WARWICK BUSINESS SCHOOL
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DEFINING AND MEASURING THE INNOVATIVENESS OF FIRMS

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Objectives

To define and measure the innovativeness of firms via an encompassing indicator that:

- can be measured using publicly available accounting data

- illustrates inter firm, international, intersectoral and intertemporal heterogeneity and provides s.e. by which the significance of the differences between means can be calculated.

DEFINITIONS

Defining Innovativeness

The most commonly cited definition of innovation is that in the Oslo manual:

“A business innovation is a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and that has been introduced on the market or brought into use by the firm” (OECD/Eurostat, 2018, p.20).

Products encompass goods or services (functional or soft), business processes encompass production processes, marketing methods, organisational methods, business practices, workplace organisation or external relations.

Advantages/Disadvantages of OECD definition

Advantages

New to firm concept
Widely used in CIS surveys
Advantages over R&D (and related) measures

Disadvantages

Usually yes or no measure
Measure of activity levels and not output

Alternative Definition

Following Hansen and Birkenshaw (2007), Roper, Du and Love, (2008), DTI(2007) and DBERR (2008), **innovativeness** may be defined as:

‘**the successful exploitation of new ideas**’

where:

exploitation of new ideas encompasses use of products or processes new to the firm (as OECD), and also may include investment in intangibles (Haskel and Westlake, 2017).

success involves improvements in firm performance viz. profit gain.

Employed definition

The measure of the innovativeness of firm i in time t used here is:

the contribution to profit growth of firm i in time t from the first or more intensive deployment within that firm in time t of products, processes, materials, management and marketing methods new to that firm.

This stresses the output of the innovation process rather than the inputs to that process (e.g. R&D) or the level of innovation activity (eg. CIS, OECD)

THEORY

Profits

We measure firm performance by Operating Profits (S(i,t)) defined as the sum of normal profits (cost of capital) = rK(i, t) and net/ excess profits = Π(i,t), thus

$$S(i,t) = rK(i, t) + \Pi(i,t).$$

Imperfect product markets are assumed because under perfect competition excess profits are zero and innovation will not impact upon profits.

Defining Profits

By definition, operating profits are:

S(i,t) = V(i,t) – W(i,t)H(i,t)

Where for firm i in time t:

S(i,t) = operating profits, measured by ebitda
V(i,t) = P(i,t)Y(i,t) gross nominal value added or total revenue;
Y(i,t) = output; P(i, t) = the price of output;
W(i,t) = the wage per unit of human capital;
H(i,t) = total human capital employed

The firm's demand curve

Under the assumption of imperfectly competitive markets, each firm produces differentiated products and faces its own downward sloping demand curve (see Hall, 2011)

$$P(i,t) = C(i,t)Y(i,t)^{(1/\eta(i))}$$

where :

C(i, t) is a shifter representing exogenous changes in price level of output and demand shifts in the market in which the firm sells

η(i) is the (negative of the) price elasticity of demand for the firm

Exploitation of ideas

Ideas are allowed to impact upon firm performance in two main ways:

1. **disembodied innovation:** incorporation of ideas not embodied in capital goods (manna from heaven) that increase the output of given capital and labour inputs over time. Represented, as in the growth accounting literature, by a term in the production function A(i, t))

2. **embodied innovation:** investment in new capital goods encompassing machinery, software etc. emdodying new ideas determined by their date of installation. This vintage model approach essentially treats gross investment and additions to the capital stock as expenditure on embodied innovative activity rather than a separate input to production process per se.

Modelling Production (1)

Adapting the vintage model of Solow (1960) with embodied and disembodied innovation, output from capital goods of vintage τ for firm i in time t is given by:

$$Y(i, \tau, t) = \mathbf{A(i, t)}[\mathbf{B(i, \tau)}.I(i, \tau)]^{\alpha(i)} H(i, \tau, t)^{\gamma(i)}$$

A(i, t) is a disembodied innovation shifter; and **B(i,τ)** is an embodied innovation shifter increasing the productivity of capital goods over the vintages.

I(i, τ) and H(i, τ, t) are gross investment in, and employment in time t on, capital goods of vintage τ:

Modelling Production (2)

With labour reallocated at each t such that the marginal productivity of labour is equalised across vintages, summing over vintages we get:

$$\mathbf{Y(i,\ t) = A(i,t).Z(i,t)^{\alpha(i)}.H(i,\ t)^{\gamma(i)}}$$

where **Z(i,t)** may be interpreted as a weighted sum of the technological capabilities of all the capital installed.

Employment determination

Assume competitive labour markets with W(i,t) determined exogenously to the firm and independent of innovativeness (in time t).

The firm chooses employment to maximises profits and **employs labour to the point where the marginal value product of labour equals the money wage**, then

$$W(i,t)H(i,t)/V(i,t) = \gamma(i)(1+\eta(i))/\eta(i) \equiv 1 - \beta(i)$$

where **$1 - \beta(i)$** equals the share of labour in value added (here a constant) and the non-labour share **$\beta(i) \equiv S(i,t)/V(i,t)$**

Profit growth

Using **lower case to represent growth rates**, profit growth is then given by

$$\mathbf{s(i,t)} = \mathbf{c(i,t)}/\beta(i) - \mathbf{w(i,t)}(1-\beta(i))/\beta(i) + \mathbf{a\,(i,t)} + \alpha(i)\mathbf{z(i,t)})(1-\beta(i))/\beta(i)\gamma(i)).$$

The first two terms on the rhs reflect the impact on profit growth of: (i) inflation/demand shift in the market for the firms output, **c(i,t)** (+) and; (ii) the growth in nominal wages **w(i,t)** (-).

The latter two terms represent the impact on profit growth of:

(iii) the growth in the utilisation of disembodied ideas, **a(i,t)**(+);

(iv) the growth in the utilisation of embodied ideas, **z(i,t)** (+), where **z(i,t) =** (B(i, t).I(i, t)/Z(i,t)) is the rate of growth in time t of the technological (process) capabilities of the capital stock installed in firm i at time t with weights equal to the amount of each vintage installed.

The sum of these latter two terms model the impact of successful exploitation of new ideas on the rate of growth of nominal profits.

The measure of innovation

The measure of innovation, **M(,i,t),** is the contribution of embodied and disembodied innovation to the growth of nominal profits:

$$\mathbf{M(i,t)} = ((\mathbf{a(i,t)} + \alpha(i)\mathbf{z(i,t)}).(1 - \beta(i))/\beta(i)\gamma(i))$$

which may be calculated as a residual:

$$\mathbf{M(i,t)} = \mathbf{s(i,t)} - \mathbf{c(i,t)}/\beta(i) + \mathbf{w(i,t)}(1 - \beta(i))/\beta(i).$$

M(i, t) can be positive or negative (no, or unsuccessful, innovative activity).

Usual problems of a residual approach.

Relation to GTFP

In the model here the nominal profit share in value added, $S(i,t)/p(i,t)Y(i,t) \equiv \beta(i)$, is a constant over time which enables us to derive that:

$M(i,t) = GTFRP(i,t)$.

Defining GTFP as the impact of the exploitation of new ideas on the growth of real output we may also derive that

$GTFP(i,t) = M(i,t)/(1 + 1/\eta(i))$.

MEASUREMENT

The sample

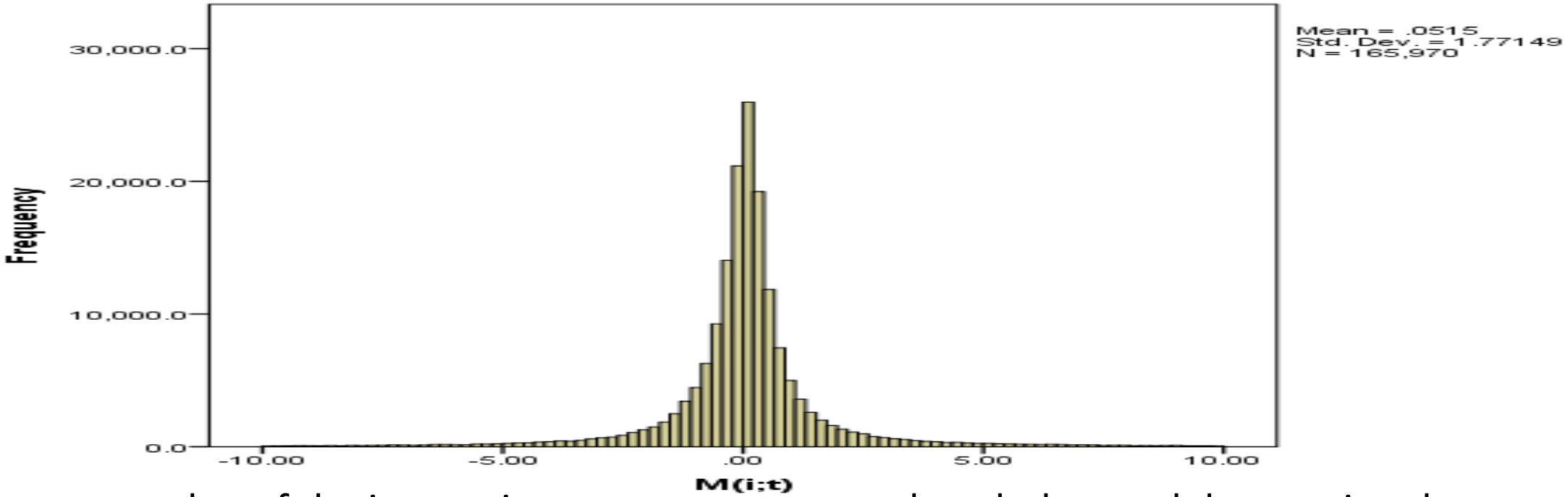
A multinational sample of firms from those present on DataStream between **1988 and 2012**.

Originally 22055 firms but: removed firms attributed to countries with less than 500 observations; excluded those firms that were suspended or died in the sample period; and removed extreme outliers from the sample.

The final dataset is an unbalanced sample of **16,457** quoted firms over the period 1988-2012, operating in **39 sectors** and in **38 countries** (yielding a total of 165,970 observations).

Issues re c(i,t) and β(i).

Histogram of Innovativeness M(i;t)
(N=165970, i=16404, t=1988 – 2012)



The mean value of the innovativeness measure over the whole panel data set i.e. the **average annual rate of growth of nominal profits that is the result of utilisation of new ideas, is 0.0515** i.e. 5.15% p.a. (Me 6.93% pa) with a standard error of 0.004. Large variability, standard deviation being 1.77

Annual averages of the three components of M(i ;t))

M(i,t) = **s(i,t)** – **c(i,t)**/β(i) + **w(i,t)**(1 – β(i))/β(i).

0.0515 = 0.0237 - 0.02420. + **0.0520**

Successful innovation ~ increasing wages contributions

Patterns of variation

Wide variation across, firms, countries, sectors and time.

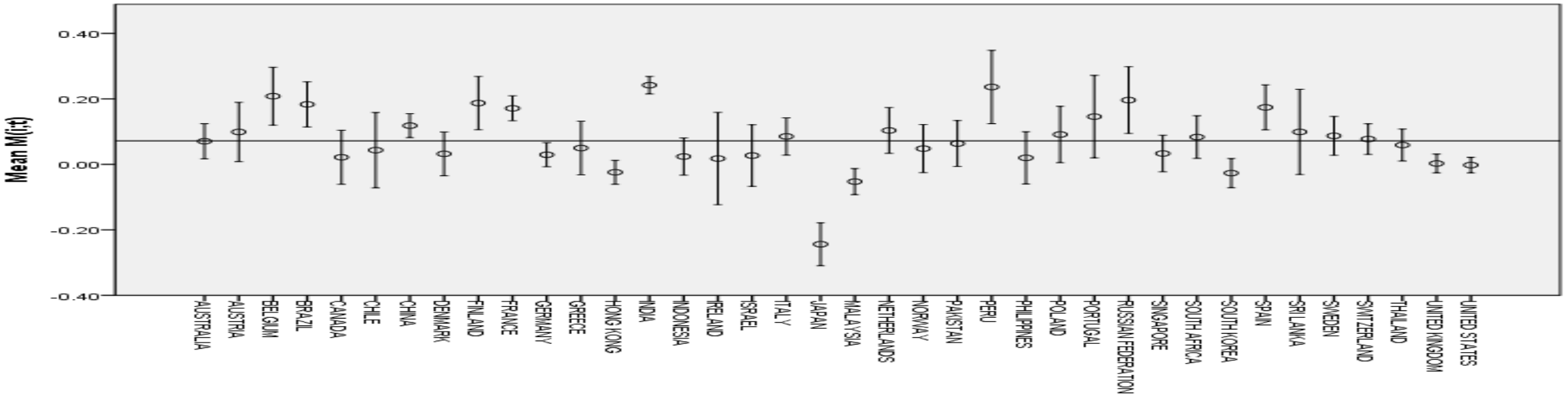
Variability largest across time, then countries, then sectors and then firms.

Variability of average M(i,t) greater within than across individual firms over time.
Greater differences across firms than across firm averages.

Variability in average M(i,t) is higher across years than in a specific year, across sectors than within sectors and across countries than within countries.

Weak correlation to R&D spend.

Innovativeness, dispersion within and across countries: means and 95% confidence intervals (1988 -2012)



- BRIC , Peru and four EU countries (F,E, B and Finland) are sig above the pop mean 9/38
- Hong Kong, Japan, Malaysia, South Korea, US and UK are sig below the pop mean 6/38
- Only Japan and Malaysia are 2 s.e. below average.

International comparisons

Measure of new to firm and not new to market or new to the world.

Innovative performance does not differ from the population mean in 2/3 of the countries studied.

Further ANOVA confirmed that intra-country differences are greater than inter-country differences. Suggests aggregated economy wide indicators have only limited value

Sectoral comparisons

8/39 above population mean:

Automobile and Parts; Electricity, Gas Water; General Industrials; Healthcare Equipment; Industrial Engineering; Mobile Telecom; Tech hardware and equipment.

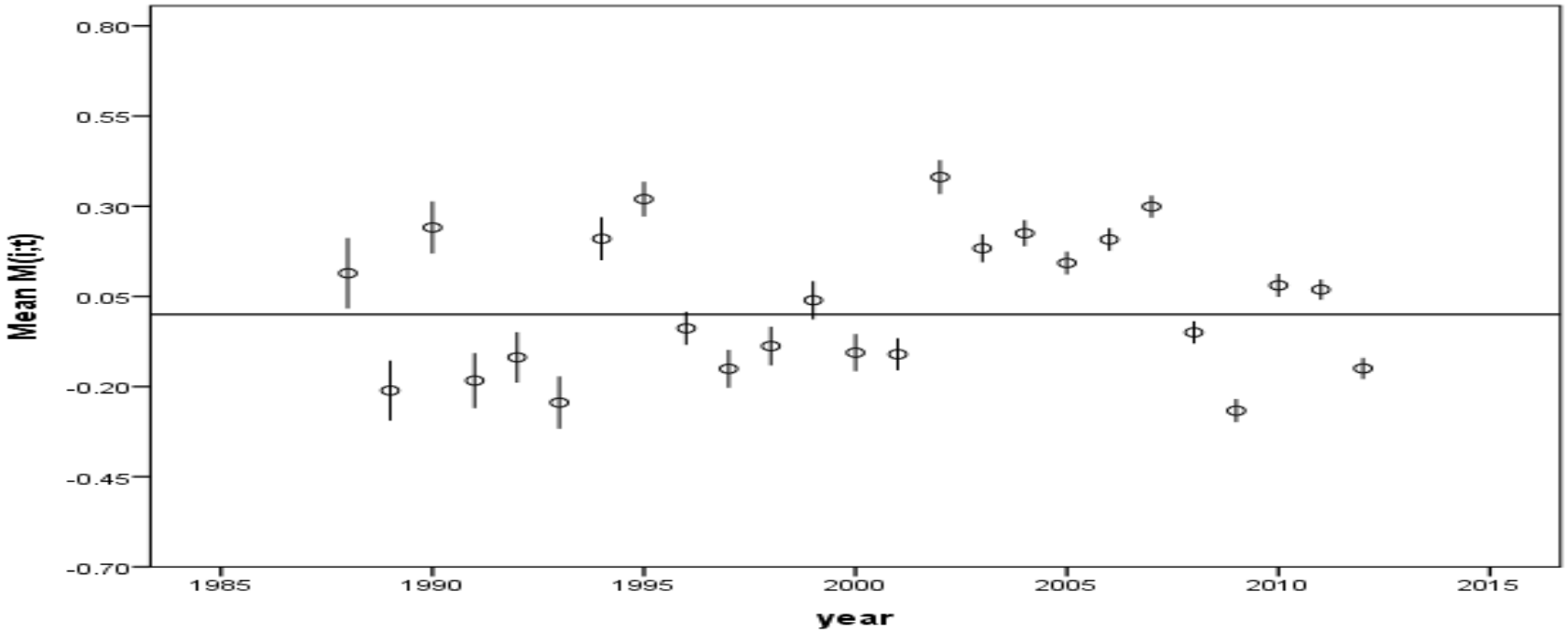
4/39 below population mean:

Banks; Equity and non equity investment; Oil and Gas producers; Real Estate Investment.

- no systematic differences between manufacturing and service sectors
- R&D intensive sectors do not show themselves as more innovative

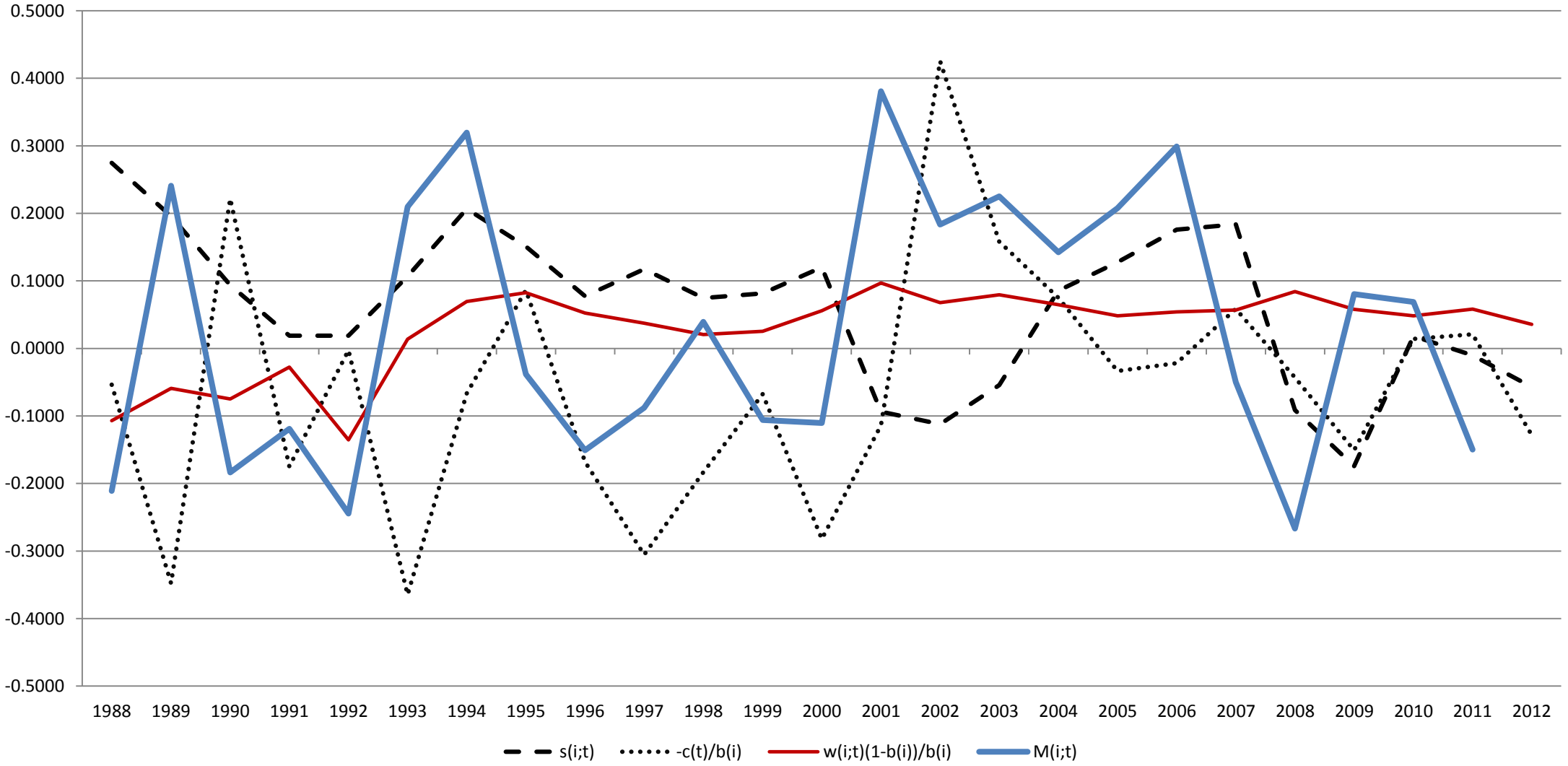
Sectors are innovative in different ways

Innovativeness over time, 1988 – 2012



Multivariate analysis reveals that although the **best performers at one point in time are not necessarily the best performers at other points in time**, after allowing for industry, country and time effects there is some evidence of persistence with good performing firms in one period performing well in the next.

The three components of M(i ;t), annual averages



Causality testing, whole sample

M(i,t) is caused by X			M(i,t) is causal to X		
M(i,t) =f(X)	F	P>|t|	X = f(M(i,t))	F	P>|t|
Path dependency of M(i,t) Ho: $\Sigma\gamma_{M(i,t)}=0$	6.03	0.05	-	-	-
s(it) causes M(i,t) Ho: $\Sigma\ \beta_{s(i,t)}=0$	22.44	0.000	M(i,t) causes s(i,t) Ho: $\Sigma\beta_{M(i,t)}=0$	0.27	0.848
c(i,t) causes M(i,t) Ho: $\Sigma\ \beta_{c(i,t)}=0$	10.43	0.000	M(i,t) causes c(i,t) Ho: $\Sigma\beta_{M(i,t)}=0$	10.24	0.000
w(i,t) causes M(i,t) Ho: $\Sigma\ \beta_{\omega(i,t)}=0$	2.83	0.037	M(i,t) causes w(i,t) Ho: $\Sigma\beta_{M(i,t)}=0$	0.89	0.44

Conclusions

The innovativeness of firms should be measured by the output of the innovative process not the inputs.

Embodied and disembodied exploitation of new ideas significantly contribute to the rate of growth of firms' nominal profits.

There is a wide variation across firms, countries, sectors and time in this contribution.

Point estimates of mean values are of limited value.

There is a need to further explore the complexity of the transmission over time of the impact of innovation impact on wages, prices and outputs.

Innovativeness by sector, t = 1988 – 2012

	Mean	Median	Standard Deviation	Valid N	s.e of mean
Aerospace & Defense	.01	.04	1.63	885	.054
Alternative Energy	.07	.07	2.40	714	.089
*Automobiles & Parts **above**	.22	.19	1.54	3570	.025
♣Banks **below**	.02	.08	1.19	16443	.009
Beverages	.08	.07	1.33	1936	.030
Chemicals	.07	.03	1.48	5468	.020
Construct. & Material	.03	.02	1.73	9047	.018
E/tronic & E/cal Equ.	.00	.04	1.93	6124	.025
*Electricity **above**	.12	.08	1.51	2939	.028
♣Eq and noneq. Invest. **below**	-.23	-.10	2.14	675	.082
Financial Services	.02	.04	2.01	9273	.020
Fixed Line Telecom.	.12	.10	1.54	1406	.041
Food Producers	.05	.06	1.56	6637	.019
Forestry & Paper	-.02	-.03	1.91	1386	.051
*Gas, Water & Mul Util **above**	.15	.10	1.26	1522	.032
*General Industrials **above**	.12	.06	1.51	2915	.028
General Retailers	.09	.11	1.68	4512	.025
*Healthcare Equip.Svs. **above**	.12	.09	1.84	3164	.032
Hhold Gds & Home Con.	.02	.05	1.72	3814	.028
*Ind. Engineering **above**	.10	.12	1.68	7793	.019
Ind. Metals & Mining	.08	.04	1.69	4229	.026
Industrial Transport	.09	.07	1.41	4494	.021
Leisure Goods	.04	.03	1.87	1909	.042
Life Insurance	.04	.12	1.74	302	.100
Media	.01	.04	2.01	5333	.027
Mining	.03	-.01	2.15	4292	.032
*Mobile Telecom. **above**	.19	.13	1.61	1075	.049
Nonlife Insurance	-.01	.11	1.74	990	.056
♣Oil & Gas Producers **below**	-.04	-.04	1.94	3178	.034
Oil Equip. & Services	.11	.12	1.58	1386	.042
Personal Goods	.02	.07	1.81	5477	.024
Pharm. & Biotech	.05	.05	1.68	4842	.024
REITs	.05	.06	1.63	1359	.044
♣Real Estate Inv & Svs **below**	.00	.03	1.93	7814	.022
Software & Comp. Svs.	.08	.11	2.35	7670	.026
Support Services	.03	.05	2.00	6167	.025
*Tech Hware & Equipmnt **above**	.17	.19	2.12	4983	.030
Travel & Leisure	.02	.04	1.84	6826	.022
Unquoted equities	.02	.03	1.78	3421	.030
Total	.05	.06	1.77	165970	.004