AFE HDR Confirmation Seminar

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Economies of Scale and Scope in Australian Universities: Implications for Structural Reform, Institutional Specialization, and Cross-Institutional Collaboration

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Nathan Campus

Date: 30 April 2014
Time: 10:30am

Outline of this presentation

- Motivation
- Methodology and data
  - Four stages to estimate economies of scale and scope
  - Two models to estimate the parameters
- Preliminary results
  - Use one of the two models to answer first two topics in research questions
- Progress to date

Motivation

- Australian universities: Toward to a larger and more comprehensive institutions
  - 1965-1987: Binary system
    - A College of Advanced Education sector: teaching-oriented
    - A university sector: research-oriented
  - 1988-now: A unified national system
    - Dawkins Reform of 1988
      - Institutions lower than 2000 FTE students are forced to merger with other institutions.
    - The number of universities is slashed down from 70 to 41.
  - The scale of student number has been increased and the scope of provided service has also been expanded in each university
- Beliefs behind these mergers:
  - Economies (cost savings) could be gained from larger scale and scope!
  - However, is there any theory to support them?

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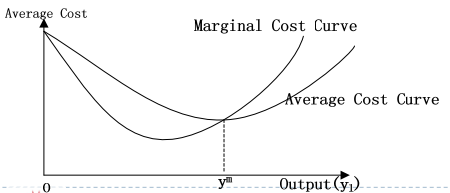
Motivation
Economies of scale vs. economies of scope

Economies of scale

been extensively applied to many resource-using industry such as bank

- How many **quantities** of output should I produce?
- **Average cost** is lower at large firms than the cost at small firms
  - the fixed costs are spread over more units of product.



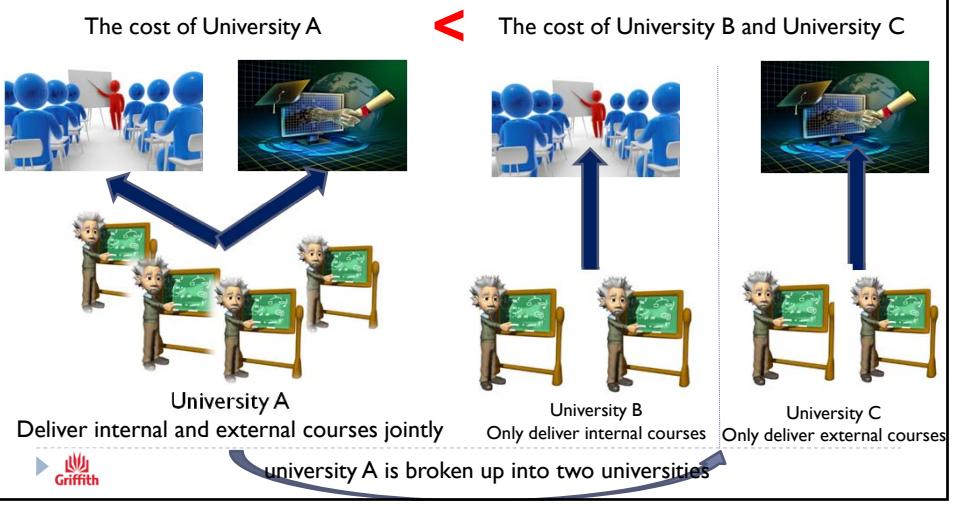
Griffith Economies of scale

Economies of scope

- How many **types** of output should I produce?
- **Total cost** of producing different types of products jointly is less than the cost of producing them separately.
  - Result from the sharing utility of inputs

Motivation
Economies of scope

- the cost of producing different types of products jointly is less than the cost of producing them separately



Motivation
Major Gaps in Literature

- 29 studies (from 1989 to 2013) have applied analyses to higher education in nine areas (Australia, China, German, Japan, Italy, Spain, Taiwan, UK, and US).
- Major Gaps
  - Out-of-date data
    - Most studies still use the dataset before 2006.
    - In Australia, the demand driven funding system has remove the limitation of enrolment in 2012 (partial uncapping starts in 2008)
      - Make estimating scale and scope economies more meaningful, because universities have more freedom to modify their own scales and scopes.
  - The discussion of output is not complete
    - Another possible form of instruction output, distance education, is obviously ignored by previous studies.
  - No study offers further strategies for universities to achieve scale and scope economies.

Motivation
Research Questions

- Topic 1. Current economies of scale and scope in the Australian university sector
  - What is the cost structure of the Australian university sector?
  - Do economies of scale exist in the Australian university sector?
  - Do economies of scope exist in the Australian university sector?
- Topic 2. Implications from the estimates of scale and scope economies
  - What are the possible modifications in scale based on the estimates of scale economies?
  - What are the possible modifications in scope based on the estimates of scope economies?
- Topic 3. Further strategies to achieve economies of scale and scope
  - What further strategies are available for universities to achieve scale and scope economies?

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Motivation_Research Questions
Further strategies used in Australian universities.

- Operating multiple campuses
  - 3.4 on average
  - Adjust the number of campuses to save costs
    - QUT closed its Carseldine campus in 2008
    - The University of Ballarat merged with Monash University's Gippsland campus in 2014.
    - UQ is planning to transfer its campus to USQ.
- Forming alliance groupings
  - Group of Eight (go8)
  - Innovative Research Universities (IRU)
  - Australian Technology Network (ATN)
  - Regional Universities Network (RUN)
- Cooperating with Open Universities Australia (OUA)

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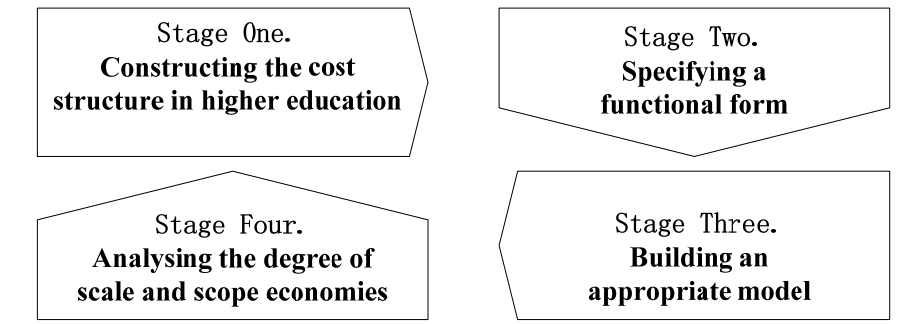
Methodology



Methodology

Stage 1. Constructing the cost structure in higher education

- Whole 37 Australian public universities over the years 2010-2012.
- 7 Outputs (y_i)
  - Internal completions (y_1 ,y_2 ,y_3)
  - External completions(y_4 ,y_5 ,y_6)
  - Research grants (y_7)
- 3 Prices(w_p)
  - Labour (staff) (w_1,w_2)
  - Physical capital (w_3)

The number of degrees conferred

Stage 2. Specifying a functional form

- Associate the cost with outputs and other variables constructed in stage one
- Quadratic cost function (QCF)
  - Permit an output to have zero value without further transformation like other two cost functional forms.
    - Constant elasticity of substitution (CES)
    - Hybrid translog (TL) function

Methodology
Stage 3. Building an appropriate model

Impose Linear homogeneity in prices
(w_3) as a numeraire price and will be omitted

$$C'_{ht} = C(\boldsymbol{y}, \boldsymbol{w}) + \varepsilon_{ht}$$
$$= \left(\beta_0 + \sum_{i=1}^{7} \beta_i y_{iht} + 0.5 \sum_{i=1}^{7} \beta_{ii} (y_{iht})^2 + \sum_{i,j=1;\, i \neq j}^{21} \beta_{ij} y_{iht} y_{jht} + \sum_{p=1}^{3-1} \beta_p w'_{pht}\right) + \varepsilon_{ht}$$

Total cost and other factor prices are divided by numeraire price .

- Goal: estimate $C(\boldsymbol{y}, \boldsymbol{w})$ (i.e. their parameters β)
  - Q1 Inefficient production
    - Stochastic frontier model (SFA)
      - $\varepsilon_{ht} = v_{ht} + u_{ht}$; $v_{ht} \sim Normal$; $u_{ht} \sim halfNormal$
      - u_{ht} is one-sided error and accounts for the cost inefficiency
  - Q2 Heterogeneity across universities
    - Random stochastic frontier model- still based on SFA model
      - Allow parameters vary with universities

Methodology Stage 3.
Account for heterogeneity across universities

$$C'_{ht} = \beta_0 + \sum_{i=1}^{7} \beta_i y_{iht} + 0.5 \sum_{i=1}^{7} \beta_{ii} (y_{iht})^2 + \sum_{i,j=1;\, i \neq j}^{21} \beta_{ij} y_{iht} y_{jht} + \sum_{p=1}^{3-1} \beta_p w'_{pht} + \varepsilon_{ht}$$

$$\beta_{k,k=\{0,i,ii,ij,p\}} \sim N(\overline{\beta_k}, \Omega)$$

modify basic SFA model by allowing parameters to vary

Fixed stochastic frontier model

- $\Omega = 0$
- Each institution shares the same cost function
  - Institutions share homogenous characteristics.
- Maximum Likelihood Estimation (MLE)
  - Unknown parameters are assume to be **fixed**
- Most past studies use this model.

Random stochastic frontier model

- $\Omega \neq 0$
- Each institution has its own cost function
  - Account for heterogeneity across universities
- Bayesian estimation
  - Unknown parameters are assume to be **random**
- ***No*** study applies this model to universities.

Methodology

Stage 4. Analysing the degree of scale and scope economies

- Economies (diseconomies) of scale would exist when estimate is larger (less) than ***one***.
- Estimates of economies of scale
  - Ray scale economies
    - $S(RAY) = \frac{C(y_1,y_2,y_3,y_4,y_5,y_6,y_7)}{y_1*\frac{\partial C}{\partial y_1}+y_2*\frac{\partial C}{\partial y_2}+y_3*\frac{\partial C}{\partial y_3}+y_4*\frac{\partial C}{\partial y_4}+y_5*\frac{\partial C}{\partial y_5}+y_6*\frac{\partial C}{\partial y_6}+y_7*\frac{\partial C}{\partial y_7}}$
    - The effect of a proportional increase of ***all*** types of output scale along a ray in output space while holding the composition of each firm's outputs constant
  - Product-specific scale economies ($\mathbf{S(y_i)}$)
    - $S(y_i) = \frac{C(y_1,y_2,y_3,y_4,y_5,y_6,y_7)-C(y_{-i})}{y_i*\frac{\partial C}{\partial y_i}}, i = 1 \dots 7$
    - Allow only ***one*** type of output scale to vary at a time while holding all other types of outputs constant.

Methodology

Stage 4. Analysing the degree of scale and scope economies

- Economies (diseconomies) of scope would exist when estimate is larger (less) than ***zero***.
- Estimates of scope economies
  - Global scope economies (GSE)
    - $GSE = \frac{\sum_{i=1}^{7} C(y_i)-C(y_1,y_2,y_3,y_4,y_5,y_6,y_7)}{C(y_1,y_2,y_3,y_4,y_5,y_6,y_7)}$
    - The percentage increase in costs from separate production
  - Product-specific scope economies (PSE)
    - $PSE(y_i) = \frac{C(y_i)+C(y_{n-i})-C(y_1,y_2,y_3,y_4,y_5,y_6,y_7)}{C(y_1,y_2,y_3,y_4,y_5,y_6,y_7)}, i = 1 \dots 7$
    - Cost savings arise from joint production of ***a particular type*** (***i***)of output with other types of outputs.

Preliminary Results

- Fixed stochastic frontier model with ML estimation
  - Use ML estimation with R Package "frontier"
- Contents
  - Likelihood ratio test will be used to decide whether SFA model has a better model fit than regression model.
  - Estimates of the scale and scope economies for the **Australian university sector**
    - Constructed at different ***percentage*** mean output with estimated parameters
    - All prices are set to their respective means in all of the calculations.
    - R codes have been developed.

Preliminary Results
Model selection

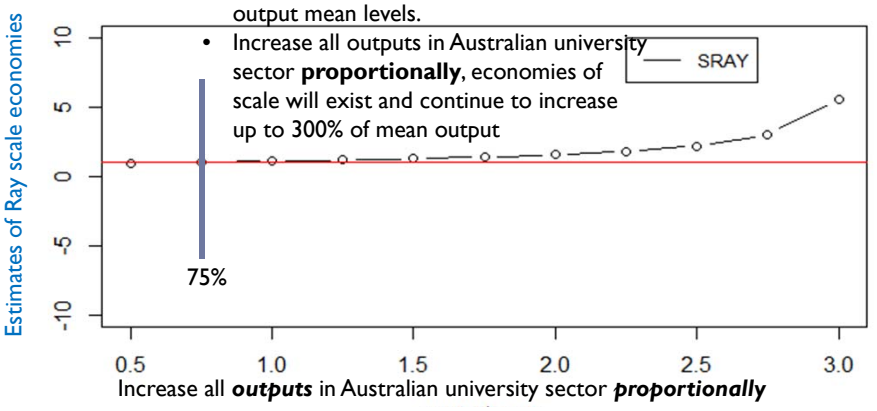
Model 1:	Regression (pooled OLS)				
Model 2:	SFA				
Model	DF	LLV	DF	Chisq	p-value
1	39	-1075			
2	40	-1072.182	1	5.636	0.009

The test statistic is
2*(LLV(Unrestricted model) - LLV(Restricted model))
=2*(LLV(SFA) - LLV(Regression)) = 2*(-1072.1820 - (-1075))
= 5.636.

This statistic asymptotically follows a mixed χ^2 distribution with degree of freedom = 1.

Preliminary Results
Estimates of scale economies

- Ray scale economies exist up to 300% output mean levels.
- Increase all outputs in Australian university sector **proportionally**, economies of scale will exist and continue to increase up to 300% of mean output



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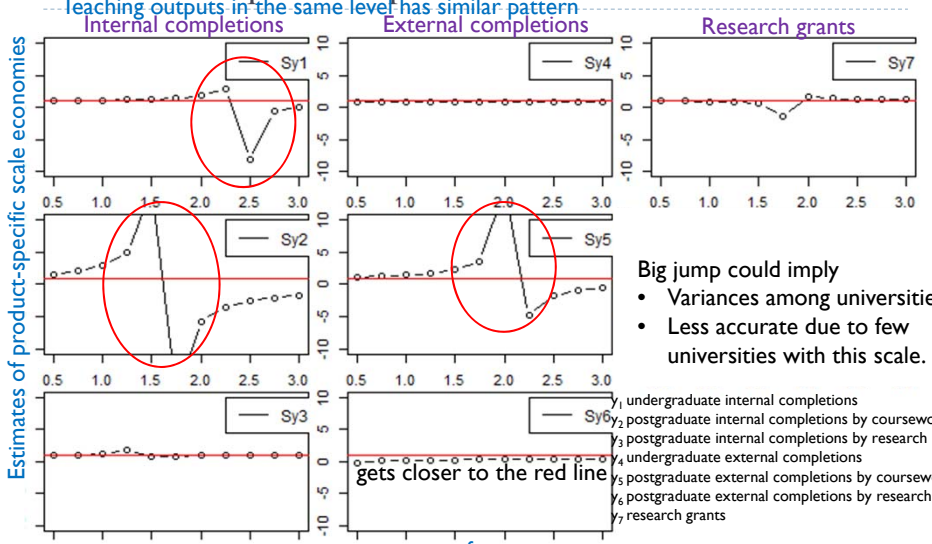
Preliminary Results
Increase the quantity in ***one*** type of output at a time.

Estimates of product-specific scale economies

Teaching outputs in the same level has similar pattern



Big jump could imply

- Variances among universities
- Less accurate due to few universities with this scale.

gets closer to the red line

y_1 undergraduate internal completions
y_2 postgraduate internal completions by coursework
y_3 postgraduate internal completions by research
y_4 undergraduate external completions
y_5 postgraduate external completions by coursework
y_6 postgraduate external completions by research
y_7 research grants

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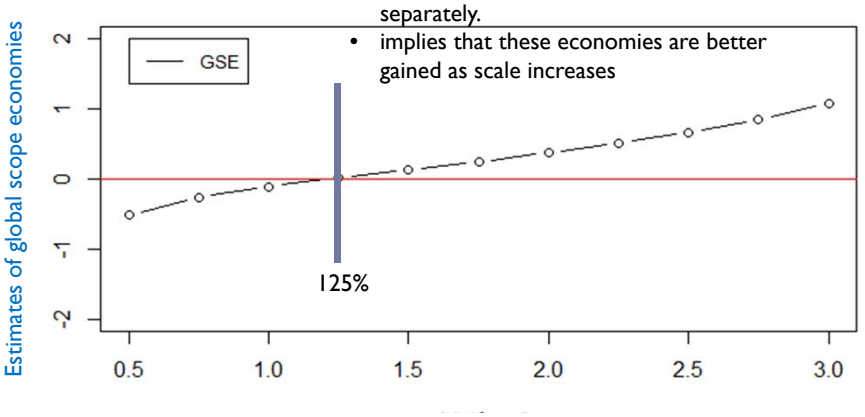
Preliminary Results
Estimates of global scope economies

- the cost of producing current output jointly is less than the costs of producing them separately.
- implies that these economies are better gained as scale increases



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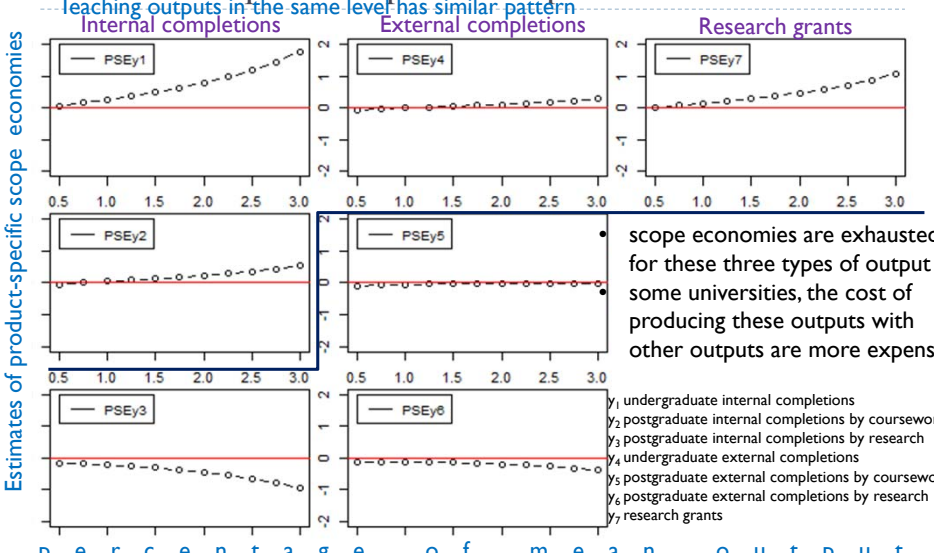
Preliminary Results
Estimates of product-specific scope economies

Teaching outputs in the same level has similar pattern



- scope economies are exhausted for these three types of output some universities, the cost of producing these outputs with other outputs are more expensiv

y_1 undergraduate internal completions
y_2 postgraduate internal completions by coursework
y_3 postgraduate internal completions by research
y_4 undergraduate external completions
y_5 postgraduate external completions by coursework
y_6 postgraduate external completions by research
y_7 research grants

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Joint production of ***a particular type*** (*i*) of output with other types of outputs

Progress to date
Results

Plan

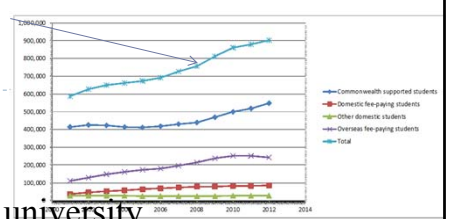
- Develop two models
  - Fixed SFA with MLE
  - Random SFA with Bayesian
- Answer 3 topics in research questions
  - Topic one
  - Topic two
  - Topic three

Tasks completed so far

- Develop two models
  - Completed
  - Codes developing
- Answer 3 topics in research questions
  - Completed with ML
  - Completed with ML
  - Not yet

Implications so far

Partial uncapping 2008-2011



- Timely research for Australian university
  - Further structural changes are unavoidable
  - But the increases in scale and scope should be based on solid evidence
    - Not because universities are lack of money!?
- Heterogeneity among universities in Preliminary results
  - The big jump in product-specific scale economies
    - Suggest that random stochastic frontier model could be more appropriate
  - Shows different types of output development
    - Not all universities are appropriate for increasing all outputs
    - Main issues for the following works after confirmation

Thanks for your attention!

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Possible questions

Australian university sector at a glance

Today

- 41 universities
  - 37 public universities
  - 4 private universities
- Two types of teaching output
  - 10% External
  - 90% Internal

University size by number of enrolled students in 2012	
With < 10,000 students	4
10,000 - 20,000 students	19
20,000 - 30,000 students	7
40,000 - 50,000 students	6
>50,000 students	4

Much larger

- The government allocated student places to public universities.
- Uncap the limitation of enrollment after 2012: Demand driven funding system

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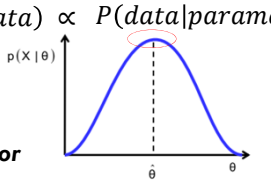
MLE vs. Bayesian estimation

MLE: the likelihood function derived from a convolution of u_{ht} *and* v_{ht} . Choose a parameter that maximize this function

$$P(parameters|data) \propto P(data|parameters) \times P(parameters)$$



Modify the likelihood function into a ***posterior density*** which is ***proportional to*** (∝) likelihood function multiplied by prior density

- Parameters are the means of the posterior density of the parameters through Monte Carlo Markov Chain (MCMC) simulation

Bayesian Estimation: Impose "prior" knowledge about the parameters in inferences, in this thesis,

$\beta_{k,k=\{0,i,ii,ij,p\}} \sim N(\overline{\overline{\beta_k}}, \Omega)$

- this knowledge is available on parameters ***prior to*** the observation of the data
- decided on practical grounds.
  - We refer to Griffin & Steel (2007), Tsionas (2002) and Widmer et al.(2011)

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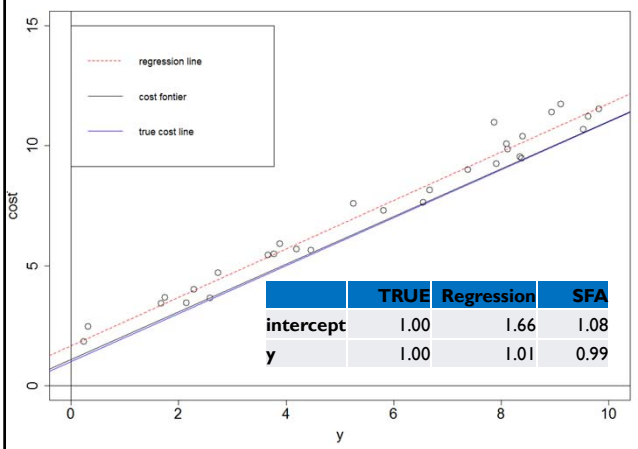
Use R to simulate the true cost function

```
sz=30
err<-rnorm(sz)
cost<-numeric(sz)
x<-10
y<-runif(sz)*x
a<-1
b<-1
for(i in 1:sz){
 cost[i]=a+b*y[i]+abs(err[i]) }
```

Use R to estimate cost functions from models

```
Regression<-lm(cost~y)
SFA<-sfa(cost~y, ineffDecrease = FALSE)
```



	TRUE	Regression	SFA
intercept	1.00	1.66	1.08
y	1.00	1.01	0.99

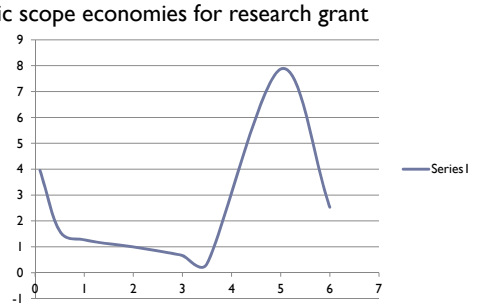
Consider inefficient production

- Regression Vs. SFA
- Parameters except for constant are similar with true cost function
- Regression model Overestimates fixed cost -> Overestimate the estimates of scope economies, evidence:
  - Cross-sectional data: Johnes (1996)
  - Panel data: Lenton (2008)

Big jump

- Also found in the paper of Cohn, E., Rhine, S., & Santos, M. (1989:286)

Estimates of product-specific scope economies for research grant



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- parameters is assumed distributed as normal distribution: {Johnes, 2009 #426:110}
- Why did you not add publication as a research output?
  - This output is similar to research grant and there is no need to add two similar outputs in one cost function. They are usually co-exist and unbundling either one is weird.
- How to deal with the possible endogeneity? Use instrumental variables?
  - I have read that distance function has the similar question, they tend to estimate the equation under the Bayesian framework (it enables us draw exact finite sample inferences concerning nonlinear functions of the unknown parameters. {O'Donnell, 2007 #586:2} {Fernández, 2000 #584:58}). I believe that this study would also solve the problem by the Bayesian framework.

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- You did not control the quality?
  - In fact, there is no common quality indicator. I choose to control quality by Cross-classification (instructional outputs are further disaggregated into internal and external) and choose outputs (completions and research grant) that have involved variance of quality.
- Number of campuses and cooperation with OUA do not incoprate in equation?
  - They are time-invant variables, actually are controlled in panel data analysis.

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