Stochastic Frontier Estimations of Technical Progress and Efficiency in Malaysian Manufacturing: A Study of Disaggregated Panel Data

IKM Mokhtarul Wadud
School of Account. Economics & Fin.
Deakin University, Australia.

Introduction

- Industry evaluation in disaggregated framework
- Efficiency and productivity issues
- Malaysian economy:
  - High & consistent GDP growth (indep. In 1957; 7-9% growth 1970s → 1990s)
  - FDI; High export growth
  - Rising share of manuf. (13.4% in 1970→26.9% in 1990→31.5% in 2005); Sector expanding at 8-10% in 2003-04 (Wah, 2008, WTO, 2005).
  - Manuf export share 1.9% in 1970 →58.8% in 2002
  - Diversified manuf. activities.

- Changing specialisations: semi skilled labour intensive (food, textiles) →machinery, metal & electronics
- Growth and operations assessed:
  - Mahadevan (2001): input gr.→Output gr. (low & varying TFP)
  - Mahadevan (2003): Mixed evidence on TFP (method diff.)
  - Wadud (2008): Average TFP 0.8% (1981-1997).
  - Mixed evidence on productivity spill over effect (establishment level) (Khalifah and Adam, 2009)
  - Is TFP gr. In Malaysian manuf. Low? No evidence of high productivity (existing studies, at least).
  - Source of TFP gr.: Technical change and Technical efficiency (TE)
  - Studies identified TE as source of sluggish gr.

- This study
  - Examines TE over 1981-1999
  - 114 five digit manuf. Industries
  - Uses stochastic frontiers [Wadud, 2008, Malmquist growth indices; Kim & Shafi'i, 2009, used 2000-04 & higher aggregation)

Stochastic Functions and Efficiency

- Frontier functions- parametric estimates of elasticities, efficiency scores, tests of prod. Tech.
- Farell (1957)→Aigner & Chu (1968), deterministic front (sensitive to outliers, lack stat. prop., ignores stochasticity)
- Stochastic frontier functions: Aigner, Lovell & Schmidt (1977); and Meeusen & van den Broeck (1977)→ assumed efficiency to be affected by factors within (inefficiency)/ outside of (randomness) control of an econ agent.

- SFPF: $Y_i = f(X_i, \beta, t)\exp(\varepsilon_i)$ $\varepsilon_i = v_i - u_i$

  $TE = \frac{Y_i}{[f(xi;\beta)\exp(vi)]} = \exp(u_i)$
- u>=0 (non negative), Assumed a truncated normal distn. for u, Translog functional form (flexibility),
- SFPF for panel data: technical progress and technical eff. Change, differences in industry specific environ factors (Coelli, 1995; Nishimizu & Page, 1982; Perelman, 1995)
- SFPF with environ. Factors: Modelling ineff/ efficiency on environ. Factors (Pitt & Lee, 1981; Kalirajan, 1989; caves, 1992)→ examined effects of envorn factors in two stages (inconsistent assumptions re *u*)

- This study: environ factors modelled in single stage (following Kumbhakar, Ghosh and McGukin, 1991 and Battese & Coelli, 1993; Battese & Coelli, 1995).
- SSPF for Panel with time varying inefficiency effects:

$$Iny_{it} = \exp(x_{it}\beta + x_i x_j \alpha + v_{it} - u_{it}) \qquad u_{it} \sim N(m_{it}, \sigma_u^2)$$

  – Mean $m_{it} = g(z_{it}, \delta)$

Where z_{it} is the (1xR) vector of explanatory variables with a constant term associated with technical inefficiencies.
δ is (Rx1) vector of unknown coefficients with a chosen functional form g(.).
The technical inefficiency effects u_{it} can be specified as,

$$u_{it} = z_{it}\delta + \omega_{it}$$

ω_{it} is defined by the truncations of N(0, σ_u^2) distribution with point of truncations at $-z_{it}\delta$ (i.e. $\omega_{it} \geq -z_{it}\delta$)

- Maximum likelihood (ML) used (Battese and Coelli, 1995) (more efficient than COLS)
- Technical Efficiency:
  $TE_{it} = \exp(-u_{it}) = \exp(-z_{it}\delta - \omega_{it})$
- Translog SFPF with two factors (L & K):

$$InY_{it} = \beta_o + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \tfrac{1}{2}\beta_{LL}(InL_{it})^2 + \tfrac{1}{2}\beta_{KK}(InK_{it})^2 + \beta_{LK}(\ln L_{it})(\ln K_{it})$$
$$+ \beta_t t + \tfrac{1}{2}\beta_{tt} t^2 + \beta_{tL} t(\ln L) + \beta_{tK} t(\ln K) + v_{it} - u_{it}$$

- The Mean m_{it} defined by industry sizes (S) & K-L ratio (FP)

$$m_{it} = \delta_0 + \delta_1 S_{it} + \delta_2 FP_{it}$$

- Mean & industry specific TE prediction:

ESSA Biennial Conference, Port Elizabeth, Sept. 7-9, 2009

- ***Mean and industry specific technical efficiency predictions***

$$E[\exp(-u_i)] = 2[1 - \Phi(\sigma\sqrt{\gamma})]\exp\left(-\frac{\gamma\sigma^2}{2}\right)$$

  – Following Rao (1973), TE→ predicted by conditional distribution of u_i, given combined residuals $\hat{\varepsilon}_i = v_i - u_i$
  – Jondrow et al. (1982)→conditional distribution of u_i → otained the point estimates of the u_i's (var. parameter $\lambda = \sigma_u / \sigma_v$
  – Truncated norm. Dist. of the u_i's (Stevenson, 1980), also Battese & Coelli (1998).. Used the min. squared error prediction for $\exp(-u_i / \hat{\varepsilon}_i)$

ESSA Biennial Conference, Port Elizabeth, Sept. 7-9, 2009

Data Sources and Variables

- Obtained from the Department of Statistics Malaysia for 1983 – 1999
- Malaysian manuf. classified in 130 five-digit categories and 114 included in the sample (missing observation & other probs.)
- Not survey conducted in 1998 (Asian crisis)→final panel: 114 (16 yrs:1983-'99)
- Output= industry gross output – materials (single deflation); Labour = total number of employees and capital = value of fixed assets (deflated by aggreg. PPI).

ESSA Biennial Conference, Port Elizabeth, Sept. 7-9, 2009

Table 1 Summary statistics of Main Variables: Malaysian Manufacturing, 1983-1999

	Years					
	1983	**1987**	**1991**	**1995**	**1999**	**Pooled Series**
Value Added Mean [S.D] (Max.; min.)	118,810 [199,959] (1601,995; 1161)	150,884 [269,585] (2040,489; 1972)	301,912 [569,571] (5051,663; 3071)	518,035 [1185,219] (11493,986; 3824)	715,661 [2337,360] (23915,226; 5074)	361,404 [1163,899] (23915,226; 166)
Labour Mean [S.D] (Max., min.)	4,306 [7,892] (67,492; 124)	4,519 [8,334] (67,766; 179)	8,569 [18,340] (160,761; 158)	12,089 [27,966] (257,209; 284)	11,882 [31,423] (306,330; 180)	7,969 [20,002] (306330; 37)
Capital Mean [S.D] (Max., min.)	174,156 [417,421] (3941,807; 696)	256,867 [483042] (359,666; 1,764)	442,465 [767406] (5605,329; 3,233)	854,352 [1787927] (14526,394; 2,746)	1145,757 [2629355] (21862,550; 3,656)	582,255 [181,855] (37751,947; 401)

Note: All values are expressed in thousand units of the national currency in 1995 constant prices.
Source: Author's calculation.

ESSA Biennial Conference, Port Elizabeth, Sept. 7-9, 2009

- Sum. Stat (Table 1): mean value added & capital (fixed assets) rose from 1983 to 1999→ expansion of the industries. Rising SD→rising spread of these variables across industries.
- Labour: Less than proportionate increased in the mean and S.D. (Declining labour intensities).
- Diversities of the industry sizes→ large max. – min. deviaitons.

ESSA Biennial Conference, Port Elizabeth, Sept. 7-9, 2009

Results

- Translog SFPF estimates:
- Parameters estimated (ML) for the time varying inefficiency effect model
- Estimates (Table 2): parameters statistically significant for K, the interaction K*L & squared factor (L^2 & K^2).
- Technical Change: neutral (parameters of t & t^2 →insignificant; , factor biased (L sig. K insig.)

Table 2 Stochastic Production Frontier Estimation of Malaysian Manufacturing, 1983-1999 (114 industries)

Variables	Parameters	Estimated coefficients	t-ratios
Constant	β_0	0.856	0.87
lnL	β_L	0.076	0.605
lnK	β_K	0.977	5.017***
(lnL)(lnL)	β_{LL}	0.222	7.367***
(lnK)(lnK)	β_{KK}	0.064	4.024***
(lnL)(lnK)	β_{LK}	-0.137	-6.98***
T	β_t	-0.027	-1.391
(t)(t)	β_{tt}	-0.000548	-0.483
(t)(lnL)	β_{tL}	0.0055	1.752*
(t)(lnK)	β_{tK}	0.000158	0.061
Explanatory Variables for Inefficiency Effect			
Constant	δ_0	0.163	1.029
Size (S)	δ_2	-0.0000000589	-2.786***
Capital-labour ratio (FP)	δ_3	0.0000000976	4.112***
Variance Parameters			
	σ^2	0.276	8.684***
	γ	0.561	9.387***
Log likelihood Function		-1067.269	

*** Significant at 1% level, * Significant at 10% level.
Source: Author's estimates.

- Variance parameters σ^2 = 0.276 & γ=0.561 (both sign. At 1%). $\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} = 0.561$ → 56% of total variation due to inefficiencies (hence both u and random v).

Table 3 Output Elasticities and Technical Change in Malaysian Manufacturing, 1983-1999

	Mean	Time Variant 1983	Time Variant 1990	Time Variant 1999
	Elasticities			
Labour (L)	-1.505	0.273	0.298	-2.90
Capital (K)	0.635	0.633	0.626	2.133
	Technical Change			
	0.015	0.017	0.016	0.017

Source: Calculated by the Author from the SFPF reported in Table 2.

- Output elasticities (w.r.t. K, L & t) – computed at the mean values and at three selected years (1983, '90 & '99).
- The elasticity of labour at mean →negative. However, time variant measures→ elasticities changed from 0.273 & 0.298 in 1983 and 1990, respectively to -2.90 (high negative) in 1999.
- K elasticity: 63.5. Time variant estimates: 0.633 (1983), 0.626 (1990) and 2.133 (1999). Higher K share expected as industries grow.

- Elasticity estimates in 1999: The large negative and positive elasticities of L & K → impact of Asian crisis?
- Malaysian industries in Asian Crisis: labour retrenchments, disinvestment and fall in profitability.
- Other studies: Ahmed [effects of human capital formation on productivity in Malaysian manuf. (1970-2000) using growth account.] →elasticities of skilled (-0.41), semi skilled (0.0136) and unskilled labour (0.23)→ overall negative elasticity.

- Technical change:
  - Average: 1.5% for the period.
  - Over 1983-’99: Steady & low/moderate at 1.7% in 1983 and in 1999 and 1.6% in 1990.

- ***Industry Efficiencies***
  - ***Aggregated at 3 digit level (using 5 digit ind.-specific TE scores)***
  - Mean TE: from around 59% (paper and paper products) to 88% (tobacco); a majority of industries within 65%-80%.
  - Time varying TE, 1983-1999:
    - TE declined: ice, tea, & noodles (76% to 65%), tobacco (90% to 82%), Footwear (72% to 66%), printing and publishing (84% to 73%), other chemicals (84% to 78%), petroleum and refineries (76% to 36%), non-metallic minerals (68% to 59%) and iron & steel (69% to 56%)
    - TE improved: industrial chemicals (66% to 72%), petroleum & coal (79% to 91%), pottery & earth ware (62% to 72%) and glass products (62% to 77%)

Table 4 Mean Technical Efficiency[a] in Malaysian Manufacturing, 1983-1999

Industry Groups	*Mean Technical Efficiency (%)*					
	Years					
	1983	1987	1990	1994	1999	Overall 1983-1999
Dairy, edible oil, grain and other food proc (311)	74.12	72.59	71.59	71.68	74.77	72.31
Ice, coffee, tea, noodles etc. (312)	76.72	70.05	64.42	64.29	65.61	68.67
Beverages (313)	82.78	81.48	87.48	77 .84	72.51	80.34
Tobacco (314)	90.10	90.80	88.10	89.40	82.50	88.21
Textiles (321)	62.72	65.94	67.41	65.67	67.30	65.56
Wearing Apparel (322)	70.90	73.70	73.50	71.60	74.90	72.32
Leather (323)	70.18	57.23	58.94	72.54	71.59	66.77
Footwear (324)	72.30	70.80	70.60	64.60	66.10	71.03
Wood products (331)	66.24	68.96	68.01	68.49	66.76	67.24
Furniture and fixtures (332)	73.60	64.20	63.80	70.80	72.50	68.05
Paper and paper products (341)	62.24	50.06	57.63	58.34	58.33	59.09
Printing and publishing (342)	83.90	80.30	81.10	80.40	73.10	80.70
Industrial chemicals (351)	66.37	67.43	72.77	63.00	71.85	68.58
Other chemical products (352)	84.65	82.67	82.05	89.18	77.58	82.49
Petroleum and Refineries (353)	75.80	68.10	80.50	48.90	35.80	67.57
Petroleum and Coal products (354)	79.10	73.40	82.30	90.30	90.60	84.13

Table 4 (continued)

Rubber products (355)	76.42	77.05	71.70	70.99	71.90	74.30
Plastic products (356)	70.80	70.80	71.60	91.10	73.20	72.27
Pottery, China and Earth ware (361)	61.60	65.70	58.60	64.60	72.20	64.17
Glass and glass products (362)	62.00	57.00	67.90	61.80	77.00	62.77
Non-metallic minerals (369)	68.11	62.02	67.48	67.71	58.94	65.12
Iron and Steel (371)	69.42	63.15	68.80	58.06	55.68	63.43
Non-ferrous metal (372)	75.40	56.20	68.20	80.80	73.30	69.58
Fabricated metal (381)	73.62	69.13	70.54	71.94	75.03	70.93
Machinery (except electrical) (382)	81.17	74.24	76.17	75.85	82.91	78.00
Electrical machinery (383)	77.62	72.96	78.69	81.01	82.23	77.44
Transport equipment (384)	72.48	66.11	79.39	76.35	75.47	74.93
Professional scientific (385)	79.21	79.06	64.28	72.79	77.14	74.27
Other manuf. (jewellery, pens, toys, brushes) (390)	73.87	70.76	74.46	67.80	71.79	70.97
Total Manufacturing	73.05	79.09	81.76	71.32	71.74	71.40

- Overall mean TE: 71.4% (74% in 1983 to 72% in 1999).
- Hence, no evidence of continuing/ sig TE improvement (suppoted by other studies).

- ***Industry Sizes, Input Ratios and Efficiency***
  - SFPF estimates: statistically significant parameters of industry sizes and factor proportions (capital-labour) (Table 2).
  - Industry sizes: less inefficiencies are associated with the larger industries.
  - Factor prop.: Higher proportion (K/L) → lower industry TE.

Conclusions

- Manufacturing industries →a key role towards V*ision 2020*.
- This paper: the diversity of manufacturing activities and dynamics in operative performances, allowing for both random noise and inefficiencies.
- SPFP estimates:
  - significant & positive impact of K with larger mean K elasticity.
  - Significant & positive non linear effect on output with large negative elasticity. Time variant elasticities: positive (0.27 & 0.3, 1983-1990); high negative in 1999 (crisis effect etc.)
  - Insig. & negative neutral technical progress; positive growth in factor augmented technology; Overall mean technical progress: 1.5% → steady over 1983-'99.
- Mixed evidence on time variant TE.
- No evidence of sig. TE improvement overall.
- Mean technical efficiency for all the 114 industries (16 years): Moderate 71%.
- Larger (lower K/L) industries ..more efficient.

- First, with higher capital share prudent use for labour forces is needed. Important in the transition process (from traditional or unskilled sectors to more capital deepening and skill based).
- Secondly, a moderate, but non-increasing technical progress & low growth in technical efficiency (1983-1999)→ sluggish productivity growth. Requires segregation of the high/low growth industries fro micro policy.
- Thirdly, raising of technical knowledge and skills, capacity expansion → raise TE→ improve productivity. Policy priority for raising TE to solve the core problem of sluggish TFP growth.

Thank you