



# Innovation and productivity in firms

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## Outline

- Intro
- Innovation
- Productivity
- Modeling the relationship
- Empirical evidence

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## Motivation

- Why this topic?
- Productivity growth a major determinant of economic welfare
- Innovative activity (new goods and services, improvements to production efficiency) widely thought to contribute to productivity growth
- Is this true? And by how much?

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## Introduction

- What are the mechanisms connecting innovation and 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 and firms on technology frontier
  - Exit of less efficient firms

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## Definition of innovation

- The first attempt to put a new product or process into practice (Fagerberg, Mowery, and Nelson, *Oxford Handbook of Innovation*, Chapter 1)
- “An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.” (*Oslo Manual*, OECD 2005, third edition, p. 46)

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## Measuring innovation

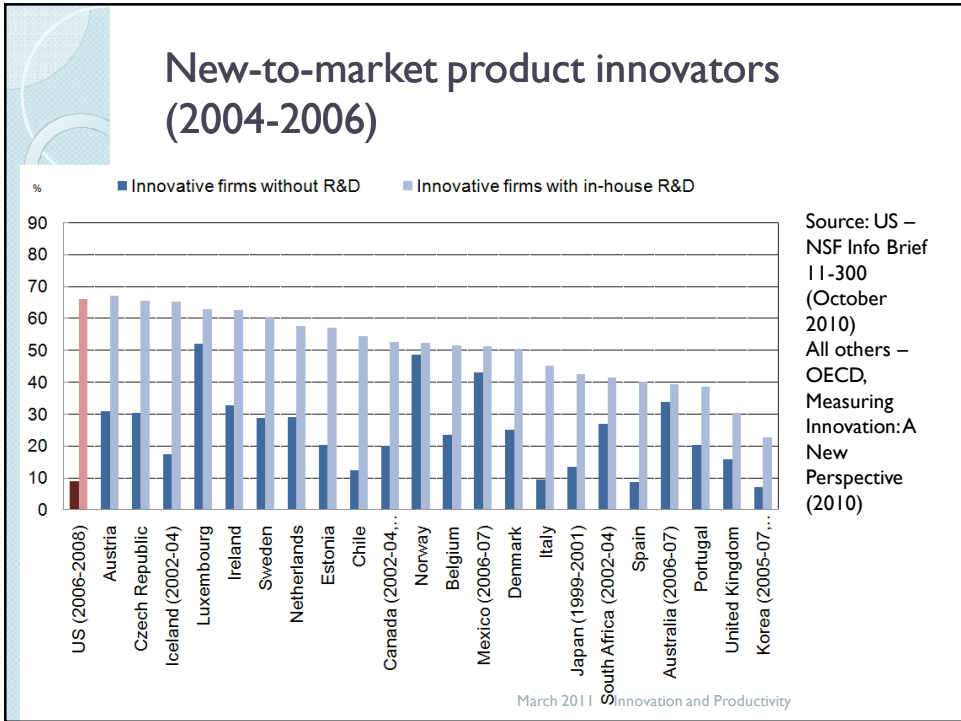
- Large literature using R&D (capital) as a proxy for innovation input
  - Hall, Mairesse, Mohnen 2010 survey
- Smaller literature using patents as a proxy for intermediate innovation output
- Both measures have weaknesses, especially outside manufacturing sector.
- Now we have more direct measures – do they help?

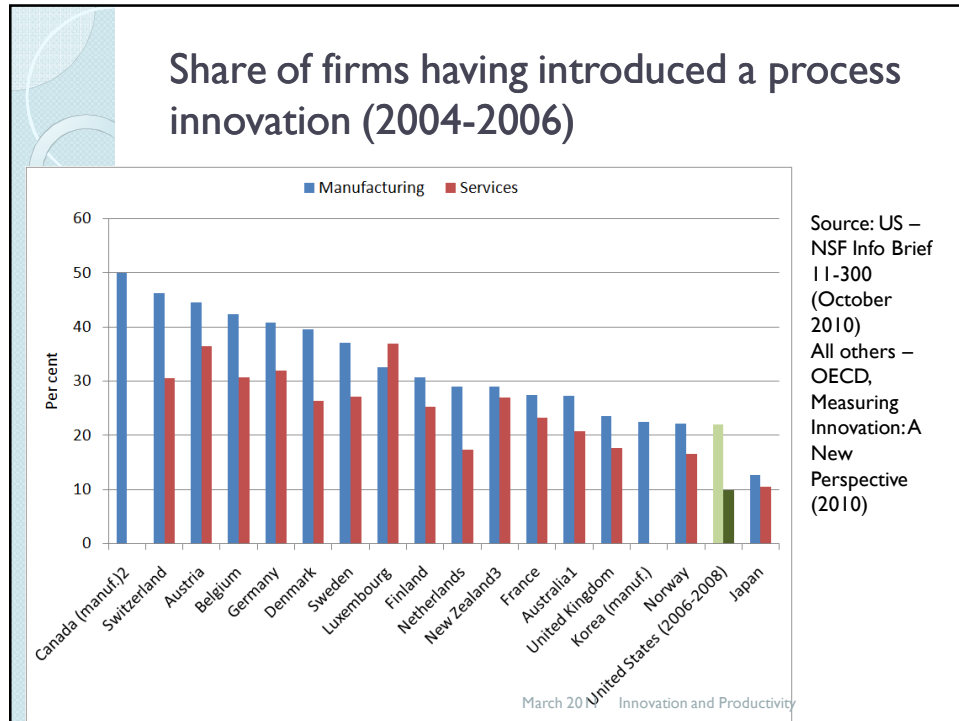
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## Measuring innovation

- Earlier work:
  - SPRU – obtained by asking industry participants
  - Acs & Audretsch – 1982 trade journals, etc.
- Innovation surveys (CIS in Europe, also in Latin American and other countries, in US as of 2008):
  - Product or process new to market (yes/no)
  - Share of sales during past 3 years from new products
  - Later surveys have expenditures on various kinds of innovation investments – nonresponse problems
- Next two figures add the new US data to graphs produced by OECD in *Measuring Innovation*

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## Productivity

- Output that can be produced given a set of inputs combined efficiently
- Measures:
  - Labor productivity – output per employee or person-hour
  - Multi-factor productivity – adjusted for capital and other inputs
- Modeled by simple Cobb-Douglas in logs:

$$q_{it} = \alpha c_{it} + \beta l_{it} + a_{it}$$

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## Estimating productivity

- Two approaches:
  - Growth accounting – use shares to estimate coefficients and compute an estimate of  $a_{it}$
  - Regression – output on labor, capital, materials, etc to obtain coefficient estimates
- Measurement issues:
  - Quality adjustment for RHS variables – affects allocation of productivity gains
  - Usual data gives sales deflated by industry-level deflator, but innovative activity may affect firm output quality (and possibly market power)

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## Adding demand and innovation

- Denote innovative capital by  $k_{it}$ 
  - Add to production with coefficient  $\gamma$
- Isoelastic demand curve  $q_{it} = \eta p_{it} + \varphi k_{it}$ 
  - $\eta < 0, \varphi > 0$
- Revenue  $r_{it} = q_{it} + p_{it}$
- Then model for estimation becomes

$$r_{it} = \left( \frac{\eta + 1}{\eta} \right) (a_{it} + \alpha c_{it} + \beta l_{it}) + \left( \frac{\gamma(\eta + 1) - \varphi}{\eta} \right) k_{it}$$

- => innovative capital increases efficiency (if demand is elastic) and also increases demand for firm's product
- If demand is inelastic, shifting supply and demand curves out may result in lower price and lower revenue

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## Reviewing the evidence

- Focus here on micro evidence using CDM model (Crepon Duguet Mairesse 1998)
  - Innovation survey data reveals that some non-R&D firms innovate and some R&D firms do not innovate
  - Data is usually cross-sectional, so simultaneity between R&D, innovation, and productivity
  - Model attempts to accommodate these features of the data

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## CDM Model

- Stylized summary
  - Doing R&D and R&D intensity =  $f$  (firm size, industry, other characteristics)
  - Innovating and Innovation intensity =  $f$  (predicted R&D, other firm characteristics)
  - Labor productivity =  $f$  (capital or investment, predicted innovation, .....

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## What have we learned from CIS about the innovation measures?

- R&D-productivity revisited
  - CDM model of R&D  $\Rightarrow$  innovation  $\Rightarrow$  productivity
  - estimated for ~12 countries (or more)
  - confirmed rates of return to R&D found in earlier studies
  - Like patents, innovation output statistics are much more variable (“noisier”) than R&D, and R&D tends to predict productivity better

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## Papers estimating the CDM model and variants

- Crepon, Duguet, Mairesse 1998
- Duguet 2006
- Loof et al 2001
- Janz et al 2003
- Loof and Heshmati 2003
- Criscuolo and Haskel 2003
- Huergo and Jaumandreu 2004
- Benavente 2006
- Jefferson, Bai et al 2006
- Loof and Heshmati 2006
- Van Leeuwen and Klomp 2006
- Parisi et al 2006
- Griffith et al 2006
- Mairesse et al 2009
- Polder et al 2009
- Mairesse and Robin 2010
- Hall et al 2011

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## Level vs growth

- CDM is in terms of productivity *levels* primarily for data availability reasons
- It seems more natural to think of innovative activity as affecting productivity growth
- Some work along these lines, but matching across surveys usually leaves a very selected sample, possibly not representative

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## TFP level results

	Elasticity wrt Innov sales share	Process innovation dummy
Swedish mfg sector 1996-98	0.12	
Swedish service sector 1996-98	0.09	
Swedish mfg sector 1994-96	0.18	-0.16
Swedish K-intensive mfg sector 1998-2000	0.29	0
Norwegian mfg sector 1995-97	0.26	0
Finnish mfg sector 1994-96	0	0
German K-intensive mfg sector 1998-2000	0.27	-0.14
Dutch mfg sector 2002-06	0.13	-1.2
French HT mfg 1998-2000	0.23	0.06
French LT mfg 1998-2000	0.05	0.10
Italian mfg sector 1995-2006	0.18	-0.31
Chilean mfg sector 1995-98	0.18	
Chinese R&D-doing mfg sector 1995-99	0.04	

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## TFP levels on innov sales share

- Robustly positive, supports the view that product innovation shifts the firm's demand curve out
  - Elasticities range from 0.04 to 0.29 with a typical standard error of 0.03
  - K-intensive and hi-tech firms have higher elasticities (equalized rates of return)
- Coefficient of process innovation dummy usually insignificant or negative, suggesting market power – profits may increase, but revenue productivity does not

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## TFP level results

	Product innovation dummy	Process innovation dummy
French mfg sector 1998-2000	0.06	0.07
German mfg sector 1998-2000	0	0.02
Spanish mfg sector 1998-2000	0.18	0
UK mfg sector 1998-2000	0.06	0
French mfg sector 1998-2004	0	0.45
French service sector 1998-2004	0	0
Italian mfg sector SMEs 1995-2003	0.60	0.19
Italian mfg sector 1995-2003	0.38	0.01

Product dummy supports innovation sales share result, although noisier. There is substantial correlation between product and process innovation, especially when they are instrumented.

SMEs look somewhat different from large firm samples.

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## TFP growth results

	Elasticity wrt Innov sales share	Product innovation dummy	Process innovation dummy
Swedish mfg sector 1996-98	0.07		
Swedish service sector 1996-98	0.08		
Italian mfg sector 1992-97		0.17	0
Spanish mfg sector 1990-98		0.015	
UK mfg sector 1994-2000	0/0.065		0.016/ -.038
French mfg sector 1986-90		0.02	
French mfg sector 1986-90	0.065		

Consistent with prior results. Elasticity wrt innov sales share is very stable at around 0.07 across countries.

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## Conclusions

- Product innovation generally has a substantial positive impact on revenue productivity at the firm level
- Process innovation less so, impact is zero or negative in general, although not for SMEs.
  - Suggests that demand facing large firms is less elastic than that facing SMEs.
  - Existing firms improve their productivity by pushing out the demand curve rather than by increasing production efficiency
  - Suggests a closer look at the role of entry and exit in improving sectoral productivity

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