The Public Private Partnership effect on Productivity of the Italian District Heating Industry

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Eighteenth CEPR/JIE School on Applied Industrial Organization, 2017

Motivation

- Input quality is usually unobserved in micro-level data. Source of TFP dispersion.
- Not observing capital quality invalidates correct tfp estimations.
- Public Private Partnership (PPP) is a procurement tool which forces firms to a temporary bundle and affects the final level of capital quality.
- **Scope**: Test and measure the effect of PPP on productivity

Outline

1. How does a procurement tool influence input quality?
   - PPP contracts
   - My case study: The District Heating Industry
2. My Contribution
   - Does PPP lead to a cost reduction and a quality improvement?
   - Data
   - Results

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Related Literature

- Contract Theory:
  - **Hart (2003)**, **Bennet et al. (2006)**, **Martimort et al. (2008)**, **Hoppe et al. (2013)**
- Production Function estimation:
  - **Olley and Pakes (1994)**, **Levihnson and Petrin (2003)**,**Ackerberg et al. (2015)**, **De Loecker (2011)**, **De Loecker and Warzynski (2012)**, **Doraszelski and Jamandreu (2012)**, **Ghandi et al. (2013)**
- Literature on dispersion of TFP:
  - **Grilichles (1957)**, **Bartelsman et al. (2000)**, **Fox and Smeets (2011)**

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What is a Public Private Partnership?

Public Private Partnership (**PPP**) is an alternative to the Traditional Procurement (**TP**):

- A contracting authority (**Buyer**) and **multiple** private suppliers (**Seller**)
- Different firms form a **Consortium (a new legal entity)** to enter the tender
- A **Unique Sealed Bid** for **Two** or **More** tasks
- Private funding, for example construction

What is a Public Private Partnership?

The economic insight:

- Company A choose facility's layout, but the cost of providing the service is carried by company B
- A does not internalise the **reduced future marginal cost** of a better infrastructure and finds optimal to **shirk** on **capital quality.**
- B's marginal cost of operating the infrastructure is unaffected
- A **Consortium** will **account** in the construction stage for the reduced marginal cost of providing the service.
- A **Higher capital quality** is implemented to reduce future cost of providing the service.
- B's marginal cost of operating the higher quality infrastructure is reduced (**Externality Effect**)

Moral Hazard problem Setup

- Each **Builder** implements a minimum level of capital quality, $\underline{a} \in \mathbb{R}_{>0}$.
- Eventually a **Capital Quality Investment**, $a^i \in \mathbb{R}_+$,

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- $c(a, e)$, unit cost function with $\frac{\partial C(.)}{\partial e} \leq 0$ here
- **Martimort et al. (2008)** prove $a^*_{PPP} \geq a^*_{TP}$ when $\frac{\partial C(.)}{\partial a} \leq 0$ is sufficiently large

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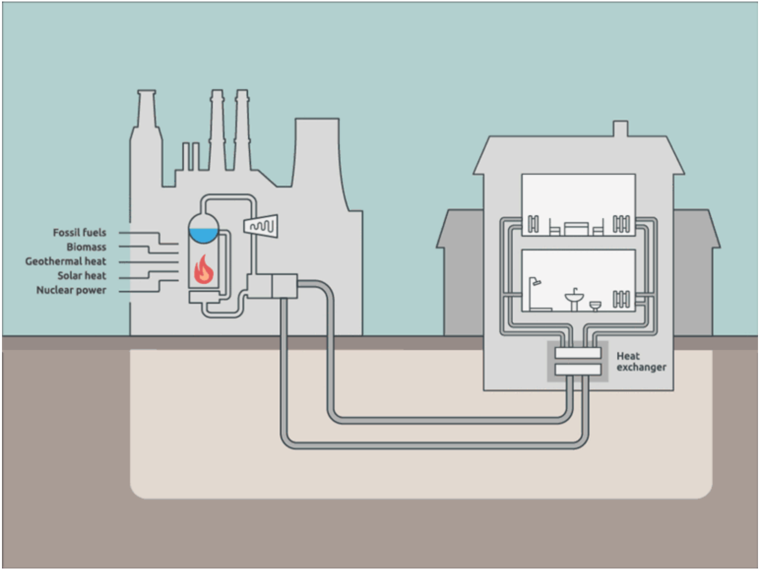
District Heating

- A district heating (DH) is an integrated system aimed at **distribution** of thermal energy

District Heating



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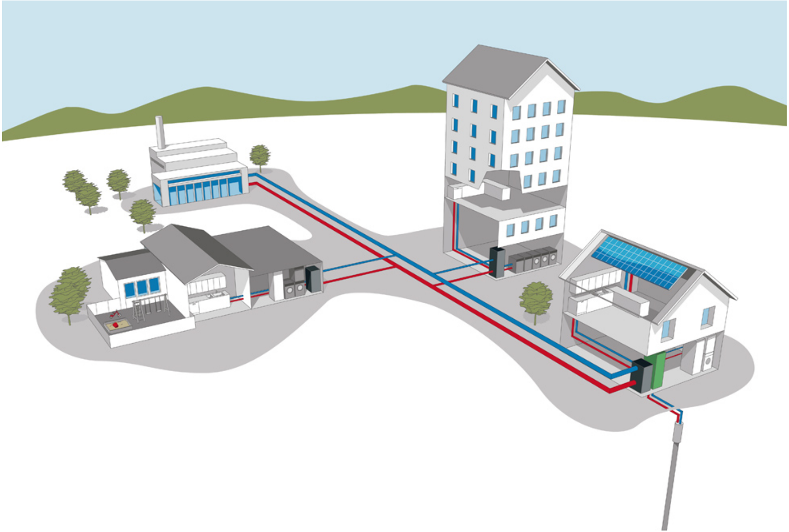

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  - **Better design of the pipeline network reduces cost of operation (managerial anecdotal evidence)**

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- The DH constitutes the perfect industry to observe the externality effect between the construction and the operation phase:
  - Better design of the pipeline network reduces cost of operation (managerial anecdotal evidence)
- PPP is **widespread** in this industry:
  - 13% of contracts and the 35% in terms of value in the district heating sector

DH: Technological Production Process

$$DE = F(K, TE, L) \cdot exp(\Omega)$$

- The measure of output DE, **Distributed Thermal Energy**, *mWh*.
- A proxy for capital, **Heat Exchanger Substations**.
- **Homogeneous** intermediate material, *TE*, thermal energy supplied to compensate heat losses, *mWh*.

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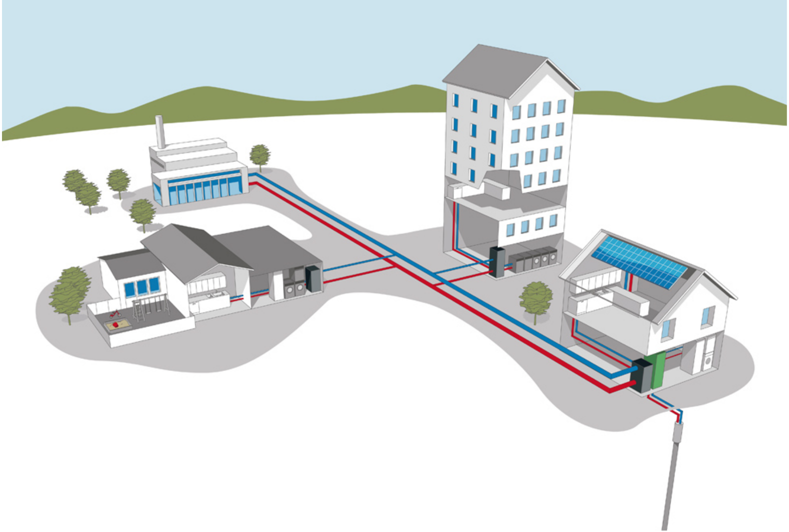

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- Proxy for labor, number of workers, L
- Ω is the **Unobserved Productivity** term.

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The empirical model (1)

- DH implements the lower quality level $\underline{a}$.
- PPP **induces** DH to make a quality investment a^i_{PPP}.
- The total quality is:

$$a = \underline{a} + PPP \cdot a^i_{PPP}$$

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$$a = \underline{a} + PPP \cdot a^i_{PPP}$$

- Similarly, we can define the total effort:

$$e = \underline{e} + PPP \cdot e^i_{PPP}$$

The empirical model (2)

- Unknown TFP function,

$$\omega(a, e) = \omega^{notPPP}(\text{a}, e) \cdot (1 - PPP) + \omega^{PPP}(\text{a}, e) \cdot PPP$$

where ω^{notPPP}, ω^{PPP} are at least C^1. Taylor Expansion here

$$\omega(a, e) \backsimeq \underbrace{\left[\frac{\partial \omega^{not\,PPP}(\underline{a}, \underline{e})}{\partial a_{it}}\right]}_{\beta_a} a_{it} + \underbrace{\left[\frac{\partial \omega^{PPP}(\underline{a}\,\underline{e})}{\partial a_{it}} - \frac{\partial \omega^{not\,PPP}(\underline{a}, \underline{e})}{\partial a_{it}}\right]}_{\beta_{int}} a_{it} PPP_i + \tag{1}$$

$$+ \underbrace{\left[\omega(\underline{a}\,\underline{e})^{PPP} - \omega(\underline{a}\,\underline{e})^{not\,PPP}\right]}_{\beta_{PPP}} PPP_i$$

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- Plugging Ω_{it} into a linearized **structural** Cobb-Douglas production function:

$$de_{it} = \alpha_c k_{it} + \alpha_l l_{it} + \beta_a a_{\mathrm{it}} + \beta_{int} a_{\mathrm{it}} PPP + \beta_{PPP} PPP_i + \omega_{it} + \varepsilon_{it} \tag{2}$$

Identification Strategy: Proxy for quality of capital

- Capital quality is **the negative (-) ratio**:

$$a = \frac{pipeline's\, length}{heated\ volume}$$

- and measured as the needed m of pipes every $10^2 m^3$

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- Capital quality is **the negative (-) ratio**:

$$a = \frac{pipeline's\, length}{heated\ volume}$$

- and measured as the needed m of pipes every $10^2 m^3$
- Increasing value of this index has a negative impact on output since **leaks of thermal energy** are **physically correlated** to the **length of the pipeline**

Identification Strategy

- Buyer's choice of PPP is **conditional independent** from unobservables related to the firms in the market: **Buso et al.** (2016) and further evidence here

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- **Size dummies** to **fix the heated volume** and be able to interpret capital quality as **variation in terms of pipeline's length** only:

$$de_{it} = \alpha_c k_{it} + \alpha_l l_{it} + \beta_a a_{\mathrm{it}} + \beta_{int} a_{\mathrm{it}} PPP + \beta_{PPP} PPP_i + \mathbf{S}_i \gamma + \omega_{it} + \varepsilon_{it}$$

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- Accounting for the simultaneity problem between output and inputs through the Lp/Op's control appoach, see Assumptions here :

$$de_{it} = \alpha_c k_{it} + \alpha_l l_{it} + \beta_a a_{\mathrm{it}} + \beta_{int} a_{\mathrm{it}} PPP + \beta_{PPP} PPP_i + \mathbf{S}_i \gamma + h(\cdot) + \varepsilon_{it}$$

Identification Strategy: Structural production Function (1)

- Labour and Materials are both chosen as a function of **productivity** and the **state variables**, $\mathbf{x}_{it} = [k, a]$:

$$m_{it} = m(\omega_{it}, \mathbf{x}_{it})$$
$$l_{it} = l(\omega_{it}, \mathbf{x}_{it})$$

- **Ackerberg et al. (2015)** provide the following result:

$$l_{it} = l\left[h^{LP}(m_{it}, \mathbf{x}_{it}), \mathbf{x}_{it}\right]$$

- **Gandhi et al. (2013)** provide the following result:

$$m_{it} = m\left[h^{ACF}(m_{it}, \mathbf{x}_{it}\, l_{it}), \mathbf{x}_{it}, l_{it}\right]$$

Identification Strategy: Structural production Function (2)

$$DE = \min\{\Omega \cdot K^{\alpha_c} \cdot L^{\alpha_l}, \alpha_{et} TE\}$$

- **Leontief** pf could be not **sufficient** to guarantee the identification.
- **Intuition**:
  - K_{it} and L_{it} are chosen before to TE_{it}.
  - P_{it}^{TE} suddenly varies such that revenues do not cover the cost of the intermediate material required to produce that output.
  - DH firms would not generally choose TE_{it} to satisfy DE$=\alpha_{et}$TE$= \Omega \cdot K^{\alpha_c} \cdot L^{\alpha_l}$

Not a big problem. "*DH either satisfy DE=α_{et}TE$= \Omega \cdot K^{\alpha_c} \cdot L^{\alpha_l}$ or produce 0 output, and if they produce 0, they will presumably not be in the dataset of those operating and thus it is not a problem for estimation.*" Appendix of Ackerberg et al. (2015)

Controls

- The geographical position, ex. an indicator called “Days Degrees”
- The need of energy of buildings
- Co-generation regime
- The thermal vehicle, ex. hot water, steam
- Warm winter

Estimation

- Estimation Algorithm here

Outline

Data

- Data are released every year by Airu, the Italian association of district heatings. 148 district heating facilities between 2007 and 2014.
- Representing the entire population, distributed in north and centre of Italy.
- Merged with a governmental dataset on energy utilities to recover the fiscal ID
- Merged with the Aida dataset to recover balance sheets data

Data

	(1) whole Firms	(2) no PPP Firms	(3) PPP Firms
Total energy, mwH	86487.42	90484.34	46689.48
Heat Energy lost, mwH	37674.17	40423.89	8188.78
Number of Workers	54.44	58.59	13.11
Network Length, m	28070.51	28447.37	24012.00
Heat Exchanger Substations	504.89	510.08	449.05
Heated Volume, 1000xm3	2377.80	2466.65	1270.55
Quality Design, m/100xm3	2.60	2.61	2.42
Between 1400-2100 GG	0.10	0.11	0.00
Between 2100-3000 GG	0.55	0.53	0.86
Above 3000 GG	0.35	0.36	0.14
Cogeneration	0.78	0.76	0.95
Heat vehicle: steam	0.56	0.58	0.32
Average Temp extracted	30.45	30.56	29.36

Table: Summary Statistics

Omitted price bias

- Ideal case where physical quantities of input and output are available.
- Hard life:
  - the (deflated) **revenue** $r_{jt} = q_{jt} + p^q_{jt}$
  - the (deflated) **input expenditures** $v_{jt} = x_{jt} + p^x_{jt}$
- The **true model**, with ε_{jt} iid measurement errors:

$$r_{jt} = f(v_{jt} - p^x_{jt}, \theta_0) + p^q_{jt} + \varepsilon_{jt}$$

- vs the **estimated model**, with u_{jt} a composite error:

$$r_{jt} = f(v_{jt}, \tilde{\theta}_0) + u_{jt}$$

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	Simple		Augmented		
	Pooled OLS	FE	Pooled OLS	Pooled OLS	Model
L, number of workers	0.030	0.023	0.030	0.029	0.073^{*}
Number of Substations	0.349^{***}	0.470^{***}	0.348^{***}	0.362^{***}	0.402^{***}
Quality of Capital, a			0.001	0.001	0.000
PPP contract				-0.103	0.327^{***}
Interaction, a*PPP				0.112^{***}	0.257^{***}
Cogeneration dummy	0.318^{**}	0.133	0.317^{**}	0.353^{***}	0.159^{***}
Zone 2	0.511^{**}	0.053	0.512^{**}	0.534^{**}	0.921^{***}
Zone 3	0.541^{**}	0.295^{*}	0.542^{**}	0.557^{**}	0.783^{***}
2014 dummy	-0.265^{***}	-0.187^{***}	-0.269^{***}	-0.262^{***}	-0.287^{***}
Extracted Temperature	0.004	0.003	0.004	0.005	0.011
Small (<p25)	-0.970^{***}	-0.216	-0.975^{***}	-0.925^{***}	-0.886^{***}
Big (p75<>p50)	0.630^{***}	0.341^{*}	0.631^{***}	0.643^{***}	0.690^{***}
Very Big (>p75)	1.475^{***}	0.440^{**}	1.478^{***}	1.468^{***}	1.270^{***}
N	724	724	724	724	724

Zone 2 between 2100-3000 GG. Zone 3 above 3000 GG.

All SD errors are clustered. The model SD are block bootstrapped

* $p < .1$, ** $p < .05$, *** $p < .01$

Results

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- I find a significant positive effect of the PPP dummy of 0.327, which corresponds to a 38% increase in total output
- I find a non significant marginal effect of our proxy for total quality investment in building's design, which controls for the capital quality a_i
- I find a strong and highly significant marginal effect on output of a quality investment in building's design for PPP firms, the interaction term. In particular, reducing by one unit (negative) the length of pipeline every $10^2\,m^3$, shifts up the expected change in log of output by 0.257 for PPP firms. In level terms, it corresponds to an output increase of 29%.

Robustness check

- I estimated the model using a Joint GMM as proposed by **Wooldridge (2009)**
- I used other function for pf
- Other proxies for the size dummies
- Results are similar and significant.


THANK
YOU
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ATTENTION

Framework (1)

- In traditional procurement, B and O face two consecutive optimization problem:

$$\textbf{Builder's}: \max_{a} \underbrace{\tau_B}_{Revenues} - \underbrace{\psi^a(a)}_{Costs}$$

$$\textbf{Operator's}: \max_{e \geq 0} \underbrace{\tau_O + \gamma_O R_O}_{Revenues} - \underbrace{C(e, a) - \psi^e(e)}_{Costs}$$

- In PPP, B and O are joint in a Consortium and the I. C. C. becomes:

$$\textbf{Consortium's}: argmax_{a, e \geq 0} \underbrace{\tau_c + \gamma_c R_c}_{Revenues} - \underbrace{C(a, e) - \psi^a(a) - \psi^e(e)}_{Costs}$$

- Where we assume $\psi^a_a \geqq 0$, $\psi^e_e \geqq 0$, $C_a < 0, C_e < 0$, $C_a < 0$, $C_{aa} > 0$ and $C_{ee} > 0$ here.

Framework (2)

- **Buyer** to the builder (B) **payment Scheme** is $\tau_B + \gamma_B C_B$ with $\{(\tau_B, \gamma_B)\} \in \mathbb{R} \times [0,1]$. Costs are **Contractible** (τ_B, γ_B are contractible).
  - τ_B is a **transfer**
  - γ_B the percentage of **cost** (C_B) **shared** with the firm.
  - the case $\gamma_B = 1$ corresponds to a **Cost-Plus** contract where the contractor is fully reimbursed for its own costs
  - $\gamma_B = 0$ stands for a **Fixed-Price** contract, where the contractor receives a fixed payment.
- **Buyer** to the operator (O) **payment scheme** is $\tau_O + \gamma_O R_O$ with $\{(\tau_O, \gamma_O)\} \in \mathbb{R} \times [0,1]$.
  - τ_O is a **transfer**
  - γ_O the percentage of **revenues shared** with the firm.
  - a payment mechanism **solely based on user charges** corresponds to $\tau_O = 0$ and $\gamma_O = 1$
  - a payment mechanism **based on availability** corresponds to $\tau_O > 0$ and $\gamma_O = 0$, so that the contractor's reward is fixed.

Taylor's expansion(1)

$$\omega(a,e) \backsimeq \omega(\underline{a}\,\underline{e})^{not\,PPP} + \frac{\partial \omega^{not\,PPP}(\underline{a},\underline{e})}{\partial a_{it}}(a_{it}-\underline{a}) + \frac{\partial \omega^{not\,PPP}(\underline{a},\underline{e})}{\partial e_{it}}(e_{it}-\underline{e}) +$$

$$-\omega(\underline{a}\,\underline{e})^{not\,PPP} \cdot (PPP) - \frac{\partial \omega^{not\,PPP}(\underline{a},\underline{e})}{\partial a_{it}}(a_{it}-\underline{a}) \cdot PPP - \frac{\partial \omega^{not\,PPP}(\underline{a},\underline{e})}{\partial e_{it}}(e_{it}-\underline{e}) \cdot PPP$$

$$+\omega(\underline{a}\,\underline{e})^{PPP} \cdot (PPP) + \frac{\partial \omega^{PPP}(\underline{a}\,\underline{e})}{\partial a_{it}}(a_{it}-\underline{a}) \cdot PPP + \frac{\partial \omega^{PPP}(\underline{a},\underline{e})}{\partial e_{it}}(e_{it}-\underline{e}) \cdot PPP =$$

Taylor's expansion(2)

$$= \underbrace{\left[\frac{\partial \omega^{not\,PPP}\left(\underline{a},\underline{e}\right)}{\partial a_{it}}\right]}_{\beta_a} a_i + \underbrace{\left[\frac{\partial \omega^{PPP}\left(\underline{a}\,\underline{e}\right)}{\partial a_{it}} - \frac{\partial \omega^{not\,PPP}\left(\underline{a},\underline{e}\right)}{\partial a_{it}}\right]}_{\beta_{int}} a_i PPP +$$

$$+ \underbrace{\left[\omega(\underline{a}\,\underline{e})^{PPP} - \omega(\underline{a}\,\underline{e})^{not\,PPP}\right]}_{\beta_{PPP}} PPP$$

here.

Selection issue

- Firm's "expertise" to deal with a particular form of contract or to enforce the public body's choice may be an issue:
  - Seven firms represent the 56,51% of the entire PPP market. Conversely, the same seven firms (Cofely and Siram seems to be connected) account for the 47,53% of the not-PPP market
  - Between PPP and not PPP projects, firms seem to retain their relative market share.

Selection issue

	2002-2013	
	# PPP won	Market share % (100=326,47 mln)
SIRAM SPA (Veolia)	1	18,38%
Hera	1	9,95%
ATZWANGER SPA	1	8,21%
A2A SPA	3	6,46%
Egea SPA	4	5,27%
METANALPI ENERGIA SRL	1	5,05%
T.E.S.I. SRL	1	3,19%
% share of PPP market		56,51%

Table: PPP market

Selection issue

	2002-2013	
	# non-PPP won	Market share % (100=4244 mln)
HERA SPA	9	9,07%
COFELY	10	8,55%
A2A SPA	5	6,49%
Egea SPA	8	5,94%
ATZWANGER SPA	1	5,19%
METANALPI ENERGIA SRL	4	5,18%
SIRAM SPA (Veolia)	4	3,90%
T.E.S.I. SRL	5	3,21%
% share of non-PPP market		47,53%

Table: non-PPP market

here

Assumptions

1. $p_{it} = p_{it}(\mathbf{x}_{it},, l_{it}, \omega_{it})$ is the proxy variable policy function (i_{it} in the case of OP, m_{it} for LP)
2. Strict monotonicity holds for p_{it} relative to ω_{it}
3. ω_{it} is scalar unobservable in $p_{it} = p(.)$
4. The state variable are decided at time $t-1$.The less variable labor input, l_{it}, is chosen in $t-b$, where $0 < b < 1$. The free variables are chosen in t when the firm productivity shock is realized.

here

First Stage

- We suppose that DH firm's expectation about its productivity can be recovered by inverting the series of intermediate materials choices:

$$\omega_{it}^{A} = te_{it}^{-1}(te_{it}, k_{it}, l_{it}, \mathbf{x_{it}}) \tag{3}$$

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- Substituting 3 into the production function in order to obtain the first stage equation:

$$de_{it} = \alpha_s \cdot k_{it} + \alpha_l \cdot l_{it} + te_{it}^{-1}(k_{it}, te_{it}, l_{it}, \mathbf{x_{it}}) + \varepsilon_{it}$$

$$= \Phi(k_{it}\, te_{it}\, l_{it}\, \mathbf{x_{it}}) + \varepsilon_{it} \tag{4}$$

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$$= \Phi(k_{it}\, te_{it}\, l_{it}\, \mathbf{x_{it}}) + \varepsilon_{it} \tag{4}$$

- Φ is a polynomial in $(k_{it}, te_{it}, l_{it}, \mathbf{x_{it}})$.
- In order to prevent collinearity issue, parameters coefficient are not identified.
- First stage is meant to get rid of the error component, ε_{it}, and obtain the sample counterpart $\hat{\Phi}$

Second Stage

- At the true value of the coefficient vector (α^*, β^*), $\hat{\Phi}$ could be used to recover a reliable proxy of the productivity ω_{it}, then $\widehat{\omega_{it}}$ is calculated as:

$$\hat{\omega}_{it} = \hat{\Phi}_{it} - \alpha_s^* \cdot k_{it} - \alpha_l^* \cdot l_{it} - \mathbf{x_{it}}\beta^*$$

- ω_{it} follows a first order Markov process, and make capital's quality endogenous :

$$\omega_{it} = g(\omega_{it-1,} a_{it-1} * PPP_i) + \xi_{it}$$

- g is a non-parametric function of ω_{it} and ξ_{it} is a shock to productivity between time $t-1$ and t,
- The sample counterpart is recovered by regressing non parametrically $\widehat{\omega_{it}}$ on a polynomial of $\widehat{\omega_{it-1}}$:

$$\xi_{it} = \hat{\omega}_{it} - g(\omega_{it-1}, \widehat{a_{it-1} * PPP_i})$$

Second Stage (2)

- Exploiting the timing assumption, we can construct a moment estimator using the following set of moments:

$$E\begin{bmatrix} \xi_{it}\cdot l_{it-1} \\ \xi_{it}\cdot k_{it} \\ \xi_{it}\cdot a_{it} \\ \xi_{it}\cdot a_{it}PPP_i \\ \xi_{it}\cdot PPP_i \\ \xi_{it}\cdot D_i^n\ \forall n \\ \xi_{it}\cdot Cog_i \\ \xi_{it}\cdot Tech_i \\ \xi_{it}\cdot dTemp_{it} \\ \xi_{it}\cdot S_i^n\ \forall n \\ \xi_{it}\cdot 2014_t \end{bmatrix} = 0$$

here.