Water recirculation decisions by Canadian manufacturing firms

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87th Annual Conference of the WEAI
San Francisco, CA

Outline

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Definitions

- **Water recirculation**: water discharged from a particular process in a plant and subsequently recycled into the same process or into a different process ***in the same plant***

- **Water re-use**: using water more than once but in different applications and different locations

Motivation

- Limited previous analysis
- Surprising observations from Industrial Water Use Survey
- Potential for inefficient decision-making due to withdrawal and discharge regulations
- Potential source of water conservation

Observations from IWUS

Water recycling varies across ***time***

- Aggregate ratio of water recirculation to intake fell from 1.08 (1981) to 0.93 (1986) and rose to 1.15 (1996).

- Over 1981-1996, 90% of plants recycled at some time but in any one year, only 55% of plants recycle.

STATUS		# recyclers	Share of plants
NO CHANGE IN STATUS		**1126**	**0.413**
Recycled in all 3 periods	Y Y Y	857	0.314
Did not Recycle in any period	N N N	269	0.099
BEGAN RECYCLING		**397**	**0.146**
Recycled in 1991 and 1996 but not in 1986	N Y Y	188	0.069
Recycled in 1996 only	N N Y	209	0.077
STOPPED RECYCLING		**716**	**0.263**
Recycled in 1986 only	Y N N	450	0.165
Recycled in 1986 and 1991but not in 1996	Y Y N	266	0.098
CHANGED STATUS		**486**	**0.178**
Recycled in 1986 and 1996 but not in 1991	Y N Y	384	0.141
Recycled in 1991 only	N Y N	102	0.037

Observations from IWUS

Recycling varies across ***sectors***

- In 1996, ratio of water recirculation to intake was 0.48 in Food & Beverage and 1.46 in Petroleum
- Recycling frequency and intensity also appear to differ by size of plant, purpose of intake and source of intake

Purpose of research

- Identify factors explaining variations in water recycling by manufacturing sector
- Assess potential for policy instruments to influence recycling

Past research

Not much has been done

Dupont and Renzetti (2001):

- Estimate cost fn for Candn manu sector, price elasticity of water recirculation is
  -0.66
- Water intake and recirculation are subs; relationship is stronger when water intake is process-related rather than cooling

Past research

Féres (2007):

- Endogenous switching regression model of Brazilian industrial water intake demands
- Decision to recycle water is positively related to price of intake water but negatively influenced by cost of capital

Past research

Bruneau, Renzetti and Villeneuve (2010):

- Estimate Heckman 2-stage model with 1996 cross sectional survey
- 1st stage: LR factors (relative water scarcity, technology) influence decision whether to recirculate water.
- 2nd stage: IV prices of intake and recirc'n; output influence optimal quantity of water to recirculate.

Data and estimation method

Plant-level observations from 1986, 91, 96 Industrial Water Use Surveys:

- water uses, quantity and sources of intake water
- expenditures on water
- quantity and purpose of water recirculation
- location, labour force, and primary activity
- value of output

Data limitations

- No information on non-water inputs
- No input prices
- Response rate on value of output question low (10-15%)
- Repeated cross-section but not panel data

Estimation

Begin with a series of T independent cross-sections of I observations:

$$y_{it} = x_{it}^{'}\beta + \mu_i + \nu_{it} \quad t = 1,\ldots,T \quad i = 1,\ldots,I$$

Where y_{it} = 1 if $QRCR_{it} > 0$

=0 if $QRCR_{it} = 0$

Estimation

- Deaton (1985) proposed estimation method to deal with ‘pseudo panel data’
- Trace aggregated cohorts of similar individuals (households or firms)
- Estimate relationships based on the constructed cohort data rather than on individual observations

Estimation

- Define set of C cohorts based on 3 digit NAICS.
- Each observation is average of observations in each cohort.
- Dep var is proportion since each observation is (0,1)
- Fixed effects and GMM for consistent estimates

Estimation model

$$\overline{RCRDUM_{ct}} = \sum_i \beta_i \overline{P_{ict}} + \beta_{tr} \overline{TREAT_{ctr}} + \sum_j \beta_j \overline{PROV_{cj}} + \beta_T T + \overline{\mu_c} + \overline{\nu_{ct}}$$

$$c = 1, \ldots, C \quad t = 1, \ldots, T$$

Estimation

- T= 3, C = 55 and avg cohort = 277 plants

RHS vars:

- Price of intake, recirculation, discharge rep'd by instrumented MC
- Treatment, Province dummies
- Output proxied by # workers
- Time trend

Results

Variable	FE	GMM
Number of workers	0.000049 (0.00028)	0.000051* (0.000012)
Price Intake	-139.577* (46.102)	35.628* (15.814)
Price Recirculation	-35.5071* (19.302)	-4.4855* (1.8234)
Price Discharge	8.73480* (4.4607)	3.5065* (1.5031)
Treatment	0.898523* (0.1193)	0.36253* (0.00802)
Prov (Nfld)	0.406238 (1.1854)	-0.06249 (0.03308)
Prov (NS)	-1.29233* (0.6045)	0.02325 (0.01996)
Prov (NB)	0.480704 (0.8282)	-0.04084* (0.02018)
Prov (Que)	-0.61727 (0.3618)	0.04345* (0.01087)
Prov (Ont)	-1.07856* (0.3518)	0.04714* (0.01025)
Prov (Man)	-3.10432* (0.9629)	0.04785* (0.01892)
Prov (Sask)	-1.72488 (1.2457)	-0.10667* (0.02241)
Prov (Alb)	1.42644* (0.5443)	0.06416* (0.01498)
T	0.45706* (0.1725)	-0.16617* (0.05941)
LLF	-41026.72	
Wald χ^2 (14)	1722.51	237.99
Prob > χ^2	0.00	0.00

Results

- P_{rcr}, P_{dis} have predicted signs
- P_{in} mixed results
- Scale increases prob of recirculation as does need to pretreat
- Strengthen of prov'l dummies: climate, regulations?

Discussion

- Estimation moderately successful – data detailed but limited
- Lack of external prices may limit influence
- Some evidence of importance of prices, scale and technology

Discussion

Results suggest policies to promote recycling:

- raise cost of discharge
- lower cost of recycling

Next steps in estimation

- Add more recent cross sections
- Include non-water inputs
- Consider recirculation ‘intensity’ as dep var
- Adopt dynamic model