Productivity, efficiency, and technical change in Indonesia's pre- and post-crisis provincial economies

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ABSTRACT

In the neoclassical economic framework, economic growth in a region is determined by change in two factors: production factor endowment and total factor productivity. We measure the productivity change over time in Indonesia's pre-and post-crisis provincial economies, by employing the data envelopment analysis (DEA) based Malmquist productivity index (MP). It can be further decomposed into two components: catch-up index (relative efficiency change) and frontier shift index (the technical change).

Using the annual observations of 26 contiguous provincial GDP and factor inputs (labour, physical, and human capital) for 1990–2010, we found that Indonesia experienced favorable relative efficiency improvement and stagnant technical progress on provincial average. We also found the convergence in the relative efficiency that the less (more) relative efficient province in the initial study period has improved more (less) for the period.

However, several innovative provinces contributed to the technological progress at the aggregate provincial level for most periods, such as Jakarta and West Java. Some provinces keeping relative efficient in the input-output operation, for example, East Kalimantan, failed to contribute the technological progress at the national level.

Keywords: data envelopment analysis, Malmquist productivity index, region, Indonesia
JEL classification code: R11, R12, R58

1. Introduction

Economic growth is inevitably uneven across subnational regions. Some regions—usually those with better connections to the international economy, with the presence of rich mining enclaves, with good market-oriented governance, with urban agglomeration effects — experienced the favorable economic growth. In particular, the large East Asian economies such as China, Indonesia, Malaysia, Thailand, and Vietnam have been facing these issues. Hill (2002) describes significant interregional income growth gaps between the coastal and inland regions in China, between West and East Malaysia, between Bangkok and the rest of the country in Thailand, and between the northern and southern parts of Vietnam.

On account of nation's size, insular geography, the world's fourth most population size, and its rich endowment of natural resources, Indonesia consists of the widely different socioeconomic sub-national regions: the nation's largest urban agglomeration province (Jakarta), the resource-rich provinces (Ache, Riau, East Kalimantan, and Papua), the internationally well-known tourist destinations (Bali and Yogyakarta), the emerging manufacturing cluster provinces (West and Central Java), and the labor-intensive agricultural provinces (the rest of provinces). Given extraordinary diversities, the nation is beset by a serious resource imbalance, uneven economic growth, and income inequality among provinces. To address this issue, the government has implemented various policies; however, outcomes are still far below the target level.

In the neoclassical economic framework, economic growth in a region is determined by change in two factors: production factor endowment and total factor productivity. This paper measure the productivity change in Indonesia's provincial economies over a 20-year period spanning the global economic crisis, by employing the data envelopment analysis (DEA) based Malmquist productivity index (MP). DEA is a non-parametric linear programming (LP) method for assessing the relative efficiency of decision-making units (DMUs), using inputs to produce outputs. DEA derives a surface called a "frontier," which follows the peak performers and envelops the remainder. The frontier connects all the DMUs with the best relative performance in the observed data and thus represents the estimated maximum possible production that a DMU can achieve for any level of input (Cooper et al. 2006).

Originally, DEA was applied used in productivity analysis at the micro level, but it has recently become increasingly popular at the macro level as a non-parametric alternative to growth accounting (Enflo and Hjertstrand 2009). Charnes et al. (1989) applied this technique to regional economic performance analysis, evaluating relative efficiency in terms of economic development in 28 Chinese cities. The DEA technique subsequently became a popular tool in regional economic analysis (Stimson et al. 2006).

However, the original DEA technique cannot analyze the efficiency frontier shifting over time. Then, we apply MP that evaluates the time series change in input-output efficiency at the aggregate provincial level. The MP analysis, introduced by Caves et al. (1982), measures the ratio of DEA efficiencies in two different time periods with shifting DEA efficiency frontiers. The Malmquist index can be decomposed into two components: "catch-up" and "frontier shift". While the former measures how much closer to the frontier that a DMU moves, the latter does the movement of the frontier. Since the frontier is composed of the "DEA efficient" DMUs among all the firms in a time period, the frontier shift means the change at the province level. Using this frontier shift, we display the input-output efficiency change of Indonesia's provincial economies throughout the decade 1990-2010.

2. METHOD AND DATA

2.1. DEA analysis of provincial efficiency

Assuming the constraint returns to scale (CRS), we employ the CCR model[1] that derives the frontier without inefficiency in order to measure the input-output efficiency in the provincial economies. In the CRS frontier, all DMUs operate at the optimal scale and the maximum level. Imperfect competition, government regulation, financial constraints, and other factors can cause DMUs to operate at non-optimal scales. At a given scale, managerial underperformance can cause DMUs to operate below their maximum level. Each DMU is assigned an efficiency score between zero and unity (efficient: score = 1; inefficient: score < 1).

DEA models have two orientations: input-oriented and output-oriented. The former minimizes DMUs' levels of inputs while keeping output unchanged, whereas the latter maximizes DMUs' outputs while keeping inputs unchanged. We treat a province as a DMU and use output-oriented model in order to take into account given province-specific resource endowments.

Suppose that each province i ($i = 1, ..., n$) uses m inputs X_{ij} ($j = 1, ... m$) to produce gross regional domestic products (GRDP) Y_i. The following output-oriented DEA CCR model in the dual form generates the technical efficiency score for the province of interest $i0$, gi0 ($=1/\theta$) ($0 \leq gi0 \leq 1$).

$$
\begin{aligned}
&Max_{\theta,z}\ \theta,\\
&s.t.\ \sum_{i=1}^{n} z_i Y_i \geq \theta \cdot Y_{i0}\\
&\qquad \sum_{i=1}^{n} z_i X_{ij} \leq X_{i0j}\\
&\qquad z_i \geq 0
\end{aligned}
\tag{1}
$$

where θ and z are model's decision variables. We can generate DEA scores, $gi0$ for all provinces by solvong Equation (1). The target provinces $i0$ under evaluation with $gi0 = 1$ are judged DEA efficient while those with $gi0 < 1$ are defined as DEA inefficient.

2.2. Malmquist productivity index measuring the change in efficiency over time

To measure the productivity change over two decades, we employ the Malmquist (productivity) index (Malmquist, 1953) analysis within DEA framework. Details of this framework are given, referring to Hashimoto et al (2009).

Figure 1 presents a single input and output DEA case where province A was at point A in period α, and line OCD represents the CCR DEA frontier. The output-oriented efficiency of DMU i0 is then measured by PA/PC (<1, DEA inefficient). When point A is on the frontier, the DEA efficiency is the unity (DEA efficient). Suppose that in period β (β > α), province i has moved to point B and the frontier itself has also shifted to line OEF. DEA efficiency change of province i can be measured by the ratio of DEA efficiency in period β to that in period α, but the frontier has shifted, so that we compute the geometric mean of ratios as to the two

[1] The CCR model is named after the authors of Charnes et al. (1978).

frontiers in periods α and β. The Malmquist index of province *i* between periods α and β, based on this CCR output-oriented DEA model is expressed as

$$MI_i[\alpha,\beta]=\left(\frac{QB/QD}{PA/PC}\cdot\frac{QB/QF}{PA/PE}\right)^{1/2} \qquad (2)$$

Here, MI > 1 means a gain in DEA efficiency of province *i*0 from period α to β, while MI = 1 and MI < 1 mean the status quo and loss respectively. Multiplying the right-hand side of Equation (2) by $\left[\frac{QB/QF}{QB/QF}\cdot\frac{PA/PC}{PA/PC}\right]^{1/2}$, the Malmquist index can be decomposed multiplicatively into the following two components as;

$$\begin{aligned}MI_i[\alpha,\beta]&=\frac{QB/QF}{PA/PC}\times\left(\frac{PA/PC}{PA/PE}\cdot\frac{QB/QD}{QB/QF}\right)^{1/2}\\&=CU_i[\alpha,\beta]\times FS_i[\alpha,\beta]\end{aligned} \qquad (3)$$

The first term in the right hand side of Equation (3) indicates catch-up index, denoted as CU, i.e, CU > 1 means that DMUi has moved closer to the period β frontier than to the period α frontier and indicates progress in the relative efficiency over time. CU = 1 and CU < 1 mean that it has the same distance and that it has moved farther, respectively.

The second term indicates frontier shift index, denoted as FS, and FS > 1 means a gain in frontier shift from period α to β (shift upward) as measured from the location of province *i*, i.e., the frontier has moved so as to have the more output with the fewer input as shown in Figure 1. On the other hand, FS < 1 means a loss in frontier shift (shift downward). FS = 1 means no change.

Since PE/PA in Figure 1 is, for example, the DEA efficiency of the period α in province *i* measured by means of the period β frontier, we denote it as $\theta[D^\alpha, F^\beta]$. Then from formula (3) can be expressed as follows:

$$MI_i[\alpha,\beta]=\frac{\theta[D^\beta,F^\beta]}{\theta[D^\alpha,F^\alpha]}\cdot\left(\frac{\theta[D^\alpha,F^\alpha]}{\theta[D^\alpha,F^\beta]}\cdot\frac{\theta[D^\beta,F^\alpha]}{\theta[D^\beta,F^\beta]}\right)^{1/2} \qquad (4)$$

In the liner programing (1), let X_i^α and Y_i^α be X_i and Y_i in the period α, respectively. $\theta\,[D^\alpha, F^\alpha]$ can be obtained as the maximum of the following liner programing, the ordinary DEA model:

$$\begin{aligned}&Max_{\theta,z}\theta\\&s.t. \le \textstyle\sum_{i=1}^{n} z_i Y_i^\alpha \ge \theta\cdot Y_{i0}^\alpha\\&\quad \textstyle\sum_{i=1}^{n} z_i X_{ij}^\alpha \le X_{i0j}^\alpha\\&\quad z_i \ge 0\end{aligned} \qquad (5)$$

$\theta\,[D^\alpha, F^\beta]$ can also be obtained by the liner programing (6) replaced α by β. While $\theta[D^\alpha, F^\beta]$ is obtained as the maximum of

$$
\begin{aligned}
& Max_{\theta,z}\theta \\
& s.t. \leq \sum_{i=1}^{n} z_i Y_i^{\beta} \geq \theta \cdot Y_{i0}^{\alpha} \\
& \quad \sum_{i=1}^{n} z_i X_{ij}^{\beta} \leq X_{i0j}^{\alpha} \\
& \quad z_i \geq 0
\end{aligned}
\tag{6}
$$

This forms the DEA exclusion model (Andersen and Petersen, 1993). Finally, we can obtain θ [D^{β}, F^{α}] by using the DEA exclusion model (6) with α and β switched.

2.3 Cumulative Malmquist index

Applying the data to LPs (5) and (6), and through formula (4), we can compute the catch-up (CU [α, β]), the frontier shift (FS [α, β]), and the Malmquist indices (MI [α, β]). Normally, these indices, for year β, would be compared to those in the preceding year, i.e., α = β – 1. However, such annually successive indices, used by Färe et al. (1994) and Coelli et al. (1998), do not seem appropriate to observe chronological change over 21-year sample period, because the Malmquist index as well as the frontier shift index do not satisfy the circular test that requires the product of index values for successive price changes to be equal to the index value for the whole change, i.e., MI_i [α, α + 1] × MI_i [α + 1, α + 2] ≠ MI_i [α, α + 2]. Therefore, we employ another index, cumulative index values, introduced by Hashimoto and Haneda (2008).

They measure successive changes from the standard year through to year β. The cumulative indexes can be all compared to the standard year 1990, which was the beginning of our sample period, i.e., MI_i [1990, β], CU_i [1990, β], and FS_i [1990, β] (β = 1991, ..., 2010). Here, the cumulative index values when β = 1990 are all one. Note that we should employ geometric rather than arithmetic means as averages of the CU, FS and MI indices since they are all multiplicative in nature.

2.3 Data

We use GRDP, factor inputs (labor, physical, and human capital), and the population of 26 contiguous Indonesian provinces for 1990–2010.[2] The data for provincial GRDP are sourced from *Gross Regional Domestic Product of Provinces in Indonesia by Industry*. The population data are sourced from *Population Census* and *Intercensal Population Census Indonesia*. The data for the provincial labor force by education attainment are sourced from *Labour Force Situation in Indonesia*. Average period of education of labor force is used as a proxy variable for human capital, weighted by the provincial labor force’s share of education attainment. The Central Bureau of Statistics, Indonesia, officially publishes all the aforementioned datasets; however, data on physical capital stock have not been officially published in Indonesia. Therefore, we use provincial estimates from Kataoka (2013) and Kataoka and Wibowo (2014).

[2] Political reforms after the economic crisis in 1998 increased the number of provinces from 27 to 34. Until now, no effort has been made to adjust historical data to account for these changes; therefore, we consider only 26 provinces, aggregating data on the new and existing provinces for each year. The eight newly established provinces are as follows: North Maluku (Maluku, 1999), West Papua (Papua, 1999), Banten (West Java, 2000), Bangka-Belitung (South Sumatra, 2000), Gorontalo (North Sulawesi, 2000), the Riau Islands (Riau, 2002), West Sulawesi (South Sulawesi, 2004), and North Kalimantan (East Kalimantan, 2012). Within parentheses are the original province and the year in which the new province was established (Kataoka and Wibowo 2014).

3. EMPIRICAL RESULTS

3.1 Cumulative changes for 1990−2010

The Malmquist index indicates the DEA efficiency of a province taking both the catch-up and frontier shift into consideration. Table 1 presents the cumulative values of three indices, MI_i [1990, 2010], CU_i [1990, 2010], and FS_i [1990, 2010] by province and the corresponding values of geometric mean for the observation period 1990–2010. In addition, the table presents the DEA efficiency scores measured by the frontier in the corresponding year, $\theta\ [D^{\alpha}, F^{\alpha}]$ in 1990 and 2010.

The cumulative catch-up index value indicates that the relative input-output efficiency (shown at the fourth and seventh columns) has increased by 78.6 percent from the start year 1990 to 2010 in average and improved at the annual rate 37.6%. The DEA efficiency scores indicate that more (less) efficient provinces in the initial year improved less (more) over the observation period. For example, the provinces with the three largest mean values of the cumulative catch-up index (Bengkulu 2.438, Jambi 2.089, and Central Sulawesi 2.155) are those with the least DEA efficiency scores in 1990: (Bengkulu 0.184, Jambi 0.191, and Central Sulawesi 0.187). These are the resource-poor off-Java peripheral provinces. We found the strong negative correlations between the efficiency scores in 1990 and the corresponding mean values of cumulative catch-up index: −0.813.

The cumulative frontier shift index values indicate that the technology level (shown at the fifth and eighth columns) has decreased by 47.0 percent to 2010 in average and has deteriorated at the annual rate 33.1%. Only five provinces, Jakarta (1.596), West Java (1.362), East Java (1.355), Riau (1.135), and Central Java (1.019), showed the indices over the unity and those could have improved the technological level compared to the starting year. Those are mostly located in Java Island and the higher income provinces.

The cumulative Malmquist index values indicates that the productivity has in year 2010 dropped to 5.4 percent of the start year 1990 and has become worse in average at the annual rate 8.0% over the period. Considering the two multiplicative components above, the productivity decline on provincial average over the period is due to the large negative growth in the technological change, which could not be covered by the large efficiency growth.

3.2 Cumulative changes for 1990−2010 for selected provinces

The set of three cumulative indices gives us much valuable information about the productivity changes within each province. Next, we focus on the cumulative annual changes in productivity and their corresponding components for any province (s) of interest, using the cumulative indices. Figures 2(a)–(d) presents such graphs for four selected provinces, Jakarta, West Java, East Kalimantan, and Bengkulu, each of which includes three cumulative indices, CU, FS and MI. Note that cross-sectional DEA for the start year, 1990, treating each prefecture as a separate DMU, found them all originally on the productivity frontier, $\theta\ [D^{1990}, F^{1990}] = 1$.

For Jakarta, shown by Figure 2(a), the cumulative catch-up indices are all one. That is, Jakarta was on the frontier throughout the period 1990–2010. From Equation (3), we see that the Malmquist and frontier shift for Jakarta move together. Since the former evaluates the productivity change of a province while accounting for a frontier shift, its productivity first rose, reached its peak (31% better than the start year) in 1996, and has once declined by 18% to the year of 2000. Then, the productivity rose monotonically by 59.6% in 2010.

This observation for Jakarta is also reasonable in light of the two financial crises: the Asian financial crisis in 1997/1998 and global financial crisis in 2007/2008. From 1997, the productivity figure declined steeply and the impacts of the 1997/1998 crisis were much more severe in the relatively higher income Java-Bali region than in other regions (Akita and Alisjahbana 2002). In 2008, the productivity in Jakarta remained increasing, because Indonesia's performance during the 2007/2008 crisis was vastly better than during the 1997/1998 crisis and superior to that of most other countries in the East Asia region (Kuncoro et al. 2009). We observe the similar trend in West Java to Jakarta, from the graph in Figure 2(b). Also seen is movement of the productivity frontier versus the positions of Jakarta and West Java on the annual frontiers.

For the province of East Kalimantan, the cumulative catch-up indices are all one sown at Figure 2(c). Like Jakarta, it was on the frontier throughout the period 1990–2010 and consequently the Malmquist and frontier shift move together. The both indices initially increased to 1992 and then turned to decrease for the remaining period. This exhibits that CU [1990, β] = 1 (β = 1990, ... , 2010) and FS [1990, 1994] < 1 for East Kalimantan. But, for Jakarta, which was on the frontier from 1990 to 2010, FS [1990, 1994] > 1 (Figure 2(a)). By comparing the two years, 1990 and 1994, we thus find that their frontiers cross one another, shown by Figure 3. From 1990 to 1994, that part of the frontier on which Jakarta was located has now moved upward, while the section on which East Kalimantan was located has moved downward. This finding provides some advance insight on our further research questions.

The province of Bengkulu presents the positive values of the cumulative catch-up index for all years except the year of 1991. The catch-up index measures how much a province is closer to the frontier; thus, this observation indicates the improvement in efficiency for the observation period. On the other hand, the frontier shift index declined the values monotonically (Figure 2(d)).

3.3 Shifts in Indonesia's productivity for 1990−2010

As the cumulative frontier shift index indicates the move of the province's input-output efficiency frontier from the location of each province, the frontier shift on average could be an appropriate indicator to measure the technological change at the aggregate provincial level. In order to evaluate how the technological level in Indonesia has changed over the study period 1990–2010, we exhibits the average, cumulative frontier shift indices of all 26 provinces FS [1990, β], β =1990, ... , 2010 at Figure 4.

The index has monotonically droped to 53.2% in year 2005 from the start year 1990, in spite of the slight improvement for 2002−2003. After 2005, it remains almost constant between 53.0 % and 54.0%. This indicates that Indonesia experienced the large loss in the technological growth at the aggregate provincial level for 1990−2010 although the deterioration has become less severe since 2005.

For the two decades with the Indonesia's provincial efficiency frontier almost annually shifted downward, shown at Figure 4; however, it is difficult to assume that all provinces experienced the downward shift in efficiency frontier for years. Then, we examined each province's influences positively on frontier shift at the national level, every four year. Referring to Färe et al. (1994) and Hashimoto et al. (2009), we employed the following three conditions to designate the provinces that caused the frontier-upward shift from the preceding sub-period:

$$(\mathrm{a}): \frac{FS_{i0}[1990, \beta]}{FS_{i0}[1990, \beta - 4]} > 1, (\mathrm{b}): \theta[D^{\beta}, F^{\beta}] = 1, (\mathrm{c}): \theta[D^{\beta}, F^{\beta - 4}] > 1$$

$$\beta = 1990 + 4\gamma\,(\gamma = 1, \ldots, 5)$$

That is, those provinces *i* in year β must be on the year β frontier (condition b), which is judged as ‘‘shifted upward from year β − 4” (condition a), and on the upward section of the frontier (even in the crossed-frontiers case as shown in Figure 3) (condition c). Any of the four provinces of Jakarta, West Java, East Java, and East Kalimantan are listed on Table 3 as frontier-upward shifters that satisfy the above three conditions in each sub-period in all sub-periods except 1994−1998. Indonesia experienced the economic crisis in 1997/1998 of which impacts differed by region and were much more severe in the relatively populous high-income Java-Bali provinces than in other regions (Akita and Alisjahbana 2002). We note that the provinces of Jakarta and West Java appear most frequently on the lists of frontier-upward shifter and have been the innovative provinces in the period 1990−2010.

4. CONCLUSION

We examine the change in DEA efficiency over time in Indonesia's provincial economies, by employing the DEA based Malmquist productivity index. Using the cumulative frontier shift index, we could quantitatively show the time series change in the input-output efficiency of Indonesia's provincial economies throughout the decade 1991-2010. We here found that the productivity decline on provincial average over the period is due to the large negative growth in the technological change (measured by the frontier shift index), which could not be covered by the large positive growth in relative efficiency (measured by the catch-up index). The large positive efficiency growth at the aggregate provincial level was contributed by the off-Java recourse poor low income provinces that have successfully performed their utilizations and allocations. Among many provinces with the negative technological growth, on-Java provinces of Jakarta and West Java contributed to the technological progress at the aggregate provincial level for most periods. The central government has been pursuing the balanced economic growth, promoting infrastructure investment more on the off-Java low income provinces. In equity-efficiency trade-off, the government should tackle some difficult policy options.

Our work has several potential extensions. First, we can detect the factors affecting each index related to province-specific factors such as R&D expenses, infrastructure investment, and interprovincial linkages, employing panel data analysis. The second extension is to measure a negative-DEA score. It has a tendency to take insufficient account of a unit's inferiority and is different from the traditional DEA model that involves an upper-bound evaluation that focuses on each DMU's superiority. We can consider both ‘‘good’’ and “bad’’ shifts in the Indonesia’s provincial economies.

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Table 1 Cumulative value of three indices, Malmquist index and two components by province and the corresponding mean values

Province		Cumulative value 2010			Mean value for 1990–2010			Efficiency score θ [D^{α}, F^{β}]	
		MI	CU	FS	MI	CU	FS	1990	2010
1	Aceh	0.289	0.780	0.370	0.515	0.965	0.533	1.000	0.780
2	North Sumatra	1.206	1.517	0.795	1.129	1.305	0.865	0.624	0.946
3	Riau	0.955	0.841	1.135	0.993	0.923	1.076	1.000	0.841
4	West Sumatra	1.012	2.402	0.421	0.948	1.602	0.592	0.325	0.781
5	Jambi	1.440	4.063	0.354	1.189	2.089	0.569	0.191	0.777
6	Bengkulu	1.527	5.440	0.281	1.137	2.438	0.467	0.184	1.000
7	South Sumatra	1.009	1.148	0.879	0.986	1.044	0.944	0.582	0.668
8	Lampung	0.769	1.932	0.398	0.787	1.414	0.556	0.387	0.748
9	West Java	1.362	1.000	1.362	1.135	0.998	1.137	1.000	1.000
10	Jakarta	1.596	1.000	1.596	1.268	1.000	1.268	1.000	1.000
11	Central Java	1.119	1.098	1.019	0.997	1.045	0.954	0.800	0.879
12	Yogyakarta	0.938	2.274	0.413	0.949	1.602	0.592	0.224	0.510
13	East Java	1.312	0.968	1.355	1.098	0.963	1.140	1.000	0.968
14	Bali	1.218	2.933	0.415	1.105	1.847	0.598	0.264	0.774
15	West Kalimantan	0.969	1.640	0.591	0.986	1.330	0.742	0.318	0.521
16	Central Kalimantan	0.626	1.271	0.492	0.720	1.125	0.640	0.320	0.407
17	East Kalimantan	0.784	1.000	0.784	0.888	1.000	0.888	1.000	1.000
18	South Kalimantan	1.108	3.198	0.347	0.997	2.047	0.487	0.313	1.000
19	North Sulawesi	0.895	2.746	0.326	0.941	2.037	0.462	0.279	0.766
20	Central Sulawesi	1.309	4.027	0.325	1.074	2.155	0.498	0.187	0.753
21	South Sulawesi	1.081	2.118	0.510	1.047	1.576	0.664	0.401	0.849
22	Southeast Sulawesi	0.532	1.649	0.323	0.610	1.312	0.465	0.364	0.600
23	West Nusa Tenggara	1.196	2.713	0.441	1.091	1.782	0.612	0.187	0.506
24	East Nusa Tenggara	0.932	3.103	0.300	0.814	1.752	0.464	0.210	0.652
25	Maluku	0.855	2.880	0.297	0.719	1.328	0.541	0.268	0.772
26	Papua	0.333	0.681	0.490	0.472	0.829	0.570	0.818	0.557
Mean		0.946	1.786	0.530	0.920	1.376	0.669	0.509	0.771
Maximum		1.596	5.440	1.596	1.268	2.438	1.268	1.000	1.000
Minimum		0.333	0.681	0.281	0.472	0.829	0.462	0.184	0.407
No. of province with value > 1		14	22	5	10	21	4	-	-

Table 2 Shifts in frontier-upward technological change by period and province

Sub-period	Frontier-upward shifters
1990–1994	West Java, Jakarta, East Java
1994–1998	No provinces
1998–2002	West Java, Jakarta, East Kalimantan
2002–2006	West Java, Jakarta
2006–2010	West Java, Jakarta

Figure 1 DEA efficiency change with frontier shifting overtime

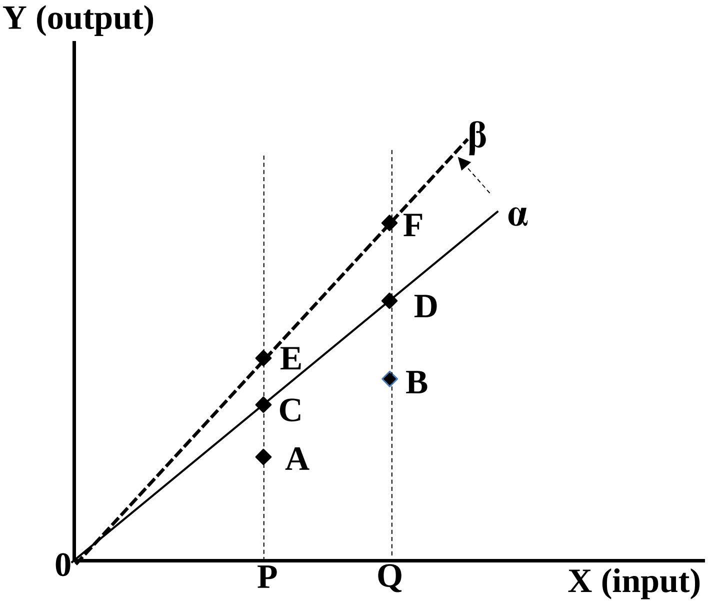
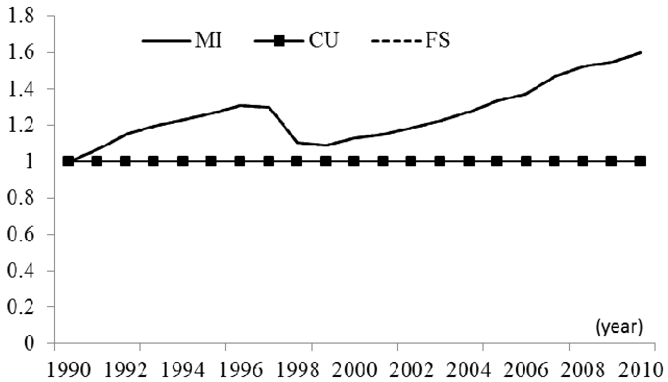
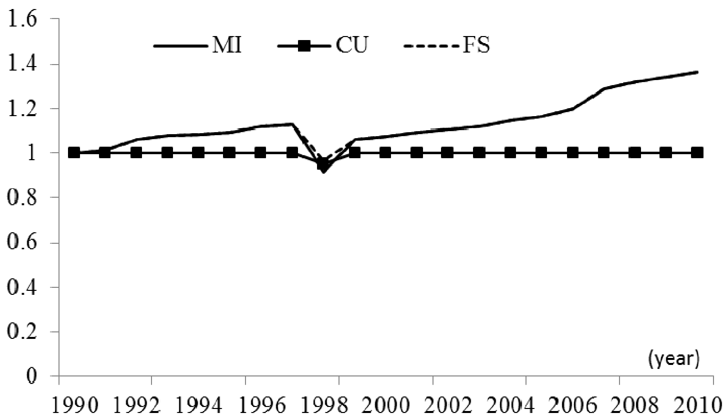


Figure 2(a)–(d). Cumulative values of Malmquist and catch-up, and frontier shift indices for selected provinces

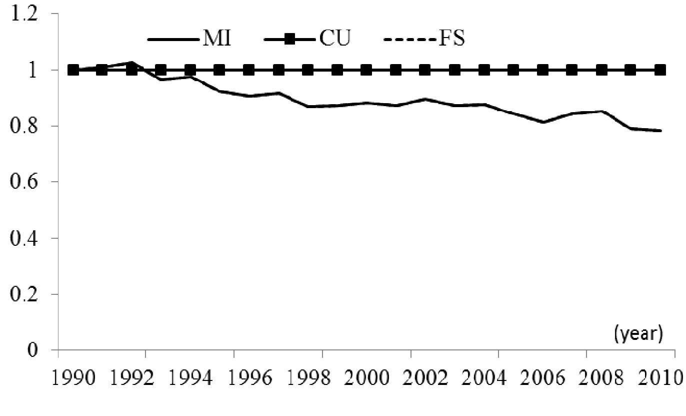
2(a) Jakarta



2(b) West Java



2(c) East Kalimantan



2(d) Bengkulu

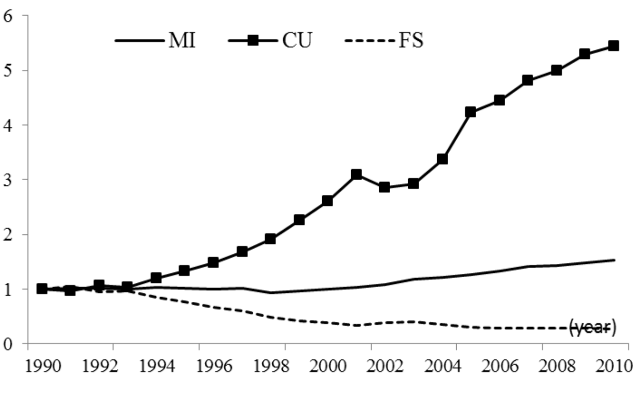


Figure 3 The case of crossed-frontier

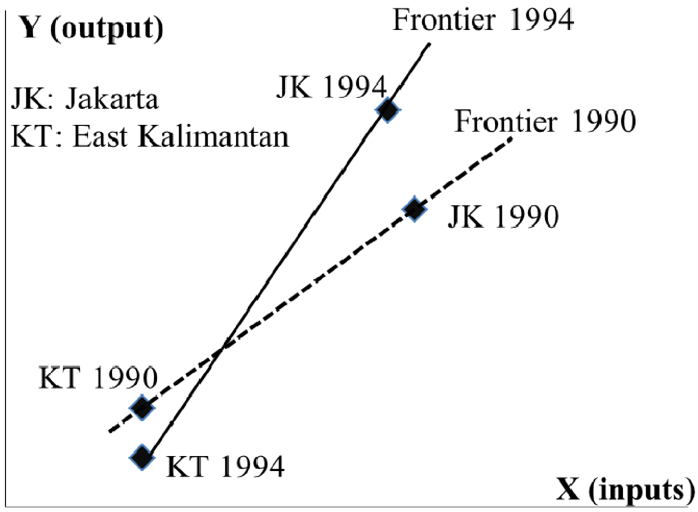


Figure 4. Indonesia's cumulative frontier shift on average over the period 1990-2010