R&D, innovation, and productivity

Bronwyn H. Hall

University of California at Berkeley, NBER, IFS London, NIESR London, and MPI Munich

R&D, innovation and productivity

Note the broader topic, given the importance of non-R&D based innovation for productivity

- Some facts about R&D/innovation
- Framework for interpreting results
- Brief summary of what we know
- Policies toward both R&D and innovation
  - How they differ
  - Are they effective?

R&D and innovation -> productivity

- What are the mechanisms connecting R&D and innovation with aggregate productivity?
  - Improvements within existing firms
    - Creation of new goods & services, leading to increased demand for firm's products
    - Process and organizational innovation leading to efficiency gains in production
  - Entry of more efficient firms
  - Entry of firms on technology frontier
  - Exit of less efficient firms

Measuring innovative activity

- Large literature using R&D flows or stocks as proxies for innovation input
  - Hall, Mairesse, Mohnen 2010 survey, *inter alia*
- Smaller literature using patents as a proxy for intermediate innovation output
- Both measures have well-known weaknesses, especially outside the manufacturing sector
- Recently more direct measures are available, thanks to CIS firm surveys

R&D vs innovation

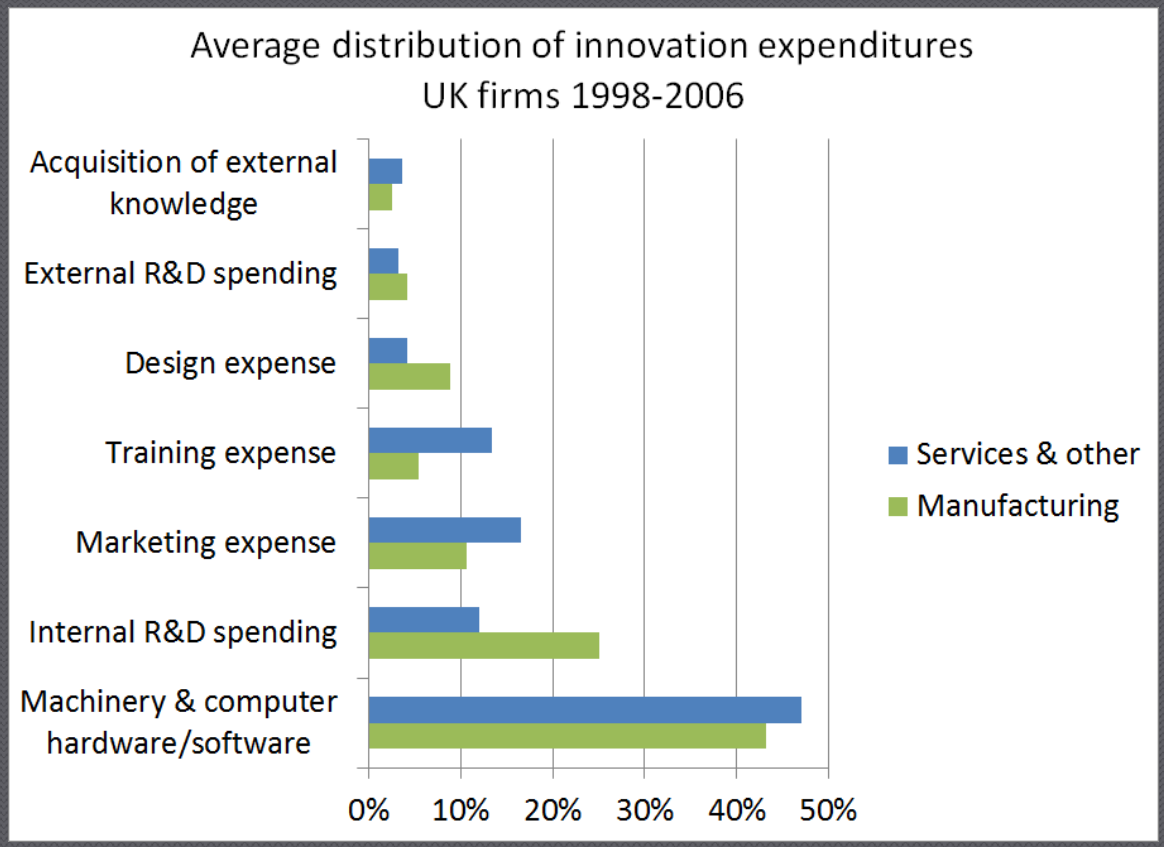
- Not all innovative firms do formal R&D
- R&D-doing firms do not innovate every year (or even every 3 years)
-

Italian firms 1995-2006		
	Non-innovator	Innovator
Does not do R&D	30.9%	34.8%
Does R&D	6.2%	34.3%

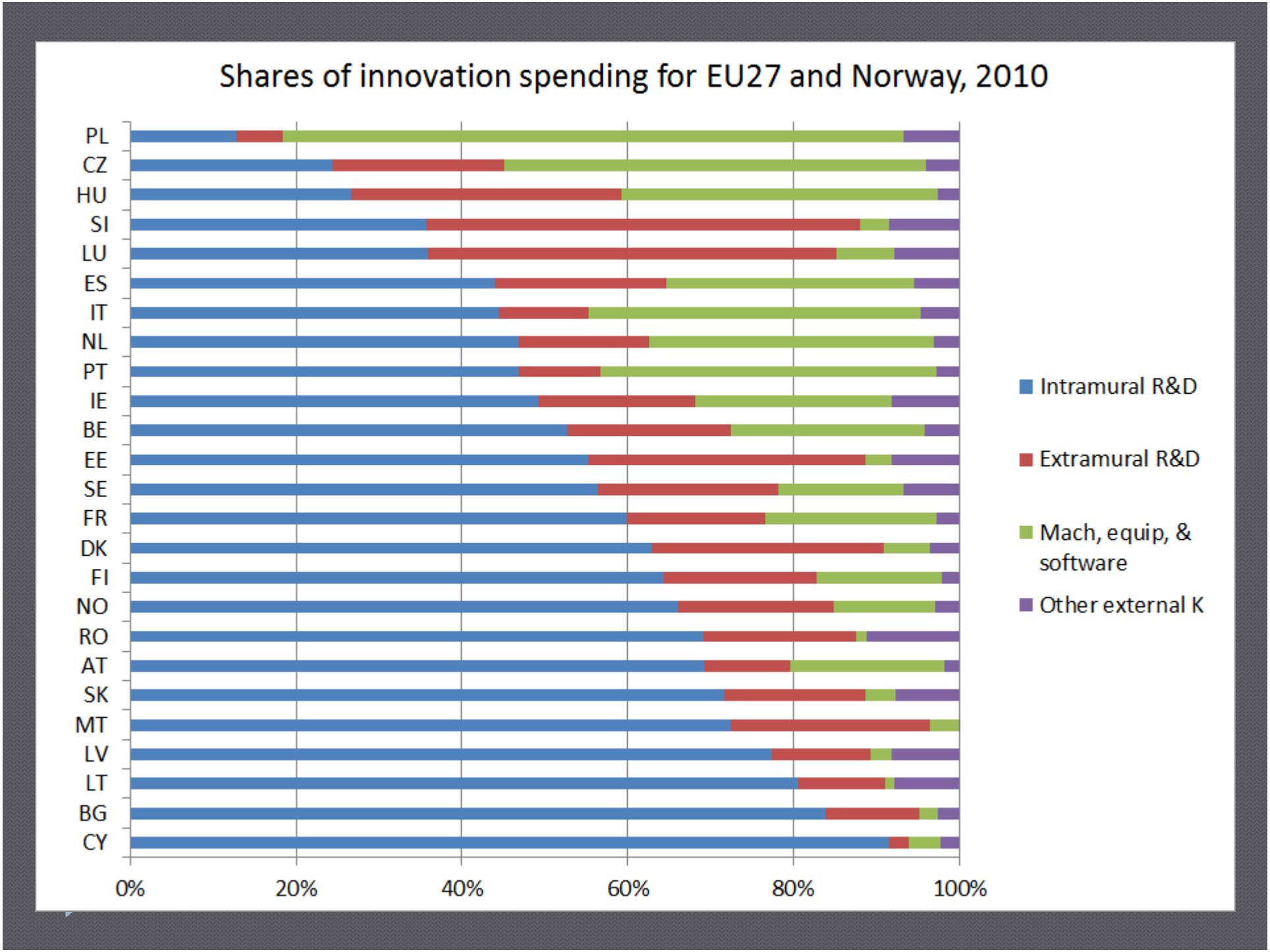
- Especially true in the service sector:
  - Many innovations are not technological, such as new ways of organizing information flow, new designs, etc.
  - Many innovations rely on purchased technology, such as adoption of computer-aided processes, CRM software, etc.

R&D vs innovation spending

- Service sector firms spend more on new equipment, training, and marketing and less on R&D.



The shares shown are for firms that have some form of innovation spending reported.


Shares of innovation spending for EU27 and Norway, 2010
PL
CZ
HU
SI
LU
ES
IT
NL
PT
IE
BE
EE
SE
FR
DK
FI
NO
RO
AT
SK
MT
LV
LT
BG
CY
0%
20%
40%
60%
80%
100%
Intramural R&D
Extramural R&D
Mach, equip, & software
Other external K

What do we know?

- A great deal about
  - Contribution of R&D and innovation to firm-level productivity
  - Contribution of R&D and innovation to the productivity of other industries and countries
- Something about
  - Contribution of entry of more efficient and exit of less efficient firms to aggregate productivity growth
  - Contribution of R&D to quality improvement and therefore productivity growth (via lower prices)
- Much less about
  - Contribution of R&D and innovation to welfare and to poorly measured but important outputs (health, environmental quality, etc)
  - Aggregate growth implications in detail
  - Distribution of the benefits from gains in productivity

Interpretive framework

- Innovation-productivity regressions use revenue productivity data
  - Include coarse sectoral dummies
  - Relative within-sector price changes not accounted for
  - Quality change not generally accounted for
- Omitting price change at the firm level can be helpful, as it allows estimation of the contribution of innovation to firm demand as well as efficiency
- Hall (2011) - analysis of the implications of distinguishing productivity from revenue productivity

Productivity-innovation model

- Innovation affects
  - price the firm can charge (product)
  - quantity the firm produces from a given set of inputs (process)
- Output measure -- revenue (sales or turnover)
  - joint response of price*quantity to product and process innovation
- Labor demand responds both to increased efficiency (negatively) and to increased output (positively, due to output increases)
- Assume the following:
  - Imperfect competition (positive markup)
  - Downward sloping demand with constant elasticity

Conclusions from analysis

- Product innovation unambiguously increases *revenue productivity* and *labor demand*
- Process innovation will increase *revenue productivity* and *labor demand* only if demand is elastic; even in this case impact is dampened unless there is perfect competition (price taking)
- Empirical results largely confirm these predictions
  - Hall (2011), *Nordic Economic Policy Review;* Hall and Mohnen (2013), *Eurasian Business Review*
  - Product innovation and share of innovative sales strongly positive for both output and labor demand
  - Process innovation much less so, sometimes negative
  - R&D (if present) a better predictor, since better measured.

Spillovers

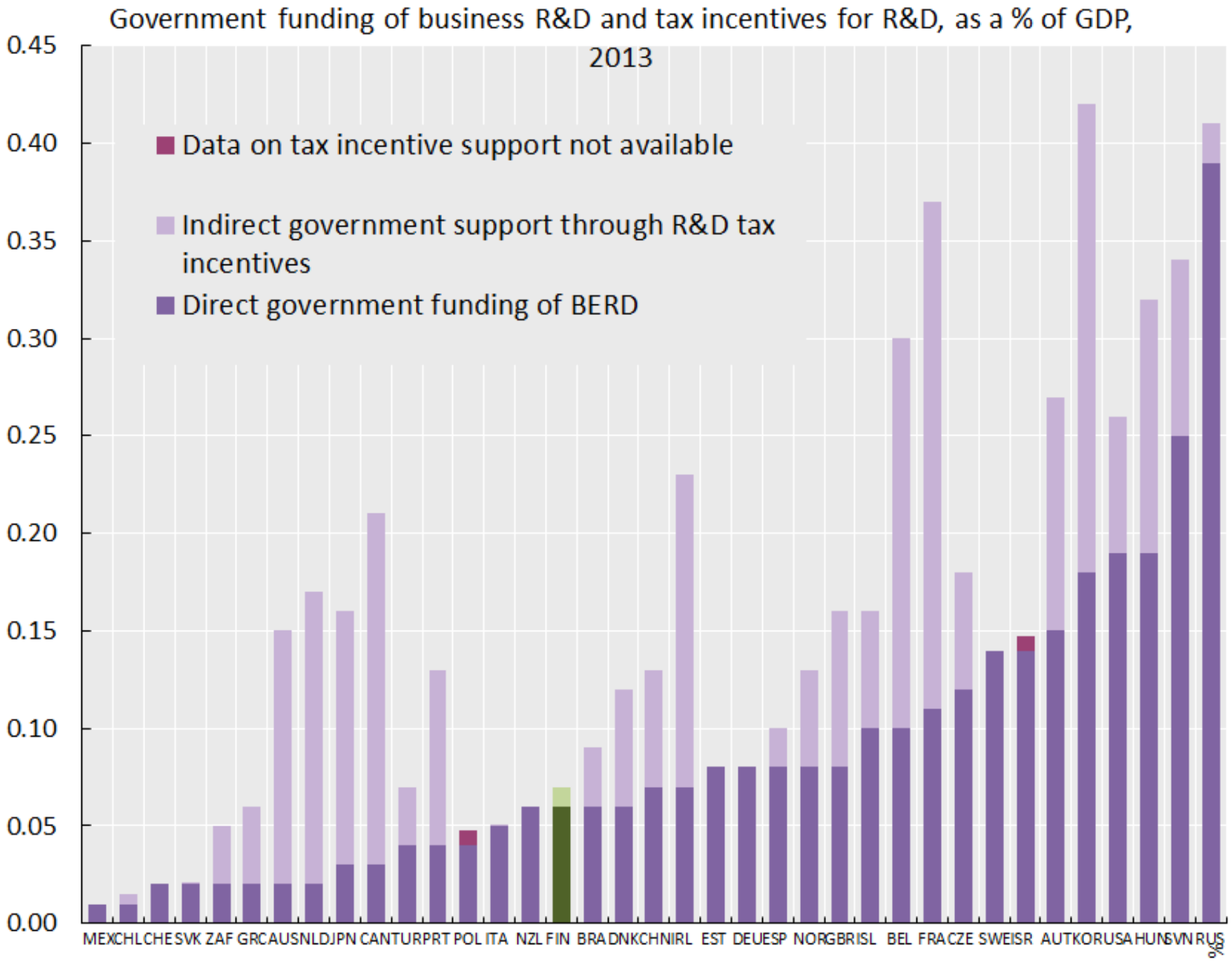
- Principle argument for R&D/innovation policy is the presence of unpriced spillovers to firms that are adjacent in industry, technology, or geographically.
- Lots of evidence that this is true (e.g., Kao et al 1999, Keller 1998, 2001, Coe and Helpman 1995). Some nuances:
  - For foreign R&D, export/import channel is important (Macgarvie 2004)
  - Spillovers from foreign R&D more important for smaller open economies than for countries like US, Japan, and Germany (Park 1995, van Pottelsberghe 1997)
  - Domestic spillovers usually larger than those from other countries (Branstetter 2001, Peri 2004)
  - Absorptive capacity of recipient country is important for making use of R&D spillovers (Guellec and van Pottelsberghe 2001)
  - Typical social rates of return are quite large, but very imprecisely determined

R&D and innovation policy

- Two different emphases
  - Inducing spending on R&D will be successful using fairly direct measures
  - Success in innovation depends to a greater extent on multiple factors in the environment, outside the direct innovation orbit

R&D policy

- Main policies (widely used)
  - Property rights (at the cost of restricted output)
  - Subsidies (often targetted; high administration costs)
  - Tax credits of various kinds
- Brief summary of evidence
  - IP important in some (but definitely not all) sectors
  - Subsidies have a mixed record, but mostly positive in the sense that they increase R&D spending by the firm
  - R&D tax credits unambiguously increase R&D spending, usually with price elasticity around unity
- With the exception of some subsidy programs, these policies target the private rate of return, not the social


Government funding of business R&D and tax incentives for R&D, as a % of GDP, 2013
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Data on tax incentive support not available
Indirect government support through R&D tax incentives
Direct government funding of BERD
MEX CHL CHE SVK ZAF GRC AUS NLD JPN CAN TUR PRT POL ITA NZL FIN BRA DNK CHN IRL EST DEU ESP NOR GBR ISL BEL FRA CZE SWE ISR AUT KOR USA HUN SVN RUS
%

R&D and innovation policy

- Some governments have turned to IP or patent boxes in order to broaden supported activities.
- However, R&D tax credits *strongly preferred* to patent boxes for a number of reasons:
  - Directly related to cost of activity (firm decisions)
  - Relative size of non-R&E budget does not affect credit (depending on box design)
  - No incentive to choose projects with high non-R&E expenses (depending on box design)
  - No tax subsidy for patent trolling
  - No incentive to use zombie patents to reduce taxes
  - Less arbitrage across firms possible – doesn't matter who does the R&D
  - Lower audit cost

Broader policy context

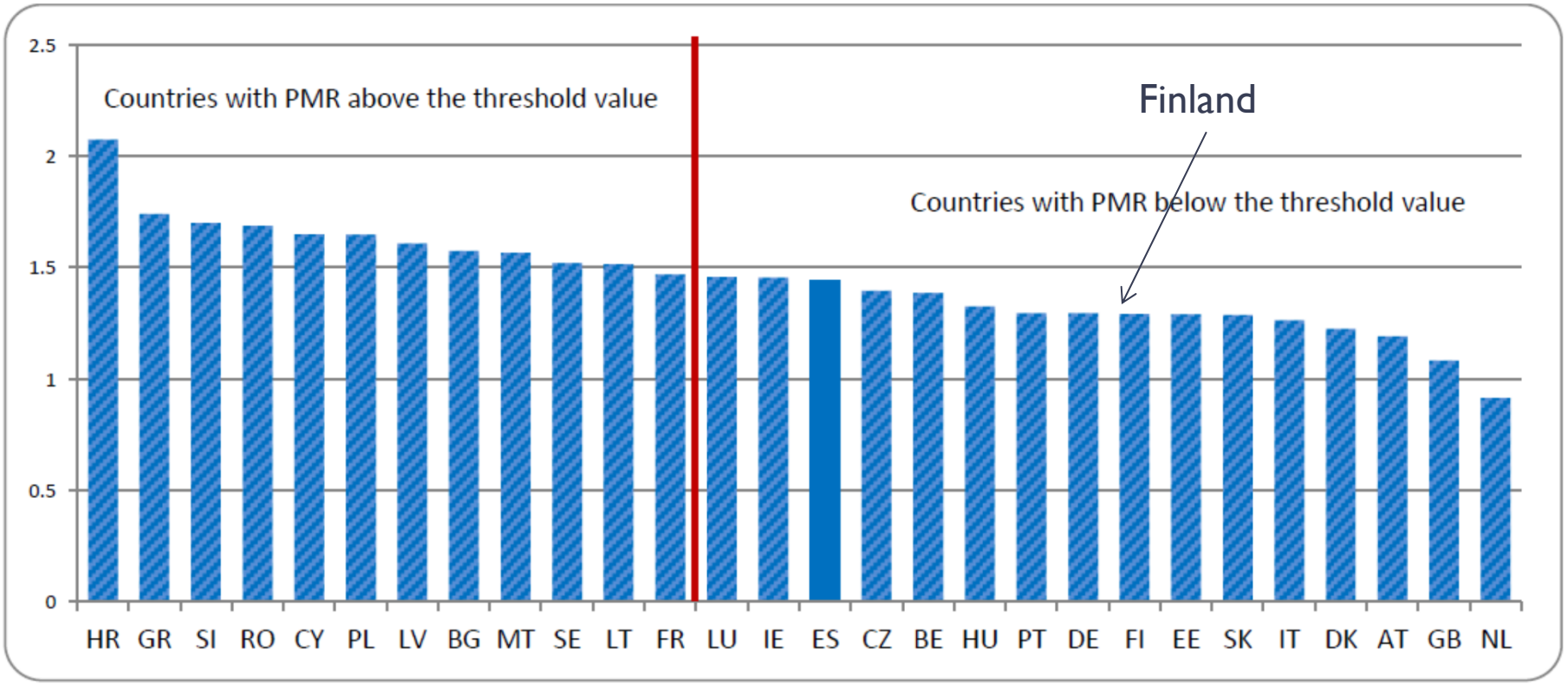
- Innovative activity (including diffusion) affected by many things, not all of which are viewed as susceptible to "innovation policy"
  - Timely bankruptcy procedures and contract enforcement
  - Entry costs and regulation
  - Product market regulation
  - Labor market regulation – startups need flexibility
    - Corollary: lifetime training availibility
  - Political resistance from affected firms and workers
- Data on these factors now available, thanks to OECD and IMF

Institutions and innovation

- Barbosa and Faria (2011) – look at product/process innovation 2002-2004 in 10 European countries
  - Product and labor market regulation affects innovation intensity negatively
  - More developed credit markets foster innovation
  - Strengthening of intellectual property rights does not seem to stimulate innovation
- Ciriaci et al. (2016) – Above a threshold of PMR, EPL is negative for R&D location.

Product market regulation in 2013 and threshold value for EPL impact (EU 28)

- PMR measure: 1) state control; 2) barriers to trade and investment; 3) barriers to entrepreneurship
- EPL measure: costs of firing and of hiring on fixed term or temp contracts



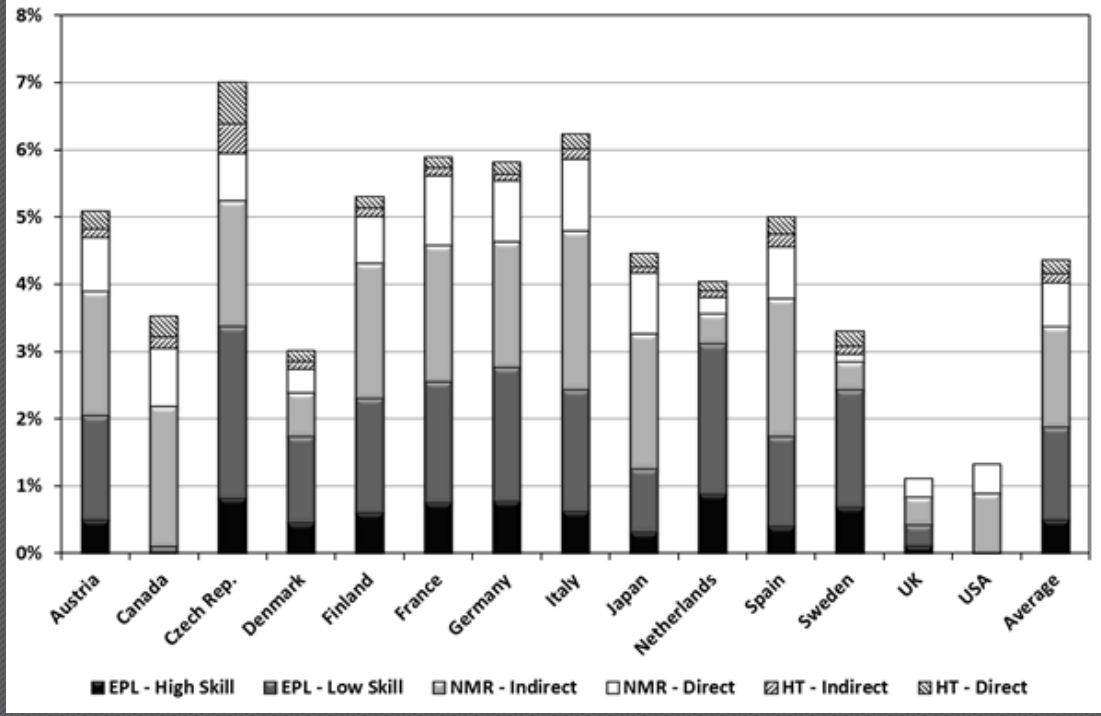
Allocative efficiency & regulation (AE)

- Can resources (capital and workers) move to their most productive use?
- Andrews & Cingano (2014) – controls for endogeneity of policies
  - Higher barriers to entry and creditor-friendly bankruptcy legislation tend to lower AE
  - Tighter employment protection lowers the efficiency of employment allocation
  - Stringent product & labor market regulation, bankruptcy legislation more disruptive to AE in innovative sectors

Cette, Lopez, Mairesse (2016)

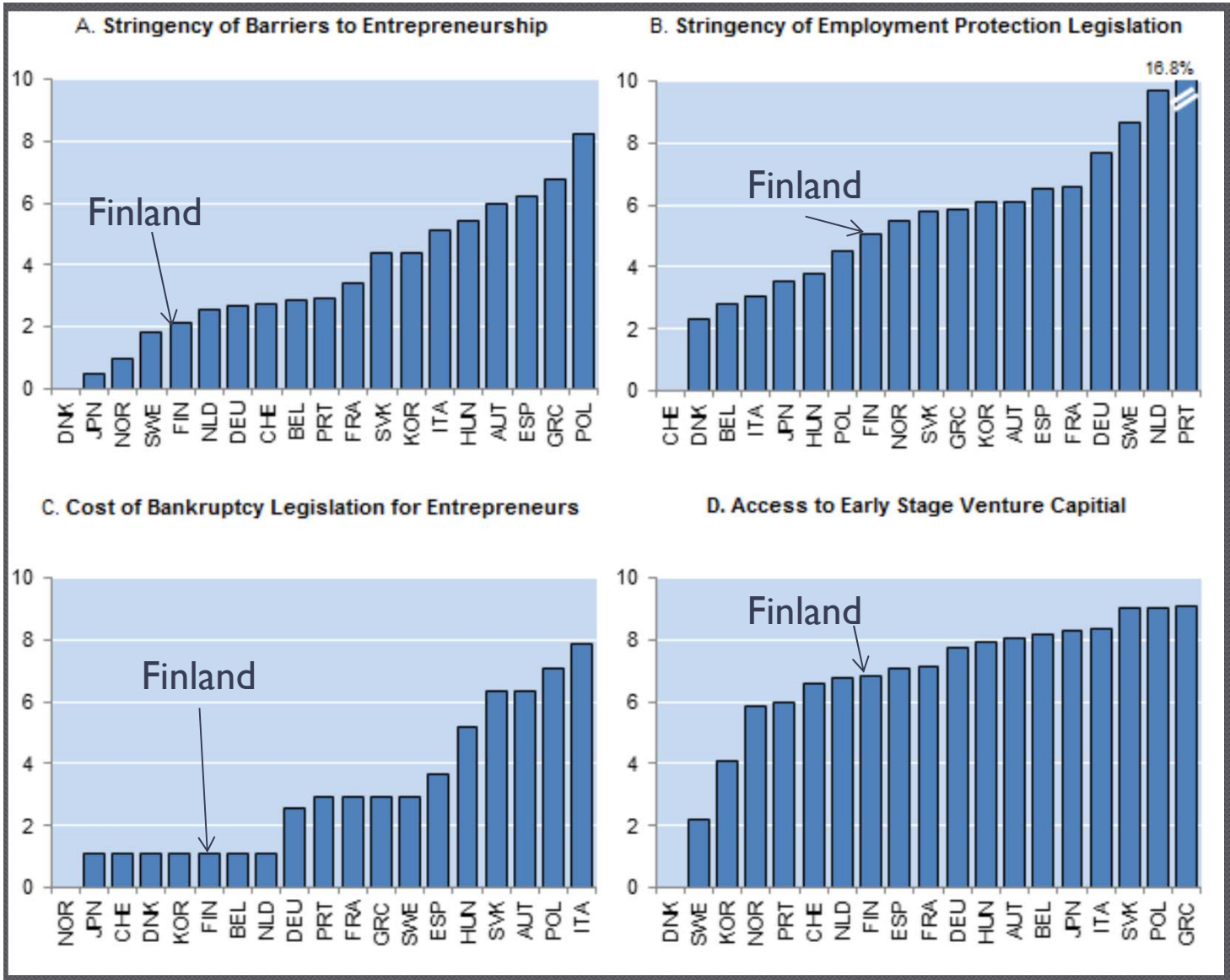
- Industry-country study for 14 OECD countries, 18 industries, both mfg and services
  - Impact of non-mfg regulation, harmonized tariffs and EPL on TFP is negative
  - Finland: both non-manufacuring regulation and EPL depress MFP

Potential TFP gain from move to lightest regulation



Institutions and catch-up

- Andrews, Criscuolo, and Gal (2015) – study gap between firms on tech frontier and other firms in OECD countries
- Productivity gaps between national frontier and global frontier firms smaller in countries where
  - education systems are of higher quality;
  - product market regulations are less cumbersome;
  - businesses and universities collaborate intensively;
  - markets for risk capital are more developed.
  - Mixed results on patent strength: lower gap in R&D intensive sectors, but not in more dynamic sectors
- Country-industry results:
  - Lower PMR associated with higher MFP growth for firms in industries with high firm turnover rates,
  - Lower EPL associated with higher MFP growth for firms in industries with high job turnover rates,
  - Higher R&D collaboration between universities and firms is associated with higher MFP growth for laggard firms in K-intensive industries



Cross-country gains to aggregate labour productivity from reforms to best practice level of four policy variables that partly explain cross-country industry differences in the size of national frontier (NF) firms, relative to global frontier (GF) benchmark. Source: Andrews et al. (2015)

Finland's position is mixed, relative to global frontier firms (lower is better)

Tentative suggestions for Finland

"Conclusions" would be too strong a word – these are topics for discussion

- Framework conditions fairly favorable for innovation, could be improved - appear to reduce level of TFP by about 5%, after controling for other inputs
  - PMR (retail, transport, construction, according to OECD 2016 report)
  - EPL (or just labor costs in general?)
- Publicly funded R&D as a share of GDP surprisingly low
  - Why is the takeup of the R&D tax credit so low?

Thank you for listening

(a bit more on aggregate effects and CDM results below)

Aggregation

- How does individual firm relationship aggregate up to macro-economy?
  - productivity gains in existing firms
  - exit and entry
- Aghion et al (2009); Gorodnichenko et al (2010)
  - Competition and entry encourages innovation unless the sector is very far behind
- Djankov (2010) survey – cross country
  - stronger entry regulation and/or higher entry costs associated with fewer new firms, greater existing firm size and growth, lower TFP, lower investment, and higher profits

Entry and exit

- Olley & Pakes, Haltiwanger & co-authors have developed decompositions that are useful
- Foster, Haltiwanger, and Syverson (2008) – US data
  - Distinguish between revenue and quantity, and include exit & entry
  - Revenue productivity understates contribution of entrants to real productivity growth because entrants generally have lower prices
  - Demand variation is a more important determinant of firm survival than efficiency in production (consistent with productivity impacts)

Future work?

- Full set of links between innovation, competition, exit/entry, and productivity growth not yet explored
- Bartelsman et al. (2010): Size-productivity more highly correlated within industry if regulation is "efficient"
  - Evidence on Eastern European convergence
  - Useful approach to the evaluation of regulatory effects without strong assumptions
- Similar analysis could assess the economy-wide innovation impacts

Innovation surveys contain…..

- Data on innovation:
  - Product or process new to firm/market (yes/no)
  - Share of sales during past 3 years from new products
  - More recent surveys have expenditures on various kinds of innovation investments
- Data on productivity and employment:
  - Usually sales per worker (labor productivity)
  - Sometimes TFP (adjusted for changes in capital)
  - Issues arising from deflation and level of aggregation
    - of goods, and of enterprises

More information in Mairesse and Mohnen (2010)

What do the data say about the relationship?

- Results from a large collection of papers that used the CDM model for estimation (Crepon Duguet Mairesse 1998):
  - Innovation survey data reveals that some non-R&D firms innovate and some R&D firms do not innovate during the relevant period
  - Data is usually cross-sectional, so possible simultaneity between R&D, innovation, and productivity (productivity sometimes measured a year later)
  - Sequential model: R&D→innovation→productivity

The CDM model

1. The determinants of R&D choice: whether to do it and how much to do (generalized Tobit)
2. Innovation production function with innovation variables as functions of predicted R&D intensity (regression or probits)
3. Production function including the predicted innovation outcomes to measure their contribution to the firm's productivity.

Effectively a triangular simultaneous equations model, but nonlinear. (bootstrap s.e.s if sequentially estimated)

CDM model applied to CIS data

- Estimated for 20+ countries
- Confirms high rates of return to R&D found in earlier studies
- Like patents, innovation output statistics are much more variable ("noisier") than R&D,
  - R&D tends to predict productivity better, when available
- Next few slides - results summary
  - regressions of individual firm TFP on innovation
- Sources: Hall (2011), *Nordic Economic Policy Review* and Hall and Mohnen (2013), *Eurasian Business Review*

Productivity-innovation relationship in TFP levels

Sample	*Time period*	*Elasticity with respect to innov sales share*	*Process innovation dummy*
Chilean mfg sector	1995-1998	0.18 (0.11)*	
Chinese R&D-doing mfg sector	1995-1999	0.035 (0.002)***	
Dutch mfg sector	1994-1996	0.13 (0.03)***	-1.3 (0.5)***
Finnish mfg sector	1994-1996	0.09 (0.06)	-0.03 (0.06)
French mfg sector	1986-1990	0.07 (0.02)***	
German K-intensive mfg sector	1998-2000	0.27 (0.10)***	-0.14 (0.07)**
Norwegian mfg sector	1995-1997	0.26 (0.06)***	0.01 (0.04)
Swedish K-intensive mfg sector	1998-2000	0.29 (0.08)***	-0.03 (0.12)
Swedish mfg sector	1994-1996	0.15 (0.04)***	-0.15 (0.04)***
Swedish mfg sector	1996-1998	0.12 (0.04)***	-0.07 (0.03)***
Swedish service sector	1996-1998	0.09 (0.05)*	-0.07 (0.05)
Innovative sales share and process innovation included separately in the production function:			
French Hi-tech mfg	1998-2000	0.23 (0.15)*	0.06 (0.02)***
French Low-tech mfg	1998-2000	0.05 (0.02)***	0.10 (0.04)***
Irish firms	2004-2008	0.11 (0.02)***	0.33 (0.08)***

TFP levels on innov sales share

- Robustly positive, supports the view that product innovation shifts the firm's demand curve out and increases revenue
  - Elasticities range from 0.04 to 0.29 with a typical standard error of 0.03
  - R&D-intensive and hi-tech firms have higher elasticities (consistent with equalized rates of return across sectors)
- Coefficient of process innovation dummy usually insignificant or negative, suggesting either inelastic demand and/or substantial measurement error in the innovation variables

Productivity-innovation using dummies

Sample	*Time period*	*Product innovation dummy*	*Process innovation dummy*
Argentinian mfg sector	1998-2000	-0.22 (0.15)	
Brazilian mfg sector	1998-2000	0.22 (0.04***	
Estonian mfg sector	1998-2000	0.17 (0.08)**	-0.03 (0.09)
Estonian mfg sector	2002-2004	0.03 (0.04)	0.18 (0.05)***
French mfg sector	1998-2000	0.08 (0.03)**	
French mfg sector	1998-2000	0.06 (0.02)***	0.07 (0.03)**
French mfg sector	1998-2000	0.05 (0.09)	0.41 (0.12)***
French mfg sector	2002-2004	-0.08 (0.13)	0.45 (0.16)***
French service sector	2002-2004	0.27 (0.52)	0.27 (0.45)
German mfg sector	1998-2000	-0.05 (0.03)	0.02 (0.05)
Italian mfg sector	1995-2003	0.69 (0.15)***	-0.43 (0.13)***
Italian mfg sector SMEs	1995-2003	0.60 (0.09)***	0.19 (0.27)
Mexican mfg sector	1998-2000	0.31 (0.09)**	
Spanish mfg sector	2002-2004	0.16 (0.05)***	
Spanish mfg sector	1998-2000	0.18 (0.03)***	-0.04 (0.04)
Swiss mfg sector	1998-2000	0.06 (0.02)***	
UK mfg sector	1998-2000	0.06 (0.02)***	0.03 (0.04)
Innovative sales share and process innovation included separately in the production function:			
Irish firms	2004-2008	0.45 (0.08)***	0.33 (0.08)***

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Sample	*Time period*	*Product innovation dummy*	*Process innovation dummy*
German mfg sector	2006-2008	0.04 (0.02)*	
German mfg sector	2006-2008		0.09 (0.05)**
German service sector	2006-2008	0.21 (0.07)***	
German service sector	2006-2008		0.16 (0.06)***
Irish mfg sector	2006-2008	0.18 (0.22)	
Irish mfg sector	2006-2008		0.24 (0.24)
Irish service sector	2006-2008	0.51 (0.30)*	
Irish service sector	2006-2008		0.19 (0.28)
UK mfg sector	2006-2008	0.05 (0.02)***	
UK mfg sector	2006-2008		0.07 (0.02)***
UK service sector	2006-2008	0.07 (0.03)**	
UK service sector	2006-2008		0.04 (0.02)*

Source: Peters et al. 2014

TFP level results with dummies

- Product dummy supports innovation sales share result, although much noisier.
- There is substantial correlation between product and process innovation, especially when they are instrumented by R&D and other firm characteristics.
  - Without instruments, innovation dummies frequently do not enter productivity equation at all.

NB: Correlated measurement error can lead to bias in both coefficients (upward for the better measured one and downward for the other) – see Hall (2004)
http://bronwynhall.com/papers/BHH04_measerr.pdf

Employment impacts

- Harrison et al (IJIO 2014) and Hall, Lotti, Mairesse (ICC 2008) - decompose employment change as a function of process and product innovation, using coefficients from a regression of employment growth on innovative sales growth and process innovation:

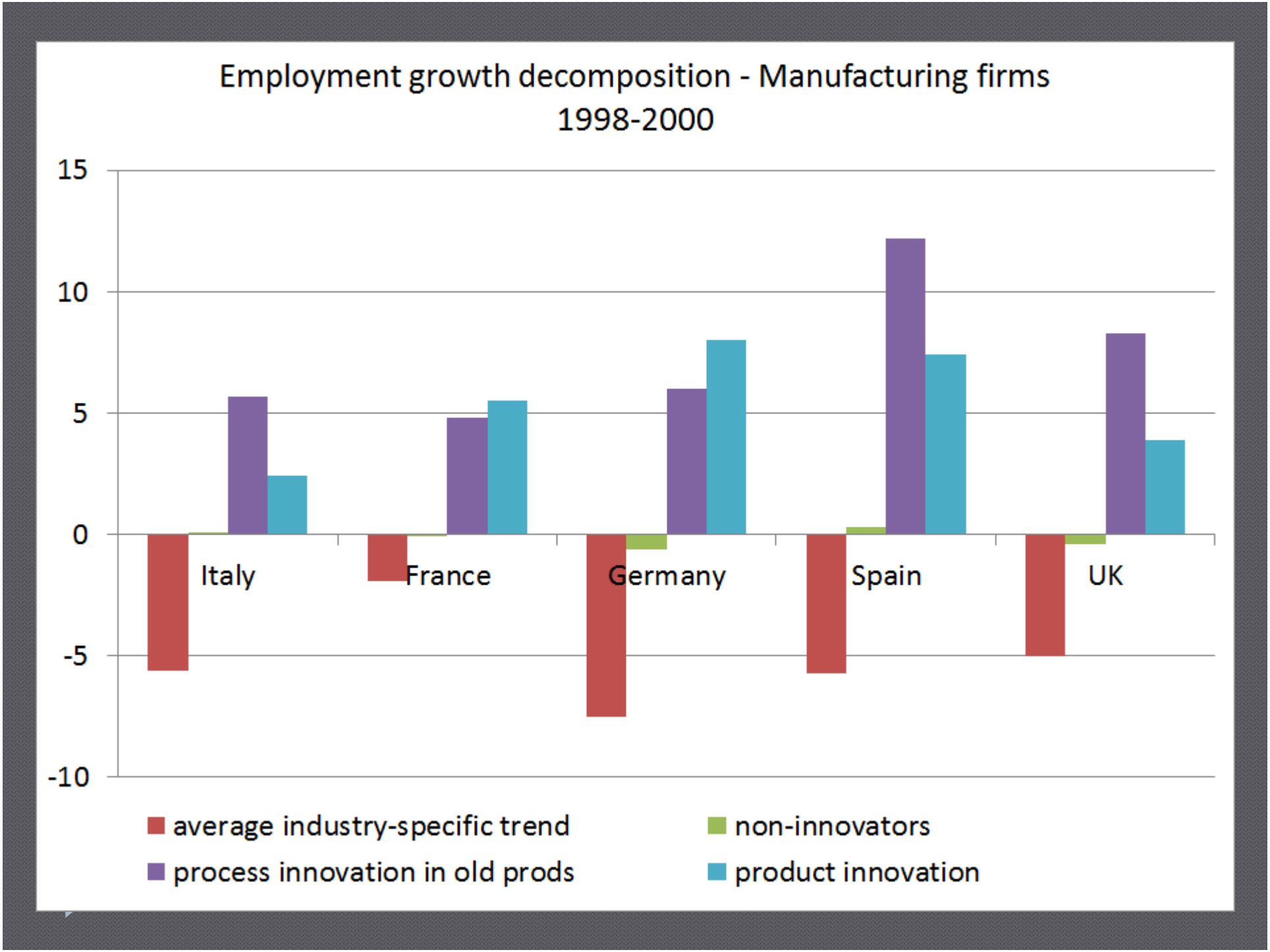
  Growth = industry productivity trend in old products

  + growth due to process innovation in old products

  + growth due to output growth of old products

  + growth due to product innovation (net of substitution away from old products)

- A reinterpretation of the labor productivity equation to focus on employment


Employment growth decomposition - Manufacturing firms
1998-2000
15
10
5
0
-5
-10
Italy
France
Germany
Spain
UK
average industry-specific trend
non-innovators
process innovation in old prods
product innovation

Summary

- Elasticity wrt innovative sales centers on (0.09, 0.13)
  - higher for high tech and knowledge-intensive firms
  - Lower on average for low tech and developing countries, but also more variable
- With product innovation included, process innovation often negative or zero
- Without product innovation, process innovation positive for productivity
- When not instrumented, little impact of innovation variables in production function (unlike R&D)
  - See Mairesse & Mohnen (2005), Hall et al. (2012)
- Both process and product innovation are positive on average for firm employment growth in manufacturing,
  - at least during the late 1990s in Europe
- What if we had spending on innovation (rather than just R&D, a component of innovation spending)?

UK evidence

- Definition of IS: internal & external R&D; new equip & software; design expense; training; acq of patents & knowhow; marketing – all associated with intro of new products or processes
- Out of 10,500 firm obs 2001-2006
  - 6500 have some form of innovation spending (IS)
  - 3400 have internal R&D
  - R&D firms: median IS is 5 times median R&D
- Compared to R&D:
  - IS more strongly associated with info from suppliers and innovation to meet environmental or H&S stds; less strongly with exports, collaboration, and info from customers (that is, more process than product)
  - IS is a better predictor of innovation probability
  - Doubling IS has the same impact on TFP as doubling R&D – increase of 0.05

Discussion

- R&D spending remains a better predictor of productivity improvement at the firm level
- Innovation dummies may be too noisy a measure to be very useful.
  - Share of sales due to new products is more informative.
  - What measure would be useful (and reportable) for process innovation?
- Further exploration with innovation investment (instead of R&D) is warranted