ECO-INNOVATIONS AND FIRMS' MARKET VALUE: A MICRO-ECONOMETRIC ANALYSIS OF EUROPEAN DATA

Alessandra Colombelli, Claudia Ghisetti, Francesco Quatraro

DIGEP, Politecnico di Torino
Department of Economics and Statistics, University of Torino
BRICK, Collegio Carlo Alberto
Department of Economics and Management, University of Ferrara

Outline

1. Background Literature
2. Research Question(s)
3. Empirical strategy
   - Data
   - Approach
   - Variables
4. Preliminary Results
5. Extensions

Background Literature (A)

- Broad literature investigated market value returns of innovative activities
- R&D is an I activitity that creates an *asset*, intangible in nature

- Market valuation of the firm should:
  - i) reflect such intangible capital - «knowledge stock»
  - ii) reflect the current present value of expected returns from the invention and/or R&D (Griliches, 1984)

- MV is a function of firms' bunch of assets

$$MV = f(A_{it} + K_{it} + I_{it})$$

  - A is the book value of tangible assets,
  - K the replacement value of R&D capital stock,
  - I the replacement value of other intangible assets
- All in all, strong support that knowledge stock increases firm market value, either R&D or patents

Background Literature (B)

- Whether being «green» pays for the firm is still a debated issue

- Horváthová (2010) on the effects of) of environmental performances on economic performance:
  - 15% negative (Cordeiro and Sarkis, 1987)
  - 55% a positive (Al Tuwaijri et al. 2004; Bragdon and Marlin 1972; Dowell et al. 2000; King and Lenox, 2001, 2002; Russo and Fouts, 1997; Salama, 2005;),
  - 30% neutral (Freeman and Jaggi; 1992; Wagner et al., 2002)
  -

- Using different measures for profitability (namely ROE, ROA, ROS or Tobin's q index) and in different contexts and sectors

- These heterogeneous results pointed to the conclusion that the question is no longer *if* it does pay to be green, rather *when* or *for whom* it pays (Telle, 2006; King and Lenox, 2001).

  - …And more recently it has been argued that such question has to be qualified in terms of the ***typology of environmental innovations*** considered (e.g. Ghisetti and Rennings, 2014).

Research Question(s)

1. RQ1: *Do green Technologies (GT) positively affect MV* (as for standard innovations and R&D)?
2. RQ2: *Are there differential effects for heterogeneous GT?*
3. RQ3: *Does the quality of GT play any role on MV?* (in progress)

Empirical strategy - Data

1. Data:
   - ORBIS – data on public companies from 2002 to 2011
   - REGPAT (Through HAN) – assignement of patents and ipc(s) to listed firms. Patent applications at EPO from 1985 to 2011

2. Sectors: Manufacturing + Knowledge intensive services
3. Countries: 5 EU countries UK, FR, DE, IT, NL

- N= 4499, panel of 9 years (2002-2011)

Empirical strategy – Core variables

- Market Value (**MV**) = Tobin's q index
  - Market value (market capitalization) over book value (Tangible fixed assets)

- **PAT_R&D** = Patent yield of R&D (as in Hall et al. 2005)
  - Knowledge stock from patent applications at EPO since 1985 on R&D stock
  - Perpetual inventory method with =15% (Hall, 1990)

- **ReD_A**= R&D intensity
  - Ratio of deflated R&D stock and value of intangible assets
  - PIM with =15% and an annual growth rate of 8%
  - Initial R&D constructed artificially

- **GT**= Green technologies
  - Patent applications at EPO since 1985 in «environmental» technologies
  - Labeled as «environmental» from two alternative classifications:
    - WIPO IPC Green Inventory (GT_WIPO)
    - OECD EnvTech (GT_OECD) * [Robustness – results not reported but similar]

Empirical strategy – GT typologies

Type WIPO IPC GI	Description	Label
Agriculture and Forestry	Forestry techniques; Alternative irrigation; Pesticide alternatives; soil improvement	GTWIPO1
Alternative energy production	Bio-fuels, fuelcells, from biomass or waste, solar, wind, ocean thermal, hydro energy	GTWIPO2
Energy conservation	Storage of electrical therman energy, low energy lighting; Thermal building insulation, recovery of mechanical energy	GTWIPO3
NUCLEAR POWER GENERATION	-	excluded
Transportation	Vehicles including rail, marine vessel, EV, charging stations for EV…	GTWIPO5
Waste Management	Waste disposal, Treatment of waste, reuse of waste	GTWIPO6

Core variables statistics

Variable	count	mean	sd	min	max
RD_real	4149	120.1	482.5	-54.47	5649
PAT	4499	5.463	51.82	0	1385
GTWIPO_all	4499	0.889	11.78	0	388
GTWIPO1	4499	0.245	3.596	0	115
GTWIPO2	4499	0.255	3.523	0	117
GTWIPO3	4499	0.104	2.168	0	93
GTWIPO4	4499	0.00489	0.125	0	5
GTWIPO5	4499	0.249	7.827	0	363
GTWIPO6	4499	0.126	1.273	0	31
lnSize	4499	11.89	2.890	0.257	19.57
lnINTASS	4302	10.34	3.055	-0.0488	18.78

Empirical strategy - Approach

- Firm level market value equation – hedonic pricing model

- Tested through several estimation choices:

- **1° model**: MV equation on only RD reporting firms

- Rough model: MV equation replacing R&D =0 for RD non reporting firms (Hall et al. 2005) [results not reported here]

Empirical strategy – Approach (II)

- Correcting for potential selection bias through two-step Heckman. Selection Equation:

$$D\_R\&D_{it} = \beta_1 CTRL_{it} + k_i + u_{it}$$

  - $D\_R\&D_{it}$=1 if $D\_R\&D_{it}$>0, $D\_R\&D_i$=0 otherwise
  - CTRL = Intangible Assets (I) and Size (firms' sales);
  - *Ki*= Sector Dummies
  - Year D included

- **2° model:** MV equation including inverted mills ratios estimated through Heckman two step (Heckman, 1979)
  - Probit at first stage
  - Pooled OLS on MV equation

- **3° model**: MV equation on whole sample with RD_hat estimated for non reporting RD firms
  - Pwcorr between reported (real) R&D and RD_hat is 0.34

Empirical strategy – Inclusion of GT

- R&D is overal R&D expenditures: no green R&D
- Green Technologies have been included so far in two alternative ways:
  - By augmenting the MV equation by GT stock

$$GT_{R\&D} = \frac{GTstock_{it}}{RDstock_{it}}$$

  - By augmenting the MV equation by a weighted GT stock

$$\mathrm{W}_{GT_{STOCK}} = \frac{PATstock_{it}}{RDstock_{it}} * GTstock$$

Results – Model 1

	(1)	(2)	(3)
PAT_R&D	0.0408***	0.0341***	0.0391***
	(0.0110)	(0.0116)	(0.0111)
ReD_A	0.4346***	0.4349***	0.4335***
	(0.0391)	(0.0391)	(0.0391)
GT_R&D		0.1064*	
		(0.0592)	
W_GT _stock			0.0021**
			(0.0009)
lnSize	-0.2363***	-0.2354***	-0.2392***
	(0.0074)	(0.0074)	(0.0075)
Constant	-1.3835***	-1.3983***	-1.3520***
	(0.4222)	(0.4222)	(0.4222)
N	4499	4499	4499
adj. R^2	0.4329	0.4332	0.4335

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
D time & D sector included

Results – Model 2 (IMR or RD_hat)

	(1)	(2)	(3)	(4)
PAT_R&D	0.0317***	0.0597	0.0384***	0.1109***
	(0.0112)	(0.0497)	(0.0107)	(0.0357)
ReD_A	1.7181***	0.0475***	1.7068***	0.0474***
	(0.1490)	(0.0020)	(0.1491)	(0.0020)
GT_R&D	0.1349**	0.1621*		
	(0.0570)	(0.0904)		
W_GT_stock			0.0019**	0.0030***
			(0.0008)	(0.0010)
lnSize	-0.2885***	-0.2263***	-0.2944***	-0.2290***
	(0.0152)	(0.0060)	(0.0153)	(0.0060)
_cons	0.6093	-2.2856***	0.7228	-2.2589***
	(0.7017)	(0.2744)	(0.7028)	(0.2744)
N	4172	11007	4172	11007
adj. R^2	0.4353	0.3803	0.4352	0.3807
IMR	Y	N	Y	N
RD_hat	N	Y	N	Y

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
D time & D sector included

Results – Different GTs

	(1) Model 1	(2) Model2-IMR	(3) Model2-RD_hat
GT_R&D_WIPO1	0.2856***	0.3253***	0.3018**
	(0.0894)	(0.0857)	(0.1208)
GT_R&D_WIPO2	0.0288	0.0441	0.0607
	(0.0783)	(0.0756)	(0.1046)
GT_ReD_WIPO3	3.0930***	3.2656***	2.4657**
	(0.6768)	(0.6505)	(0.9642)
GT_R&D_WIPO5	2.1419	1.9898	5.5114
	(2.4988)	(2.3940)	(6.0352)
GT_R&D_WIPO6	-0.3453	-0.2015	-0.2827
	(0.2932)	(0.2846)	(0.3443)
ReD_A	0.4345***	1.7214***	0.0475***
	(0.0390)	(0.1485)	(0.0020)
PAT_R&D	-0.0218	-0.0275*	0.0378
	(0.0172)	(0.0166)	(0.0513)
lnSize	-0.2349***	-0.2875***	-0.2261***
	(0.0074)	(0.0152)	(0.0060)
Constant	-1.4045***	0.5991	-2.2858***
	(0.4211)	(0.6994)	(0.2743)
N	4499	4172	11007
adj. R^2	0.4362	0.4392	0.3807
IMR	N	Y	N
RD_hat	N	N	Y

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
D time & D sector included

Preliminary conclusion

- Confirmed hypothesis on the expectations of a market which positively evaluates «environmental» knowledge stock
  - The derived demand of green technologies, either to comply with environmental regulation or to pursue socially responsible corporate strategies, is likely to engender positive expectations concerning the profitability of firms generating eco-innovations, leading to better evaluations from prospective stockholders.

- Confirmed that the type of the «environmental» technology under scrutiny shapes the ultimate effect on MV

  - Some GT are better evaluated by the market than other GTs
  - …But deeper investigation on the reasons behind such results is needed

Extension(s)

- Account for the number of ***citations*** received by PAT and GT (forward citations) → technological importance of the patent and reflects the economic value of inventions (e.g. Trajtenberg, 1990; Hall, et al., 2005).
  - To limit truncation problems we use the OECD forward citation index (5 years) (Squicciarini et al. 2013)
  - Limitation: 18 months on avg for patent to be granted + 5 y to be cited
  - last valid year would be 2004 → our dataset would span from 2002-2004.
- Test for alternative estimation strategies.
  - Bloom and Van Reenen (2002) and Hall et al. (2005) *non-linear least squares* (NLLS) estimating the full MV equation

$$log\left(\frac{Vit}{Ait}\right) = logq + log(1 + \gamma K_{it}/A_{it} + \delta I_{it}/A_{it})$$

  - Wooldridge (1995) panel approach to capture unobserved time-variant factors behind the selection that affects R&D magnitude