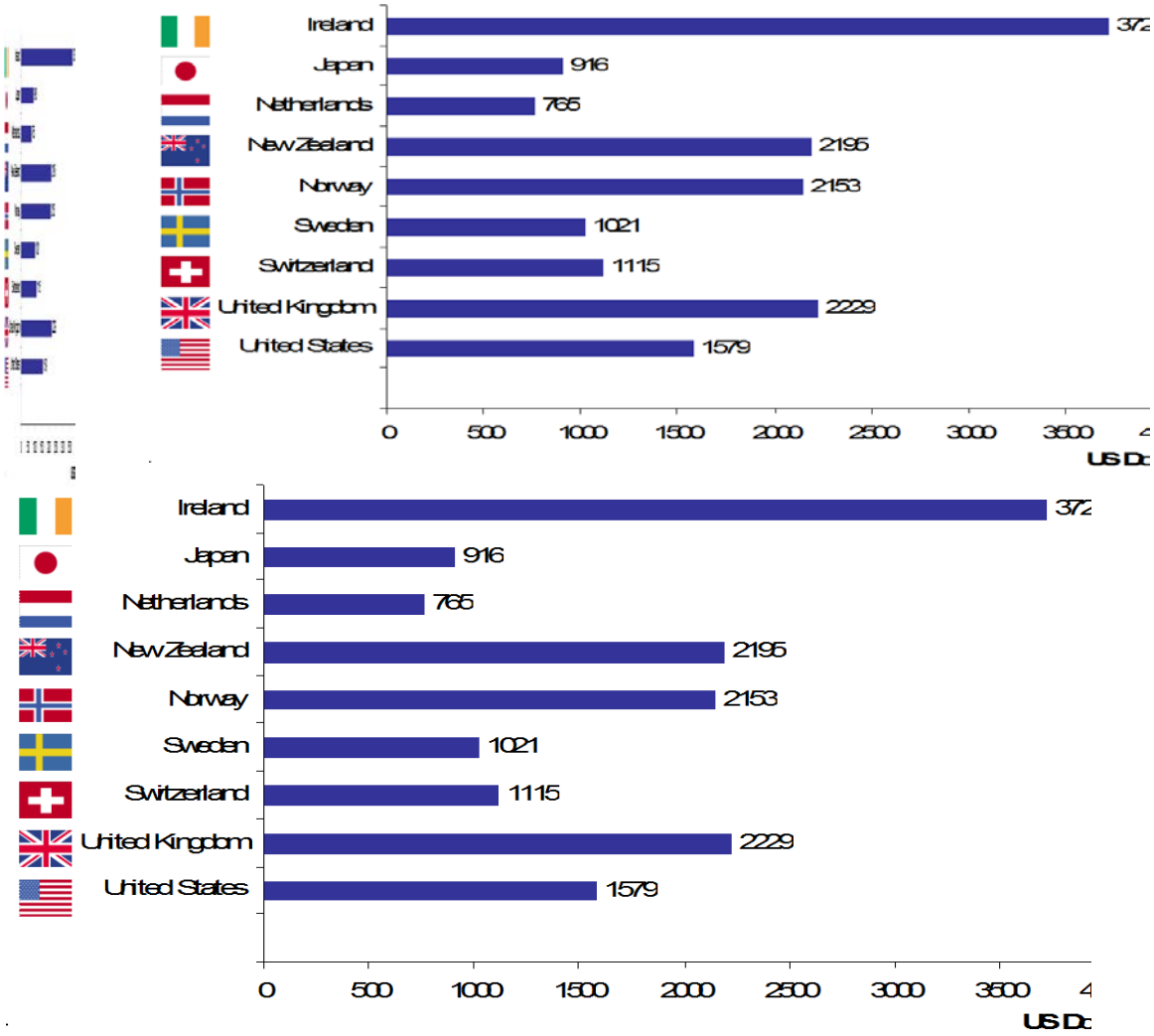
Counterfactual GDP/capita in Germany
(if Germany had had a 10% higher BB penetration in 2003)



Germany missed out on GDP growth opportunities

Quelle: Czernich, Falck, Kretschmer und Wößmann, 2011

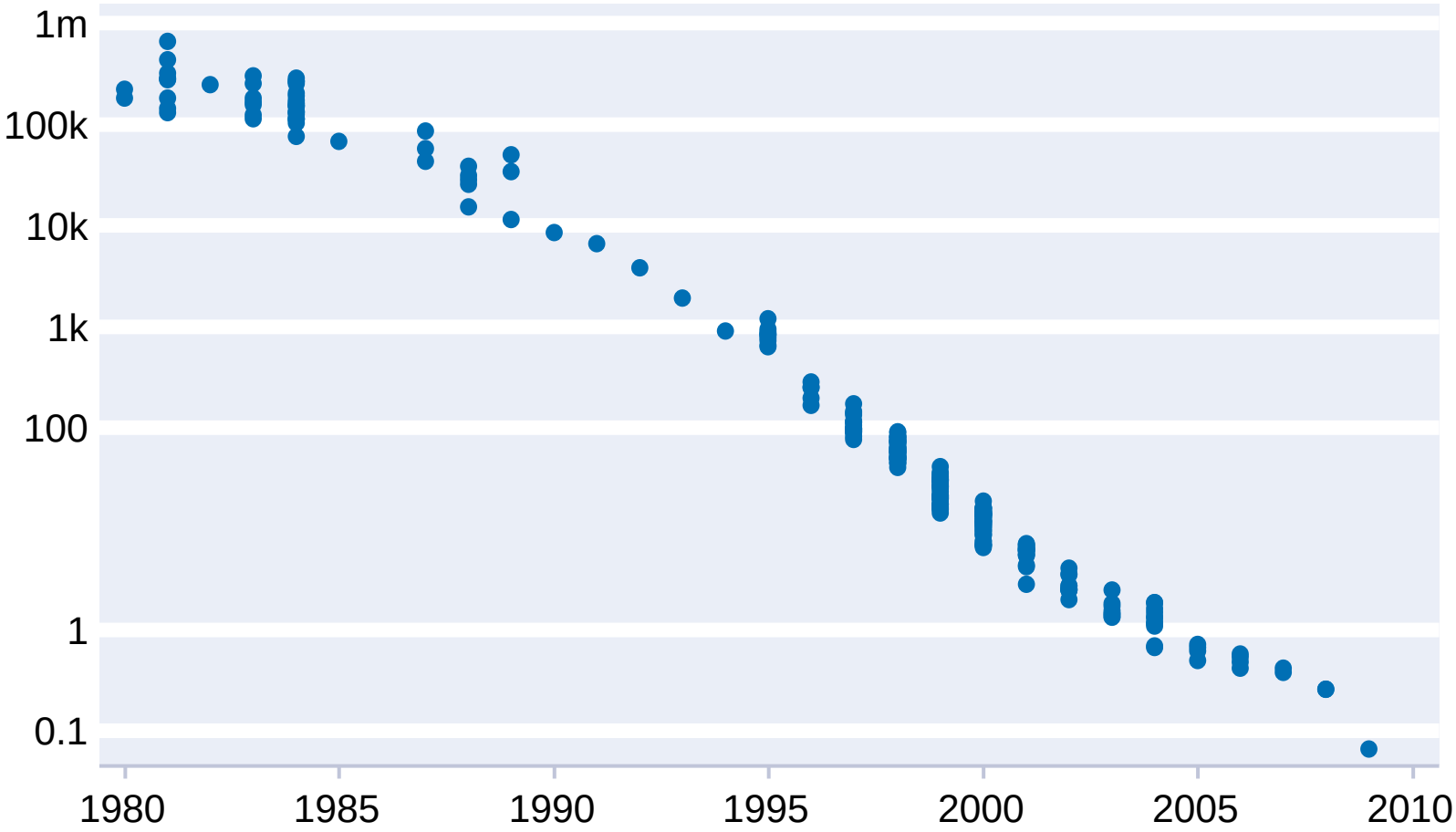
Additional 2007 GDP/cap if Country had BB Penetration of max. (Canada) in 2003



Results and Open Issues

- Positive effect broadband infrastructure on economic growth
  - Introduction of broadband leads to increase of per-capita GDP by 2.7% to 3.9% (controlling for country and year fixed effects)
  - Increase of broadband penetration rate by 10 percentage points leads to increase of GDP growth by 0.9 to 1.5 percentage points
- Results prove highly robust
- Open issues for future research:
  - Longer time frame (here: medium-term effects)
  - Definition of broadband very rough: connection > 256 kbit/s
  - Consider intensive margin of diffusion (here: only extensive)
  - Channels through which broadband increases growth

Saving a single holiday picture in 1980 would have cost $3500



Hard Drive Prices per Gigabyte in USD, 1980-2009
Source: http://www.mkomo.com/cost-per-gigabyte