Green Innovation

Assessing the Porter Hypothesis for the Netherlands

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The economic issue

- Market failure regarding environmental concerns
- Presence of externalities, asymmetric information
- Environmental regulations (ER) to overcome market failures: carbon taxes, cap-and trade, emission limits, standards,...
- Complying with ER increases production costs and reduces profits

The Porter Hypothesis (PH)

- Porter (1991), Porter and van der Linde (1995)
- from empirical regularities found in country/industry comparisons of stringency of environmental regulation (ER) and economic performance: countries with more stringent ER showed better performance!
- stringent and properly designed environmental regulation can trigger innovation (and increase static and dynamic efficiency of firms), the benefits of which exceed the costs of compliance with ER.
- A win-win situation with potentially large private and social benefits

Examples of environmental innovations

- Reduce pollution at "end of pipe":
  - ✓ scrubbers in smokestacks to reduce pollution (process innovation)
  - ✓ catalytic converters for automobiles (product innovation)

- New products:
  - ✓ organic drugs that use less environmentally harmful fertilizers in production and are healthier for consumers

- New production processes more environmentally friendly:
  - ✓ increased resource efficiency (e.g. less energy use)

Empirical evidence

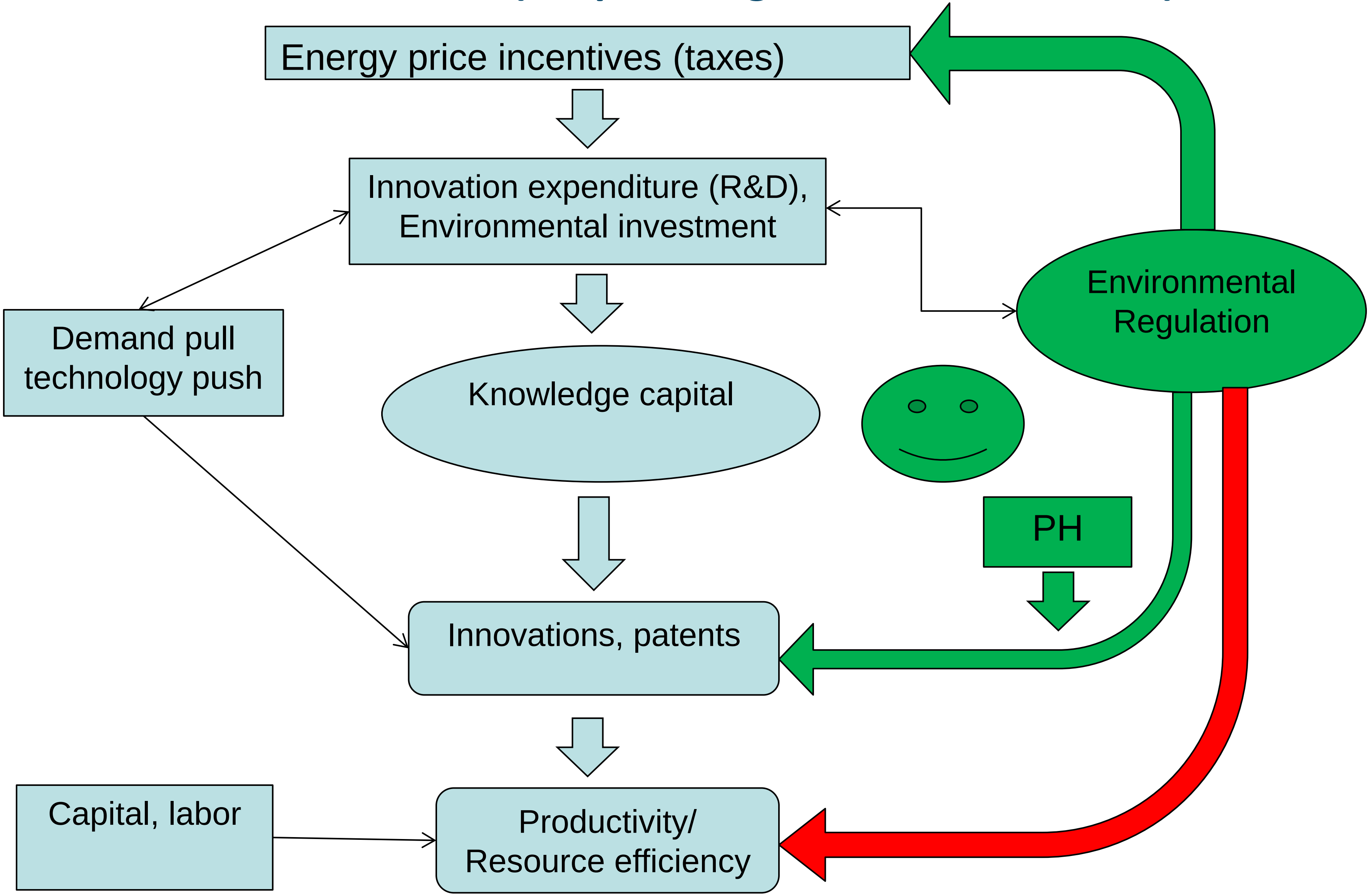
- ER and productivity or profitability:
  - In general weak and scanty evidence in support of PH
  - Often negative impact of ER on productivity/efficiency!
  - See Lanoie, Laurent-Luccheti, Johnstone and Ambec (2011)

- ER and innovation:
  - Little research on firm-level data: Cainelli, Marin, Mazzanti (2010), Rennings, Rexhäuser (2010), Rennings, Rammer (2010), Rexhäuser, Rammer (2011)
  - Mixed results (depending on type of ER)

This paper

- Uses micro data
- Data on environmental regulation, energy prices (incl. taxes) , eco investments and eco-innovations
- Structural model (CDM) with different types of innovation inputs, different types of innovation outputs, and productivity as a measure of economic performance
- Analyzes complementarities between innovation strategies
- Tests weak and strong version of the Porter hypothesis

"Green CDM model (Crépon-Duguet-Mairesse, 1998)"



Model

- Investments:
  - Eco R&D, non-eco R&D, end-of-pipe eco investments, process-integrated eco-investment (tobit type II)
- Innovation output:
  - Product, process and eco-innovations (Lewbel SEM probit model)
- Productivity with endogenous innovations (GMM) – test of complementarity

Implementing the SEM 'Lewbel' model (II)

- Section 4.1 Lewbel (IER, 2007)
- Suppose there are two strategies $y1$ and $y2$
- Total profit $V = V1 + V2$
- $V1 = (xb1 + a1y2 + e1)y1$

  $V2 = (xb2 + a2y1 + e2)y2$
- 4 combinations possible (0,0), (0,1), (1,0), (1,1)
- Profit from each combination of strategies:

  $V(y1 = 0, y2 = 0) = 0$ (V1)
  $V(y1 = 1, y2 = 0) = xb1 + e1$ (V2)
  $V(y1 = 0, y2 = 1) = xb2 + e2$ (V3)
  $V(y1 = 1, y2 = 1) = xb1 + xb2 + (a1+a2) + e1 + e2$ (V4)

Implementing the SEM ‘Lewbel’ model (III)

- Profit from each combination:

  V(y1 = 0, y2 = 0) = 0 (V1)
  V(y1 = 1, y2 = 0) = xb1 + e1 (V2)
  V(y1 = 0, y2 = 1) = xb2 + e2 (V3)
  V(y1 = 1, y2 = 1) = xb1 + xb2 + a + e1 + e2 (V4)

  a measures complementarity (if a > 0) or substitutability (a < 0) in adoption stage

- Firm chooses y1 = 1 and y2 = 1 (i.e. V4) if
  - V4 > V3, i.e. xb1 + a + e1 > 0, i.e. e1 > -(xb1 + a)
  - V4 > V2, i.e. xb2 + a + e2 > 0, i.e. e2 > -(xb2 + a)
  - V4 > V1, i.e. xb1 + xb2 + a + e1 + e2 > 0, i.e. e1 > -(xb1 + xb2 + a + e2)

- And similarly for every other combination

Implementing the SEM 'Lewbel' model (IV)

- e2 > -(xb2 + a)
- e1 > -(xb1 + a); e1 > -(xb1 + xb2 + a + e2)

- Hence the likelihood of observing P(y1 = 1, y2 = 1) is:

$$P(y1=1, y2=1) = \int_{L2}^{\infty} \left(\int_{L1}^{\infty} f(e_1, e_2) de_1 \right) de_2$$

with: L2 = – xb2 – a

L1 = max[– xb1 – a; –(xb1 + xb2) – a – e2]

- The overall likelihood is the product of the likelihoods of all choice combinations
- Method generalized for N = 3, using GHK simulation based ML.

Data(I)

Unbalanced panel constructed from 4 surveys:

- Survey Environmental costs of firms (ECF): (2000-2008)
  - Environmental current exploitation costs
  - Eco R&D
  - Eco subsidies received
  - Eco investment (“end-of-pipe” and “process integrated”)
- Community Innovation Survey (CIS): 2002-04, 2004-06, 2006-08
  - Types of innovation adopted (Product, Process or Eco innovation);
  - Innovation expenditures (incl. R&D) and R&D subsidies;
  - Importance of ER (existing or anticipated);
  - Innovation cooperation;
  - Dependence on foreign market;
  - Foreign ownership or not.

Data(II)

- Energy Statistics (ES): 2000-2008
  - Volumes of gas and electricity consumption;
  - Energy prices and taxes (tariff schemes) for constructing marginal energy prices;
  - Energy prices gas and electricity (unit values).

- Production Statistics (PS): yearly
  - Gross output and value added;
  - Employment;
  - Total costs of energy consumption;

- Deflators from Supply-Use tables National Accounts

Data (III)

- Period 2004-2008 (2002 used for constructing lags);
- Data for manufacturing only (due to use ECF survey);
- Loss of data (due to small overlap surveys);

Table 1b: Descriptive statistics

	PS&ECF *			CIS **			PS&ECF&CIS **		
	N	**Mean**	**std**	**N**	**mean**	**std**	**N**	**mean**	**std**
eco R&D per fte (1000 Euro)	19090	0.094	0.249				3784	0.132	0.395
non-eco R&D per fte (1000 Euro)				2860	4.190	12.874	2193	4.371	12.312
eco investment per fte (1000 Euro)	19090	0.190	2.047				3784	0.311	3.745
employment in fte's	19120	99.0	414.4	5571	115.4	487.7	3784	142.5	340.0
log marginal energy price per TJ	15042	5.863	0.276				3369	5.852	0.314
share energy tax (after linking with ES)	4742	0.161	0.103				1427	0.155	0.099
eco subsidies received (dummy)	19120	0.232	0.422				3784	0.388	0.487
energy cost share t-2	12311	0.017	0.025				3784	0.017	0.026
belonging to enterprise group (dummy)				5571	0.560	0.496	3784	0.638	0.481
engaged in innovation cooperation (dummy)				5571	0.256	0.437	3784	0.307	0.461
dependent on foreign markets (dummy)				5571	0.719	0.450	3784	0.794	0.404
subsidies received from local authorities (dummy)				5571	0.053	0.223	3784	0.061	0.240
subsidies received from government bodies (dummy)				5571	0.234	0.423	3784	0.283	0.451
subsidies received from EU institutions (dummy)				5571	0.038	0.190	3784	0.046	0.209
existing and anticipated ER (dummy)				5571	0.267	0.442	3784	0.310	0.463
share of environmental R&D in total R&D				2860	0.308	0.410	2193	0.274	0.389
share of process integrated eco investment in total eco investment	9452	0.443	0.361				1694	0.424	0.363
value added per fte (1000 Euro)							3778	63.7	58.4
log (TFP)							3571	3.731	0.504
product innovation adopted (dummy)				5571	0.385	0.487	3784	0.443	0.497
process innovation adopted (dummy)				5571	0.302	0.459	3784	0.349	0.477
eco innovation adopted (dummy)				5571	0.385	0.487	3784	0.436	0.496

* Averages for 2003-2008

**Averages for 2004, 2006, 2008

Table 2a: Investment equations (Tobit type II)

	R&D investment				Other eco investment			
	eco R&D		**non-eco R&D**		**end-of-pipe**		**process integrated**	
N total	6210		2833		6210		6210	
N censored	28		690		3782		3933	
N uncensored	6182		2143		2428		2277	
1) Selection	**coeff.**	**SE**	**coeff.**	**SE**	**coeff.**	**SE**	**coeff.**	**SE**
log(fte) t-2	0.217	0.114	0.241	0.028	-0.045	0.016	-0.071	0.017
log(energy cost share) t-2	0.101	0.114			0.126	0.020	0.116	0.020
log(share environmental levies) t-2	0.268	0.079			0.063	0.014	0.070	0.015
environmental regulation (ER)	0.220	0.342	0.062	0.075	0.155	0.037	0.209	0.038
firm belongs to enterprise group			0.001	0.061				
firm is dependent on foreign markets			0.455	0.076				
demand pull objective important			0.482	0.064				
cost push objective important			-0.193	0.064				
industry dummies	yes		yes		yes		yes	
time dummies	no		no		no		no	
rho	-0.070	0.161	0.655	0.081	0.691	0.088	-0.032	0.079
Log likelihood	-8941.0		-5163.6		-8404.9		-8083.9	

Table 2b: Investment equations (Tobit type II, continued)

	R&D investment				Other eco investment			
	eco R&D		non-eco R&D		end-of-pipe		process integrated	
N total	6210		2833		6210		6210	
N censored	28		690		3782		3933	
N uncensored	6182		2143		2428		2277	
2) Outcome: log(investment per fte)	**ME**	**SE ME**	**ME**	**SE ME**	**ME**	**SE ME**	**ME**	**SE ME**
log(fte) t-2	-0.117	0.017	-0.032	0.035	-0.050	0.043	0.108	0.045
environmental regulation (ER)	0.055	0.031	0.152	0.067	0.358	0.088	0.144	0.077
log(p_investment/p_labor) t-2	-0.537	0.066			-0.620	0.140	-0.505	0.139
log(energy cost share) t-2	0.105	0.017			0.471	0.047	0.335	0.042
eco subsidies received	0.736	0.048			1.020	0.119	1.021	0.136
firm belongs to enterprise group			0.223	0.072				
firm is dependent on foreign markets			0.357	0.104				
innovation subsidies local authorities			0.252	0.100				
innovation subsidies government bodies			0.653	0.064				
innovation subsidies EU bodies			0.666	0.122				
demand pull objective important			0.490	0.074				
cost push objective important			-0.324	0.070				
industry dummies	yes		yes		yes		yes	
time dummies	yes		yes		yes		yes	

Table 3: Innovation decisions (multivariate probit model with and without endogenous dummies)

	Product innovation (1)				Process innovation (2)				Eco innovation (3)			
	MVP		Lewbel MVP		MVP		Lewbel MVP		MVP		Lewbel MVP	
	ME	SE	ME [a)]	SE	ME	SE	ME [a)]	SE	ME	SE	ME [a)]	SE
N observations (2002 – 2008)	3793				3793				3793			
predicted log(non-eco R&D per fte)	0.497	0.031	0.552	0.032	0.212	0.027	0.142	0.022	0.123	0.032	0.076	0.023
predicted log(eco R&D per fte)	0.024	0.022	0.048	0.022	0.074	0.021	0.072	0.017	-0.019	0.024	0.032	0.019
predicted log(end-of-pipe eco investment per fte)	0.016	0.021	0.020	0.021	0.046	0.020	0.041	0.013	0.037	0.023	0.019	0.014
predicted log(process integrated eco investment per fte)	0.090	0.030	0.121	0.030	0.049	0.029	0.042	0.020	0.064	0.034	0.045	0.022
environmental regulation	0.301	0.023	0.177	0.026	0.296	0.022	0.088	0.018	0.949	0.030	0.679	0.021
log(fte) t-2	0.100	0.014	0.108	0.014	0.027	0.013	0.012	0.010	0.024	0.015	0.003	0.009
innovation cooperation	0.444	0.023	0.421	0.024	0.345	0.021	0.214	0.016	0.207	0.026	0.153	0.018
industry dummies	Yes				yes				yes			
year dummies	Yes				yes				yes			
synergy product - and process innovation			0,334	0,038			0,334	0,038				
synergy product - and eco innovation			0,328	0,045							0,328	0,045
synergy process - and eco innovation							0,398	0,032			0,398	0,032
rho21	0,279	0,031	0,010		0,279	0,031	0,010					
rho31	0,292	0,037	0,025						0,292	0,037	0,025	
rho32					0,356	0,033	0,078		0,356	0,033	0,078	
Log likelihood	-4690,3		-6240		-4690,3		-6239,7		-4690,3		-6239,7	

Table 4_Productivity regressions

Method	OLS		GMM [a)]	
Dependent variable	**LP**		**LP**	
	coeff.	**SE**	**coeff.**	**SE**
log(K/L)	0.206	0.010	0.202	0.014
log(L)	0.067	0.034	0.076	0.017
ecoR&D per fte t-1	0.341	0.065	0.244	0.099
eco end-of-pipe investment per fte t-1	-0.016	0.008	-0.020	0.012
eco process integrated investment per fte t-1	-0.014	0.014	-0.022	0.039
environmental regulation (dummy)	0.016	0.029	0.070	0.063
d001	0.001	0.042	-0.164	0.165
d010	-0.130	0.050	-0.602	0.790
d011	-0.010	0.044	0.462	0.327
d100	0.082	0.036	0.721	0.370
d101	0.032	0.039	0.554	0.318
d110	0.008	0.042	-0.224	0.522
d111	0.006	0.034	0.051	0.107
_cons	3,313	0.051	3.259	0.090
Year dummies	yes		Yes	
Industry dummies	yes		Yes	
R2	0.278			
Wald Chi2			447.9	
P-value Hansen's J statistics			0.08	

Table 5 Results for testing super- and sub-modularity using the LP equation

I) H_0: complementarity

Combination	**Product-Process**	**Product-Eco**	**Process-Eco**
Kodde-Palm Test Statistics	2,974	0,032	9,409-E-5

II) H_0: substitutability

Combination	**Product-Process**	**Product-Eco**	**Process-Eco**
Kodde-Palm Test Statistics	5,588E-05	2,930	4,982

The lower bound for the Kodde-Palm test for 2 degrees of freedom is 1.642 at 5% level of significance and 3.808 at the 10% level of significance. The respective upper bounds are 2.706 and 5.138. The null hypothesis is not rejected if the test statistic falls below the lower bound and is rejected if it falls above the upper bound. In between the two bounds the test is inconclusive.

Conclusions:

All in all, a strong corroboration of PH:

1) environmental subsidies, energy prices and taxes are very important determinants of environmental investment

2) a significantly positive contribution of environmental investment to the propensity of adopting environmental innovations

3) R&D investment and the propensity of adopting all types of innovations significantly depend on existing or anticipated environmental regulations

4) significantly positive synergy effects when adopting different innovation modes

5) For productivity (TFP): complementarity between eco innovation and product and process innovation