REGIONAL PRODUCTIVITY GROWTH IN INDONESIA:
A DEA MALMQUIST PRODUCTIVITY INDEX ANALYSIS

By

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ABSTRACT

Accurate assessment of regional productivity growth is important for policy making. However, most of the productivity growth analyses of Indonesia are conducted at the national level. This thesis presents a comprehensive study of Indonesian regional productivity growth. It covers twenty-six provinces during the period 1985-2010. It aims to make several contributions. First, due to the unavailability of regional capital stock data, this research will construct a new database of Indonesian regional capital stock. Second, most of the previous studies of Indonesia’s productivity growth followed the growth accounting method. This study for the first time decomposes productivity growth at the regional level in Indonesia by using the DEA Malmquist productivity index (MPI) approach. Third, the examination applies different versions of the DEA-MPI (namely the conventional, fixed base year, sequential and metafrontier) and compares the results. Fourth, it provides probably the first study comparing regional productivity growth between Indonesia and China which will enrich the cross-country comparison literature. Finally, the productivity growth decomposition in this study makes it possible to examine the sources of productivity convergence or divergence in Indonesia’s regions.

The estimation results show that most of the Indonesian regions experienced productivity growth. On average, regional productivity growth was more than one per cent. The dominant factor of regional productivity growth was efficiency change which was offset by technical regress. However, estimation based on the islands shows that Java-Bali and Sulawesi islands experienced productivity growth which was dominated by technical change. In addition, based on technological gap estimates, Indonesian regions can be classified into three groups. These are regions that were very close to the global (national) frontier but experienced an inward shift of their group frontier, regions that were relatively close to the global (national) frontier and experienced an outward
shift of their group frontier and regions that were far from the global frontier but experienced an outward shift of their group frontier. Regional productivity growth comparison shows that regional productivity growth in Indonesia was higher than that in China and it was dominated by efficiency change whilst China’s was dominated by technical change. Three convergence tests, namely sigma, absolute beta and conditional beta convergence tests, support the existence of productivity convergence in Indonesian regions. The tests also reveal that efficiency change is the main source of regional productivity convergence while technical change is the source of divergence.

Overall, this study of productivity growth at the regional level in Indonesia sheds more light on regional development. It fills the gap in the literature on regional productivity growth in Indonesia by employing the DEA-MPI technique and decomposing productivity growth into several components. This topic becomes important for the discussion of the decentralization policy. Therefore, the findings may have policy implications for both national and regional development in Indonesia.
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LIST OF ABBREVIATION

AEC : Asian Economic Crisis
ALKI : Alur Laut Kepulauan Indonesia (Indonesian Sea Lane of Communication)
ASEAN : Association South East Asian Nation
BAPPENAS : Badan Perencanaan Pembangunan Nasional (National Planning Bureau)
BNSMP : Bali, Nusa Tenggara, Sulawesi, Maluku and Papua
BPC : Best Practice Change
BPG : Best Practice Gap
BPS : Badan Pusat Statistik (Central Bureau of Statistics)
BRIICS : Brazil, Russia, India, Indonesia, China and South Africa
CBS : Central Bureau of Statistics
CM : Combined Method
CMB : Combined Method Both
CMBC : Combined Method Both Corrected
CMS : Combined Method Sigit
CPC : China Productivity Centre
CRS : Constant Returns to scale
CV : Coefficient of Variation
DEA : Data Envelopment Analysis
DFC-MPI : Dominant Factor of Conventional Malmquist Productivity Index
DI : Daerah Istimewa (Special Region)
DKI : Daerah Khusus Ibukota (Special Capital Region)
DMU : Decision Making Unit
DRS : Decreasing Returns to scale
EFFCH : Efficiency Change
EIGRP : Export plus Import over Gross Regional Product
EPA : European Productivity Agency
EU : European Union
FDI : Foreign Direct Investment
FTZ : Free Trade Zone
GBHN : Garis-garis Besar Haluan Negara (State Guidelines for National Development)
GDP : Gross Domestic Product
GFCF : Gross Fixed Capital Formation
GRIPS : National Graduate Institute for Policy Studies
GRP : Gross Regional Product
GRPL : Gross Regional Product Level
GVA : Gross Value Added
HDI : Human Development Index
HPAEs : High Performing Asian Economies
ICT : Information Communication Technology
ICF : International Finance Cooperation
ILO : International Labour Organization
IPTN : Industri Pesawat Terbang Nasional (National Aircraft Industry)
IQPMA : Indonesian Quality and Productivity Management Association
IR-CGE : Indonesian Regional Computable General Equilibrium
IRS : Increasing Returns to scale
IRSA : Indonesian Regional Science Association
ITD : Industrial Technological Development
ITU : International Telecommunication Union
JBS : Java-Bali and Sulawesi
JICA : Japan International Cooperation Agency
JK : Java Kalimantan
KACC : Capital Accumulation
KLEMS : Capital Labour Energy Material Service
KP : Capital Productivity
LP : Labour Productivity
LPCH : Labour Productivity Change
Manupa : Maluku Nusa Tenggara and Papua
MCIT : Ministry of Communication and Information Technology of the Republic of Indonesia
MDG : Millennium Development Goal
METR : Marginal Effective Tax Rate
MFP : Multifactor Productivity
Mobnas : Mobil Nasional (National Car Industry)
MP3EI : Masterplan Percepatan dan Perluasan Pembangunan Ekonomi Indonesia (Master Plan for the Acceleration and Expansion of Indonesia's Economic Development)
MPI : Malmquist Productivity Index
MTFPI : Malmquist Total Factor Productivity Index
NAD : Nangro Aceh Darusalam
NKMP : Nusa Tenggara Kalimantan Maluku Papua
NMP : Nusa Tenggara Maluku Papua
NPC : National Productivity Centre
NRC-IRAP : National Research Council's Industrial Research Assistance Program
NSW : New South Wales
NTB : Non-tariff Barriers
NUTS : Nomenclature of Territorial Units for Statistics
OECD : Organisation for Economic Co-operation and Development
OLS : Ordinary Least Square
PC : Productivity Commission
Pelita : Pembangunan Lima Tahun (Five Years Development Planning)
PIM : Perpetual Inventory Method
PPS : Production Possibility Set
R&D : Research and Development
<table>
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<th>Acronym</th>
<th>Description</th>
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<tr>
<td>RDI</td>
<td>Regional Development Index</td>
</tr>
<tr>
<td>RTD</td>
<td>Research and Technological Development</td>
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<tr>
<td>SAKERNAS</td>
<td>Survey Ketenagakerjaan Nasional (National Labour Survey)</td>
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<tr>
<td>SBM</td>
<td>Slack Base Model</td>
</tr>
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<td>SBY</td>
<td>Soesilo Bambang Yudoyono</td>
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<tr>
<td>SLoC</td>
<td>Sea Lane of Communication</td>
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<tr>
<td>SM</td>
<td>Sequential Malmquist</td>
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<tr>
<td>SME</td>
<td>Small Medium Enterprise</td>
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<tr>
<td>SNA</td>
<td>System of National Account</td>
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<td>SSM</td>
<td>State Space Model</td>
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<td>TECCH</td>
<td>Technical Change</td>
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<td>TFP</td>
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<td>Technological Gap Ratio</td>
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<tr>
<td>TPSDM</td>
<td>Tim Pengembangan Sumber Daya Manusia (Human Resources Development Division)</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>UNCSTD</td>
<td>United Nations Commission on Science and Technology for Development</td>
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<tr>
<td>UNDP</td>
<td>United Nation Development Program</td>
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<tr>
<td>UNIDO</td>
<td>United Nations Industrial Development Organization</td>
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<tr>
<td>US</td>
<td>United State</td>
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<tr>
<td>UUD</td>
<td>Undang-Undang Dasar (National Constitution of Indonesia)</td>
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<tr>
<td>VRS</td>
<td>Variable Returns to scale</td>
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<tr>
<td>WDI</td>
<td>World Development Indicator</td>
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<td>WEF</td>
<td>World Economic Forum</td>
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CHAPTER 1
INTRODUCTION

The Law No. 32/2004 on local government in Indonesia gives more power to the provinces by the expansion of provincial government authorities in health, education, and investment\(^1\). The Indonesian provincial governments can be the key for the alleviation of economic disparities through planning, budgeting and monitoring (UNDP, 2009). Hartono and Irawan (2008) argued that the extension of provincial government power in Indonesia implies that development policies should consider different regulations among provinces.

Concurrently, the provincial economic performance has become the centre stage of development policies in Indonesia (Resosudarmo et al., 2009; BAPPENAS and UNDP, 2010, pp.45). Accordingly, researchers, economists and policy makers have assessed provincial economic performance by utilizing several economic measures such as gross regional product (GRP), regional development index (RDI), human development index (HDI) and other single or composite economic indicators. However, academic researches and economic policy discussions have shown that productivity is a crucial source of economic growth and hence affects the standard of living (UNIDO (2005a, pp.3); McKinsey Global Institute (2012, pp.1); PC (2013, pp.6)). This thesis contributes to economic performance assessment by estimating and analysing provincial productivity growth in Indonesia.

1.1 Background

Productivity estimation has long been recognized as one of the most important parts of economic measurement (see, Hulten (1979); Jorgenson (1991); Schultze et al. (1991);

\(^1\) Law No. 22/1999, the decentralisation law, gives more powers and authorities to regency/city governments. Less responsibility has been assigned to the provincial government on this new law. The revision of this law to the Law No. 32/2004 expands the functions of the provincial government.
Diewert and Fox (1999); Diewert and Nakamura (2007); OECD (2008, pp. 7) and PC (2013, pp.3), to name just a few). Bernanke (2012) mentioned that a good decision in many aspects of life including economic policies is mostly influenced by the accuracy of measurement. It means that the estimation of a particular indicator as a basis of problem solving will affect the final judgment we choose in the decision making process. Schultze et al. (1991) pointed out that one of the most important aspects of economic measurement should be productivity analysis which covers productivity level, productivity growth, and productivity growth decomposition. Growing concern about national productivity performance has also been supported by the establishment of institutions specialized in productivity such as the Productivity Commission (PC) in Australia, China Productivity Center (CPC), the National Productivity Council in India (NPCI), the Malaysian Association of Productivity (MAP) and the European Productivity Agency (EPA).

In Indonesia, the interest of the government in boosting national productivity began with the establishment of the National Productivity Center (NPC) in 1968. The explicit priority of productivity in Indonesia’s development planning can be found in the working document of United Indonesia’s Cabinet II 2009-2014, namely the master plan of acceleration and expansion of Indonesia’s economy (MP3EI)\(^2\). Productivity is mentioned as the fourth basic principle with productivity, innovation and creativity being driven by science and technology. The plan clearly explains that efforts to increase productivity towards the creation of competitive advantage can be achieved with innovation based human resource capacity development (Coordinating Ministry for Economic Affair Republic of Indonesia, 2011, pp.41). Therefore, careful measurement and analysis of productivity performance in Indonesia are needed at both the national

\[^2\]MP3EI is the master plan in which the Indonesian economy is divided into six integrated economic corridors to boost the exploration and development of the natural resources and infrastructure in each corridor by considering their economic potential (Coordinating Ministry for Economic Affair Republic of Indonesia, 2011, pp.24).
and regional level. These form an important part of development planning and the policy making process.

Many studies have explored Indonesia’s productivity growth performance\(^3\). Most estimation results show that Indonesia’s total factor productivity (TFP) growth was positive during the period of analysis (Figure 1.1). The studies with 2000 as the final year (which include the Asian Economic Crisis (AEC) in 1997) exhibit negative productivity growth. The studies covering the period of 1975-1990 (which involve the fall of oil price and other Indonesia’s export commodities in the 1980s) also display negative productivity growth.

**Figure 1.1** Average productivity growth based on estimation period


Source: Van der Eng (2010) and Timmer (1999)

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\(^3\) The studies are summarized in Van der Eng (2010) and Timmer (1999) and can be seen in Figure 1.1.
Accordingly, Van der Eng (2010) noticed that there are four periods in which productivity growth depicts a significant contribution to the Indonesian economy (Figure 1.2). He explained that a positive contribution of productivity growth in these periods was a result of recovery from economic slowdown accompanied by sound economic policies and institutional changes which improved efficiency and productivity of the country⁴.

**Figure 1.2** Contribution of TFP growth to Indonesia’s economic growth

![Graph showing TFP contribution and GDP Growth for four periods: 1933-1941, 1951-1961, 1967-1974, 2000-2008. TFP contributions are 3.8, 4.2, 8.5, and 5.1% respectively.]

Source: Van der Eng (2010)

Among the existing studies, little consideration has been given to productivity growth decomposition, particularly at the regional level. At the national level, Isaksson

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⁴ Van der Eng (2010) noticed that “all of the four periods came after significant setbacks in Indonesia’s economic development: respectively the 1930–32 crisis, the 1942–49 Japanese occupation followed by the war of independence, the mounting political and economic chaos of the early 1960s, and the 1997–98 crisis”
(2007b) and Krisnasamy and Ahmed (2008) examined the decomposition of Indonesia’s TFP growth into efficiency and technical changes as part of their international study. The estimation of regional TFP was first done by Wibisono (2005) who looked at trends of income and TFP inequalities among Indonesian regions. His study employed the growth accounting approach to estimate Indonesia’s provincial TFP growth. However, the decomposition of regional productivity growth into efficiency and technical change cannot be done using this method. Van der Eng (2009) stated that the TFP estimates from growth accounting could not be decomposed into several components. A recent study that decomposed Indonesia’s provincial productivity growth was done by Margono et al. (2011). They utilized the stochastic frontier method to estimate productivity growth in the period 1994-2000.

Empirical studies on regional productivity growth in Indonesia suffer from several shortcomings. The first is the unavailability of regional capital stock data which plays a vital role as an input factor in estimating TFP growth. The second is the lack of effort for productivity growth decomposition into efficiency change, technical change and technological gap change. As a consequence, detailed examination of the factors behind productivity growth is ignored. The third problem is that none of the previous productivity studies account for Indonesia’s heterogeneity in their estimation process. Another shortcoming is inadequate investigations of regional productivity convergence. Finally, regional comparisons between Indonesia and other countries in the area of productivity growth are rare.

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5 This implies that the method cannot clearly explain whether TFP growth is a result of efficiency improvement or the implementation of new technology or innovation.

6 The productivity growth study in this dissertation differs from Margono et al. (2011) in their scopes and approaches. Margono et al. (2011) employ the stochastic frontier method and decompose productivity growth into technical efficiency and technical progress. This study employs data envelopment analysis-Malmquist productivity index (DEA-MPI) and decomposes productivity growth into efficiency change, technical change and technological gap change. Despite relatively long period of study, this study also accounts for regional heterogeneity. Another difference is that this study also employs sequential DEA-MPI which doesn’t allow the possibility of technical regress.
All of these problems must be resolved since productivity growth estimation, decomposition and analysis are very important for Indonesia. The implementation of decentralization policy in Indonesia gives more power to the regional government and hence requires accurate assessments of regional economic performance. As a consequence, the estimation, decomposition and analysis of productivity growth at the regional level are necessary. This research thus addresses several questions. 1) What is the capital stock level in Indonesia’s regions 2) Why is Indonesia’s regional productivity growth important? 3) How is regional productivity growth measured, and what are the obstacles to such measurement? 4) Is there any evidence of productivity convergence in Indonesia’s regions, and if so, what are the sources of the convergence?

1.2 Research Objectives and Contributions

This thesis has several objectives. First, productivity growth in Indonesia’s provinces will be estimated. Second, productivity growth will be decomposed into efficiency change, technical change and technological gap change, followed by the identification of the factors that dominated Indonesia’s provincial productivity growth. Third, productivity growth will be estimated by employing four different approaches of data envelopment analysis Malmquist productivity index (DEA-MPI) and their results will be compared. Fourth, the estimation results will be analysed by considering several scenarios, which are economic development zones, fifth year development planning, spatial analysis using islands as cluster, economic development stages, and a cross country regional performance comparison (between Indonesia and China). Finally, regional productivity convergence will be tested and its sources may give a more insight into the study of Indonesia’s convergence.

Therefore, the following contributions are identified. First, due to the unavailability of regional capital stock data, this research will construct a new database of regional capital stock. The estimation incorporates sensitivity analysis with different
rates of depreciation. Second, most of the previous studies of Indonesia’s productivity growth have only explored productivity using the growth accounting method. This study is the first of its kind which decomposes productivity growth at the regional level by DEA-MPI. Third, the examination uses different versions of the MPI (conventional, fixed base year, sequential and metafrontier) and compares the results.

Fourth, this is the first comparison of productivity growth performance between Indonesia and China which will enrich the cross country comparison literature. Finally, the productivity growth decomposition in this study makes it possible to examine the sources of productivity convergence or divergence in Indonesia’s regions. The analysis of productivity convergence will also be conducted by comparing Indonesia and China.

1.3 Methods and Data

To achieve the stated research objectives, this research employs DEA in conjunction with MPI. Hitherto, neither of these methods has been applied in the case of the Indonesia’s provincial productivity growth measurement. DEA is a nonparametric approach which establishes an efficiency frontier from the data to assess performance of decision-making units (DMUs). Some literature also mentions the efficiency frontier as the best practice frontier since it is constructed from the best performing unit of the sample used in the analysis. To evaluate the efficiency of a unit, its performance is compared to the efficiency frontier. Inefficient units are the ones that are not in the efficiency frontier. Despite its suitability for assessing performance of DMU with multiple inputs and outputs, DEA doesn’t need to assume a functional form for the production function. Empirically, DEA has also been applied to the small sample analysis which is remarked as one of the valuable abilities and advantages of applying

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7 The DMUs can be regions, organisations, companies, schools, universities, countries, hospitals, hotels, banks, ports, airports, etc.
DEA\(^8\). The empirical application of DEA also supports inputs and outputs data with different measurement units.

As it will be explained over the chapters, DEA can be utilized to estimate MPI and assess the changes of efficiency of DMU overtime. Four approaches of DEA-MPI will be utilized. They are conventional, fixed base year, sequential and metafrontier MPI. DEA-MPI opens up the possibility for productivity growth decomposition which supports the extensive examination of productivity convergence in Indonesia’s regions. By the ordinary least square (OLS) method, the regression of average growth of efficiency change, technical change and input factor against the logarithm of initial labour productivity could be used for convergence tests. Furthermore, the application of this index doesn’t need the data of input and output prices which are required in other productivity indices (e.g. Devisia or Tornqvist index).

The estimation of DEA-MPI needs panel data of Indonesian regions. The data set of 26 provinces over a 26-year time period (1985-2010) are employed using gross regional product (GRP) as the output and labour and capital stock as inputs respectively. Other data to support the basic analysis including China’s panel data (GRP, labour and capital stock) and data of productivity growth determinants (openness, human development index, ICTs) are also utilized.

1.4 Thesis Structure

This thesis consists of eight chapters. Chapter 2 provides a summary of regional development indicators in Indonesia and presents a brief overview of the relation between regional development and productivity growth. This chapter also outlines how productivity growth improvement projected in the recent working document of Indonesia’s government, i.e., MP3EI, could be achieved.

\(^8\) Margaritis et al. (2007) used 19 OECD countries in their analysis, Tongzon (2001) utilized 4 Australian ports and 12 international ports for his study. The studies which also deal with small samples (under 20) are Krisnasamy and Ahmed (2008), Fare et al. (2006) and Suhariyanto and Thirtle (2001), among others.
In Chapter 3, a number of important concepts of productivity growth are discussed, such as productivity level and growth, partial and total factor productivity, and efficiency and technical change. Standard DEA models to estimate MPI will be described, followed by empirical works in the area of productivity. The chapter continues with a description of productivity-related policy development. This chapter will provide theoretical foundations for the subsequent analysis used in this thesis.

In Chapter 4, regional capital stock is estimated by employing the perpetual inventory method (PIM). The database is constructed for 26 Indonesia’s provinces over the period 1985-2010. Since there are no officially published data of regional capital stock in Indonesia, the PIM’s estimation results are compared with another database estimated by the state space approach. A simple analysis of these new databases will be presented.

Chapter 5 presents the results of productivity growth estimation and its decomposition. The key findings of conventional and fixed base year DEA-MPI are compared on a yearly and regional basis. Productivity change and its components over the period 1986-2010 are analysed. In this chapter, the results of sequential approach are also reported. The estimation of productivity growth will be continued by considering regional groups on the basis of islands, productivity growth over time and productivity growth based on Indonesian economic development stages. Finally, all of these approaches (conventional, fixed base year, sequential) will be compared with respect to productivity growth decomposition.

Chapter 6 provides the decomposition of metafrontier MPI into efficiency change, best practice change and technological gap change which may improve the results of productivity growth estimation. It is common knowledge that different groups of regions may have different production frontiers since they vary in backgrounds and
development paths. To gain more insight into different regional productivity growth performance, this chapter further presents a comparison between Indonesia and China.

In Chapter 7, a detailed examination of productivity convergence will be conducted to find out whether productivity convergence exists in Indonesia’s regions. Convergence of Indonesia’s provinces will also be analysed in comparison that of Chinese regions. The last chapter summarizes the relevant findings of the thesis, considers policy implications and deals with the potential for further research.
CHAPTER 2
PRODUCTIVITY GROWTH AND
INDONESIAN REGIONAL ECONOMIC DEVELOPMENT

2.1 Introduction

Indonesia is known as the largest archipelagic nation in the world. Geographically, the nation is in a strategic position. Indonesia lies at the intersection of two oceans, namely the Pacific Ocean and the Indian Ocean. Indonesia is also located between two continents (Asia and Australia) acting as a sea line of communication. It comprises more than 17,000 islands distributed in thirty-four provinces.

The largest province in Indonesia is Papua with a land share of 16.70 per cent. Other large provinces are located on Kalimantan Island including East Kalimantan (10.70 per cent), Central Kalimantan (8.04 per cent) and West Kalimantan (7.71 per cent). Riau, West Sumatera and South Sumatera are the remaining provinces with a land share greater than four per cent. The smallest provinces are in ascending order, Jakarta (0.03 per cent), Yogyakarta (0.16 per cent), Bali (0.30 per cent), Riau Island (0.43 per cent) and Gorontalo (0.59 per cent).

Conventionally, Indonesia’s regions can be classified into two development zones, namely, the east and the west. The east includes Kalimantan, Sulawesi, Nusa Tenggara, Maluku and Papua while the west features Sumatera and Java-Bali (Figure 2.1). It is easy to determine that the area of the east is bigger than that of the west. However, this does not guarantee that the GRP of the east is higher than that of the west. In 2010, the GRP contribution of the west was over 80 per cent compared to 16 per cent of the east. The domination of the west was due to a high share of more than 60 per cent from Java and Bali islands. This figure reminds us that Java and Bali play a significant role in Indonesia’s economic development.
Figure 2.1 Indonesian archipelago and provinces

Note:
The codes in the figure are the province codes. Before 2012, the number of provinces in Indonesia was 33. Based on the Law No 20/2012, North Kalimantan becomes a new Indonesian province since November 16, 2012. NAD refers to Nangroe Aceh Darussalam which is the formal name of Aceh Province. DKI Jakarta is ‘Daerah Khusus Ibukota Jakarta’ which refers to Special Provincial District of Capital of Jakarta. DI Yogyakarta is ‘Daerah Istimewa Yogyakarta which refers to Special Region of Yogyakarta.

Source: BPS (2011b, pp. xxiii)
Per capita income shows a similar trend in that the western part of the nation overwhelms the eastern zone. In 2010 average per capita income in the western regions was 25 million rupiah while in eastern regions it was 19 million. All regions in the west showed per capita income more than 10 million rupiah while some regions in the east still have per capita income under 10 million rupiah (Figure 2.2). These eastern regions include East Nusa Tenggara, Gorontalo, West Sulawesi, Maluku and North Maluku. The highest per capita income was recorded by East Kalimantan. The high per capita income of this province was supported by income from natural resources (oil and gas) and small population. In the second place was Jakarta. As the capital city Jakarta has greater ability to achieve high level of economic development and hence high per capita income. In third place was Riau followed by Riau Island, West Papua and West Sulawesi. It is important to note that the inequality of per capita income between provinces was extremely high, from the lowest North Maluku (5 million rupiah) to the highest East Kalimantan (90 million rupiah).

When per capita income among Indonesian islands is compared, the inequality was relatively moderate. The highest per capita income in 2010 was shown by Kalimantan Island which reached 35 million rupiah. The second highest per capita income was Sumatera followed by Java-Bali, Maluku-Papua, Sulawesi and Nusa Tenggara (Table 2.1). The per capita income ranking suggests that the high share of GRP of Java-Bali over the national GDP does not mean that these regions display the strongest performance in per capita income. This is because the size of population varies considerably. Although four provinces in Java, namely Jakarta, East Java, West Java, and Central Java, had high share of GDP in 2010, only Jakarta (ranked 2nd) and East Java (ranked 10th) belonged to the top ten in terms of per capita income.

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9 The gap between the lowest and the highest provincial per capita income is almost 85 million rupiah while the gap between the island with the lowest per capita income and the highest per capita income is only 27 million rupiah. In 2010, the exchange rate was 9,036 rupiah/USS.
The modest income per capita differences among islands do not imply lower inequality. In fact, the gap in per capita income remains unsolved. In Table 2.1, it can be seen that in Nusa Tenggara per capita income is around a quarter of that of Kalimantan’s per capita income. Income disparity among Indonesian regions has long been a subject of empirical studies such as Esmara (1975), Uppal and Budiono (1986), and Akita and Lukman (1995), Garcia and Soelistianingsih (1998), Akira and Alisjahbana (2002), Resosudarmo and Vidyattama (2006) and Nugraha and Lewis (2013), among others.

**Figure 2.2 Per capita income by provinces, 2010**

Note: The GRP per capita is obtained by dividing the region’s GRP at current prices by total population
Source: Author’s own calculation
Table 2.1 Per capita income by islands, 2010

<table>
<thead>
<tr>
<th>Islands</th>
<th>Per capita income (million rupiah)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Sumatera</td>
<td>24.158</td>
<td>2</td>
</tr>
<tr>
<td>Java-Bali</td>
<td>22.355</td>
<td>3</td>
</tr>
<tr>
<td>Nusa Tenggara</td>
<td>8.417</td>
<td>6</td>
</tr>
<tr>
<td>Kalimantan</td>
<td>35.165</td>
<td>1</td>
</tr>
<tr>
<td>Sulawesi</td>
<td>13.787</td>
<td>5</td>
</tr>
<tr>
<td>Maluku-Papua</td>
<td>20.782</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

The information of GRP and per capita income is valuable for the comparison of regional performance. However, these indicators are not enough to describe standards of living. Some factors that influence standard of livings are not taken into account by the measurement of GRP and per capita income. Per capita income informs us as to the average amount of input per person but fails to describe the distribution of wealth. GDP and per capita income also cannot fully describe changes in the quality of life. This is one of the reasons that the study of productivity growth in this thesis is needed to assess regional economic performance, as productivity is important for achieving high standards of living.

Despite the west-east per capita income inequality, the lagging behind of the eastern regions may also be reflected by a lower human development index (HDI) compared to the west. In Figure 2.3, it is clear that in 2010, all of the regions in the west exhibited an HDI of more than 70 whereas 50 per cent of the regions in the east had an HDI of less than 70. Two regions in Kalimantan with an HDI of more than 70 are Central and East Kalimantan. All regions in Sulawesi exhibit an HDI of 70 or more except West Sulawesi. Only Maluku showed an HDI of greater than 70 in Maluku-Papua.
An interesting picture from the data is that half of the Sumatera regions were part of the top ten provinces in terms of the HDI in 2010. Although Java is famous for its top universities, this advantage did not support all regions in Java to be the top ten performers in terms of HDI. Riau and Riau Island provinces ranked 3rd and 6th in 2010 respectively. North, West and South Sumatera ranked 8th, 9th and 10th in 2010 respectively. Jambi ranked 10th in 2004 and the Bangka Belitung province ranked 10th in 2007. In Java only DKI Jakarta (ranked 1st in all years) and Yogyakarta (ranked 4th in 2007-2010 and ranked 3rd in 2004) belonged to the top ten in terms of the HDI. Regions in the east that were included in top ten in the period 2007-2010 were North Sulawesi (ranked 2nd), East Kalimantan (ranked 5th) and Central Kalimantan (ranked 7th).

The different performance of Indonesia’s regions implies that responses to economic development vary among Indonesia’s regions (Hill et al. 2008). Consequently, the role of the regional economy must be the major concern for Indonesia’s national development. Hill (2000) mentioned that regionalism is very crucial in Indonesia as the world’s largest archipelagic state. This statement was in the spirit of Krugman (1991a, pp.3) who suggested that to understand the economy as a whole the best starting point is at the regional level, which describes the phenomena inside the nation. Similarly, Williamson (1965) found that there is a link between national economic development and the distribution of welfare among regions within a country. Some papers, among others, that examined the importance of regionalism in Indonesian economic development include Hill (1992), Sonis et al. (1997), Resosudarmo and Vidyattama (2006), Nazara et al. (2006) and Resosudarmo et al. (2009).

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10 Another province of Sumatera that was in top ten is Bengkulu. This province ranked 10th in 2005 (the year 2005 is not included in Figure 2.2)
Figure 2.3 HDI by provinces, 2004-2010

Source: BPS website (www.bps.go.id)
The last two papers highlight the importance of exploring Indonesia’s regions for greater development. Nazara et al. (2006) found that ignoring regional interaction patterns (either horizontal or vertical) leads to a poor result in the policy making process due to a lack of understanding of this interaction in Indonesia. Resosudarmo et al. (2009) employed the IRSA-Indonesia5 model to analyse some determinants of regional development and showed that reducing the regional development gap among regions is the main problem for the Indonesian economy\textsuperscript{11}.

The insight from the IRSA-Indonesia5 model is that regional tax policy and regional productivity shocks are two important factors for examining national regional interrelation. The relationship between these two factors was explained by Baumol et al. (1988, pp.357) who argued that productivity growth can increase tax revenue of the country without changing tax policy since productivity growth can induce increases in real income. The increase of this revenue can improve the budget allocation towards financing social expenditures. The example of this productivity-policy relation of Baumol et al. (1988, pp.357) is explained in the Queensland Treasury Report by Louca (2003) which found evidence that a higher level of per capita income in New South Wales, Victoria and Western Australia is the reason behind the difference in their regional productivity. Consequently, different regions need different policies to promote productivity growth.

This chapter aims to present a review of productivity growth in Indonesia in the regional setting. It will also discuss the important role of productivity at the regional level. The rest of the chapter is organized as follows. The next section is a discussion about the relationship between productivity and economic development. It also explains the importance of productivity in Indonesian regional economic development. The

\textsuperscript{11} As mentioned in Resosudarmo et al (2009), IRSA-INDONESIA5 is “a multi-year (dynamic) CGE model which divides Indonesia into five regions: Sumatera, Java-Bali, Kalimantan, Sulawesi and Eastern Indonesia. The connections between regions are due to the flow of goods and services (or commodities), flow of capital and labour (or factors of production) and flows of inter-regional transfers which can be among households, among governments, or between governments and households”.

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evolution of productivity growth and the strategic position of productivity growth in Indonesian development planning will be examined in section three. The final section is the conclusion.

2.2 Productivity and Economic Development

2.2.1 Productivity and Economic Growth

The problem of economic development is mainly the problem of per capita income inequality across the world and across time (Lucas, 1988). The main source of per capita income improvement is economic growth. The mechanics of economic development to increase output growth explained by Lucas (1988) can be simply shown by the mechanism of a production function. The ability of a country to produce more output without using more factor inputs (capital and labour) can influence the standard of living and hence the welfare of the country. In this mechanism the outputs are produced from input factors in which productivity plays its role as a source of output growth. This implies that productivity is the indicator of long term prosperity as remarked in Krugman (1991b, pp.9).

In the simple input output relation, productivity is the improvement in output with the same amount of input. Productivity has also been associated with the efficient utilisation of factor inputs. Productivity has been formulated by the ratio of output to input factors. As a composite indicator, productivity has been widely used to evaluate and assess performance of units of analysis by policy and decision makers, academicians and researchers. The analysis of productivity can be made by comparing different production units or comparing productivity over time.

Lucas (1988) emphasized the growth in productivity is endogenous, and is affected by human capital. The most interesting feature of Lucas (1988) in relation to productivity is the role of human capital as the engine of growth and hence the source of

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12 Further theoretical foundation of productivity can be seen in Chapter 3
productivity improvement. The increase in human capital will improve labour productivity and also contributes to the growth of physical capital.

Isaksson (2007a) found that at least four major aspects were associated with productivity determinants. These are creation, transmission and absorption of knowledge; factor supply and efficient allocation; institutions, integration and invariants; and competition, social dimension and environment. Given the productivity-economic growth relation, the connection between the two comes from the main factors that affect productivity growth. These factors involve capital investment, human capital, openness, knowledge transfer, institutions, research and development and the country’s macroeconomic and microeconomic foundations that affect the country’s efficiency (Isaksson (2007a), Wu (2008a, pp.29-31)). The level, intensity and existence of these factors are different among countries. Consequently, the effects of these factors are also different. Determining which factors affect Indonesia’s productivity and hence economic growth is the question that should be addressed.

Lucas (1988) remarked that Indonesia’s economic growth almost doubled in one decade, increasing from 3.9 per cent in 1960s to 7.5 per cent in 1970s. However, van Leeuwen (2007, pp.329-332) found that Indonesia was a follower country in which the role of human capital was not to create a new technology that could improve country’s productivity growth through innovation. This implies that economic growth in Indonesia between the 1960s and 1970s was mainly due to capital accumulation rather than productivity. The high growth of Indonesia in the 1970s was supported by the gain received from high profits due to the oil price boom. Van Leewen (2007, pp.329-332) found that Indonesia were lagging behind the world technology frontier and hence belonged to the Lucasian countries in which the human capital is used to apply the technology adopted from abroad. If this is the case then productivity growth is the most important aspect that can help Indonesia to catch up to the world technology frontier.
2.2.2 Productivity and Regional Development

In this section, three important questions in terms of productivity are explored. What is the role of productivity in regional economic development? Why is productivity important for Indonesia’s regions? How can the answer to the second question affect Indonesia’s development policy and regional planning?

Before answering these questions, it is necessary to take a glance at the optimistic views of Global Research of Standard Chartered Bank (2011, pp.2), the OECD (2012) and McKinsey Global Institute (2012, pp.1) about Indonesia’s productivity. The importance of productivity to Indonesia’s economy has been addressed by OECD (2012) in its long-term global growth prospect report. As one of the emerging Asian economies, Indonesia will experience productivity convergence toward 2060 with an average growth rate of 3.2 per cent in the period 2011-2060. This places it second only to China, which has a predicted productivity growth rate of 3.8 per cent (Figure 2.4). The report estimated that Indonesia’s productivity level was among the lowest in 2011 (15.5) while China and India were 19.5 and 21 respectively.

This prediction follows the common rule of convergence in which countries with low productivity will grow faster than high productivity countries. Although it is relatively easy to grasp the reason behind productivity convergence, a question still remains for Indonesia. In the case of Indonesia and India, it is clear that Indonesia will grow faster than India since its initial productivity was lower. However, in the case of China and Indonesia, it requires further explanations. Initial productivity in China was higher than Indonesia, but why is China predicted to grow faster than Indonesia? This question could be one of many important reasons to examine the role of productivity in Indonesia’s economic development in comparison with China.
The Global Research of Standard Chartered Bank (2011, pp.2) and McKinsey Global Institute (2012, pp.1) predict that Indonesia will become one of the top ten economies in the world by 2030. However, several challenges remain, including the productivity imperative, regional inequality and growth distribution, and infrastructure and resources constraints (McKinsey Global Institute, 2012, pp.2). Indonesia’s productivity improvement is one of the requirements to reach economic growth of up to 7 per cent (World Bank, 2011, pp.37). A recent report of the McKinsey Global Institute (2012, pp.1) found that Indonesia needs a 60 per cent productivity improvement from the base case of 2000-2010 in order to follow the World Bank’s (2011) explanation (Figure 2.5).

All of these optimistic views point out that productivity is the key to Indonesia’s future. However, the critical point is to analyse whether these national forecast statements also work for the Indonesian regions or in other words whether productivity
also matters for regional development. Hill at al. (2008) argued that Indonesia’s national economy can explain regional economic development but not the other way around. This is also one of the reasons to examine Indonesia’s regional productivity growth as the main objective in this thesis.

**Figure 2.5** Labour productivity growth vs. GDP growth

![Figure 2.5 Labour productivity growth vs. GDP growth](image)


One of the main goals of Indonesia’s regional economic development policy is to close the gap between more and less productive regions. Consequently, understanding the role of productivity in all levels of development is the starting point toward a roadmap of regional productivity improvement. Productivity affects three important aspects of regional development: living standards, social expenditures (public health, education and the environment) and inflation (Baumol et al., 1988, pp.352). In line with this, Isaksson et al. (2005) argued for at least three reasons for the importance of productivity study. Kaci (2006) also stated that an increase in productivity will increase purchasing power, investment through profit surplus and public spending as a support to investment. Eslake and Walsh (2011) mentioned that productivity growth could be the channel to deal with demographic changes, environmental or ecological constraint and the survival of businesses and jobs.
All of these factors will affect the ability of the regions to exist in the era of globalization which is determined by their own competitiveness (Gardiner et al., 2004). This competitiveness is a key to the future economic development of the regions since it covers complex factors that are known as the multidimensional concept of regional development in Nijkamp and Abreu (2009). This complexity may be better explained by the pyramid model of regional competitiveness as shown in Figure 2.6.

**Figure 2.6** The pyramid model of regional competitiveness

Lengyel (2004) created the pyramid to review the hierarchy of regional competitiveness as the basis for regional development planning. He divided the pyramid into direct (development or programming factors) and indirect (success determinants) factors. The development factors include research and technological development (RTD), small medium enterprises (SME), foreign direct investment (FDI), infrastructure and human capital and institutions and social capital (Figure 2.6). The success determinants include economic structure, innovative activity, regional accessibility, skills of the workforce, social structure, decision centres, environment and regional identity. At the top of the pyramid is the target outcome which is quality of life or standards of living. Between the programming factors and the target are basic categories.
which are regional performance indicators including income, labour productivity, employment and openness.

According to the pyramid it is clear that productivity leads to wider aspects of regional performance. It is therefore vital to reshape Indonesian regional development by introducing productivity as a development target. This productivity involvement should be incorporated in regional planning in order to give a new perspective to regions in boosting their competitiveness. This goal can also be part of the vision and mission of Indonesian regional development in order to achieve international and national excellence within the regions.

These complex systems of relation between productivity and regional economic development have been studied by Resosudarmo et al. (2009) by using IRSA-Indonesian model. They found that the regions in the eastern part of Indonesia experience faster productivity growth than their western counterparts. This model also shows that the faster productivity improvement will support higher GDP growth for eastern regions in the next decade. Higher productivity growth in eastern Indonesia has stimulated higher welfare through the improvement of per capita income both in rural and urban areas in these regions. The IRSA-Indonesia model has also shown that higher per capita income induces a lower level of poverty which is one of the most important targets of millennium development goals (MDGs). The final conclusion from this model is that productivity growth improvement is a factor behind higher economic growth as well as balanced development (a decrease in the gap) among regions. Nevertheless, Indonesia’s regional productivity growth has not been fully posted as an important mechanism to achieve the national goal. This is why productivity analysis is under-documented, particularly in regard to Indonesia’s regional development planning.
2.3 The Evolution of Indonesia’s Productivity Growth

2.3.1 Productivity Growth and Indonesian Economic Development

After recovering from economic and political instability during the early independence period (1945-1957) and guided democracy period (1958-1965), Indonesia achieved a stable, high level of economic growth for over three decades (1966-1996). From 1966 to 1972, the average GDP growth rate in Indonesia was 6.6 per cent annually. During its oil boom period (1973-1981) Indonesia maintained a high level of GDP growth (8 per cent per annum) until the fall of oil prices in early 1982 which led to a low GDP growth rate of 1.1 per cent (Figure 2.7). During the period 1988-1996, Indonesia experienced dynamic economic growth at a rate of 7.9 per cent annually. This achievement was acknowledged by the World Bank (1993, pp.1) in its classification of Indonesia as one of the “high performing Asian economies”.

However, a sharp fall in GDP growth in 1998 due to the Asian economic crisis (AEC) started in late July 1997 changed Indonesia’s economic outlook and fundamentals. The growth rate decreased from 4.7 per cent in 1997 to -13.1 per cent in 1998. This also placed Indonesia’s GDP growth rate as the lowest among the ASEAN5 countries in one decade (Hayashi, 2005)\(^\text{13}\). These economic changes in Indonesia have raised some questions regarding productivity growth which is one of the important sources of GDP growth. How have the trends of Indonesia’s productivity growth changed during the pre AEC period, in the AEC period and the post AEC period? Do the changes of Indonesia’s productivity growth follow the trends of GDP growth? Are the national patterns of productivity growth in these three periods similar to regional productivity growth patterns?

\(^{13}\) ASEAN5 involves Indonesia, Malaysia, Philippines, Singapore and Thailand
There are some studies exploring Indonesia’s productivity growth in the three periods (pre AEC, post AEC and AEC periods\textsuperscript{14}). The study by Sarel (1997) found that Indonesia’s productivity growth in the period 1978-1996 was 1.2 per cent annually. This period covered the period of high economic growth as a result of high profit from the oil price windfall and the post oil price boom period. In the latter period, the government’s policies of deregulation, export led growth and extended liberalization policies played a significant role in Indonesia’s positive productivity growth (Firdausy, 2005).

In the AEC period, productivity growth was similar to GDP growth which showed a negative value. Margono et al. (2011) estimated TFP growth in 26 Indonesian provinces which showed that the TFP growth dropped to -16.99 per cent in the AEC period. This annual productivity growth rate represented a great slowdown and becomes the lowest rate among other economic bust periods in Indonesia. However, national TFP growth in the AEC period estimated by Van der Eng (2009) displayed a different result. His study found that the TFP growth in the AEC period sank to -7.68 per cent. The discrepancy between the two studies lies in their scope and approach, i.e., methodology,

\textsuperscript{14} The pre AEC is before 1997, the AEC period is 1997-1999 and post crisis is beyond 2000. The reasons to choose the AEC as a decisive point are: 1) the periodization enables the examination of Indonesia’s productivity growth trends as an impact of AEC 2) the crisis is the period of evaluation of Indonesia’s long-term economic growth strategies and 3) the crisis provides a chance to start a new development paradigm for better standards of living which is the ultimate goal of productivity improvement.
period of study and data issues. Nonetheless, both results support that the AEC period is the period in which Indonesia’s growth pattern significantly differed from that in the previous periods.

During the years of 2000-2007 (the post AEC), TFP growth was positive and reached 1.67 per cent (Van der Eng, 2009). This was a sign of successful economic recovery from AEC. The contribution of TFP to economic growth in this period was also positive (33 per cent) meaning that this period could be characterized by crisis-driven economic reform. Firdausy (2005) identified Indonesia’s economic development phases by relating government policies to productivity growth. The phases are stabilization (1966-1970), petroleum boom (1971-1981), oil price adjustment period (1982-1985), effective liberalization (1986-1991), deregulation fatigue (1992-1997) and economic crisis and transition period (1998-2004).

In the early period of stabilization, Firdausy (2005) mentioned that productivity growth reached 8.6 per cent but declined sharply to 1.8 per cent in 1970. This period was characterized by the struggle of Indonesia’s government to control high inflation and boost infrastructure to improve economic development over the entirety of the country. Kawai (1994) estimated that during the petroleum boom period, Indonesia’s TFP growth was moderately high reaching 3.1 per cent (1970-1980). The better performance of this period was due to the profit from high oil prices followed by appropriate trade policies.

The third and fourth periods were the periods of crisis and recovery. The crisis was caused by the decline of the oil price during the early 1980s that resulted in Indonesia’s government implementing devaluation policy in 1983 and 1986. The recovery of this situation in the fourth period was achieved by financial reform in 1988 followed by the export-led growth policy which improved economic growth by more
than 8 per cent in the early 1990s. However TFP growth in the period 1980-1990 showed a negative value of -0.1 per cent (Kawai, 1994).

The last two periods have several features such as changes in trade policies to support economic growth, the economic crisis, economic recovery and reform and an attempt to implement decentralization policy. The changes in trade policies include the removal of non-tariff barriers (NTBs) and several tariff reductions. The economic crisis, recovery and reform were the most painful periods in Indonesia’s economic history. The era was marked by changes in the political landscape toward democratization, the conflict of interests among different political parties and their elite politicians, the pressure from international institutions through their economic recovery packages and the weak foundation of other economic fundamentals. This led Indonesia’s economy to an economic transition period characterized by vulnerability, fragility and instability. The efforts to implement decentralization for broader authorities and expansion of the roles of local government have raised new problems with the absence of regional government capabilities, high quality of human resources and strong regional institutions. This uncertainty could be the source of negative productivity growth in the period 1994-2000 (-9.94 per cent) shown by Margono et al. (2011).

The long term productivity growth estimation covering the period 1971-2007 can be found in Van der Eng (2009). Figure 2.8 exhibits the complete yearly evolution of Indonesia’s TFP from the early period of the oil price boom toward higher economic growth and faster social development as a result of economic reform and recovery. The latter period saw better performance of productivity growth in 2000 (1.76 per cent). The growth was also positive in the subsequent years and reached its peak in 2007 (2.45 per cent).

In general, the trend of yearly movement of Indonesia’s productivity growth in Figure 2.8 has followed the periodization of Firdausy (2005). The success of the
stabilisation period in the early 1970s was shown by the positive TFP growth in 1971 followed by more than 10 per cent growth in 1973. Although there was a sharp decline of TFP growth in 1975, on average TFP growth during 1971-1980 was still positive (2.36 per cent). Combining the three periods of Firdausy (2005), i.e., oil price adjustment period (1982-1985), effective liberalization (1986-1991), deregulation fatigue (1992-1997), TFP growth in the period 1981-1996 was negative (-1.36 per cent on average). This implies that productivity growth was not the source of high GDP growth in the economic dynamic period (1988-1996).

**Figure 2.8 Indonesia’s TFP, 1971-2007**

![TFP graph](image)

Source: Van der Eng (2009)

The finding in the previous paragraph regarding national TFP growth is reflected in Indonesia’s provincial TFP growth. Wibisono (2005) showed that in the period 1984-2000 most of the Indonesian regions experienced negative productivity growth. Only five regions (when including oil and gas in the estimation process) and nine regions (when excluding oil and gas in the estimation process) exhibited positive TFP growth (Figure 2.9). Another study by Margono et al. (2011) found that all regions experienced negative productivity growth during the period 1993-2000. The second insight from the estimation results is that the best performance was not found in the most developed regions. Most regions in Java and Sumatera that belong to this category showed
negative growth while laggard regions like East Nusa Tenggara and Papua exhibited relatively high and positive TFP growth.

**Figure 2.9 Indonesia’s regional TFP**

Source: Wibisono (2005) and Margono et al. (2011)

### 2.3.2 Institutional Development

In 1968 the National Productivity Centre (NPC) was established as a starting point in Indonesia’s productivity movement. The NPC was the productivity unit within the Ministry of Manpower and sought to reconcile the stakeholders related to productivity in Indonesia. The goal of the NPC was to develop productivity awareness by introducing the productivity principles to government bodies, businesses, labour, researchers, academicians and other private institutions. However, the NPC failed to promote productivity to these stakeholders since there was a lack of roadmaps and programs to be supported. This unit made no significant contribution to the needs of Indonesia’s economic development (Aroef and Djamal, 2009, pp. xlvi).

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15 The productivity movement refers to the movement to improve cooperation among three productivity chains which are businesses, labour and government. The main goal of the cooperation was productivity improvement of the countries (Boel, 2003, pp.149-184). Productivity movement refers to the commitment and active involvement by government, employers and workers in activities to increase productivity (Ohno and Kita, 2011).
In 1988 the NPC was changed to the Labour Productivity Center (LPC). Since 1993, the name of NPC has been changed to the Directorate General of Manpower Training and Productivity Development. The directorate established the Manpower Productivity Centre in 2002 which was renamed as Productivity Development Center (PDC) in 2007. Indonesia’s productivity movement under these working units mainly concentrated on the development of partial productivity, i.e., labour productivity (Sigit, 2004). To support the national productivity movement and to incorporate productivity with the stages of Indonesia’s economic development, Sigit (2004) suggested that it is crucial establish a national body that has specialized knowledge in regards to all aspects of productivity. The effort to follow this idea was made in 2005 by the creation of the National Productivity Organization, which was a separate government body under Indonesia’s president. However, the director of this organization is the Minister of Manpower and could be affected by the main task of the ministry, i.e., labour provision.

The productivity movement has also been promoted by the Ministry of Education through the establishment of the National Centre of Entrepreneurship and Productivity in 2010. This provides an opportunity for Indonesia’s universities to apply for financial assistance for a one-year program. However in practice this program is mostly reserved for entrepreneurship development among university students.

The interest of Indonesia’s private sector in productivity began with the establishment of the Indonesian Quality and Productivity Management Association (IQPMA) in 2008. The most important contribution of this productivity organisation has been the promotion of productivity to private institutions, companies and workforces. IQPMA has organized national and international quality and productivity conventions annually. As a relatively new association, IQPMA is in the stage of finding its role for national productivity improvement. It seems likely that IQPMA will mostly move
around the areas of product quality and training centres for individual productivity improvement.

In 2012 the Ministry of Women Empowerment published its policies and strategies to improve productivity amongst Indonesian women. The improvement of productivity amongst women is part of the program to eliminate discrimination against women which further supports a people-based economy, women entrepreneurs in small medium enterprises, increasing people-based female productivity improvement and the development of women empowerment for household poverty alleviation at the village level. These policies will be implemented with three strategies, namely, 1) improving, facilitating and bridging nongovernmental organizations, private institutions, businesses, and universities to participate in female empowerment, 2) developing awareness of female productivity improvement and 3) increasing cooperation and networking.

Until now, Indonesia’s productivity movement is still in the process of building and searching for a formula to success. First, unlike other countries the chair of Indonesia’s productivity movement is the Minister of Manpower. In the case of government-led productivity movements in Australia and Singapore, for example, the leading body is the Ministry of Trade and Industry. Second, productivity movements in other countries are often supported by high profile leaders. Weak government initiated movements cannot support the new mindset toward productivity improvement in all segments and stakeholders. Third, there is no special organization in charge of all aspects of productivity. This has led the Indonesian productivity movement to lose its momentum in building awareness as a starting point to accomplish the goal of productivity as the key driver of the country’s welfare improvement. Fourth, there is lack of effort and design programs for regional productivity improvement (at provincial, regency or city level). The last is a lack of international cooperation in terms of
productivity. Programs for bilateral and multilateral cooperation in the field of productivity are needed as pathways to learn from the world’s most productive economies.

2.3.3 Productivity and National Economic Planning

Despite unsuccessful experiences of Indonesia’s productivity movement, there is a strong signal from the Indonesian government of increasing awareness of the importance of productivity growth for the nation. If we refer to productivity growth as efficiency and technical change associated with the catch-up process and innovation, then the explicit priority of productivity in development planning can be found in the 11 national priorities of the United Indonesia Cabinet II 2009-2014\(^{16}\). The last priority mentions productivity growth components, which feature technological innovation. This priority is part of the indirect factors which are the success determinants in the pyramid model of regional competitiveness (Figure 2.6). This indirect factor affects regional development in the long term.

However like other priorities, this technological innovation is a general target without a specific real goal and strategy implementation. The government under SBY is well aware that these priorities and other national planning have to be realized by a working program\(^{17}\). Therefore this government has released a working document as the starting point for a new transformation of the Indonesian economy. The details of this master plan can be seen in Figure 2.10.

\(^{16}\) The priorities involve bureaucratic reform and governance, education, health, poverty reduction, food security, infrastructure, investment and business climate, energy, environmental and post disaster management, disadvantaged areas, isolated areas, post-conflict areas and the last is culture, creativity and technological innovation.

\(^{17}\) SBY refers to Soesilo Bambang Yudhoyono, the Indonesian President in two time periods, 2004-2009 and 2009-2014.
In the main strategy, productivity was mentioned as part of the third strategy, which is to strengthen national human resources capability and science and technology. The whole concept of this productivity improvement goal can be seen in Figure 2.11. The figure describes three stages of economic development which are factor driven (natural resource-based economy), investment driven (industry-based economy) and innovation driven (innovation-based economy). The figure clearly explains that increased productivity will move Indonesia into an innovation-based economy but gradual steps have to be considered. The first step is the availability of natural resources that can support labour-intensive investment, followed by capital and technology improvement which is skilled and labour-intensive. The last step is innovation which is associated with human capital.

The plan clearly explains that the efforts to increase productivity towards the creation of competitive advantage can be achieved with innovation-based human resource capacity development (Coordinating Ministry for Economic Affair Republic of Indonesia, 2011, pp.41). This idea will be applied by the President’s Initiative 1-747. The ‘one’ represents the 1 per cent GDP allocated to support research and development.
programs. The ‘first 7’ covers seven steps of innovation system improvement. The ‘four’ represents the four modes of economic accelerations and the ‘last 7’ are the seven objective visions of Indonesia 2025\(^\text{18}\).

**Figure 2.11** Productivity improvement towards competitive advantage

Recalling the pyramid in Figure 2.6, its framework may be in the same spirit as the graph of productivity improvement towards competitive advantages of MP3EI (Figure 2.11). In the document it is mentioned that sustainable economic growth can be achieved through technological progress in an innovation-based economy. This is the second fundamental of the pyramid model. Other fundamental productivity determinants that are highlighted in the master plan (which are included in the pyramid) are investment, skilled labour and human capital.

However, the focus of productivity performance in this master plan is at the national level, which contradicts its goal of accelerating national economic development through regional specialization. Another problem with Indonesia’s effort to improve

\(^{18}\) Further explanation of 1-747 can be seen in page 41 of Coordinating Ministry for Economic Affair Republic of Indonesia (2011, pp.41)
regional productivity growth is that the importance of productivity in Indonesia’s regional development is not reflected in decision-making and by public awareness.

Regional productivity improvement is needed in Indonesia. Previous sections explained that this improvement is required for a greater standard of living and regional competitiveness. To achieve the latter goals, high regional economic growth and hence per capita income that are equally distributed among regions is required.

Wibisono (2005) found that productivity growth is a significant factor of convergence. Improving productivity growth can help to overcome the income gap in Indonesia. The income gap is influenced by the different level of technology between regions. Therefore, productivity growth has to be the main policy target in Indonesian regions and a future concern of policy implementation. After examining the IRSA-Indonesia5, Resosudarmo et al. (2009) suggest that both central and regional Indonesian governments can play a role in improving regional productivity by increasing the budget and quality of the education system in less developed regions.

Therefore, the most important task toward Indonesian regional productivity improvement is to provide valid current data of regional productivity growth. This was also suggested by Porter (2001, pp. xi) in regard to regional development by mentioning that one of the most important government tasks is to supply better data for measuring economic performance at the regional level. This will be addressed as the main topic in this thesis.

2.4 Conclusion

The most urgent problem in the Indonesian regions is the nation’s unbalanced development. This has become a structural problem when spatial distribution of the development resources has followed the distribution of demographic and economic activities (Nazara, 2010). One of the factors that could overcome this problem is the existence of convergence among regions which could be achieved through TFP growth
improvement (Wibisono, 2005). The complex relations between the regional and national are the main source of problems for Indonesian development in which productivity must be examined and clearly explained. As the IRSA-Indonesia5 model (Resosudarmo et al., 2009) found that regional productivity performance could be the factor behind consumption, revenue (taxation), and poverty reduction, it is reasonable to put productivity as one of the Indonesian regional development goals.

At least eleven factors have been identified as the channels through which regional productivity growth affects regional development. Standards of living, social expenditures (public health, education and environment), inflation, poverty alleviation, better environment, purchasing power, investment (through profit surplus), public spending, demographic changes, environmental or ecological constraint and the survival of businesses and jobs (for sensitive sector) are recognized as the current major challenges of productivity growth improvement that affect regional development.

Therefore, in the case of Indonesian regional development, the different regime and structural changes of the country and regions have to be depicted in the framework of long term productivity growth analysis. The failure to address this in the long term will lead to hidden fundamentals of development. The detailed analysis of the decomposition and comparability of productivity growth can provide a description of Indonesia economic cycle. Productivity growth could be employed as a tool of reshaping development planning, policy and hence achieving the goals at both a national and regional level. Finally, the cooperation among the tripartite, namely, government, businesses and labour is needed to boost regional productivity movement in Indonesia.
CHAPTER 3
PRODUCTIVITY ANALYSIS: A REVIEW

3.1 Introduction

The recognition of productivity as an important factor of economic growth has arisen since the technique of its measurement was discovered in the early 1960s (Abramovitz (1956), Solow (1957) and Jorgenson and Griliches (1967). Between the 1970s and the mid-1990s, Germany and Japan were prominent with their flexible production systems which supported their productivity improvement while the United State took the lead as the preferred model since the 1990s due to information and communication technology (ICT) acting as the main driver of its productivity growth (Broadberry and O’Mahony, 2004). In the European continent, productivity growth became an important topic as European countries aimed to close their productivity gap with the US, through the establishment of the European Productivity Agency (EPA) (Boel, 2003, pp.37). In Asia, the debate has focused on whether economic growth in East Asia is due to perspiration or inspiration (Krugman, 1994b).

Although there is agreement among policy makers, academicians, scholars, and decision makers about the importance of productivity, there are still differences in choosing the ways to analyse it. The choices between partial and total factor productivity, techniques of measurement, productivity growth decompositions, sectoral or aggregate analysis and regional or national analysis vary. Therefore, it is imperative to understand the theoretical foundations of productivity growth. How can productivity be defined? How can productivity be measured? What productivity studies have been conducted? What government policies could promote productivity growth? These are the questions which are related to a better understanding of productivity. The first two questions will be the main subject of discussion in this chapter. Since this thesis will
estimate and analyse Indonesia’s regional productivity growth by using DEA-MPI then the concepts of productivity related to DEA-MPI will be introduced too.

A review of prior studies of productivity must be done for better insight of the application of productivity concepts and measurements. In doing so, this chapter will survey empirical work related to DEA-MPI. The last review in this chapter is an overview of the literature concerning the link between government policies and productivity improvement. This chapter is divided into five sections. The second section discusses the basic productivity concepts that are commonly used. The third section briefly reviews the measurement issues and the relevant estimation techniques used in this thesis. Section 3.4 focuses on the data envelopment analysis (DEA) approach followed by DEA-MPI in section 3.5. Section 3.6 presents the literature on productivity and DEA-MPI. Section 3.7 examines the relationship between productivity and policies. The last section is the conclusion of the chapter.

3.2 Productivity Concepts

The origin of productivity concept comes from the relationship between inputs and outputs. This relationship is prominently known in the form of the ratio of outputs to inputs. From this basic ratio, productivity has been associated with at least three sets of important concepts, namely efficiency, level versus growth and partial versus multifactor productivity. Each of the concepts has been developed to facilitate productivity studies in different analysis. In practice, a complete background of productivity concepts and measurements can guide policy makers toward a better understanding of productivity analysis, which will lead to appropriate policies for productivity improvement.
3.2.1 Efficiency and Productivity

Efficiency is associated with productivity (OECD (2001b, pp.11); Kaci (2006); PC (2009, pp.xi)) since productivity is determined by how efficient the inputs are used in the production process. However, Mahadevan (2004, pp.6) argues that productivity is more often associated with various types of efficiencies and sometimes their measurements are interchangeable, though they are in fact different. In the frontier approach, efficient decision making units (DMUs) are defined as the ones that operate on the production frontier\(^\text{19}\). This frontier is constructed from a set of DMUs as a reference set. An increase in efficiency will contribute to improve productivity. Another source of productivity growth is the shift of the production frontier. These sources of productivity growth would be the main purpose of this thesis that decomposes productivity into changes in efficiency and outward shift of production frontier.

Farrell (1957) is the pioneer in efficiency measurement. He divided overall efficiency into technical efficiency and allocative efficiency. The definition of technical efficiency is based on the radial expansion of the factors of production, i.e., inputs and outputs. Technical efficiency could be achieved through either the maximization of outputs with a given amount of inputs or input minimization to produce a given amount of outputs. Allocative efficiency is the result of choosing the combination of inputs subject to their prices to maximize outputs.

The basic productivity framework is based on the economic theory of production. Jorgenson and Griliches (1967) explained that the changes in productivity have to be differentiated between the shift in the production frontier and the movement along the production frontier. The sources of these movements are different. The former comes from the effect of advanced technology implementation and the latter is based on the change of combinations of factor inputs.

\(^\text{19}\) Further explanation of frontier approach will be discussed in productivity measurement section.
OECD (2001b, pp.11) mentioned that the technical and efficiency changes are two among five objectives of productivity growth. The technical change is induced by either the embodiment or disembodiment of advances in technology. The efficiency is related to the maximum achievable outputs with available technology and fixed inputs. This is in line with Jorgenson and Griliches (1967) who mentioned that the efficiency change is the movement along the frontier line as a result of the elimination of inefficiency barriers.

Golany and Yu (1997) summarized that there are five basic ways to achieve productivity improvement: (1) producing the same outputs with less inputs, (2) producing more outputs with the same amount of inputs, (3) producing more outputs with less inputs, (4) a larger increase in outputs than an increase in inputs used and (5) a smaller reduction of outputs than a reduction in inputs used. They explained how these productivity improvement directions are associated with efficiency in DEA model. The directions (1)-(3) are related to technical efficiency and (4)-(5) are associated with scale efficiency.

In conclusion, both productivity and efficiency can be defined in different ways. First, productivity and efficiency are different if the former is defined as the ratio of outputs over inputs and the latter can only be determined through relative performance of DMUs. Second, they are related since productivity growth could be decomposed into efficiency and technical change. The latter refers to an upward shift of the production frontier as a result of change in technology while the former refers to the more efficient input used in production under the same technology.

### 3.2.2 Productivity Level and Productivity Growth

Productivity level and productivity growth are different. The differences between both of them follow a common practice in assessing the level and growth of economic variables. Two dimensions, which are time and space, play an important role in
determining the concept of productivity level and growth. The comparisons between
different points in time (space) are associated with the TFP growth (level) which is
connected to a dynamic and static concept of productivity (Mahadevan (2002, pp.5;)
Kalirajan and Wu (1999, pp.8)). In a nutshell, productivity level refers to the value of
productivity at a given point in time while productivity growth is associated with a
comparison of productivity at some discrete points of time (for instance two time
periods, t and t+1).

The different measures of productivity level and productivity growth are
explained in Diewert and Nakamura (2007). In the production process, productivity is
associated with how to maximize output (y) with the same amount of input (x) or how
to produce the same outputs with fewer inputs in a particular period (t). The relations of
the two are computed as productivity in the form of a ratio between input and output:

\[
\text{Productivity} = \frac{y_t}{x_t}
\]  

(3.1)

while productivity growth can be formulated as

\[
\text{Productivity growth} = \frac{y_{t+1}}{x_{t+1}}/\frac{y_t}{x_t} \quad \text{or} \quad \frac{y_{t+1}/x_{t+1}}{y_t/x_t}
\]  

(3.2)

PC (2009, pp.10) explained that despite differences in formulations, the
distinction of productivity level and productivity growth is very crucial for analysis
purposes. The effect of a higher level of productivity is a higher level of income over
time while higher productivity growth will increase income margin (income gains) over
time\(^{20}\). This is the reason why some researchers and policy makers argue that
productivity growth is more important than productivity level. Bucifal (2013) argues
that higher and sustained productivity growth is more difficult to achieve than

\(^{20}\) Empirical example from PC (2009, pp.10) “…a permanent increase in the level of productivity of 0.5
per cent will result in income being forever 0.5 per cent above what it would otherwise be, but a
permanent increase in the productivity growth rate of 0.5 per cent will result after 20 years in income
being 10.5 per cent higher than otherwise…”
productivity level. He stated that the introduction of new technology could increase the productivity level in the long term but does not guarantee a sustained high growth in productivity.

The Conference Board of Canada (2013) argues that both productivity level and productivity growth are equally important but the former is the interest of the media publication. The reason for this argument is that when a rank of economic performance uses a benchmark, i.e. the U.S. as a benchmark, the productivity level can show a relative position of countries in comparison. This benchmarking analysis has been done in some literature which stresses the importance of productivity level (Jorgenson and Nishimizu (1978); Caves et al. (1982) and Cette et al. (2009), among other).

Jorgenson and Nishimizu (1978) used the terms ‘translog index of difference in technology’ and ‘translog index of technical change’ to differentiate productivity level and productivity growth respectively. The former has been expressed as the difference between the logarithm of output of countries and a weighted average of the logarithm of their factor inputs (capital and labour). The weighted is the average value shares of these factor inputs.  When this comparison takes into account two time periods then the productivity growth is recognized through a trans-log index of technical change.

The framework provided by productivity growth and productivity level was applied by Caves et al. (1982) in their proposal of the Malmquist index as a basis of measurement. Hulten (2000) explained that the comparison of relative productivity level in the Malmquist index framework is simply done by the interchangeability of input and technology between countries in comparison. This can be illustrated by two questions that he proposed: (1) How much output could country A produce if it used country B’s technology with its own inputs? (2) How much output could country B produce if it used country A’s technology with its own inputs? Productivity growth can be easily

21 The formulation uses Japan and US as a comparison, \( \ln Y(US) - \ln Y(Japan) = PK \ln K(US) - \ln K(Japan) \) \( + VL \ln L(US) - \ln L(Japan) + VD \), where \( K = 2[VK(US) + VK(Japan)], L = 2[VL(US) + VL(Japan)], VD = 2[VD(US) + VD(Japan)] \)
computed after determining this relative productivity level by taking into account different time periods.

From policy and regulatory point of views, the assessment report of Shuttleworth et al. (2006) explained that a regulatory policy on the basis of productivity level suffers from subjective regulatory decisions. They made this argument from the experiences of European regulatory regimes, which were characterized by the arbitrary and subjective nature of analysis based upon the productivity level. They suggested the use of Tornqvist productivity index as it accounts for productivity growth. Their suggestion could also imply the adoption of DEA-MPI since the estimation results of Tornqvist are proven to be similar to DEA-MPI if technology is in the form of trans-log (Caves et al. 1982).

### 3.2.3 Partial Productivity and Total Factor Productivity

Official statistics offices in different countries as well as researchers in different fields have different preferences in reporting productivity. Some of them prefer to present productivity as a single factor comparison, i.e., output per unit of labor (LP) and output per unit of capital (KP). This single output-input comparison is known as partial productivity. If the output is $y$ and the primary inputs of the entire economy are labor ($l$) and capital ($k$) then the partial productivity is given by

$$\text{LP} = \frac{y}{l} \quad \text{and} \quad \text{KP} = \frac{y}{k} \quad (3.3)$$

However the right hand side of productivity measurement (KP) is rarely reported. The most common partial productivity measure is labor productivity. This single or partial productivity only uses a single input in the estimation process without considering other inputs. Some literature also mentions intermediate inputs as part of the production process so they could also be taken into account in productivity
measurement. Since outputs are a result of many different inputs in the production process then partial productivity may ignore the effects of change in different input compositions. Thus, the partial measure could be improved by taking into account all inputs in productivity measurement. This kind of productivity is called total factor productivity (TFP) or multi factor productivity (MFP). Mahadevan (2004, pp.5) differentiated TFP and MFP by formulating them as follows:

\[
\text{TFP} = \frac{y}{\alpha l + \beta k} \quad \text{and} \quad \text{MFP} = \frac{y}{\alpha l + \beta k + \gamma m}
\] (3.4)

The equations show that productivity is the ratio of output to the weighted average of factor inputs. Mahadevan (2004, pp.6) argued that TFP only considers the basic elements of input factors (labor and capital) and MFP takes into account the joint productivity of labor, capital and intermediate inputs (m)\(^\text{22}\).

OECD (2001b, pp.13) classified TFP and MFP in Mahadevan (2004, pp.5) as capital-labor MFP and KLEMS MFP respectively (Table 3.1). Some literature distinguishes TFP and MFP due to their discrepancy in the ability to measure the output and total output (Diewert and Nakamura, 2007). However, some studies also use the two terms interchangeably (Mahadevan (2002); Coelli et al. (2005); PC (2009); Appleton and Franklin (2012)). Further, OECD (2001b) shows that productivity can be evaluated on the basis of value added or gross output. The summary of the partial and multi factor productivity can be seen in Table 3.1.

In practice, the choices between partial and total factor productivity depend upon researchers’ preferences and the purposes of study in which the productivity will be analysed. The sequence of preferences is labor productivity followed by capital-labor MFP and KLEMS MFP (OECD, 2001b, pp.13). This is reasonable since labor productivity is a simple single productivity that is easy to compute and the input data for

\(^{22}\) Mahadevan (2004, pp.6) explains that the intermediate inputs comprise material, supplies, energy and other purchased services.
estimation is easy to collect. However, this kind of productivity could give a misleading analysis since it does not cover the overall change in productive capacity (Mahadevan, 2004, pp.5). In some cases the partial productivity, in particular labor productivity, also cannot represent the real productivity since there is no distinction between full-time and part-time workers (Baumol at al., 1988, pp.347).

**Table 3.1 Partial and multifactor productivity**

<table>
<thead>
<tr>
<th>Output measure</th>
<th>Partial productivity</th>
<th>Multifactor productivity (MFP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Input measure</td>
<td>Labour</td>
<td>Capital</td>
</tr>
<tr>
<td>Gross output</td>
<td>Labour productivity</td>
<td>Capital productivity</td>
</tr>
<tr>
<td>Value added</td>
<td>Labour productivity</td>
<td>Capital productivity</td>
</tr>
</tbody>
</table>

Source: OECD (2001b, pp.13)

In a technical argument, PC (2009, pp.2) explained that it is better to consider the productivity on the basis of both capital and labor. The reason behind this is that the partial productivity (labor productivity) cannot capture the overall quality of economic development and hence improvement in quality of life. Mahadevan (2002, pp. 2) also mentioned that the bias of labor productivity could also be caused by changes in scale economies that are unrelated to the labor used in production. She argued that the misleading report of partial productivity arises if the reduction of labor used in production leads to a decrease in the efficiency of capital utilization which overall increases labor productivity.

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23 PC (2009, pp.2) formulated the labor productivity is equal to MFP plus capital deepening. The increase in labor productivity could come from MFP or capital deepening. If the MFP is equal to zero then the labor productivity is equal to capital deepening. However, when the cost of capital fully offsets the increase in output then the increase in labor productivity is meaningless.
Despite its weaknesses, Mahadevan (2002, pp. 2) also remarked some valuable aspects of labor productivity. First, labor productivity can explain the efficiency of labor in combination with other factor inputs. Second, labor productivity is a useful tool for national economic policy. The close relation of labor productivity to output per capita through labor force participation makes it important for a country’s welfare assessment. The last remark is that labor productivity could be the best choice for productivity measurement when the problems and biases of other measurement of productivity arise.

3.3 Productivity Measurement

Productivity measurement is not as uncomplicated as the basic concept of productivity. Some issues of measurement could be difficult without appropriate techniques and additional assumptions. For instance, the exact functional form of the production function is still an unresolved problem. The problems of input and output data availability have also added difficulties.24

Another issue is the actual economic aspect that can be explained by the numbers behind TFP. Mahadevan (2002, pp. 23) mentioned four criticisms of the interpretation of TFP: as (1) TFP growth is “a measure of our ignorance” (Abramovitz, 1956), (2) there is no general agreement about what the estimate of productivity growth actually measures (Griliches, 1988), (3) TFP cannot explain what we do not know (Felipe, 1999) and (4) The static measure of TFP does not include the induced effect of technology (Hulten, 2000). However, Mahadevan (2002, pp.24) argues that measurement and interpretation problems should not be a source of long-term debates around TFP. She highlighted that the most important thing is how to solve the problem in order to improve the theoretical foundations and measurement techniques of TFP for better assessment of economic performance.

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24 Complete explanations of these measurement problems can be seen in Diewert and Nakamura (2007).
From non-economist perspectives, the productivity measurement problem reflects a small percentage growth of productivity which may not be so important (Sharpe, 2002). However this is not the case behind the productivity growth measurement since these small differences may have a big impact upon the standard of living of the country. Sharpe (2002) mentioned 1 per cent productivity growth could need three generations or around 72 years to make the real output (and hence income) double. He also compared this calculation under 3 per cent productivity growth scenario which takes one generation for real income to double.

A complete and valuable survey about the methods of productivity measurement was conducted by Diewert and Nakamura (2007). They reflected six important aspects of recent development for productivity measurement and possibilities for further research. These aspects involve the choice of measured effects, better price measurement, the measurement of capital services, labour services of workers and service products, a need for statistics and business harmonization, and the role of official statistics. Basically, these aspects form two core parts for productivity measurement, i.e., methods and data. The input data mostly deals with the tricky part of capital stock measurement, the problem of aggregation when multiple outputs are considered, the choices between numbers of employees or worked hours and the availability of appropriate input data at both regional and sectoral levels.

There are two basic methods for productivity estimation; parametric and non-parametric (Figure 3.1). The parametric approach often uses the Cobb-Douglas model since it is simple. The nonparametric approach does not need a functional form assumption of the production function. The methods can be divided into two branches, namely, the frontier and non-frontier techniques. The difference between the two approaches is their assumptions: non frontier assumes that the units of analysis are technically efficient (Mahadevan, 2002, pp.7). The frontier approach constructs the
frontier on the basis of the best performance. Another difference between frontier and non-frontier is found in their components. The frontier approach can be decomposed into technical progress and technical efficiency while the non-frontier approach only covers technical progress.

**Figure 3.1** Productivity growth estimation flow chart

![Productivity growth estimation flow chart](source: Mahadevan (2002, pp.6))

The current thesis employs the nonparametric method that belongs to deterministic frontier approach, namely DEA, to estimate the Malmquist productivity index (MPI). Therefore, the following sections will focus on the theoretical frameworks of DEA and the MPI.

### 3.4 The Data Envelopment Analysis (DEA) Approach

DEA approach stems from an idea to establish a method which is based on available data and can be used to evaluate the performance of comparable DMUs in which an efficient frontier would be established (Cook and Seiford, 2009). This implies that the virtuousness of DEA is an establishment of frontier as a benchmark while taking into account multiple inputs and multiple outputs.
DEA also does not depend upon many assumptions compared to the parametric approach. These advantages make it acceptable for evaluating the performance of DMUs in a variety of sectors such as banking, education, manufacturing, health care, hospitalties, businesses and other profit and non-profit sectors. The impressive applications of DEA have also been supported by its theoretical developments. To provide a summary of these theoretical developments, the next sub sections will present a brief outline of DEA’s theoretical frameworks.

3.4.1 Production Possibility Set

As explained in the previous sections, there is no assumption to be made about the functional form of the production function in the nonparametric approach. Therefore the main task in this approach is to form the frontier from observed inputs and outputs. The interpretation of productivity and efficiency are deducted from the distance to and the shift of the production frontier. It is therefore imperative to introduce the concept of the production possibility set (PPS).

To define PPS, assume that technology \( Z \) is the mapping of input \( X \) into output \( Y \), \( Z: X \rightarrow Y \) such that for any vectors of inputs \( x \in X \) then \( Z(x) \subset Y \) is the set of outputs that can be produced by using \( x \). There is a set of \( n \) DMUs, \( \{ (x_j, y_j) \} \) with \( j = 1, 2, 3, \ldots, n \). Inputs of \( i = 1, 2, \ldots, m \) of vector input \( x_j = (x_j^1, \ldots, x_j^m) \in R^m_+ \) can generate output \( r = 1, \ldots, s \) of vector output \( y_j = (y_j^1, \ldots, y_j^s) \in R^s_+ \). The input and output vectors are called a production plan. The complete symbolization of technology is therefore

\[
Z = \{ (x, y) \in R^{m+s}_+ : x \text{ can produce } y \} \quad (3.5)
\]

The PPS is the set of feasible production plans. The feasible production plan can be equivalently represented by output set:

\[
P(x) = \{ y \in R^s_+ | (x, y) \in Z \} \quad (3.6)
\]
Where every $x' \in \mathbb{R}^n_+$ has output isoquant

$$\text{Isoquant}(x) = \{y : y \in P(x) : \delta y \not\in P(x), \delta > 1\} \quad (3.7)$$

The efficient subset of Equation 3.6 is

$$\text{Efficient}(x) = \{y : y \in P(x) : y' \not\in P(x), y' > y\} \quad (3.8)$$

Some axioms of PPS are:

Axiom 1: if $x = 0$ and $(x, y) \in \text{PPS}$, then $y = 0$

Axiom 2: if $(x, y) \in \text{PPS}$ then for all $x' \in x, (x', y) \in \text{PPS}$ and for all $y' \in y, (x, y') \in \text{PPS}$

Axiom 3: Inclusion of observation in which each observed decision making unit $j$ (DMU$_j$) belongs to $Z$, for $j=1,2,\ldots,n$.

Axiom 4: Constant returns to scale: if $(x, y) \in Z$, then $(kx, ky) \in Z$ for any $k \geq 0$

Axiom 5: Convexity: if

$$(x, y) \in Z \text{ and } (x', y') \in Z \text{ then } (k(x, y) + (1-k)(x', y')) \in Z \text{ for any } k \in (0,1)$$

All of these axioms are the basic assumptions of the PPS. Some literature modifies the PPS assumptions to satisfy some real cases in empirical works, e.g., the relaxation of convexity assumption has been discussed as a free disposal hull (FDH) model in Tulkens (1993).

### 3.4.2 Distance Function

Distance function was first introduced by Shepard (1953, 1970). There are two kinds of distance function which are input and output distance functions. Given the output set defined in Equation 3.6 with the inclusion of time $t$, $(P'(x'))$, then the output distance function can be defined as:

$$D_o(x', y') = \inf \left\{ \theta : (x', y' / \theta) \in P'(x') \right\} \quad (3.9)$$

the input distance function as:
Under the constant returns to scale assumption the input and output distance functions can be written with a reciprocal relation:

\[ D_t'(x^i, y^i) = \frac{1}{D_o'(x^i, y^i)} \]  \hspace{1cm} (3.11)

This thesis mainly deals with the output distance function since the MPI used in productivity estimation employs output oriented index. According to Coelli et al. (2005, pp.47) output distance function has the following properties:

(i) \( D_0(x, 0) = 0 \) and \( D_0(0, y) = + \infty \)

(ii) \( D_0(x, y) \) is a lower-semi continuous function.

(iii) \( D_0(x, y) \) is non-decreasing in \( y \) and non-increasing in \( x \),

(iv) \( D_0(x, y) \) is homogeneous of degree 1 in \( y \);

(v) \( y \in P(x) \) if and only if \( D_0(x, y) \leq 1 \);

(vi) \( D_0(x, y) = 1 \) if \( y \) belongs to the frontier of the PPS.

As a representation of the production function, the distance function is equal to unity for DMUs on the production boundary and less than unity for the DMUs inside the boundary. In this case the distance function indicates the radial expansion of output vector \( y \) given the input vector \( x \). Following Farrell (1957), a DMU is efficient if the output distance function is equal to one. In the case of the value of distance function being less than one, the DMUs are inefficient, meaning that there is room for the proportional expansion of output given the inputs.

In relation to productivity growth measurement, the output distance function will be estimated in two time periods. Output distance function in the next period (\( t+1 \)) could be defined in a similar way as in Equation 3.9

\[ D_o^{t+1}(x^{t+1}, y^{t+1}) = \inf \{\theta : (x^{t+1}, y^{t+1} / \theta) \in P^{t+1}(x^{t+1})\} \]  \hspace{1cm} (3.12)
An interchange of time period between technology and the input-output vectors used in the production could also be conducted by two formulations as follows

\[
D_{o}^{t+1}(x^{'}, y^{'}) = \inf \{ \theta : (x^{'}, y^{'}/\theta) \in P^{t+1}(x^{'}) \} \quad (3.13)
\]

or

\[
D_{o}^{t}(x^{t+1}, y^{t+1}) = \inf \{ \theta : (x^{t+1}, y^{t+1}/\theta) \in P^{t}(x^{t+1}) \} \quad (3.14)
\]

The difference between Equations 3.13 and 3.14 is that the former utilizes input-output vectors in period \( t \) and technology in time \( t + 1 \) while the latter uses input-output vectors in time \( t + 1 \) and technology in time \( t \). All of these output distance functions with respect to different technologies and different input-output vectors will be used as the basis to estimate productivity growth by employing the MPI approach. In this thesis, the output distance function will be estimated by DEA.

### 3.4.3 DEA Framework

As shown in Figure 3.2, DEA and its variants belong to a nonparametric approach. DEA was introduced by Charnes et al. (1978) as a form of mathematical programming to estimate the efficiency of DMUs. The basic idea of DEA is to construct an efficient frontier from the maximum combination of outputs for a given set of inputs. For simplicity, this idea could be described in a two output case in Figure 3.2. The efficient subset of Equation 3.8 is the ABC while the isoquant of Equation 3.7 is the boundary of HGABCDI. The output set \( P(x) \) is the space between the boundary HGABCDI, the vertical line and the horizontal line. The difference between isoquant and efficiency is
the existence of dash horizontal and vertical lines. This difference is related to the definition of Pareto optimum\textsuperscript{25}.

**Figure 3.2** Graphical illustration of DEA

![Graphical illustration of DEA](image)

Source: Author’s own elaboration

The efficiency frontier is defined by connecting points A, B and C. These three points are the best practice representing efficient DMUs since their output points lie on the convex hull established by the combination of output points. Unlike the linear regression analysis line, the convex hull is a piecewise linear envelope line. Points E and F are inefficient since they lie below the efficiency frontier. Points G and I are efficient but fail to fill the requirements of Pareto optimum.

To determine the efficiency of point E we have to measure the distance of point E to the frontier. In this case, the reference points for E are A and B since the passing line from the origin (O) through point E intersects the efficient frontier in the point between A and B. Supposing that this intersection is $E^*$ then the efficiency of point E is

\textsuperscript{25} A DMU is categorized as Pareto optimum if the increase of one of its outputs requires the decrease of at least one of other outputs
OE/OE*. Point E could also be determined as inefficient from the proportional expansion of its output compared to the efficient point. Point A dominated point E since with the same input, this point produces more output 2 than point E and produces the same output 1. In this case point E can improve its output to reach the efficient point located in the frontier.

Mathematically, the establishment of an efficient frontier employs the ratio of the weighted sum of multiple outputs to the weighted sum of multiple inputs. Suppose there are n DMUs (j=1,2,...,n) and each DMU employs m inputs (x_{ij}) (i=1,2,...,m) to produce s outputs (y_{rj}) (r=1,2,...,s). The efficiency of a DMU is measured as follows:

\[
\text{Efficiency} = \frac{\sum_{r=1}^{s} \text{weighted outputs}_{rj}}{\sum_{i=1}^{m} \text{weighted inputs}_{ij}}
\]

Following Charnes et al (1978), to maximize Equation 3.15 the mathematical formulation of programming problem for a DMU under evaluation (j_0) is shown in Equation 3.16.

\[
\text{Max } \varphi_0 = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}
\]

subject to

\[
\sum_{i=1}^{m} u_i y_{rj} \leq 1, \quad j = 1, 2, ..., n,
\]

\[
\sum_{i=1}^{m} v_i x_{ij}
\]

\[
u_1, u_2, ..., u_s \geq 0
\]

\[
v_1, v_2, ..., v_m \geq 0
\]

where u = weight of output r, v_{i} = weight of input i and y_{rj};x_{ij} are observed values of r=1,2,...,s;i=1,2,...,m, respectively. Equation 3.16 has been developed into two kinds of model which known as the linear programming (multiplier problem) and the dual
linear programming (envelopment problem) CCR models since Charnes, Cooper and Rodes (Charnes et al., 1978) first developed this DEA model. This can be done by converting Equation 3.16 into its linear form, i.e., normalizing the denominator to 1 and linearizing the constraints. The multiplier problem can be formulated as

$$\text{Max } \varphi_0 = \sum_{r=1}^{m} u_r y_{r0}$$

subject to

$$\sum_{i=1}^{s} v_i x_{ij} = 1$$
$$\sum_{r=1}^{m} u_r y_{rj} - \sum_{i=1}^{s} v_i x_{ij} \leq 0, \quad \forall j = 1, 2, \ldots, n$$
$$u_1, u_2, \ldots, u_m \geq 0$$
$$v_1, v_2, \ldots, v_m \geq 0$$

The dual linear programming of Equation 3.17 can be written as

$$\text{Min } \theta$$

subject to

$$\sum_{i=1}^{s} \lambda_j x_{ij} \leq \theta x_{i0}, \quad \forall i = 1, 2, \ldots, m$$
$$\sum_{r=1}^{m} \lambda_j y_{rj} \geq y_{r0}, \quad \forall r = 1, 2, \ldots, s$$
$$\lambda_j \geq 0, \quad \forall j = 1, 2, \ldots, n$$

where $\theta$ is the efficiency score of the DMU under evaluation and $\lambda$ is the intensity variables. A linear programming problem must be solved for each DMU. Since there are $n$ DMUs then the linear programming problem has to be solved $n$ times. Notice that the optimal objective function value of Equation 3.17 also reveals the optimal objective function value of Equation 3.18, therefore, by duality, $\varphi^* = \theta^*$. Based on the linear programming formulation, the efficient (inefficient) DMUs have an efficiency score equal to one (between 0 and 1). The boundary of PPS explained in the previous sections
is a convex combination of these efficient DMUs which establish piecewise linear efficient frontier.

There are some reasons to use DEA in productivity and efficiency analysis. First, DEA can handle multiple inputs and multiple outputs. Second, DEA doesn’t need to assume a functional form of input-output relation. Third, inputs and outputs used in DEA can be in different units of measurement. Fourth, unlike parametric approaches, DEA doesn’t need the assumption of the distribution of inefficiency, which makes it reliable, flexible and simple. The fifth advantage of DEA is that it doesn’t require the information on input and output prices. It only needs the information on input and output quantities. Six, unlike regression analysis, which shows average performance, DEA evaluates the performance of each DMU. Finally, the decomposition of pure, scale and overall efficiencies as the sources of inefficiency can be made by employing DEA.

There are also some limitations of DEA. The first limitation is that it is sensitive to measurement error. This means that the outliers can affect the frontier and influence the efficiency scores. Another drawback is that it doesn’t account for statistical noise. DEA is a deterministic method meaning that the observations are feasible with perfect probability. This also implies that the deviations from frontier in DEA are as a result of inefficiency.

3.4.4 Returns to Scale and Orientation

There are two types of general choices in a DEA model, namely, the returns to scale and orientation. In general both of them are related to the process of production (Figure 3.3). The orientation is used to describe which factors of production would be changed to reach the efficient frontier. The choice could be input reduction, increase output or the combination of both which are known as input oriented, output oriented and non-oriented. Input oriented is defined as a proportional reduction of inputs with output fixed while output oriented is defined as a proportional expansion of output with input
fixed. The selection between the two orientations has no impact on the efficient DMUs. Therefore in practice one of them can be applied. In this dissertation the output oriented will be employed.

**Figure 3.3** Framework of return to scale and orientation in DEA

![Diagram of DEA model](image)

Cited: Grosskopf’s lecture slide (2008)
Note: This slides was based on OnFront reference guide and Coelli et al. (2005)

Returns to scale refer to the change of output level due to a change in the inputs level. The model of DEA from the previous section consisted of the multiplier model and envelope model. These models are developed under constant returns to scale (CRS). The extension of these models into variable returns to scale (VRS) was done by Banker et al. (1984). By using multiplier model the formulation of the Banker model is as follows:

$$
\max_{u,v,\pi,\varrho_0} \varrho_0 = \sum_{r=1}^{m} u_r y_{r0} + \pi
$$

(3.19)

subject to
\[
\sum_{i=1}^{s} v_{i}x_{i} = 1
\]
\[
\sum_{i=1}^{m} u_{i}y_{i} - \sum_{i=1}^{s} v_{i}x_{i} + \pi \leq 0, \quad j = 1, 2, \ldots, n
\]
\[
u_{1}, u_{2}, \ldots, u_{s} \geq 0
\]
\[
v_{1}, v_{2}, \ldots, v_{m} \geq 0
\]

Model 3.19 allows for either increasing returns to scale (IRS) or decreasing returns to scale (DRS). Variable \( \pi \) represents the relaxation of outputs which can increase less or more than inputs proportionally. The value of \( \pi \) can be greater than zero, less than zero or equal to zero, which represents IRS, DRS and CRS respectively.

### 3.4.5 Methodological Extensions

In this section, examples of the extension of the DEA model will be discussed. A complete survey of DEA can be found in Seiford (1996), Emrouznejad et al. (2008) and Liu et al. (2013), among others. A survey of the development of DEA during the past three decades was conducted by Cook and Seiford (2009). The survey showed at least four categories of DEA, namely the single level models, multilevel models, multiplier restrictions and the status of different types of variables.

The most prominent extension of the single level model is the development of the free disposal hull (FDH) model by Tulkens (1993). This model goes beyond the convexity assumption of PPS as mentioned in the previous section. An example of multilevel DEA is the network DEA developed by Fare and Grosskopf (2000). This model expands the traditional DEA model which is remarked as a black box system. The network DEA tries to look inside the “box” by considering the processes inside DMUs.

Other developments of DEA-MPI can be classified on the basis of input and data structure, step of estimation, time references and different frontiers. The first category includes DEA with negative data, DEA with undesirable input and DEA-MPI with
interval and fuzzy data. Two stages and three stages DEA-MPI are categorized on the basis of the steps of estimation. DEA-Window and dynamic DEA are further developments of DEA on the basis of time assumption. In window analysis the time references are divided into several groups of combinations.

The free judgment in regards to the weights of the inputs and outputs in DEA was further developed by Dyson and Thanassoulis (1988). This free selection can be employed to differentiate efficient DMUs. Super efficiency DEA also attracts attention in empirical works. It is based on a ranking of efficient units in the analysis (Anderson and Peterson, 1993).

3.5 DEA-Malmquist Productivity Index

3.5.1 Basic DEA-MPI

DEA-MPI enables the measurement of the change of productivity performance in different time periods. The output-based MPI with time $t$ technology is defined by Caves et al. (1982) as:

$$M^t = \left[ \frac{D_o^d(x^{t+1}, y^{t+1})}{D_o^d(x^t, y^t)} \right]$$ (3.20)

Similarly, the index with time $t+1$ technology is:

$$M^{t+1} = \left[ \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \right]$$ (3.21)

Fare et al. (1994) decomposed DEA-MPI into the components of efficiency and technical changes. Their index is the geometric mean of two contemporaneous Malmquist indexes as in Chaves et al. (1982) to avoid difficulties choosing reference technologies, i.e., whether to use time $t$ or $t+1$ technologies. Their index is defined as follows:
M (x^{t+1}, y^{t+1}, x^t, y^t) = \left[ \frac{D_o'(x^{t+1}, y^{t+1})}{D_o(x^t, y^t)} \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \right]^{1/2} \tag{3.22}

It can be decomposed as:

M (x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o(x^t, y^t)} \left[ \frac{D_o'(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o'(x^t, y^t)}{D_o(x^t, y^t)} \right]^{1/2} \tag{3.23}

Equation (3.23) can be simplified as

\text{TFPCH} = \text{EFFCH} \times \text{TECCH} \tag{3.24}

The EFFCH is the efficiency change which represents the change of DMU relative to the production frontier. The TECCH is technical change showing the shift of production frontier in the two time periods. TFPCH greater than 1 indicates productivity improvement between period t and t+1 while TFPCH less than 1 indicates productivity deterioration between the two time periods. It is clear that the sources of productivity improvement are the improvement of efficiency or technical change.

The graphical illustration is presented in Figure 3.4. This figure describes the decomposition of DEA-MPI in terms of the point coordinates of a two dimensional graph. It is based on output oriented efficiency measurement by assuming constant returns to scale (CRS in the graph). To simplify the explanation, the figure only considers one input and one output combination for two time periods (t and t+1).

There are two points that will be evaluated which are point A (x^t, y^t) and point D (x^{t+1}, y^{t+1}). Both of these points are inefficient with respect its own frontier. Point A is inefficient against CRS^t while point D is inefficient against CRS^{t+1}. D_o'(x^t, y^t) is the ratio of 0a/0b, D_o^{t+1}(x^{t+1}, y^{t+1}) is the ratio of 0d/0f, D_o'(x^{t+1}, y^{t+1}) is the ratio of 0d/0e and D_o^{t+1}(x^t, y^t) is the ratio of 0a/0c.
Figure 3.4. The decomposition of MPI growth index

\[ M(x^{t+1}, y^{t+1}, x^t, y^t) = \begin{bmatrix} 0d/0e & 0d/0f \\ 0a/0b & 0a/0c \end{bmatrix}^{1/2} \]  

(3.25)

Which can be decomposed as

\[ \text{EFFCH} = \begin{bmatrix} 0d/0f \\ 0a/0b \end{bmatrix}^{1/2} \quad \text{and} \quad \text{TECCH} = \begin{bmatrix} 0d/0e & 0b \\ 0d/0f & 0a/0c \end{bmatrix}^{1/2} \]  

(3.26)

This graphical explanation gives a clear indication about how to improve output from point A to point F. There are three mechanisms through which to achieve this output improvement. The first is movement along the frontier line which refers to input growth. This is represented by the movement from B to E and C to F. The second mechanism is the gap between b-a and f-d which refers to efficiency change. The last mechanism is the upward shift in production represented by point B to C by using input...
x in time t or E to F by using input x in time t+1. This shift is the technical change. The complete changes of TFPCH can be described as the movement from A to B (efficiency change) and B to C (technical change).

To estimate DEA-MPI, four linear programming problems have to be solved:

\[
(D_0^t \left[ x^{t+1}, y^{t+1} \right])^{-1} = \text{Max } \theta
\]

(3.27)

Subject to
\[
\sum_{i} \lambda_{i}^{t} x_{i}^{t} \leq x_{j}^{t+1} \quad i = 1, 2, \ldots, m
\]
\[
\sum_{i} \lambda_{i}^{t} y_{i}^{t} \geq \theta y_{j}^{t+1} \quad r = 1, 2, \ldots, s
\]
\[
\lambda_{i}^{t} \geq 0 \quad j = 1, 2, \ldots, n
\]

\[
(D_0^{t+1} \left[ x^{t+1}, y^{t} \right])^{-1} = \text{Max } \theta
\]

(3.28)

Subject to
\[
\sum_{i} \lambda_{i}^{t+1} x_{i}^{t} \leq x_{j}^{t+1} \quad i = 1, 2, \ldots, m
\]
\[
\sum_{i} \lambda_{i}^{t+1} y_{i}^{t} \geq \theta y_{j}^{t+1} \quad r = 1, 2, \ldots, s
\]
\[
\lambda_{i}^{t+1} \geq 0 \quad j = 1, 2, \ldots, n
\]

\[
(D_0^{t+1} \left[ x^{t+1}, y^{t+1} \right])^{-1} = \text{Max } \theta
\]

(3.29)

Subject to
\[
\sum_{i} \lambda_{i}^{t+1} x_{i}^{t} \leq x_{j}^{t+1} \quad i = 1, 2, \ldots, m
\]
\[
\sum_{i} \lambda_{i}^{t+1} y_{i}^{t} \geq \theta y_{j}^{t+1} \quad r = 1, 2, \ldots, s
\]
\[
\lambda_{i}^{t+1} \geq 0 \quad j = 1, 2, \ldots, n
\]

\[
(D_0^{t-1} \left[ x^{t}, y^{t} \right])^{-1} = \text{Max } \theta
\]

(3.30)

Subject to
\[
\sum_{i} \lambda_{i}^{t} x_{i}^{t} \leq x_{j}^{t} \quad i = 1, 2, \ldots, m
\]
\[
\sum_{i} \lambda_{i}^{t} y_{i}^{t} \geq \theta y_{j}^{t} \quad r = 1, 2, \ldots, s
\]
\[
\lambda_{i}^{t} \geq 0 \quad j = 1, 2, \ldots, n
\]

The symbol j is the number of DMU, r is the number of outputs, i is the number of inputs and t is the time periods. In this case there are n DMUs in T time periods, n x
(3T-2) linear programming must be solved (Coelli, 1996). If four approaches are employed, i.e., fixed base year, conventional, sequential and metafrontier, at least 4 x n x (3T-2) linear programming should be estimated (this doesn’t include different groupings for the metafrontier approach and different scenarios of analysis in the conventional approach)\textsuperscript{26}. Some studies also differentiate (mostly at micro level) efficiency change into pure and scale efficiency. The expansion of this decomposition requires more linear programing that have to be resolved, i.e., n x (4T-2) (Coelli, 1996).

3.5.2 Further Development of DEA-MPI

DEA-MPI discussed in sub section 3.5.1 has been expanded by Banker et al. (1984) to the variable returns to scale (VRS) case\textsuperscript{27}. The combination of VRS and CRS make it possible to account for scale efficiency in DEA-MPI. Tone (2005) proposed the MPI based on the development of SBM (slack base model). Grifell-Tatje et al. (1998) introduced a quasi Malmquist index which incorporated output slacks in the non-radial efficiency measurement.

Other developments of DEA-MPI can also be classified on the basis of input and data structure, steps of estimation, time references and different frontier. The most popular DEA-MPI based on data structure is that of Lunberger DEA-MPI. It can deal with undesirable outputs. The idea behind the undesirable output is that despite regular outputs (“good” output), the production process could also produce irregular outputs (“bad” outputs).

DEA-Window-MPI, dynamic DEA-MPI and sequential DEA-MPI are based on time assumption. In window analysis the time references are divided into several groups of combinations while in the sequential approach the time plays a role in the assumption of technology feasibility in the future. The last extension of DEA-MPI, probably, is

\textsuperscript{26} The approaches and scenarios refer to the ones that will be examined in this dissertation

\textsuperscript{27} Complete theoretical and methodological issues of estimating returns to scale in DEA can be found in Golany and Yu (1997)
based on the different frontiers which involve metafrontier and free disposal hull (FDH). The first is based on the premise that different units of analysis have different technology frontiers while FDH is based upon how the frontier is established.

Pastor et al. (2011) proposed biennial MPI. This index has been claimed to be superior in comparison with adjacent and global Malmquist indices. The main new features of the index are that it avoids the infeasibility problem, allows for technical regress and doesn’t need to be recomputed when new data is added in the sample.

The choice among these kinds of DEA-MPI is much dependent upon the availability of input data, the purpose of the analysis, the structure of the unit of analysis and researcher preferences. Each approach has its own strengths and weaknesses. Multiple approaches are recommended since different techniques give more features of the results.

3.6 Studies of Productivity Growth

The study of productivity growth has received much attention in economic literature. Empirical studies of productivity growth particularly addressed the question about the sources of productivity growth and the interrelation of productivity growth and economic growth, i.e., whether the sources of economic growth are factor accumulation or productivity growth itself.

Studies of productivity growth can be classified based on their methods, scopes, time references and coverage. In the early period, most studies used the growth accounting approach to show the contribution of capital accumulation and technical progress. These studies involve Abramovitz (1956), Solow (1957), Kendrick (1961), Jorgenson and Griliches (1972), Denison (1974) and Young (1995), among others. Studies of productivity growth based on index numbers include Diewert (1976),

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28 The fact that there are differences in welfare between countries and the increases in income differentials and hence development inequalities have spurred international comparisons of productivity growth.
Jorgenson and Nishimizu (1978) and Diewert and Morrison (1986). The literature in productivity could also be classified based on the focus of analysis such as the economic sectors (Bernard and Jones, 1996), developing countries and the national-regional level. In this section the focus of literature reviews is based on the frontier method both at national and regional level.

Kruger (2003) stated that the stochastic frontier approach has an advantage since it accounts for measurement error. However he argued that this advantage is still questionable for small and medium samples. Ruggiero (1999) claimed that when the problem of misspecification of the functional form of the production function and endogeneity arise, DEA could be a better choice and become a more attractive option than the parametric method.

Maudos et al. (2000) analysed the role of efficiency change (catch up) and technical change (innovation) in OECD countries. They employed DEA-MPI and argued that the growth accounting method can be used to estimate TFP but fails to account for the contribution of technical progress to TFP when the efficiency assumption of the unit of analysis is incorrect. It means that when the unit of analysis is inefficient, the estimated technical progress would be biased. They found that there was inefficiency in OECD countries over the period 1975-1990. The final conclusion from this analysis is that the existence of innovators is the main factor to achieve economic growth in the long run while efficiency change could be the source of growth in the short run.

Wu (2011) presented a comparison of productivity growth estimation with different approaches in the case of China. He found that the productivity growth estimated by using DEA-MPI approach has shown a smaller value compared to other methods. However, this is not a sign of superiority of one method over other techniques. Wu (2011) suggests that the choices of the methods should consider the purposes,
backgrounds and constraints of the analysis. This implies that estimating productivity growth with more than one approach could give different perspectives with more insights for better policy implications. This is one of the reasons to apply more than one approach in this thesis. Although the baseline of the estimation method in this thesis is only DEA-MPI, different approaches may show different results empirically.

An empirical productivity growth study which covers three important aspects of economic development, i.e., productivity, convergence and policy, was conducted by Margaritis et al. (2007). They used panel data of OECD countries in the period 1979 to 2002 to decompose productivity growth into technical change, input biased technical change, efficiency change and capital accumulation. The most important finding of this study is that the productivity growth of OECD countries in the period of study was driven by technical change. By using regression analysis, they also found that this dominant factor of productivity growth has been a source of productivity and GDP per capita divergence.

Fare et al. (2006) analysed the determinants of productivity in the European Union. They utilized DEA-MPI to decompose productivity growth into its components. The estimation of productivity growth in their study incorporated human capital as an input factor. They found that the productivity growth estimates with and without human capital are not very different implying that human capital plays a minor role in overall productivity in EU countries during the period of study (1965-1998). They also found that human capital plays an important role in decreasing the role of capital deepening as the source of productivity growth. The final finding is similar to Margarities et al. (2007) who found the dominant factor of productivity growth of EU countries was technical change and this factor also the source of productivity divergence.

Kruger (2003) estimated productivity growth of 87 countries for the period 1960-1990 by employing DEA-MPI. He found that the role of capital accumulation is
very important in determining the rank of countries in terms of productivity particularly for OECD and Asian countries. In the period of study all countries experienced efficiency improvement except those in Sub-Saharan Africa. However, only OECD countries experienced technology progress over 1960-1990. By comparing two scenarios of productivity growth estimation (1960-1973 and 1973-1990), it was found that the world exhibited productivity slowdown, except within Asian countries, after 1973. The study also observed the existence of club convergence.

An interesting study was conducted by Czap and Nur-tegin (2011) who examined productivity performance in 22 transition economies (former socialist countries of Eastern Europe and Soviet Union) over 17 years (1990-2007). They used DEA-MPI to estimate productivity growth and divided the countries into gradual, intermediate and radical reformers. The finding of this study is that in the long run the gradual reform countries performed better in productivity growth and its components. Initially the countries with radical reform performed better than gradual reformers. They concluded that gradual reformers were superior to the radical reformers since the gradual reformers supported higher productivity growth compared to the radical reformers who could increase national competitiveness.

Nishimizu and Page (1982) were two of the pioneers in regional productivity growth decomposition. They proposed a method to decompose productivity growth into technical progress and change in technical efficiency on the basis of deterministic frontier production function. They used Yugoslavia’s regions as an example with special focus on its economic slowdown in the 1970s. They found that this economic bust was as a consequence of decreasing technical progress and technical efficiency change deterioration. The latter factor was found to be dominated. They also analysed regional productivity growth by using Yugoslavia’s economic plan periods and found

29 They mentioned that this classification is based on the indices for pace of reforms constructed by De Melo et al. (1996)
that efficiency deterioration from the period 1965-1970 to 1970-1975 contributed to the domination of technical progress over efficiency change both at the regional and national level.

Unlike Fare et al. (1994) who estimated productivity growth and then decomposed it into technical change and efficiency change, Nishimizu and Page’s (1982) study estimated technical and efficiency change separately. They computed productivity growth by summing up these two components.

Domazlicky and Weber (1997) measured the US. regional productivity growth by calculating DEA-MPI of the 48 contiguous states during 1977-1986. They decomposed regional productivity growth into efficiency change, scale efficiency change, pure efficiency change and technical change. The latter component was found to be the dominant factor in US regional productivity growth. They also found that there was significant interregional variation of productivity growth among US states due to significant differences in technical change rather than efficiency change. In the period of study the efficiency was declining and mostly dominated by scale efficiency change rather than pure efficiency change. This study also found that the low average growth rate of regional productivity in the US (0.44 percent) was affected by the economic recessions of 1980 and 1982.

Similar to Domazlicky and Weber (1997), Boisso et al. (2000) used DEA-MPI to decompose the US regional productivity growth into efficiency change and technical change over the period 1970-1986. The results showed that productivity growth was dominated by efficiency change in the period of study. By using regression analysis they tested the effect of the boom and recession periods on regional productivity growth and its components. They concluded that during recession periods both efficiency and technical change decreased and during boom periods they increased.
Alvarez (2007) decomposed productivity growth between 1980 and 1995 in 17 Spanish regions by combining fixed effect and the stochastic frontier models. The decomposition shows that technical change was the dominant factor of productivity growth in Spanish regions. Another valuable conclusion from this regional productivity growth study is that the proposed method (fixed effect stochastic frontier) is a good model to account for heterogeneity amongst Spanish regions. The aim of Indonesian regional productivity growth estimation in this thesis is similar to Alvarez (2007). The first is to find out the dominant factor in regional productivity growth and the second purpose is to account for regional heterogeneity which will be handled by employing the metafrontier approach.

Unlike Alvarez (2007), Salinas-Jimnez (2003) employed DEA-MPI to estimate, decompose and analyse productivity growth of 17 Spanish regions between 1965 and 1995. Despite the decomposition of productivity growth into technical and efficiency change (based on Fare et al., 1994), this study also decomposed it into capital accumulation. The estimation results showed that in the early period of study (1965-1985) capital accumulation was the dominant factor of productivity growth. However in the period 1985-1995 technical change was the main factor of productivity growth. It was found that the important role of technical change was in the regions with a high initial level of output per worker. However, this factor has a negative impact upon regional labour productivity convergence.

Leonida et al. (2004) decomposed productivity growth in 20 Italian regions over the period 1970-1995. The regions were classified into north-west, north-east, central and south regions. The decomposition revealed that the main factor of Italian regional productivity growth was technical change rather than efficiency change. They also found that the speed of innovation in northern regions was higher than that in southern
regions. Therefore, this finding implies that there was a convergence trend in Italian regions.

Ezcurra et al. (2009) used a fixed base year DEA-MPI to estimate the EU regional productivity growth over the period 1986-2004. They found that the dominant factor of productivity growth in the EU was efficiency change. This factor has also been the source of convergence in the European regions. They also tested whether the dominant role of efficiency change can be observed in their correlation coefficient. The test supports their result as the correlation coefficient between efficiency change and MPI index (0.739) was far greater than correlation coefficient between the technical change and MPI index (0.083). In a spatial context, this regional productivity growth decomposition also supports the traditional north-south economic development division discussed widely in the literature. This study found that the most efficient regions were in the northern and central Europe and the worst performance was shown by the southern regions.

Axel et al. (2011) used DEA in combination with regression analysis to decompose the efficiency of Germany regions. They found that the regional efficiency in Germany was not just affected by spatial factors. Non spatial factors were also found to play a role in Germany’s regional efficiency. They then suggested that different policy implementations have to be considered for different regions.

Qunli (2009) researched 29 Chinese provinces during 1990-2007, and used DEA-MPI to decompose productivity growth into technical and efficiency change. He analysed productivity growth in two scenarios, which were based on spatial contexts and time references. China’s provinces were divided into the East, Middle and West development zones and productivity growth was decomposed into two groups, 1991-1996 and 1997-2007. The results showed that productivity growth in China’s regions was dominated by technical change in the period 1991-1997. The technical change in
this period was found to be more than 1 per cent while efficiency change was negative. However, after 1997 productivity growth and its components showed negative values. In this period TFP growth was dominated by efficiency change. The eastern regions were the best TFP performers after 1997 and the worst performers before 1996. The best performance of technical change before 1997 was shown by the middle regions and after 1997 was shown by eastern regions. Overall, the contribution of technical change was by greater than that of efficiency change (75.01 per cent vs. 25.92 per cent).

More recent study on regional productivity growth was presented by Kumar and Managi (2012). They employed DEA-MPI to decompose productivity growth into technical change and efficiency change in 14 Indian states. The nation was divided into high income, middle income and low income states. The period of study (1993-2000) has also been divided into two, 1993-1996 and 1997-2004. They concluded that there were regional variations in productivity growth. The low-income states experienced negative productivity growth while middle and high-income states showed positive productivity growth. The results showed that in the first period, India experienced low productivity growth dominated by efficiency change. In this period Indian states experienced negative technical change. However after 1997 regional productivity growth was supported by technical change.

The interest productivity growth study has also been conducted on specific sector at regional level. Ng and Li (2009) examined efficiency and productivity growth of Chinese universities across regions. By employing MPI, they found that there are no significant universities’ productivity growth differences among regions between 1998 and 2002. They also found that the universities located at non-coastal regions experienced efficiency deterioration by 2002. Based on MPI decomposition they observed that the universities’ technical progress was offset by deterioration in their scale and technical efficiency.
The study of Indonesian productivity growth at the national level was surveyed by Timmer (1999) and Van der Eng (2010). An update summary of Indonesian productivity growth estimates at the national level is presented in Table 3.2. The studies of productivity in Indonesia vary in methods and results. Most of the studies use growth accounting as the main technique. The longest time period was covered by Van Der Eng (2010) while the most recent TFP measurement of Indonesia was done by Conference Board (2013). In the Introduction (Chapter 1), the trends of the results of some of the Indonesia’s productivity growth studies were explained.

Table 3.2 TFP growth estimates at the national level in Indonesia

<table>
<thead>
<tr>
<th>Source</th>
<th>Estimation period</th>
<th>Average TFP Growth (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas and Wang (1993)</td>
<td>1975–1990</td>
<td>-0.9</td>
</tr>
<tr>
<td>Young (1994)</td>
<td>1970–1985</td>
<td>1.2</td>
</tr>
<tr>
<td>Kawai (1994)</td>
<td>1980–1990</td>
<td>-0.1</td>
</tr>
<tr>
<td>Dasgupta, Hanson and Hulu (1995)</td>
<td>1978–1985</td>
<td>0.0</td>
</tr>
<tr>
<td>Sigit (2004)</td>
<td>1980–2000</td>
<td>-0.8</td>
</tr>
<tr>
<td>Baier et al. (2006)</td>
<td>1951–2000</td>
<td>-0.7</td>
</tr>
<tr>
<td>Isaksson (2007b)</td>
<td>1960–2000</td>
<td>-1.7</td>
</tr>
<tr>
<td>Van der Eng (2010)</td>
<td>1951–2008</td>
<td>0.6</td>
</tr>
<tr>
<td>Conference Board (2013)</td>
<td>2010-2012*</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Note:* Average of TFP in 2010, 2011 and 2012
Source: Author’s own compilation
There are also some studies of the manufacturing sector in Indonesia, which are summarized in Timmer (1999). Table 3.3 shows a summary. As explained by Timmer (1999) there are wide differences among the results of Indonesia’s TFP growth which make it difficult to be reconciled. This is not just for Indonesia but also for worldwide productivity studies in which researchers have so many choices in data, methods, time references and the way to analyse the results.

**Table 3.3** TFP growth estimates of manufacturing sector in Indonesia

<table>
<thead>
<tr>
<th>Sources</th>
<th>Estimation period</th>
<th>Average TFP Growth (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osada (1994)*</td>
<td>1985–1990</td>
<td>2.10</td>
</tr>
<tr>
<td>Aswicahyono, Bird and Hill (1996)</td>
<td>1976–1981</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Note: Osada (1994) uses two different capital stock estimates: a preliminary estimate by the BPS (*) and his own estimates (**)  
Source: Author’s own compilation

Most Indonesian productivity studies were conducted at the national level. To my knowledge, two pioneers of studies at the regional level which are Wibisono (2005) and Margono et al. (2011). Both studies estimated the aggregate productivity growth of Indonesian provinces. There is also a study at the micro level by Battese et al. (2004). They used stochastic frontier analysis (SFA) to estimate productivity growth of Indonesia’s garment firms in five different regions over the period 1990 to 1995.

Wibisono (2005) researched provincial TFP growth in 26 Indonesian provinces over the period 1984-2000. The most important conclusion in his study is that regional inequality has a similar pattern with regional TFP growth in Indonesia. Margono et al. (2011) estimated Indonesia’s province productivity in the period 1993-2000 which
covered the AEC. They found that there was a big change of productivity growth between pre and post AEC. From 1997 to 2000 TFP growth was found to be negative for all provinces except for Jakarta in 1997 and West Nusa Tenggara in 2000. On average, all provinces showed negative productivity growth and only six provinces experienced negative technical progress (Riau, Jambi, Bengkulu, East Kalimantan, North Sulawesi and Maluku). All provinces experienced negative efficiency change. The final conclusion was that efficiency change was the factor behind the negative productivity growth in the period of study.

These two studies represent two different methods, namely non frontier and frontier. The former employed growth accounting (non-frontier technique) and the later used stochastic frontier (frontier approach). Again, to the best of my knowledge, there is no study on aggregate productivity at the regional level in Indonesia which employed a non-parametric approach such as DEA-MPI. The studies that use DEA and MPI in Indonesian cases mostly analyse the sectoral activities. Among other studies, Hadad et al. (2011) used SBM-Malmquist to study the productivity of Indonesian commercial banks and Suzuki and Sastrosuwito (2011) use DEA to measure the efficiency of Indonesian commercial banks during the period of 1994-2008.

Despite being the first study on regional productivity growth in Indonesia employing DEA-MPI, this thesis is also the pioneer of regional productivity comparison between Indonesia and China. There are many studies of productivity growth in China or Indonesia alone. A survey of the studies of Chinese productivity was documented in Wu (2011). Wu found that there were 151 studies of China’s productivity growth and 74 of them were economy-wide studies. Based on these studies Wu found that the contribution of productivity growth to the Chinese economic growth was 33 per cent on average. This finding is similar to the conclusion of Van der Eng (2010) for the
Indonesian economy. Van der Eng found that the contribution of TFP growth to economic growth in Indonesia was 32 per cent in the period 2000-2008.

3.7 Productivity Policy

Productivity policy refers to government policies that support the achievement of high productivity growth. These policies could be national or regional economic development policies. The government sets up the policies that can boost the factors influencing productivity growth.

Thus, the most important question is what factors could affect productivity growth. Abramovsky et al. (2005) explained that there are two kinds of factors influencing productivity growth, i.e., short and long terms factors. Only for the long term factors, the government plays its role to manage economic development policies. These long term factors, mentioned in Abramovsky et al. (2005), include the rate of invention and diffusion of new technologies, the level of skills in the labour force and the extent to which the business environment encourages entrepreneurial activities and investment.

Diewert (2001) summarized some factors that can augment TFP growth. The factors include investment growth, investments in human capital, growth in primary inputs, increased specialization, improvements in the functioning of markets and access to new knowledge. He also mentioned that the government policies to improve the functioning of market include (i) improvements in personal security; (ii) improvements in property rights; (iii) reductions in trade barriers; (iv) improvement in telecommunications and (v) improvements in transportation and infrastructure.

Steindel and Stiroh (2001) argued that the sustainability in real growth and low inflation is dependent upon the continuity of improved performance of productivity. Another important conclusion was based on historical analysis of the US productivity performance: a major factor of productivity growth is a strong technology sector. The
good performance of productivity arises from multiple sources but the main influencing factor is investment in high-technology capital. This implies that the most important policy to support productivity is the policy regarding high-technology capital.

Sharpe (2007) explained three policies to improve Canada’s productivity. They are more rapid diffusion and adoption of best practice technologies, removal of the provincial sales tax on purchases of machinery and equipment and promotion of the geographical migration of workers. The first policy has been supported by the National Research Council’s Industrial Research Assistance Program (NRC-IRAP). The second policy affects investment at the provincial level. In Canada the cost of capital is valued from marginal effective tax rate (METR). It is noted that Canada is one of the countries with high METR (Sharpe, 2007). By lowering this tax at the province level, Canada could improve investment that supports productivity improvement. The last policy is concern with productivity disparity among regions. Some Canadian provinces experienced high productivity growth and some displayed low productivity growth. If development policy can move workers from low productivity regions to high productivity regions, overall productivity will increase (Sharpe, 2007). Parham (2011) proposed a flowchart to demonstrate how the policies could affect productivity. He argues that productivity is a long run matter and long term planning and strategies are required for productivity improvement (Figure 3.5).

Banks (2012) proposed three channels through which government can affect productivity at a micro level that are incentives, capabilities and flexibilities. Incentives are everything that can push the firm or organization to perform better over time. Capabilities are the main player in productivity improvement, which is human capital that can create knowledge systems and institutions for better achievement across all sectors. Flexibilities are innovations to change the way that production occurs and to remove all obstacles for achieving better performance.
McPherson and Vas (2013) argued that to achieve high productivity growth, Indonesia needed to change its development policies. The policies have to open up opportunities to potential people and more options for enterprises, experimentation, risk taking, and entrepreneurship. They also argued that Indonesia needs to improve its role in international production and distribution, which will give the nation a chance to be one of the world’s value chains. It can be done by expanding public investment in infrastructure, raising the quality of its education and learning, moderating the degree of exchange rate overvaluation and rationalizing its political decision making processes. The last one has been noted by McPherson and Vas (2013) as being costly and ineffective.

Firdausy (2005) concluded that many things have to be done by Indonesian government to promote productivity growth in its economy. The first is industrial technological development (ITD). He argued that this could be supported by a policy to improve the human resource quality through more opportunities in natural science, engineering education and training. He criticized the linkages of the government efforts to increase the capabilities of public science and infrastructure to private sector is small, due to bureaucratic burdens. He suggested that the most important government policies

Source: Parham (2011)
for Indonesia are the policies of openness for trade and investment and institutions. Thus, for Indonesia, open door policies for investment and imported technologies are in high demand.

The findings of some studies in this section show a new direction of productivity policy. The final goals of the policy direction of these studies are competitiveness, efficiency and innovation. Competitiveness is a transitory goal to a better standard of living and welfare, which could be achieved through efficiency and innovation as productivity growth components. Improved innovation leads to the convergence of lagging countries to leader countries as the follower countries grow faster than the leaders. Thus, productivity policy should focus on improving efficiency and innovation. However, to make the policy right, a better assessment of productivity (growth) has to be provided as a basis for decision makers. Productivity growth determinants must also be examined. As countries involve regions, counties or municipalities, productivity in these unit areas have to be accounted as the source of problem solving at the aggregate level. All of these are the purposes of this thesis.

The recent productivity policy of Indonesia as explained in the previous chapter which is based on innovation-based human resource capacity development with the President’s 1-747 initiative, seems to be a move in the right direction. The focus on R & D programs (1 per cent GDP for R & D of 1-747), innovation (7 step innovation system improvement of 1-747), economic acceleration (4 modes economic acceleration of 1-747) and future visions (7 objective vision of Indonesia 2025 of 1-747) could support the increase of Indonesia’s productivity growth. This step is similar to the suggestion of Woo and Hong (2010) who advised that to achieve better economic performance in 2049, the second SBY government (2009-2014) must adopt new economic policy frameworks with the basis of knowledge-based growth.
However, as remarked in chapter 2, this productivity policy framework explains only a national strategy. There are no explanations about how the regional productivity improvement could be achieved. Woo and Hong (2010) explained that the key success of the Indonesian economy towards 2049 is a science-led growth strategy at the provincial level. They suggested that the mobilization of provincial universities as the driver of economic growth is crucial for Indonesia. They argued that the role of central government and the international donor communities is to expand and upgrade agriculture, scientific and technical departments in provincial Indonesian universities. In addition, adoption of university–business partnerships that improve production techniques and develop new products in the basis of regional comparative advantages could help to improve Indonesia’s regional economic performance.

3.8 Conclusion

This chapter has discussed the basic productivity concepts, productivity measurement approaches and productivity policy. It was discussed that some concepts of productivity growth should be clearly defined for empirical analysis, i.e., efficiency, productivity level-growth and partial-multifactor productivity. These concepts have a strong relationship with the choices of the approaches and the structure of the input data. The better results could be acquired from the multiple approaches in empirical studies. The use of productivity level and growth, partial and total factor productivity and efficiency and technical change in specific studies will enrich the results rather than simply choosing one of the concepts. Multiple approaches could describe the unit of analysis in different perspectives.

The techniques of productivity measurement have their strengths and weaknesses. The methods of preferences among economists, researchers and policy makers are sometimes due to data related issues. The unavailability of input data for the estimation burdens the choices of productivity measurement methods. However, the
advancement of methods can also remove the obstacles of data availability. The combination of data availability and the right methods are the ideal conditions of productivity analysis. If both of them are available for every level and unit analysis then good results will support accurate conclusions and policy recommendations. When the problem of functional form and endogeneity arise, DEA-MPI could be a useful alternative. The growing development of DEA-MPI and the availability of data to measure productivity growth on the basis of this method also make it widely accepted.

The final goal of productivity measurement is to guide the right policy chosen by firms, organizations, governments and other decision making units. The most important factor to support productivity policies is productivity measurement and hence productivity determinants. Both of these can be conducted in one analysis with same or separated methodologies. The government is the most important agent that can affect the implementation of productivity policies. These implementations again require an assessment of productivity performance as a guideline for future or long term programs. However, productivity study is not a simple. Multiple techniques with the same data set could show different results. Different scenarios of analysis would also give better insight into the productivity performance of the unit of analysis. This is the task that this thesis has attempted to accomplish for a better assessment of Indonesia’s regional productivity growth performance.
CHAPTER 4
INDONESIAN REGIONAL CAPITAL STOCK ESTIMATES

4.1 Introduction

Capital stock estimation has been recognized as one of the most debatable subjects in economic measurement. Nehru and Dhareshwar (1993) identified three problematic aspects of capital stock: the lack of consensus about what capital is, how it can be measured, and whether it can be aggregated into a single measure. In relation to these issues, Ishiwata (1997) also identified three impediments of the data: problems with evaluations, setting the times for observations and estimating methods. Wu (2009) pointed out the technical drawbacks of estimating the series if the depreciation rates are assumed with ad hoc values.

There is no data of provincial capital stock published in Indonesia, either in official statistics or related studies which use the series. The data are available only at the national level. This makes it difficult for regional analysts to conduct productivity estimation and forces them to use ad hoc methods to generate the series. To support regional analysis in Indonesia, regional capital stock data have to be provided. Therefore, this study aims to estimate capital stock series for Indonesia regions.

Previous studies of Indonesian capital stock were carried out with different time periods, coverage, and goals. Most of them estimated capital stock at the national level. The main estimation method is the perpetual inventory method (PIM). Among these studies, Wibisono (2005) is the pioneer who developed capital stock series at regional level by employing a weighted approach in measuring its initial value. The capital stock estimation in this study extends the work of Wibisono (2005) in terms of initial capital stock estimation, the methods, and sensitivity analysis. The estimation of

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30 See section 4.2
the depreciation rate will be explored. The impact of different rates of depreciation applied in the data generating process on productivity growth will be tested. It is also interesting to examine the performance of capital stock before and after the AEC to gain more insight into the nature of the results. The study will cover twenty six provinces. It excludes seven new provinces since the input data are not completely available. The PIM will be employed as the main method to estimate the series.

This chapter will report the estimated series by looking at the structure of the data and its trends. The estimated series will also be compared with existing estimates and databases generated by other methods, namely, the state space model (SSM) and the combined method (CM). Finally, sensitivity analysis using different values of depreciation rates of PIM and capital-labour shares of SSM will also be conducted. The chapter is divided into six sections. The next section (4.2) is the literature review. Section 4.3 briefly discusses the methods and data requirement and availability. Section 4.4 reports and analyses the results and compares the results with existing estimates. Section 4.5 describes the sensitivity analysis. Section 4.6 presents the depreciation rates estimated by SSM. In section 4.7 the results of capital stock estimated by PIM will be compared with databases estimated by different approaches. Finally, in section 4.8 the concluding remarks and summary findings are presented.

4.2 Literature Review

4.2.1 General Literature

Capital stock is defined as the sum of all durable and reproducible tangible assets excluding land, mineral deposit and inventory stocks (Pyo, 1988). Three asset characteristics are involved in the definition: durable, reproducible and tangible (Bohm et al., 2002). The definition has a number of problems in empirical estimation including

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31 Consequently, the data of seven new provinces were added to the former province (before separation)
32 The explanation of state space approach can be seen in the appendix. CM is a PIM using the depreciation rates derived from the SSM.
homogeneity and heterogeneity, economic profit concept and cost concept, and gross and net capital stock (Hahn and Schmoranz, 1984). These problems are along the same lines as those identified by Ishiwata (1997) and Nehru and Dhareswar (1993). A vast literature of cross country estimations of capital stock reveals different approaches, time references, sources of data, conclusions, and noticeable remarks. Nehru and Dhareswar (1993) and Wu (2007) are two examples that estimated cross-country capital stock and China’s regional capital stock, respectively. Other studies include Maddison (1994), Hall and Basdevant (2002), Rahman and Rahman (2002), Schmalwasser and Schidlowski (2006), Pyo (2008) and Wu (2009). Maddison (1994) provided the standardized annual estimates of six developed countries. Hall and Basdevant (2002) proposed a new estimate of the capital stock by using a state space model (SSM). The method incorporates the Kalman filter and is applied to monthly Russian data (1994-1998). The finding was the reduction of capital stock by around 10 per cent in the period of study. This paper is probably the first to use this approach of the measurement of capital stock.

Rahman and Rahman (2002) and Schmalwasser and Schidlowski (2006) used the PIM to estimate the capital stock of the Bangladeshi and German economies respectively. Rahman and Rahman (2002) endorsed the need to improve the quality of the GFCF series and depreciation rates. Schmalwasser and Schidlowski (2006) stressed the importance of the so called ‘counterentries’ which mean that the consumption of capital and its retirement time must be clearly separated to avoid double counting in calculations.

Wadhani and Martin (1986) examined the issue of misleading results of the official measurement because of its assumption based on the retirement distribution. They argued that the shocks to the economic environments influence the scrapping of capital equipment. They proposed the estimation of the capital stock in the
manufacturing sector by adjusting the historical cost of accounting data. The proposed method aimed to find a good reason for the slowdown of productivity in manufacturing in the UK during the 1980s. The finding was that the decline of capital stock in manufacturing was not as great as previous research showed.

Gysting and Nguyen (2004) discussed the weaknesses of PIM in relation to the values of buildings. By re-evaluating the SNA93’s recommendations to the national statistics office of Denmark, they concluded that the derivations of measurements (productivity, balance sheet and model estimation) must be interpreted carefully since PIM is biased in estimating the value of buildings. Pyo (2008) showed the weaknesses of PIM in particular for estimating net and productive capital stock for developing and transition economies. By using the model of Dadkhah and Zahedi (1986) and the EU KLEMS database, he proposed an alternative method for evaluating initial value of capital stock. The finding suggested that in calculating the data, it was better to use the benchmark year rather than the zero value of initial capital stock. Despite the unfavorable comments on PIM, this method may still be the most appropriate technique today. Rahman and Rahman (2002) argued that there are advantages in using PIM. The most recent application of this method is the estimation of capital stock series by sector at the regional level of China (Wu, 2009).

4.2.2 Capital Stock for Productivity Analysis

This sub-section reviews the literatures that estimate capital stock for productivity analysis. The main method used in these literatures is PIM with different treatments in estimating initial value of capital stock \( (K_0) \). The availability of investment data, particularly, at regional level and the choices of depreciation rate has induced the variation in data generating process.

Badunenko and Tochkov (2010) employed PIM to estimate the regional capital stock for India, Russia and China. The initial capital stock was estimated by using growth rate approach (Harberger, 1978)\(^{34}\). The depreciation rate used was the common rate (national depreciation rate) for all regions which are 4.5 per cent for China, 6 per cent for Russia and 7 per cent for India. They used regional investment in fixed assets with 1993 as the base year as input data for China while for Russia they used regional fixed investment as input data. As there is no gross fixed capital formation (GFCF) data at regional level reported by Indian Statistics, they converted the GFCF data estimated by Lakhchaura (2004) using 1993 as the base year.

Czap and Nur-getin (2011) estimated the capital stock of 22 transition economies over 17 years (1990-2007). They used the PIM by assuming countries in evaluation were in their respective steady state in the initial year. This assumption implies that the initial capital stock could be estimated by the growth method (Harberger, 1978). They employed GFCF as investment data from the World Development Indicator (WDI) in constant 2000 US dollars. They calculated the growth rate of GDP over five years (1991-1995) as a growth rate of investment in calculating the initial capital stock.

Ezcurra et al. (2009) estimated the capital stock of 196 European regions (NUTS-2) over the period 1986-2004. They used PIM and computed the initial capital stock by using the growth rate approach. They used 1986 as the initial year and computed the investment of this year as an average of gross investment over the period 1980-1986. They considered a different depreciation rate among regions however, and found that the most reasonable cross regional estimates of capital-GVA ratios were

\[ I = (\delta + g)K_0 \]

\(^{34}\) The growth rate approach use the formulation \( I = (\delta + g)K_0 \) where \( I \) is investment, \( \delta \) is depreciation rate, \( g \) is growth rate of investment and \( K_0 \) is the initial value capital stock, see method and data section
measured by using the 5 per cent depreciation rate. The data utilized in their study were in 1995 constant price.

Qunli (2009) estimated China’s regional capital stock by employing PIM. He used 9.5 per cent as a common depreciation rate for all regions over the period 1990-2007. The input data to estimate capital stock was real investment with 1990 as the base year. Unlike Qunli (2009), Sang-Mok et al. (2013) employed a 6 per cent depreciation rate to estimate China’s regional capital stock by using PIM during 1995-2008. They utilized the growth rate approach to estimate initial capital stock with new investment in the first term and growth rate of investment in the initial five years as inputs data.

Kumar and Managi (2012) estimated capital stock for 14 Indian states over the period 1993-2004. Similar to Badunenko and Tochkov (2010), they used GFCF data of Indian states estimated by Lakhchaura (2004). Since the GFCF data from this estimation is only available until 1999, they extrapolated the GFCF data until 2004. They argued that this extrapolation has no impact on the TFP prior to 1999 since they used the data resulting from the extrapolation to estimate the productivity index.

Domazlicky and Weber (2006) estimated the capital stock of US manufacturing at regional level. They allocated national manufacturing capital stock to each state by using four different weights, i.e., state’s proportion of depreciable assets, state’s proportion of personal income, value added in manufacturing and payroll and state’s share of national value added. This method is much more dependent on the weights used in the allocation. All of the series were employed to estimate productivity growth by using DEA-MPI. They found that the effects of capital stock measurement were not significant for productivity growth estimation. However, different approaches of capital stock measurement affect significantly the measurement of the efficiency level.

Capital stock series of Indonesia were estimated by BPS (1996, 1997), Keuning (1988, 1991), Sigit (2004), Yudanto et al. (2005), Wibisono (2005) and Van der Eng

Looking at the diverse capital stock measurements of Indonesia, the intra-country estimation problems seem to reflect the international controversies of the series. The most critical hurdle for many countries is the availability of historical datasets for various purposes, in particular at the regional level.

As explained in the previous chapter, the current Indonesian economic development plans have focused on regional economic development initiatives through the implementation of decentralization policy. Therefore, various data at the regional level are needed, including the regional capital stock data. The first series of capital stock by province was estimated by Wibisono (2005). He employed a common rate of depreciation of 0.05 for all regions. The initial capital stock of each province was allocated from the national capital stock estimated by Sigit (2004) using the shares of GRP of the regions over national GDP. His data is not available to the public. Thus, until recently regional capital stock series of Indonesia was under documented. Differing from Wibisono (2005), Margono et al. (2011) who also estimated Indonesian regional productivity growth used proxy data for capital stock. They employed capital formation as a proxy since the provincial capital stock is not available.
4.3 Methods and Data

4.3.1 Perpetual Inventory Method

Theoretically, the PIM implies that the capital stock in time t equals to capital stock in time t-1, minus its depreciation plus the investment in period t. The implementation of the method at the regional level can be expressed as (Wu, 2009):

\[ K_{it} = (1-\delta_i)K_{it-1} + I_{it} \]  

(4.1)

where \( K_{it} \) is the capital stock of region i in year t, \( I_{it} \) is the investment in region i in time t and \( \delta \) is the rate of depreciation. From equation (4.1), one can determine that the outcomes of the PIM are impinged upon \( \delta \) and the initial value of capital stock (\( K_0 \)) since the equation can be rewritten as:

\[ K_{it} = \sum_{k=0}^{t-1} (1-\delta_i)^k I_{it-k} + K_{0i}(1-\delta_i)^t \]  

(4.2)

In a nutshell, to estimate capital stock series, three basic things are required: a time series of GFCF, depreciation rate and \( K_0 \). The \( K_0 \) in this study is estimated by a growth rate approach (Harberger, 1978). This approach assumes that the initial capital stock is represented by the investment in time one divided by the sum of the depreciation rate and the average growth rate of investment (\( g_i \)). Mathematically, the method can be derived as

\[ I_{it} = (\delta_i + g_i)K_{it-1} \]  

(4.3)

or

\[ K_{it-1} = \frac{I_{it}}{(\delta_i + g_i)} \]  

(4.4)

\[ ^{35} \text{A formal proof for Equation 4.4 which explained that the initial capital stock can be derived from investment in time one can be seen in Bitzer and Goren (2013).} \]
Following Wu (2009) and Czap and Nur-getin (2011), the average growth rate of investment (g) is replaced by the average growth rate of GRP over the first five years. The depreciation rate is assumed to be a common value of 0.05 as in Wibisono (2005). It will be changed into two schemes for sensitivity analysis of different methods of capital stock estimation and six scenarios for productivity growth decomposition.

4.3.2 Data

To estimate the capital stock series, the PIM requires data of gross fixed capital formation (GFCF) by provinces. In Indonesia the data at the regional level are available since 1983. The data in this study are obtained from the Directorate of Consumption Accounts, Central Bureau of Statistics of Indonesia. This data has been published in ‘Gross Regional Domestic Product of Provinces in Indonesia by Expenditure’ in various years such as 1983-1991, 1993-1996, 1995-1998, 2001-2005 and 2006-2010. The data series are available in three different constant price such as from 1983-1993 (constant price 1983), 1993-2003 (constant price 1993) and 2000-2010 (constant price 2000). At least one year of the data can be found based on two different constant prices such as the year 1993 (available in constant price 1983 and 1993) and 2000-2003 (available in 1993 constant price and 2000 constant price). Based on these data, the common backcasting approach is employed to transform all of the data into 2000 constant price.

The initial capital stock estimation uses 1984 as the initial year and 1985 as \( t \), for all provinces since the availability of GFCF data by province is from 1983 and one

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36 Later on this depreciation rate is proven to have a similar value to the average of four depreciation rates which are used in Sigit (2004)(3 per cent), the average of province depreciation rate estimated by SSM in this study (0.44 per cent, see Table 4.3), and the finding of depreciation rate in fixed assets 1997-1998 of Bu (2006) (7 per cent) and Wibisono (2005) (5 per cent).

37 The two rates are 0.04; 0.06 and the six rates are 0.03; 0.04; 0.05; 0.06; 0.065 and 0.07. See section 4.5

38 Example of backcasting method \( y_{t+1,2000} = \frac{y_{t+1,1993}}{y_{t,1993}} y_{t+1,2000} \) where \( y_{t,2000} \) is GRP in year t based on constant price 2000, \( y_{t+1,1993} \) is GRP in year t based on constant price 1993.
year later the third five-year development planning (Pelita) of Indonesia began. This is
the main reason that the analysis and the initial capital stock in this study starts from
this year. The data of GRP over the five years (1984-1988) are obtained from the
Directorate of Production Accounts (CBS of Statistics of Indonesia)\(^\text{39}\).

### 4.4 Results

#### 4.4.1 Capital Stock Series

There are two data series that can be obtained from this study which are national and
provincial series. The statistics in Table 4.1 show that the maximum capital stock at the
national level is \(5.23 \times 10^{15}\) and the minimum series is \(1.33 \times 10^{15}\) with a mean of \(3.12 \times 10^{15}\). The dispersion from the mean is quite large which reaches \(1.19 \times 10^{15}\) since the
time span is relatively long (26 years). The regional data are more varied than the
annual aggregate since they involve differences between space and time. The minimum
value of regional capital stock is \(1.65 \times 10^{12}\) exhibited by the capital stock of Bengkulu
Province in 1985 while the maximum value belonged to DKI Jakarta in 2010 which is
\(1.52 \times 10^{15}\).

**Table 4.1** Summary statistics of capital stock estimates

<table>
<thead>
<tr>
<th></th>
<th>Regional</th>
<th>National</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>1.20E+14</td>
<td>3.12E+15</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>3.47E+13</td>
<td>3.29E+15</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>1.52E+15</td>
<td>5.23E+15</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>1.65E+12</td>
<td>1.33E+15</td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td>2.25E+14</td>
<td>1.19E+15</td>
</tr>
<tr>
<td><strong>Skewness</strong></td>
<td>3.436689</td>
<td>0.042160</td>
</tr>
<tr>
<td><strong>Kurtosis</strong></td>
<td>16.19543</td>
<td>1.816426</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>8.12E+16</td>
<td>8.12E+16</td>
</tr>
<tr>
<td><strong>Sum Sq. Dev.</strong></td>
<td>3.41E+31</td>
<td>3.53E+31</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>676</td>
<td>26</td>
</tr>
</tbody>
</table>

\(^{39}\) For further explanation of GRP data, see the appendix
In the period of study, the level of capital stock increased steadily (Figure 4.1). However the growth rates behaved differently. Figure 4.2 shows that the growth rate reached the peak in the second five-year interval (1991-1995). This is the period of non-oil boom in Indonesia (Sigit, 2004)\(^40\). The growth of capital stock started to decrease in the period 1996-2000 and reached the lowest level in the period 2001-2005 but increased steadily in the last period.

**Figure 4.1.** Aggregate capital stock (trillion Rupiah)  
**Figure 4.2.** Average growth of aggregate capital stock in a five year interval

The regional trend of capital stock growth (represented by the islands in Figure 4.3) shows moderately consistence and is interestingly identical with the national level (Figure 4.3 compared to 4.2). The growth rate increased steadily and reached the peak around 1991 and 1996. In the period 1997-1999 the growth rate decreased and then started to recover since 2000 but at different average rates compared to the pre-economic crisis period. The growth rates after the crisis were relatively lower than before the crisis. Until the final year of the period of study, the rate of capital stock growth has not yet been fully shifted back to its peak before 1997.

\(^{40}\) There are deregulation packages issued in the late 1980s as a respond to the week economic foundation relying on income from oil. This deregulation supported high investment and hence economic growth in the subsequent periods (1990-1996) which was classified by Sigit (2004) as non-oil boom period.
Figure 4.3 Annual growth rates of capital stock by island

Figure 4.3 reveals that the averages of annual growth rate of Sumatera, Java-Bali, Kalimantan and Sulawesi before 1997 were 8.06 per cent, 7.75 per cent, 8.95 per cent and 7.64 per cent, respectively. Kalimantan showed the highest average of annual growth rate before economic crisis. However after the year of 2000 Sulawesi took the lead which was observed to have the highest growth of capital stock after economic crisis (purple line). An interesting feature in Figure 4.3 is that the average of annual growth rate of Java-Bali Island in the period 2000-2010 was the lowest among the four big islands (red line). Two reasons can be used to explain such growth trends. The first one is that the economic crisis has a greater impact on the Java and Bali regions than others. Both regions are dominated by industry and tourism sectors which are more vulnerable to economic fluctuations than the agriculture sector which is associated with the other islands. The second reason is that the more developed regions experienced decreasing growth of capital stock since the size of the capital was already bigger than the developing regions and the additional capital will be relatively smaller than the previous one.
The average shares are bigger (more than 3 per cent) in the advanced provinces and in the resource-rich ones (Figure 4.4). All regions in Java Island except DIY are classified as the former whereas North Sumatera, Riau, South Sumatera and East Kalimantan are categorized as the latter. All of these advanced and resource-rich regions have also been attributed as the regions which involve ‘19 enclave districts’ (districts with the highest GRP) by Tadjoedin et al. (2001) except for West Java and South Sumatera.

Figure 4.5 shows that most of the regions are located in quadrant I which is associated with the area of both capital stock and GRP below the national average. One region is in quadrant III (East Kalimantan). The GRP of East Kalimantan was higher than national average but the capital stock was a little bit under the national average. Riau and North Sumatera Provinces are the provinces outside Java that were located in quadrant IV. These trends of the four quadrants confirm that the national economy was
dominated by the regions on the Java Island. The engine of the Indonesian economy seems to be moved by the activities in these provinces. If this tendency holds in the long run then the disparity among the regions could be even larger over time.

**Figure 4.5** Capital stock and GRP, 2010

(Note: The horizontal and vertical blue lines show the average of GRP and capital stock respectively
Source: Author’s own calculation)

Since 2001 Aceh has been governed as a region with special autonomy from the central government. This grant gives a significant effect on the self-arrangement opportunity which may improve capital stock of the region. In 2004, it was ruined by natural disasters resulting in severe damage to infrastructure and public services. The efforts of recovery in all sectors boosted regional development in the later periods. This is the main reason for the significant increases of capital stock growth in 2005 (Figure 4.6).

Bengkulu and Lampung have been arranged as transmigration program zones. Huge infrastructure and development supports have been provided the provinces since
the third five-years national planning. The other provinces assigned for the same purpose are West Kalimantan, Central Kalimantan and North Sulawesi. All of those regions exhibited high growth of capital stock from early 1985 to 1997.

**Figure 4.6 Annual growth rates of capital stock in selected regions**

![Figure 4.6 Annual growth rates of capital stock in selected regions](image)

Source: Author’s own calculation

The riot in Maluku as an upshot of race and religion conflicts gave very significant impacts on regional development. The conflicts started in 1999 and were followed by sporadic disputes among groups until 2004. The negative effects of the conflict were reflected in the negative growth of the capital stock series starting from 1999.

These observations imply that there was a strong relationship between the trends of capital stock and certain circumstances of the regions. The GRP level and the historical economic development give a clear picture about how the capital stock may be correlated with the region specific factors. To provide more insight, we can relate the capital stock level and the regional development index. The index was constructed by Central Bureau of Statistics Republic of Indonesia involving five components which are economy, social, infrastructure, environment and information and communication technology (BPS, 2010). The scatter plot of the capital stock and the index is presented

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41 The third five year development planning (Pelita) was in the period 1978-1983
in Figure 4.7. The figure shows that the top ten of the regional development index do not always come from the regions with a high level of capital stock. D.I. Yogyakarta, Bali, North Sulawesi, Riau Island and Bangka Belitung Island are the regions with low levels of capital stock and high scores of regional development index. DKI Jakarta, Central Java, East Java, Riau and East Kalimantan are the provinces with high scores of regional development index and high levels of capital stock. Although West Java has a relatively high level of capital stock, it was not likely to exhibit high regional development index as its index was below the national average.

**Figure 4.7** Capital stock and regional development index, 2008

![Graph showing capital stock and regional development index for various regions in 2008](image)

Source: Author’s own calculation

### 4.4.2 Comparison with Existing Studies

Although the estimated regional capital stock cannot be compared with the previous findings due to the unavailability of the latter, aggregate comparison is possible. The data estimated by Sigit (2004) may be the most relevant for benchmarking. There are...
two series available in his study for the period 1980-2000. There are two data series available in Sigit (2004). The first is the sectoral data and the second series is aggregate data. The aggregate data (second series) was estimated by PIM with a depreciation rate of 0.03. The sectoral data in the period 1980-1994 (first series) was collected from BPS-Statistics of Indonesia and the sectoral data in the period 1995-2000 was estimated by using time series regression function based on capital output ratio in the period 1980-1994. This data was used by Wibisono (2005) to estimate unpublished capital stock series for Indonesian regional TFP analysis. Since this paper is an extension of Wibisono (2005), it is reasonable to use the same study as a reference. The comparison of the first series with the data in this study can be seen in Figure 4.8. His result is very close to mine in this study in the two first intervals by using 3 per cent depreciation rate and initial capital stock as in Wibisono (2005).

**Figure 4.8 Average level of aggregate capital stock in a five year interval**

(trillion rupiah)

![Graph showing average level of aggregate capital stock](image)

Source: Author’s own calculation

In terms of the growth rate, the average growth rates of Sigit’s capital stock and this study ($\delta=0.03$) are almost similar in the period 1986-1990 (Figure 4.9). Sigit’s first series has the same peak in the period 1991-1995 with the capital stock employing a depreciation rate of 0.05. However, the decline of the growth in the period of the AEC
in the first series of Sigit (2004) is greater compared to the decline in the growth rate of capital stock in this study. **Figure 4.9** Average growth of aggregate capital stock in a five-year interval

![Figure 4.9](image)

Source: Author’s own calculation

Figure 4.10 compares the average level of the second series of Sigit’s (2004) capital stock. By using a depreciation rate of 0.05 and growth rate method to estimate the initial capital stock, the average difference between the two series is 9.92 per cent. However, by using the weighted approach of initial capital stock and the same rate of depreciation, the difference between the two becomes 3.25 per cent.

**Figure 4.10** Average level of aggregate capital stock in a five year interval (trillion rupiah)

![Figure 4.10](image)

Source: Author’s own calculation
With the same method of estimation the growth rates of this study and the second series of Sigit (2004) are observed to have a similar trend. Figure 4.11 shows the comparison. The difference between the first series and the second series of Sigit (2004) was the average growth rate in the period 1996-2000. Unlike the first series, the average growth rate of his second series is much more similar to the growth rate of this study. The slope of the declining growth in the first series was steeper compared to the second series meaning that the average growth of capital stock estimated by time series regression function in the period of the AEC was lower than by using PIM. Overall, the differences between the data lie in the initial capital and depreciation rate used in the estimation. If the data generating process utilizes the same method then the capital stock series will be very similar. These trends can also be seen in the yearly comparison of capital stock series (Figure 4.12).

**Figure 4.11** Average growth of aggregate capital stock in a five year interval

Source: Author’s own calculation
Figure 4.12 Capital stock level (trillion rupiah)

Source: Author’s own calculation

4.5 Sensitivity Analysis

The capital stock series in this chapter is estimated by using different depreciation rates to observe the change of the final values of the data. Figures 4.13 and 4.14 show some variations to the base case of the parameters in the PIM. The changes of depreciation rates have a relatively significant impact on the percentage changes of the real values but the effects on the average growth are trivial. This effect of depreciation rate on the growth rate is in line with the findings of Bu (2006). He stated that the higher rate of depreciation in Indonesia does not necessarily imply a lower growth rate of capital.

At the same line with sub-section 4.4.2, to make the data comparable with other studies, the sensitivity analysis of Figures 4.13-4.19 in this section is based on the national capital stock series but Figures 4.17 are based on the regional series.
Figures 4.15 and 4.16 can give the similar conclusion of the degree of change in the two types of indicators. The shares of labour ($\alpha_2$) and capital ($\alpha_1$) of the SSM model have a significant impact on the change of real values of capital stock. The values of series change by more than 100 per cent. However the shares relatively have no impact on the average growth rate of the data. The average difference of growth rates between base case and the first scenario ($\alpha_1=0.6, \alpha_2=0.4$) was 0.18 per cent while the average difference of the base case and the second scenario ($\alpha_1=0.4, \alpha_2=0.6$) was 2.74 per cent.

These average differences of growth rates indicate that the effect of a change in the shares of labour and capital in SSM model on the growth of capital stock is trivial. In general there are small effects of a change in parameters on the growth rate of capital stock. A similar pattern can be observed in Figure 4.17 in which the line chart of depreciation rates of the base case is very similar to other scenarios.

Source: Author’s own calculation

43 assuming that the average difference of growth rate of capital stock series under 5 per cent is small
To assess the impact of the initial capital stock on the real value and growth rate of SSM, three scenarios of capital stock estimation are constructed on the basis of depreciation rates in Table 4.3. The three line charts move in the same direction and exhibit a similar trend (Figures 4.18 and 4.19). This is very strong evidence that $K_0$ in the SSM has no impact on the real value and growth rate of capital stock in the case of Indonesian regions in the period of study.
Based on the sensitivity analysis it is reasonable to use one of the capital stock estimates. The results show that PIM results are more stable than SSM results. The fluctuation of the real value of the PIM series is smaller than the other one and its growth rates are insensitive when different schemes of depreciation rates are applied in the estimation process. For these reasons PIM is chosen to estimate productivity growth in Indonesian regions. To sum up the sensitivity analysis, Table 4.2 presents the conclusion of the results.

**Table 4.2** Summary the impact of alternative scenarios

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Methods</th>
<th>Change in</th>
<th>(\delta)</th>
<th>(\alpha_1-\alpha_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Value</td>
<td>PIM</td>
<td>Sensitive</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>SSM</td>
<td></td>
<td>-</td>
<td>Sensitive</td>
</tr>
<tr>
<td>Growth Rate</td>
<td>PIM</td>
<td>Indifferent</td>
<td></td>
<td>Indifferent</td>
</tr>
<tr>
<td></td>
<td>SSM</td>
<td>Indifferent</td>
<td></td>
<td>Indifferent</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>SSM</td>
<td>-</td>
<td></td>
<td>Unclear</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

4.6 **Depreciation Rates**

The comparative analyses in the preceding sections show the importance of the depreciation rates in the data generating process. Therefore before continuing to the next step, it is important to know the rate of depreciation among the regions. By using
SSM, we can derive the depreciation rates of Indonesian provinces. These different rates will be applied in the combined method and the results are compared with the results from the main series (PIM with \( \delta=0.05 \)). Table 4.3 shows the results of the estimation of the average rate of the years. To get more insight, the depreciation rates based on different initial capital stock are compared. The first series of depreciation rates (column 3) employs the weighted approach (Wibisono, 2005), column 4 uses the growth method in equation (4.4) and the last column utilizes the weighted average approach. The average of the results is very close. The difference is 0.92 per cent (or 0.0092 in decimal value) of the average between columns 3 and 4, 0.65 per cent (or 0.0065) of columns 4 and 5, and 0.26 per cent (or 0.0026) of columns 3 and 5.

Table 4.3 Depreciation rates of Indonesian regions estimated by SSM

<table>
<thead>
<tr>
<th>Code</th>
<th>Province</th>
<th>( K_0 ) Sigit</th>
<th>( K_0 ) Growth Rate</th>
<th>( K_0 ) Weighted average</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>NAD</td>
<td>1.88</td>
<td>17.22</td>
<td>3.64</td>
</tr>
<tr>
<td>12</td>
<td>North Sumatera</td>
<td>5.49</td>
<td>7.29</td>
<td>6.55</td>
</tr>
<tr>
<td>13</td>
<td>West Sumatera</td>
<td>6.13</td>
<td>3.33</td>
<td>5.11</td>
</tr>
<tr>
<td>14</td>
<td>Riau</td>
<td>6.42</td>
<td>7.13</td>
<td>7.17</td>
</tr>
<tr>
<td>15</td>
<td>Jambi</td>
<td>6.25</td>
<td>3.42</td>
<td>5.05</td>
</tr>
<tr>
<td>16</td>
<td>South Sumatera</td>
<td>6.67</td>
<td>4.67</td>
<td>5.97</td>
</tr>
<tr>
<td>17</td>
<td>Bengkulu</td>
<td>2.69</td>
<td>10.19</td>
<td>4.88</td>
</tr>
<tr>
<td>18</td>
<td>Lampung</td>
<td>6.11</td>
<td>9.21</td>
<td>7.51</td>
</tr>
<tr>
<td>31</td>
<td>DKI Jakarta</td>
<td>13.59</td>
<td>5.74</td>
<td>8.84</td>
</tr>
<tr>
<td>32</td>
<td>West Java</td>
<td>6.01</td>
<td>6.66</td>
<td>6.41</td>
</tr>
<tr>
<td>33</td>
<td>Central Java</td>
<td>4.96</td>
<td>5.97</td>
<td>5.65</td>
</tr>
<tr>
<td>34</td>
<td>DI Yogyakarta</td>
<td>6.98</td>
<td>4.44</td>
<td>6.09</td>
</tr>
<tr>
<td>35</td>
<td>East Java</td>
<td>5.29</td>
<td>6.59</td>
<td>6.16</td>
</tr>
<tr>
<td>51</td>
<td>Bali</td>
<td>5.61</td>
<td>6.94</td>
<td>6.40</td>
</tr>
<tr>
<td>52</td>
<td>West Nusa Tenggara</td>
<td>9.55</td>
<td>7.47</td>
<td>8.93</td>
</tr>
<tr>
<td>53</td>
<td>East Nusa Tenggara</td>
<td>5.11</td>
<td>3.65</td>
<td>4.75</td>
</tr>
<tr>
<td>61</td>
<td>West Kalimantan</td>
<td>11.06</td>
<td>11.63</td>
<td>10.81</td>
</tr>
<tr>
<td>62</td>
<td>Central Kalimantan</td>
<td>11.91</td>
<td>11.81</td>
<td>12.52</td>
</tr>
<tr>
<td>63</td>
<td>South Kalimantan</td>
<td>3.48</td>
<td>6.50</td>
<td>4.96</td>
</tr>
<tr>
<td>64</td>
<td>East Kalimantan</td>
<td>3.87</td>
<td>8.86</td>
<td>5.74</td>
</tr>
<tr>
<td>71</td>
<td>North Sulawesi</td>
<td>4.46</td>
<td>4.27</td>
<td>4.93</td>
</tr>
<tr>
<td>72</td>
<td>Central Sulawesi</td>
<td>6.50</td>
<td>6.23</td>
<td>6.81</td>
</tr>
<tr>
<td>73</td>
<td>South Sulawesi</td>
<td>4.16</td>
<td>7.94</td>
<td>5.99</td>
</tr>
<tr>
<td>74</td>
<td>South East Sulawesi</td>
<td>7.49</td>
<td>12.77</td>
<td>9.72</td>
</tr>
<tr>
<td>81</td>
<td>Maluku</td>
<td>3.43</td>
<td>4.88</td>
<td>4.09</td>
</tr>
<tr>
<td>94</td>
<td>Papua</td>
<td>12.32</td>
<td>6.58</td>
<td>9.63</td>
</tr>
</tbody>
</table>

Average 6.44 | 7.36 | 6.70

Source: Author’s own calculation
The weakness of the weighted approach is the use of GRP to GDP shares as weights to estimate. When the $K_0$ is constructed based on these techniques then the regional variation might follow the variation of GRP and consequently it will affect the final result of the capital stock estimation. The shortcoming with Sigit (2004) as the sources of initial value of capital stock is that applied 0.03 rate of depreciation which is considerably low\(^{44}\).

An alternative is to introduce a weighted average. This technique combines the weights from Wibisono (2005) and the average shares of the first five years of regional capital stock estimated by PIM. This value is multiplied to the aggregate capital stock of Sigit (2004) in the year 1984 as the initial year. The theoretical explanation of the link is to estimate regional capital stock by combining unobserved and historical aspects.

There are two studies reported rates of depreciation capital in Indonesia. The first one is the study of Schundeln (2013) who found the depreciation rate between 8 per cent and 14 per cent by using Indonesian manufacturing data. The second study by Bu (2006) found an aggregate depreciation rate of 2 per cent in 1996-1997 and 7 per cent in 1997-1998 by employing firm level data.

### 4.7 Other Methods

The purpose of comparing two databases with different methods in this study is not to find out that one method is superior to others, rather to get more insight about the nature of the results using each database. Four scenarios of CM database are derived\(^{45}\). This comparison will assess the difference in level and growth rate and their trends over the period of study. Figure 4.20 depicts that aggregate level capital stock of the five cases

\(^{44}\) As mentioned in Bu (2006) the rate of depreciation of capital is comparatively higher in developing countries due to many economic and social forces.

\(^{45}\) CM, CMB, CMBC, and CMS are the databases which employs initial capital stock with $\delta$ in column (4) Table 4.3 and the common rate of 0.05 in the estimation process, initial capital stock and estimation process with $\delta$ in column (4) Table 4.3, the initial capital stock and estimation process with $\delta$ in column (5) Table 4.3 and initial capital stock and estimation process with $\delta$ in column (3) Table 4.3. All of them used PIM as a basis in measurement.
indicates a common pattern. Figure 4.21 shows the growth rates of capital stock. The growth of SSM exhibits a sharp decline in 1998 since it follows the trend of the GRP in that year. Otherwise, the rates are similar.

Figure 4.20 Aggregate level of capital stock

![Graph showing aggregate level of capital stock](image)

Source: Author’s own calculation

Figure 4.21 Average growth of aggregate capital stock in different methods

![Graph showing average growth of aggregate capital stock](image)

Source: Author’s own calculation

Among the regions, the level and the growth rate of capital stock series can be seen in Figure 4.22a until 4.22l. The level of the capital stock series is similar between PIM and all CM databases in all regions but great differences exist between PIM and SSM in two economic corridors, Bali-Nusa and Kalimantan (Figures 4.24e and 4.24g). In Bali-Nusa the SSM level is smaller than the PIM and CM values. It is the opposite in

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46 The classification of the regions in this section is based on six corridors of MP3EI (Coordinating Ministry for Economic Affair Republic of Indonesia, 2011, pp.46). The capital stock level of an island is the sum of the capital stock in the island divided by the number of the provinces.
the Kalimantan Island. In terms of growth rates the SSM values are more volatile in both islands.

Figure 4.22a Capital stock: Sumatera (trillion Rupiah)

Figure 4.22b Capital stock growth: Sumatera

Figure 4.22c Capital stock: Java (trillion Rupiah)

Figure 4.22d Capital stock growth: Java

Figure 4.22e Capital stock: Bali-Nusa (trillion Rupiah)

Figure 4.22f Capital stock growth: Bali-Nusa
Figure 4.22g Capital stock: Kalimantan (trillion Rupiah)

Figure 4.22h Capital stock growth: Kalimantan

Figure 4.22i Capital stock: Sulawesi (trillion Rupiah)

Figure 4.22j Capital stock growth: Sulawesi

Figure 4.22k Capital stock: Maluku-Papua (trillion Rupiah)

Figure 4.22l Capital stock: Maluku-Papua

Source: Author’s own calculation
4.8 Conclusion

The unavailability of regional capital stock databases in Indonesia makes the comparison of capital stock data estimated with different approaches valuable. In conclusion, the estimated datasets are relatively reliable. As the first estimation of capital stock series at the regional level in Indonesia, this research facilitates further work utilizing the series. There are many challenges in this field. The implementation of a common rate of depreciation (in the growth rate method) can be expanded. The application of different values of $\alpha$, at the sectoral level might also deserve future investigation.
Appendix to Chapter 4

A4 Method and Data of State Space Model

A4.1 State Space Model

Following Hall and Basdevant (2002), by assuming the technology is Cobb-Douglas, the total production in the economy is $Y_t$, employment is $L_t$ and capital stock is $K_t$, then the capital stock estimation can be formulated into state space equations as follows:

\[ yt = a_0 + a_1 k_t + a_2 l_t + e_t \quad (A4.1) \]

\[ k_t = k_{t-1} + i_t - \delta_{t-1} + v_{1t} \quad (A4.2) \]

\[ \delta_t = \delta_{t-1} + v_{2t} \quad (A4.3) \]

Equation (A4.1) is the signal equation which is comprised of observable variables (output and labour). It also includes an unobservable factor (capital stock, $k$). Equations (A4.2) and (A4.3) are the state equations which incorporate the two unobservable units ($k$ and depreciation rate, $\delta$). The variables $y_t$, $k_t$, and $l_t$ are the natural logarithms of output, capital and labour and $i_t$ is the investment as a proportional of $K_0$ ($i_t = \ln (1 + \text{GFCF}_t / K_0)$). $K_0$ is estimated by the growth method in equations (4.3) or (4.4).

As indicated in Hall and Basdevant (2002), the models (A4.1), (A4.2) and (A4.3) cannot be estimated directly without calibrating some of the parameters, i.e., the degree of labour and capital shares in the economy ($\alpha$). In this exercise, the value of $\alpha$ is calibrated by combining different options disclosed in the sensitivity analysis section. The base case of the capital ($\alpha_1$) and labour ($\alpha_2$) are 0.58 and 0.42 respectively, (Alisjahbana, 2009). These values are exerted to all of the regions as the general rate of $\alpha$. Two different values of capital and labour shares will be employed to test the effect of the change of the share on the stability of the methods (0.4 as a lower bound and 0.6 as an upper bound applied for the two inputs).
To explain it, follow Jacob et al. (1997) and let the real investment in time $t-j$ be denoted by $I_{t-j}$. The real investment which survives until time $t$, $K_{t,t-j}$, is

$$K_{t,t-j} = e_{t,j} + I_{t-j}$$  \hspace{1cm} (A4.4)

where $e_{t,j}$ is a survival rate. If $L$ is the life of durable goods, then the aggregate capital stock until time $t$ can be formulated as:

$$K_t = \sum_{j=0}^{L} K_{t,t-j} = \sum_{j=0}^{L} e_{t,j} I_{t-j}$$  \hspace{1cm} (A4.5)

The term $e_{t,j}$ depends on the assumptions and standard methods used by the researchers. This survival rate is also called the efficiency rate for all $j$ investment to time $t$. When the survival rates are assumed to follow a constant exponential rate $\delta$,

$$e_t = (1-\delta)^j, t = 1, 2, 3, \ldots$$

then the aggregate capital stock at the end of period $t$ is

$$K_t = \sum_{j=0}^{L} K_{t,t-j} = \sum_{j=0}^{L} (1-\delta)^j I_{t-j}$$  \hspace{1cm} (A4.6)

Equation (A4.2) is a standard state equation. Economically, the model can be seen as an approximation of the standard PIM. From equation (A4.5) we can rewrite the equation as:

$$\frac{K_t}{K_{t-1}} = \left[1 + \frac{I}{K_0}\right] e^{-\delta_{t-1}}$$

Taking the log of this equation then

$$\ln K_{t-1} = \ln K_{t-1} + \ln \left[1 + \frac{I}{K_0}\right] - \delta_{t-1}$$

In this case the efficiency rate follows the exponential pattern with constant rate $\delta$. In the literature this pattern is called the declining balance pattern.

There are many software packages that can be used to estimate state space model. In this study, the model is estimated by EVIEWS 7 which utilizes maximum
likelihood supported by the Kalman filter. There are two model specifications in
EVIEWS 7 which are syntax specification and auto specification. The syntax
specification for the model can be made by following Hall and Basdewant (2002) or
Basdewant (2003) while the auto specification can be made by following step by step in
EVIEWS 7 dialog boxes (EVIEWS 7 user guide, pp. 500). The capital stock series are
made by using the make state series option (EVIEWS 7 user guide, pp.508). For further
explanation of the model, results and data generating process can be seen in EVIEWS 7
user guide chapter 33 page 487-510. The state space model in this study could be
categorized as basic and simple state space model. More complex state space model and
its estimation procedure in EVIEWS can be seen in Van den Bossche (2011).

A4.2 Data

To estimate capital stock by employing the SSM, four input data (gross regional product
(GRP), gross fixed capital formation (GFCF), regional labor data and regional initial
capital stock) are required. GFCF has been explained in previous section (the method
and data section) while initial capital stock are obtained from the estimation results of
growth rate approach.

The long series of GRP are obtained from Directorate of Consumption
Accounts, Central Bureau of Statistics of Indonesia. This data has also been published
in ‘Gross Regional Domestic Product of Provinces in Indonesia by Industrial Origin’ in
various years. The data has also been published at regency and municipality level with
the title ‘Gross Regional Domestic Product of Regencies/Municipalities in Indonesia’ in
The data before 2000 are converted into 2000 constant price by the backcasting method
as in GFCF data since there is at least one year data are in the basis of two based years.

The labor data are the number of workers employed in the economy which is
mainly adopted from the Indonesian labour force survey (SAKERNAS). The data
collected in the survey are household members covering persons aged 10 years and older. In this study the workers employed in the period 1985-1995 are obtained from tabulated data which cover household members 10 years and older while from 1996-2010 the worker employed covers household members 15 years and older. The data for 1985 are based on the results of the 1985 inter-censal population survey. This survey is conducted in the mid period of two population censuses. The population census in Indonesia has been carried out every 10 years (the year with zero number). Other data are collected from SAKERNAS. In the year when this survey was conducted quarterly the data used is based on the third survey, and in the year when the surveys are conducted twice a year, the data are collected from the second half of that year.

SAKERNAS is the Indonesian national labour survey which was firstly conducted in 1976. Initially this survey was conducted annually (1977-1978) but later on it was carried out quarterly (1986-1993). In the period 1994-2001, this survey again became a yearly survey. To cover quarterly movement, from 2002-2004, there are yearly and quarterly SAKERNAS. During the period 2005–2010, SAKERNAS was carried out twice a year (February and August).

In this study the data are obtained from Directorate of Population and Social Welfare, Statistics of Indonesia, Jakarta. These data are published in ‘Labour Force Situation in Indonesia 1976-1978 and 1986-2010’. The labour data used in this study, particularly in the period 1996-2005 are also published in Data Statistic Indonesia Website which is a collaboration website between BPS Statistics of Indonesia, University of Indonesia and Australian National University that supported by AusAid. The data from 2007-2010 can also be found in ‘Trends of the Selected Socio-Economic Indicators of Indonesia 2008-2012’. The summary of descriptive statistics of the data used in this study can be seen in Table A4.1.
Table A4.1 Descriptive statistics of GFCF, GRP and labour data of Indonesian provinces, 1985-2010

<table>
<thead>
<tr>
<th>Summary</th>
<th>GFCF</th>
<th>GRP</th>
<th>LABOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Mean</td>
<td>1.16E+13</td>
<td>5.11E+13</td>
<td>3292940</td>
</tr>
<tr>
<td>Median</td>
<td>3.83E+12</td>
<td>1.88E+13</td>
<td>1583185</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.36E+14</td>
<td>4.10E+14</td>
<td>21525529</td>
</tr>
<tr>
<td>Minimum</td>
<td>7.59E+10</td>
<td>2.14E+12</td>
<td>370851</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>2.04E+13</td>
<td>7.40E+13</td>
<td>4582302</td>
</tr>
<tr>
<td>Skewness</td>
<td>3.181708</td>
<td>2.371108</td>
<td>2.33729</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>14.32589</td>
<td>8.524676</td>
<td>7.088383</td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>4753.659</td>
<td>1493.133</td>
<td>1086.292</td>
</tr>
<tr>
<td>Sum</td>
<td>7.84E+15</td>
<td>3.46E+16</td>
<td>2.23E+09</td>
</tr>
<tr>
<td>Sum Sq. Dev.</td>
<td>2.82E+29</td>
<td>3.70E+30</td>
<td>1.42E+16</td>
</tr>
<tr>
<td>Observations</td>
<td>676</td>
<td>676</td>
<td>676</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation
CHAPTER 5
PRODUCTIVITY GROWTH IN INDONESIAN REGIONS

5.1 Introduction

The 2012 World Bank and International Finance Cooperation (IFC) report on ‘Doing Business in Indonesia 2012’ chooses the phrase ‘ambitious and fast rising’ to describe the Indonesian economy. Evidence of this can be seen in Indonesia’s position as the third fastest growing economy among the G20 in 2009 (World Bank and IFC, 2012, pp. 1), with a predicted growth rate of 6.5 per cent in 2014 (World Bank, 2013, pp.13).

Meanwhile, dramatic changes have taken place in Indonesia since 1998. The most fundamental and probably perilous decision path was the implementation of the decentralization policy and political reform during the period of crisis recovery. As mentioned in previous chapters, these changes have been supported by the long term master plan, namely MP3EI, to accelerate and expand the Indonesian economy from 2011 through to 2025. This master plan adopts a cluster system to improve the efficiency of regional economies by increasing specialization according to regional comparative advantages. The most interesting feature of this master plan is its focus on the role of productivity growth. It mentions that productivity growth is the most important factor that should be considered and thus improved upon to allow for national development.

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47 This policy is based on the Law No. 22/1999 which provides constitutional foundations toward regional autonomy. The political reforms include the implementation of a direct general election to choose president –vice president, people’s representatives and regional leaders. The term crisis in this chapter refers to AEC as explained in Chapter 2 and the recovery period from this crisis started in the year 2000.

48 The cluster system in this plan refers to the specialization of certain region in certain economic activity. Fritsch and Slavtchev (2010) found that this specialization induces regional efficiency in producing knowledge and hence innovation. They mention some reasons that induce efficiency such as a pool of regional workforce with certain industry-specific skills in certain regions, specialized business services locally, sharing the same technology within regions and local collective learning processes. Maudos et al. (2000a) found ‘greater gains in composition efficiency as a consequence of the structural changes in productive specialization’. 

However, the emergence of the Indonesian economy has resulted in problems that need to be resolved\textsuperscript{49}. Hill (1995) remarked that despite the rapid industrialization that was accompanied by structural change, Indonesian technological development was among the lowest in East Asia\textsuperscript{50}. Therefore he argued that technological development and technology policy must be the main focus of policy-makers in order to encourage Indonesian economic development in the future.

Boediono (Indonesian vice president 2009-2014) stated that until 2009, Indonesia’s economic growth was not supported by innovation\textsuperscript{51}. His argument was based on the data that only six patents were registered in Indonesia in 2009, a low figure in comparison with other countries such as Japan and the US. The registration of trademarks was also lagging behind a series of other countries in 2009; Indonesia had only 15 trademarks compared to the People’s Republic of China with 84,000, Thailand with 386, Malaysia with 513 and the Philippines with 54.

In line with this, the World Economic Forum’s report on global competitiveness for 2011-2012 (pp.11) classified Indonesia as an economy that has been driven primarily by efficiency (in the same group with Malaysia, Thailand and China). This means that Indonesia’s economy is not driven by innovation. Hence the welfare of Indonesia is not driven by innovation either. This makes it different from its neighbouring countries including Singapore, Australia, South Korea and Japan, which are driven by innovation.

\textsuperscript{49} The OECD has categorized Indonesia as one of the world’s emerging economies, which is part of BRIICS (OECD, 2008a, pp. 11). Some reasons behind this were explained in previous paragraphs (as the third fastest growing economy among G20, the relatively high recent economic growth and the dynamic changes in economic fundamentals).

\textsuperscript{50} This argument based on data before 1995 is still relevant since the study in this chapter includes Indonesian data before 1995. Another reason why Hill (1995) is still relevant is that the emergence of the Indonesian economy was categorized as HPAEs (High Performing Asian Economies) by World Bank (1993, pp.1) which was based on the good performance of Indonesian economy before it was interrupted by AEC in the mid-1997. The indicators that were used by Hill (1995) to assess Indonesian technological development compared to its neighbours were R & D indicators, scientific personnel, public expenditure on education and tertiary education.

\textsuperscript{51} Boediono’s statements were released at the 12\textsuperscript{th} World Intellectual Property Day, Tuesday 8 of May 2012. The news was reported in Kompas on 9 of May 2012 (Kompas is one of Indonesian national newspaper).
The remarks of Hill (1995), Boediono (Indonesia’s vice president) and the World Economic Forum induce several research questions in regards to Indonesian economic growth, primarily questions involving the contributions of efficiency and innovation (both components of productivity growth). These questions may be more relevant at the regional level in the context of the implementation of the decentralization policy. The first question is whether there is a clear regional pattern of productivity growth in Indonesia. Secondly, this study looks at whether the productivity growth at the national level has followed the same pattern at the regional level, and what the dominant factor behind this growth is. The last question looks at whether productivity growth can explain the Indonesian economic development paths.

Many studies have explored Indonesian productivity growth performance. However, little consideration has been given to its decomposition, particularly at the regional level\textsuperscript{52}. To fill the gap, this paper explores Indonesian regional productivity growth performance by taking into account three stages of estimations. The first stage was conducted by employing a conventional DEA-MPI. The next step is the application of fixed base year DEA-MPI. The last step is the sequential DEA-MPI, completed by assuming that there is a dependency relation among production sets over times\textsuperscript{53}. The use of these methods enables the decomposition of TFP growth into efficiency and technical changes\textsuperscript{54}. Some alternative schemes are estimated to present a more complete analysis of these components. These schemes include TFP growth by island, according to five year development planning, in pre- and post-crisis and based on Indonesian economic development stages.

The structure of the chapter is as follows. The first section is the introduction followed by a review of the literature. The data and the DEA-MPI approaches utilized in this chapter will be explained in the third section. The fourth section reports the

\textsuperscript{52} The studies can be seen in Chapter 2 and Chapter 3
\textsuperscript{53} Further explanation about this assumption will be discussed in data and methods section.
\textsuperscript{54} The explanations of these components can be seen in Chapter 3.
results of productivity growth estimated by conventional and fixed base year DEA-MPI. Section five provides the results of productivity growth in different schemes as mentioned in the previous paragraph. The results of productivity growth estimated by sequential DEA-MPI are presented in section six. In the subsequent section, productivity growth estimates according to three different approaches are compared. The last section concludes the chapter.

5.2 Literature Review

The literature on productivity growth estimates employing DEA-MPI is extensively reviewed in Seiford (1996), Kontodimopoulus and Niakas (2006) and Cook and Seiford (2009), among others. The methods of productivity growth estimates depend on study goals, research considerations and study limitations. The studies that used single method (conventional or fixed base year DEA-MPI) both at national and regional level are discussed in section 3.6, Chapter 3. These kinds of DEA-MPI analysis compare productivity in two time periods and use the data at one point in time to estimate productivity growth.

Alternatively, productivity growth may employ a full dataset to construct a single intertemporal production set in which the data accumulates until the present year. This approach estimates a sequential frontier (Tulkens and Eeckaut, 1995a). Further, Tulkens and Eeckaut (1995a) suggested that in empirical analysis, several approaches support better understanding and hence form better conclusions. They concluded that implementing some techniques (e.g. conventional and sequential DEA-MPI) in the same dataset opens up the possibility of analyzing the units of analysis in several ways. Suhariyanto and Thirtle (2001) explained the curse of dimensionality in the DEA-MPI. This problem emerges when the number of observations used in the study is small relative to the total number of inputs and outputs. It is appropriate to employ the sequential frontier approach since this method is known to be more stable than
conventional DEA-MPI in the presence of this dimensionality problem (Thirtle et al., 2000).

Shestalova (2003) utilized a sequential DEA-MPI approach to estimate productivity growth in manufacturing industries of OECD countries. She argued that the sequential DEA-MPI is more suitable for estimating productivity growth of the manufacturing sector compared to conventional DEA-MPI. This is because the sequential indices are constructed by enveloping all past observations with assumptions that any technology available in the past is also available in the present and hence in the future. Further she explained that this is the reason why technical change in the sequential approach is pure technical progress and, therefore, technical regress is not possible under this approach.

Similar to Shestalova (2003), some studies also try to combine two techniques for comparison. Althin (2001) used two DEA-MPIs, namely, conventional and fixed base period, in his study to evaluate some productivity growth index. He found that the conventional DEA-MPI does not fulfill the circularity test while the fixed base period approach cannot show the base period dependency test. He argued that the application of the indices in an empirical study is much more dependent on the researcher’s economic arguments. He estimated productivity changes by employing Swedish pharmacies data over the period 1980 and 1989 with four inputs and four outputs. He observed that in some cases, there is a significant difference between the two indexes and in other cases there is no significant difference between them.

Nin et al. (2003) compared agriculture productivity growth in developing countries by using conventional and sequential approaches. In the first step, they used conventional DEA-MPI to estimate productivity growth and found that there was technical regress in some countries due to biased technical change. In the second step,

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55 The graphical explanation of this will be explained in section 5.3
they estimated productivity growth by using sequential DEA-MPI and found that there was no technical regress which was argued to be more realistic for agriculture productivity growth among countries.

Oh and Hesmati (2010) combined conventional and sequential DEA-MPI with Malmquist-Luenberger index to estimate productivity growth of 26 OECD countries for the period 1970–2003. These methods basically combined the assumption of non-technical regress (in sequential DEA-MPI) and the existence of undesirable output (in Malmquist-Luenberger index). They found that the decompositions of the conventional-Luenberger index and the sequential-Lueberger index are different, however the trends rates of average of productivity growth are similar. They also found that the dominant factor of productivity growth in their study is efficiency change.

Halkos and Tzeremes (2006) compared the results of MPI and Malmquist total factor productivity index (MTFPI), which is based on micro data from twenty companies operating in the Greek health sector over a period of two years (2004-2005). They found that the results of MPI and MTFPI are similar under the assumption of constant returns to scale. Their study supports the theoretical argument proposed in Färe et al. (1996) and Lovell (2003) that, theoretically, under constant returns to scale MPI and MTFPI give a similar result.

Asmild et al. (2004) combined DEA window with the MPI to estimate the productivity growth of Canadian banks for the 20 year period of 1981–2000. They compared the results of conventional and fixed based year DEA-MPI with the Malmquist DEA window approach. They found that the decomposition of MPI based on DEA window could be spurious although the values of productivity index from this approach seem more plausible. They argued that these results are the consequence of the averaging extreme variations in index values in the windows analysis. They showed that the decomposition of conventional and fixed base year DEA-MPI into technical and
efficiency change is not valid if the estimation procedure is converted into DEA window.

The analysis in this chapter is similar to Nishimizu and Page (1982), Domazlicky and Weber (1997), Boisso et al. (2000), Alvarez (2007), Salinas-Jimenez (2003), Leonida et al. (2004), Ezcurra et al. (2009), Axel et al. (2011), Chen et al. (2009), Qunli (2009) and Kumar and Managi (2012) which estimated and analysed productivity growth at regional level. Following Wu (2011) and Tulkens and Eeckaut (1995a) this chapter adopts the principle of ‘several approaches are better than only one’. Therefore, the productivity growth estimation in this chapter will be conducted by considering three different approaches, namely, conventional, fixed base year and sequential DEA-MPI.

5.3 Methods and Data

The productivity growth estimation in this chapter uses two inputs (labour and capital) and one output (GRP). The capital stock data is based on the results of capital stock estimation in Chapter 4. Among several scenarios of databases, this chapter uses the data estimated by PIM with the common rate of depreciation of 0.05. The labour and GRP data are both explained in the appendix of Chapter 4 (section A4.2).

The theoretical framework of conventional DEA-MPI is discussed extensively in section 3.5, Chapter 3. The basic model of Caves et al. (1982) and its decomposition (Fare et al., 1994) are also explained. Therefore, next sub section focuses on fixed base year and sequential DEA-MPI.

5.3.1 Fixed Base Year DEA-MPI

As explained in Chapter 3 that the reference technology in estimating the MPI plays a significant role in determining the final results. Fare et al. (1994) resolved this problem.

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56 see Chapter 3, section 3.6
57 The reason of using this data can also be seen in Chapter 4
by taking a geometric mean of the two time periods of the Malmquist index (t and t+1). Another choice to estimate productivity growth was delivered by Berg et al. (1992), which is called fixed base year Malmquist index. The method uses reference technology at time t₀. Following the formulation of Asmild and Tam (2007) the output Malmquist index with fixed base year can be formulated as follows:

$$M^{t} (x^{t+1}, y^{t+1}, x^{t}, y^{t}) = \frac{D_{o} \left( x^{t+1}, y^{t+1} \right)}{D_{o}^{t} \left( x^{t}, y^{t} \right)}$$  \hspace{1cm} (5.1)

Similarly to the DEA-MPI in Equation 3.23 this MPI index can be decomposed into efficiency change and technical change index as:

$$M^{t} (x^{t+1}, y^{t+1}, x^{t}, y^{t}) = \frac{D_{o}^{t} \left( x^{t+1}, y^{t+1} \right)}{D_{o}^{t} \left( x^{t}, y^{t} \right)} \left[ \frac{D_{o} \left( x^{t}, y^{t} \right)}{D_{o}^{t} \left( x^{t}, y^{t} \right)} \right] \left[ \frac{D_{o}^{t} \left( x^{t+1}, y^{t+1} \right)}{D_{o}^{t} \left( x^{t+1}, y^{t+1} \right)} \right]$$  \hspace{1cm} (5.2)

In Equation (5.2), one can determine that the efficiency change of conventional and fixed base year are the same but their technical change component is different. This difference could affect the value of MPI. The base year is chosen arbitrarily and there is no study explaining how to choose the suitable base year for this method. Following Ezcurra et al. (2009), the first year of study period (the year 1985) is chosen as the base year\(^{58}\). Another aim of choosing the fixed base year approach is based on its advantage, that is, to evaluate the progress that has been made by the current regime compared to the regime covering the base year (Odeck, 2005).

### 5.3.2 Sequential DEA-MPI

Unlike conventional DEA-MPI, the production sets in sequential DEA-MPI are assumed to be dependent across time. This is because it assumes that the past technology is still feasible in the current and future production process. Consequently,

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\(^{58}\) For exercise and comparability purposes, author also estimates productivity growth by using all of the years in this study as the base year. The results can be accessed upon request.
the information of inputs and outputs from the previous periods are needed to form the current production set. Similar to conventional DEA-MPI, for each time period \( t = 1, 2, \ldots, T \), there is technology \((Z)\) that maps inputs \((x)\) into outputs \((y)\). However in sequential DEA-MPI, the \( x^{ts} \in \mathbb{R}^N \) is transformed into \( y^{ts} \in \mathbb{R}^M \). The set of production possibilities could be formulated as

\[
Z^{seq} = \left\{ (x^{ts}, y^{ts}) : x^{ts} \text{ can produce } y^{ts} \right\} \text{ with } s = 0, 1, 2, \ldots, t-1. \tag{5.3}
\]

The output sets are defined as:

\[
P^{seq}(x) = \left\{ y^{ts} : (x^{ts}, y^{ts}) \in Z^{seq} \right\}. \tag{5.4}
\]

This is the same notion as in the previous reference production set in Chapter 3 that was constructed at each point in time, but in Equation (5.3) the data from time \( t_1 \) until \( t \) are considered. In other words, the inputs and outputs used in the production process from previous years are considered as part of the technology in the current period. To differentiate conventional Malmquist indices from sequential ones, let’s denote \( SM \) as the sequential Malmquist indices:

\[
SM (x^{t+1}, y^{t+1}, x^t, y^t) = \left[ \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \left[ \frac{D_i^t(x^{t+1}, y^{t+1})}{D_o^t(x^{t+1}, y^{t+1})} \frac{D_i^t(x^t, y^t)}{D_o^t(x^t, y^t)} \right]^{1/2} \right]
\tag{5.5}
\]

Nin et al. (2003) illustrated how both conventional and sequential DEA-MPI can be differentiated through the use of a graphical example as in Figure 5.1. To differentiate these two approaches, Nin et al. (2003) used a production frontier that is not expanding along the same ray through the origin in panel 5.1a. The estimation of productivity growth can be done by using period \( t \) in which \( M^t = (OD/OB_t)/1 < 1 \). The index can also be done by period \( t+1 \) technology in which \( M^{t+1} = 1/(OC/OB_{t+1}) > 1 \).
From the graph and the formulation results, the general conclusion can be made that productivity in country B is decreasing if the reference technology is in period t due to technical regress. Productivity in country B is increasing if the reference technology is in period t+1 due to technical progress. In Figure 5.1b, the productivity changes from B_t to B_{t+1} are characterized by technical progress, which employs a sequential frontier since the movement from these two points is a shift from $P_{seq,t}(x)$ to $P_{seq,t+1}(x)$. In Figure 5.1a, the movement from B_t to D or the shift of $P_t(x)$ to $P_{t+1}(x)$ is characterized as technical regress.

To estimate DEA-MPI models, there is a lot of optional softwares with different choices. In this study, three kinds of softwares are used to compare the results, namely, DEAP 2.1 (Coelli, 1996), MaxDEA 6 (Cheng and Qian, 2011) and Suhariyanto’s sequential DEA-MPI calculation technique. The conventional DEA-MPI is estimated by DEAP2.1 and MaxDEA 6 which provide the same results, fixed base year DEA-MPI is estimated by MaxDEA 6 and sequential DEA-MPI is estimated by MaxDEA and Suhariyanto’s sequential calculation technique. For consistency purposes particularly

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59 The Suhariyanto’s technique was used in Suhariyanto and Thirtle (2001) which basically was based on DEAP 2.1 with some additional steps of estimations.
consistency with the estimation in the next two chapters the results presented in this chapter are estimated by MaxDEA 6\textsuperscript{60}.

### 5.4 The Results of Conventional and Fixed Base Year DEA-MPI

Yearly geometric means of Indonesian regional productivity growth are presented in Table 5.1. It shows that, in the early years of the period of study, the productivity growth rate decreased to -1.70 per cent and then increased steadily until 1996. There was significant improvement in the period 1987-1996 (2.70 per cent on average), while there was a harsh decrease in productivity growth between 1997 and 1999 (-3.61 per cent on average), particularly in 1998 (-9.57 per cent). Subsequently, in the period 2000 to 2009, the productivity growth improvement changed around 0.17-2.05 per cent, and then decreased to -0.13 per cent in 2010. On average, the TFP growth of Indonesian regions base on conventional approaches was 1.07 per cent annually \textsuperscript{61}.

The results of fixed base year DEA-MPI show that the TFP of Indonesian regions increased by 1.25 per cent annually. Despite this positive average growth, the table also shows that the TFP growth deteriorated in the early period of study (-1.64 per cent in 1986) and in the period 1997-1999 (-1.18 per cent on average) with the worst performance being in 1998 (-9.92 per cent). The best performance was in 1995 when TFP growth reached 5.68 per cent. After economic recovery (in 2000) TFP growth improved 1.58 per cent on average, with the lowest growth observed in 2010 (0.1 per cent).

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\textsuperscript{60} The estimation results in the next two chapters (Chapters 6 and 7) are also derived by using MaxDEA 6.

\textsuperscript{61} In this study the average productivity growth at the regional level is used as the representation of productivity growth at the national level. Therefore, for subsequent discussions in this study, the terms national productivity growth refers to the average growth of the estimation results at the regional level.
Table 5.1 Conventional and fixed base year DEA-MPI

<table>
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<tr>
<th>Year</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
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<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
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<td>1.0381</td>
<td>1.0239</td>
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</tr>
<tr>
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<td>1.0303</td>
<td>1.0198</td>
<td>1.0129</td>
<td>1.0330</td>
</tr>
<tr>
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<td>1.0177</td>
<td>1.0462</td>
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</tr>
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<td>1.0659</td>
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<td>1.0648</td>
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<td>2007</td>
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<td>1.0871</td>
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<td>1.0125</td>
</tr>
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<td>2008</td>
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<td>1.0017</td>
<td>1.0919</td>
<td>0.9219</td>
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</tr>
<tr>
<td>2009</td>
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<td>1.0610</td>
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</tr>
<tr>
<td>2010</td>
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<td>1.0125</td>
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</tbody>
</table>

Source: Author’s own calculation

These trends could be explained by the fluctuation of the Indonesian economy between 1985 and 2010. There were some years when the Indonesian economy faced a special stage. In Mubyarto (2000, pp.222), the period 1980-1987 was classified as ‘the economy of apprehension phase’. In the early 1980s the Indonesian economy was affected by a drop in oil prices and the onset of global recession. This influenced Indonesian earning from exports, which mainly relied on oil and gas. The effect of the

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62 The economy of apprehension phrase used in this paragraph follows Dey (2009) who utilized this phrase to describe some apprehension situations like climate change, terrorist attack and the AIDS epidemic, which affected the global economy. Similar to this, in the early 1980s some apprehension situations also affected the Indonesian economy. In Indonesian language, Mubyarto (2000, pp.222) names this phase as ‘ekonomi keprihatinan’
slowdown of the economy in this period was observed through the deterioration of productivity growth in 1986. Along the same lines, the AEC inevitably dampened the growth in the period 1997-1999. The improvement of productivity growth after 2000 was the effect of the economic recovery.

The world economic crisis in 2008 had a small impact on Indonesian productivity growth. It can be seen from a positive growth of productivity in 2008 although there was a slight decrease compared to previous year. This trend has been remarked as the success of Indonesia’s response to the second episode of crisis after 1997 (Basri and Hill, 2011). Indonesia was one of the countries that experienced a relatively high economic growth in the world economic crisis environment in 2008 (Tambunan, 2010). However, the effect of the crisis might be captured two years later since in 2010 Indonesia showed low productivity growth (0.1 per cent in fixed base year DEA-MPI) and a negative growth (-0.13 per cent in conventional DEA-MPI).

In terms of productivity growth components, the estimation results show that the dominant factor of Indonesian regional productivity growth is efficiency change. The yearly trend of efficiency change exhibited a promising result since for most of the year, Indonesian regional efficiency change was positive implying a strong catch-up process. The efficiency change was only negative in the year 1991, 1999 and 2002. However, the technical change was mostly negative during the study period and only exhibited positive signs in the years 1988, 1989, 1991, 1993, 1999 and 2002 with the highest rate of technical change recorded in 2002.

The averages of regional DEA-MPI are presented in Table 5.2. The table reveals that there are five regions (NAD, Riau, Bengkulu, Central Kalimantan and East Kalimantan), which experienced TFP deterioration based on the conventional approach. Other regions experienced improvement with the highest shown by DKI Jakarta and the lowest shown by South Sumatera. Compared with the national average, most of the
regions showed TFP growth above this average, only South Sumatera (0.52 per cent) and South East Sulawesi (one per cent) were below the national average.

Table 5.2 Conventional and fixed base year DEA-MPI by regions

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>Conventional EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
<th>Fixed base year EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAD</td>
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<td>0.9461</td>
<td>0.9977</td>
<td>0.9690</td>
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<td>1.0473</td>
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<td>1.0498</td>
<td>0.9724</td>
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<td>Riau</td>
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<tr>
<td>Maluku</td>
<td>1.0547</td>
<td>0.9704</td>
<td>1.0235</td>
<td>1.0547</td>
<td>0.9576</td>
<td>1.0099</td>
</tr>
<tr>
<td>Papua</td>
<td>1.0395</td>
<td>0.9748</td>
<td>1.0133</td>
<td>1.0395</td>
<td>0.9741</td>
<td>1.0125</td>
</tr>
<tr>
<td>GmeanTotal</td>
<td>1.0425</td>
<td>0.9696</td>
<td>1.0107</td>
<td>1.0425</td>
<td>0.9713</td>
<td>1.0125</td>
</tr>
</tbody>
</table>

Note: Java Bali is 1.017743 while Manupa is 1.017658
Source: Author’s own calculation

In the case of fixed base year, four regions (NAD, Riau, Central Kalimantan and East Kalimantan) experienced productivity growth deterioration. The highest TFP growth was displayed by East Nusa Tenggara (2.8 per cent) and the lowest by South Sumatera (0.38 per cent). Five regions (South Sumatera, Bengkulu, West Java, West Kalimantan and Maluku) showed TFPCH below the national average. Similar to yearly
results, the dominant factor of the TFPCH by provinces is efficiency change. Almost all regions experienced positive efficiency change except NAD. In contrast, all regions displayed a negative rate of technical change. These results are empirical proof of Boediono’s statement that the Indonesian economy has not been driven by innovation. This also supports the premise that Indonesia is categorized as a country in the stage of being efficiency driven.

To gain more insight into the regional pattern of Indonesian productivity growth, the west and east regions are compared. The results show that the west depicts better performance than the east (Figure 5.2). However, Indonesian TFP growth performance during the AEC was more likely represented by the east performance in which the deterioration occurred from 1996 to 2000. The deterioration was observed only in two years in the west (1986 and 1998) compared to eleven years in the east (1987, 1992-1994, 1996-2000, 2006 and 2010). These findings show the gap between developed and under-developed regions. This disparity was shown either by fixed base year or conventional approaches. Both approaches illustrate that regional disparity is clearly detected in Indonesian regional productivity growth performance.

Although there is no clear consensus among scholars about the determinants of regional disparity of productivity performance, its existence represents the difference in regional competitiveness. This conclusion must be marked as one of the priority concerns of policy makers since disparity of productivity transforms into disparity of competitiveness and hence prosperity of the regions (Gardiner, et al., 2004). This evidence implies that competitiveness is a current issue of regional development in Indonesia and that balanced productivity growth among regions is important for the alleviation of regional inequality.

63 The west includes Java-Bali and Sumatera and the east includes Kalimantan, Sulawesi, Nusa Tenggara, Maluku and Papua
64 It has been mentioned in the previous chapter that west regions were associated with developed regions compared to relatively underdeveloped east regions
Figure 5.2 West-east estimation results

(a) EFFCH

(b) TECCH

(c) TFPCH

Note: Con refers to conventional while Base refers to fixed base year
Source: Author's own calculation
In terms of efficiency change both west and east regions exhibited improvement. West regions exhibit better efficiency change than east regions (3.73 per cent compared to 1.17 per cent). Efficiency change of west regions is also more stable than the east since in the periods of study, west regions experienced decreasing performance only in three years (1987, 1998 and 2002) compared to seven years in the east (1994-1995, 1998-2000, 2004 and 2006). The difference of efficiency change between the two regions is 2.56 per cent.

Different periods of technical improvement are observed between west and east regions. In the west the progress is mostly similar to the aggregate trend but the east regions depicted improvement in the period 1994-1995, 1999-2001 and 2004-2006 (Figure 5.2b). By comparing the year on year technical change trends of west-east regions, we can observe that the technical change improvement in several periods cannot be seen in the subsequent periods. Indonesian regions suffered from discontinuity of technical progress.

However, there was an interesting feature in the fixed base year estimation results, particularly in the west regions. There was continuity of TECCH in the west regions in the early period of study. Figure 5.2b show that, in the period 1987-1991, TECCH of west regions was positive. There were five years in which west regions experienced technical progress and this is relatively long period compared to the general trends of TECCH in Indonesia (maximum two years continued progress).

5.5 Productivity Growth Based on Conventional DEA-MPI

The results of fixed base year and conventional approaches in previous section show that both conventional and fixed base year follow a similar trend and that there are no significant differences between the two. The general trends of Indonesian regional productivity growth estimated by the two techniques confirm the second conclusion of Althin (2001), which stated that the indices based on the two approaches are similar in
some cases. This implies that, in the case of Indonesian regions, both of them can be used interchangeably. Therefore, in this sub section, the conventional approach will be used to estimate productivity growth based on island groups, different time references and development stages.

5.5.1 Productivity Growth by Islands

Drake (1981) argued that the analysis of spatial patterns (e.g., west-east regions, group of islands) in Indonesia is important. She also compared the case of spatial patterns between China and Indonesia by looking at the heterogeneity of their socio cultural aspects and development stages (Drake, 1992). Consequently, spatial analysis of these countries is relevant in the growing concern towards their regional economic development. Based on this reason, it is worthwhile to break up the data into groups of islands since Indonesia is characterized by its archipelagic economy. There are five large islands in Indonesia (Sumatera, Kalimantan, Java, Sulawesi and Papua). The islands include at least four provinces; only Papua involves two provinces, which will be grouped with other small island provinces in this analysis for balancing reasons. Therefore, Nusa Tenggara and Maluku are grouped into Papua and are later called Manupa (Maluku, Nusa Tenggara and Papua).

The estimation results by island show that, on average, all the islands experienced productivity improvements except Kalimantan (Table 5.3). Three islands exhibited positive efficiency change, namely, Sumatera, Kalimantan and Manupa with the highest shown by Sumatera followed by Manupa and Kalimantan, respectively. Java-Bali and Sulawesi experienced EFFCH deterioration. Java-Bali, Sulawesi and Manupa were the three top islands in terms of TFPCH. These three groups of island also showed technical progress which was different to the national level in which the average showed negative TECCH. Sulawesi’s and Java-Bali’s TFPCH were dominated

65 For further comparison of the detail of these two indices, see sub section 5.7.
by technical change compared to Sumatera and Kalimantan, which were dominated by efficiency change. The high level of TFPCH in Java-Bali, Sulawesi and Manupa could be caused by this factor.\textsuperscript{66}

**Table 5.3** Conventional DEA-MPI in spatial context

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
<th>REGIONS</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAD</td>
<td>1.000</td>
<td>0.9506</td>
<td>0.9506</td>
<td>West Kalimantan</td>
<td>1.0021</td>
<td>0.9821</td>
<td>0.9842</td>
</tr>
<tr>
<td>North Sumatera</td>
<td>1.0467</td>
<td>0.9803</td>
<td>1.0260</td>
<td>Central Kalimantan</td>
<td>0.9983</td>
<td>0.9798</td>
<td>0.9782</td>
</tr>
<tr>
<td>West Sumatera</td>
<td>1.0460</td>
<td>0.9817</td>
<td>1.0269</td>
<td>South Kalimantan</td>
<td>1.0141</td>
<td>0.9862</td>
<td>1.0000</td>
</tr>
<tr>
<td>Riau</td>
<td>1.0000</td>
<td>0.9916</td>
<td>0.9916</td>
<td>East Kalimantan</td>
<td>1.0000</td>
<td>0.9850</td>
<td>0.9850</td>
</tr>
<tr>
<td>Jambi</td>
<td>1.0502</td>
<td>0.9761</td>
<td>1.0251</td>
<td>Kalimantan</td>
<td>1.0036</td>
<td>0.9833</td>
<td>0.9868</td>
</tr>
<tr>
<td>South Sumatera</td>
<td>1.0248</td>
<td>0.9834</td>
<td>1.0078</td>
<td>North Sulawesi</td>
<td>1.0013</td>
<td>1.0277</td>
<td>1.0291</td>
</tr>
<tr>
<td>Bengkulu</td>
<td>1.0542</td>
<td>0.9360</td>
<td>0.9867</td>
<td>Central Sulawesi</td>
<td>1.0026</td>
<td>1.0329</td>
<td>1.0356</td>
</tr>
<tr>
<td>Lampung</td>
<td>1.0600</td>
<td>0.9607</td>
<td>1.0184</td>
<td>South Sulawesi</td>
<td>1.0000</td>
<td>1.0035</td>
<td>1.0035</td>
</tr>
<tr>
<td>Sumatera</td>
<td>1.0350</td>
<td>0.9699</td>
<td>1.0038</td>
<td>South East Sulawesi</td>
<td>0.9932</td>
<td>1.0055</td>
<td>0.9986</td>
</tr>
<tr>
<td>DKI Jakarta</td>
<td>1.0000</td>
<td>1.0146</td>
<td>1.0146</td>
<td>Sulawesi</td>
<td>0.9993</td>
<td>1.0173</td>
<td>1.0166</td>
</tr>
<tr>
<td>West Java</td>
<td>1.0000</td>
<td>1.0080</td>
<td>1.0080</td>
<td>West Nusa Tenggara</td>
<td>1.0074</td>
<td>0.9891</td>
<td>0.9964</td>
</tr>
<tr>
<td>Central Java</td>
<td>0.9977</td>
<td>0.9999</td>
<td>0.9975</td>
<td>East Nusa Tenggara</td>
<td>1.0087</td>
<td>1.0010</td>
<td>1.0097</td>
</tr>
<tr>
<td>DI Yogyakarta</td>
<td>1.0025</td>
<td>1.0047</td>
<td>1.0072</td>
<td>Maluku</td>
<td>1.0000</td>
<td>1.0057</td>
<td>1.0057</td>
</tr>
<tr>
<td>East Java</td>
<td>0.9980</td>
<td>1.0047</td>
<td>1.0027</td>
<td>Papua</td>
<td>1.0000</td>
<td>1.0120</td>
<td>1.0120</td>
</tr>
<tr>
<td>Bali</td>
<td>1.0000</td>
<td>1.0022</td>
<td>1.0022</td>
<td>Manupa</td>
<td>1.0040</td>
<td>1.0019</td>
<td>1.0059</td>
</tr>
<tr>
<td>Java-Bali</td>
<td>0.9997</td>
<td>1.0057</td>
<td>1.0054</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

The strong performance of Sulawesi and Manupa in terms of productivity growth is in contrast to the common explanation in the literature, in which Java-Bali is the congested nuclear core and the other islands are underdeveloped, sparsely populated periphery (Drake, 1981). The existence of technical change improvement of Sulawesi Island as the main source of its productivity growth and the positive sign of technical change of Manupa indicate that other islands could possibly be the core since they have a similar trend of productivity growth performance with Java-Bali.

\textsuperscript{66} The modern growth theory explains that the roles of technical change are crucial in supporting the long run and sustainable growth rate of countries or regions.
The productivity estimates based on islands also showed that there were differences between the trend of the national level and the regional level. Firstly, this can be compared to the results of fixed base year and conventional approaches in the previous section that on average, Indonesian regions’ TECCH was negative (which represents performance of national level). However, in spatial context the average of 14 provinces (53.85 per cent) shows positive TECCH\textsuperscript{67}.

Secondly, the overall estimation in the two approaches shows that TFPCH was dominated by EFFCH. By contrast, in the spatial estimation, Java-Bali and Sulawesi exhibit TFPCH dominated by technical change. This implies that the national productivity performance was not reflected by the profile of Java-Bali as the most developed regions since the profiles of productivity growth of Java-Bali differ from national performance. This finding simply means that if Indonesia as a whole wants to strengthen its performance, then it has to make sure that outer islands (Kalimantan, Sulawesi, Maluku, Papua and Nusa Tenggara) are not ‘falling behind’. In other word, focusing on these islands should be the priority for future policy implementation.

Looking at the regions in the island groups, in Sumatera Island, the highest productivity growth was exhibited by North Sumatera followed by West Sumatera, Lampung and South Sumatera. The other three provinces in Sumatera experienced productivity deterioration. The average of both efficiency and productivity change in this island was above the national mean and the trend of technical change follows the national trends in which all regions experienced technical change deterioration.

As the most developed island, Java-Bali showed positive productivity growth of 0.54 per cent which was associated with technical progress. However, the efficiency change of the island showed deterioration on average; only DKI Jakarta, West Java, Yogyakarta and Bali experienced positive efficiency change. The interesting picture is

\textsuperscript{67} The 14 provinces are the provinces in Jawa-Bali, Sulawesi and Manupa. Although Central Java and West Nusa Tenggara exhibited negative TECCH, the average TECCH of provinces in these islands was positive.
that Jakarta, as a capital city of Indonesia, dominates the technical change improvement by 1.5 per cent. Other provinces in this island only show technical change to be less than one percent.

Kalimantan seems to be the island with the lowest rate of productivity growth. The island experienced productivity growth regress and almost all provinces experienced productivity growth deterioration, except for South Kalimantan. Only Central Kalimantan province experienced both efficiency and technical change deterioration. Sulawesi depicted the highest productivity growth among island groups (1.66 per cent), which is characterized by technical progress. North and Central Sulawesi have a higher productivity change compared to the other two provinces in the island. Only South East Sulawesi experienced efficiency change deterioration. Manupa exhibited positive productivity growth, which was above the aggregate growth and mainly due to efficiency change. Interestingly, both Maluku and Papua regions showed technical progress compared to Nusa Tenggara that showed technical regress.

Looking at overall results, the provinces can be classified into three groups. The first group is Java-Bali and Sulawesi Island, which have positive productivity growth mainly due to technical progress. The second group is Sumatera and Manupa with positive productivity growth mainly due to efficiency change and the last group is Kalimantan which depicted negative productivity growth.

Focusing on yearly trends, all regions share similar experience in which on average, there was decreasing productivity growth from 1996-1999. This declined was due to economic crisis. However, looking at the degree of economic crisis, Java-Bali depicted the worst productivity deterioration during 1997-1999 (-14.96 per cent), while other islands’ productivity growth declined between 5-11 per cent\(^\text{68}\).

\(^{68}\) See Appendix, Table A5.2
5.5.2 Productivity Growth over Time

Two kinds of time references are described in this section. The first are the Pelita periods and the second are the pre- and post-economic crisis periods\(^69\). Table 5.4 shows the Indonesian productivity growth decomposition based on Pelita. The table reveals that the highest TFPCH was achieved in the period 1989 to 1994 (2.29 per cent). This was in the boom era for the Indonesian economy. The second highest period of TFPCH was from 1999 to 2004 (1.75 per cent), reflecting the recovery period after the economic crisis. The worst TFPCH achievement was for the period 1994-1999, which is understandable since this period includes the economic crisis.

**Table 5.4** Conventional DEA-MPI by Pelita

<table>
<thead>
<tr>
<th>PERIODS</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>1985-1989</td>
<td>1.0284</td>
<td>0.9869</td>
<td>1.0149</td>
</tr>
<tr>
<td>1989-1994</td>
<td>1.0249</td>
<td>0.9981</td>
<td>1.0229</td>
</tr>
<tr>
<td>1994-1999</td>
<td>1.0299</td>
<td>0.9645</td>
<td>0.9933</td>
</tr>
<tr>
<td>1999-2004</td>
<td>1.0358</td>
<td>0.9824</td>
<td>1.0175</td>
</tr>
<tr>
<td>2004-2010</td>
<td>1.0837</td>
<td>0.9292</td>
<td>1.0069</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

However, the questionable finding is for the period from 2004 to 2010, which exhibits significantly lower technical progress and productivity growth than the previous period. This was several years after the AEC. The period 2004-2010 has been referred to as being the era most characterized by a constitutional government as a result

\(^{69}\) Pelita is five years Indonesian Development Planning that was used in Old Order (Soeharto era). After 1999 (reform era), this terms has not been used. In this study this is used to simplify the time references and to relate the five year development stages in the reformation era characterized by a new presidential system. The Indonesian development stage classifications in this study are started from the fourth Pelita which is originally in the period 1984-1989. In this study this period is represented by the first period (1985-1989) due to data availability. The last period covers more than five years since the last period of study does not match the classification on the basis of Pelita.
of running a direct presidential election. The beginning of the period (2004) was four years after the implementation of the decentralization policy, so by 2010 it was a decade later. The question relating to the low TFPCH for this period is whether the decentralization policy dampened productivity growth of Indonesian regions, or whether other mechanisms and channels contribute significantly to this.

Regionally, the trends of TFPCH based on Pelita can be seen in Figure 5.3. This figure shows that the general pattern of TFPCH among the regions follows the aggregate pattern. It increased in the first period, reached its peak in the second period and then decreased sharply from 1994-1999 before recovering in 1999-2004 and then generally decreased in 2004-2010.

**Figure 5.3 The evolution of TFPCH**

![Figure 5.3 The evolution of TFPCH](image)

Source: Author’s own calculation

All regions exhibited a relatively high TFPCH growth in the second period except Sumatera. Two regions experienced positive growth for the period 1994-1999, with a growth rate above the total rate (Sulawesi and Manupa). Despite positive growth in the crisis period, Manupa also revealed the highest growth for the last period (2004-2010) compared to its achievement in the previous period (1986-2004) and the other regions in the period 2004-2010, and total average in the period 2004-2010. These regions also, in general, displayed higher rates than the national average (the red dash
line above the orange line). In contrast, Sumatera (blue line) was always below the orange line. Sulawesi (green) and Java-Bali (purple) were always above the orange line except for the periods 1999-2004 and 1994-1999 respectively.

The next comparison focuses on the pre- and post- crisis periods. The common trend of aggregate movement is that the TFPCH was relatively high in the period before the economic crisis and decreased (but still remained positive) after the economic crisis. This common trend is not revealed in Table 5.5. Some regions (Jambi, South Sumatera, West Java, East Nusa Tenggara, Maluku and Bengkulu) performed better after the crisis (TFPCH was increasing and positive). Four regions (Riau, Central Kalimantan, North Sulawesi and Papua) exhibited a decline in performance (TFPCH was positive before the crisis and negative after the crisis). The performance for both NAD and Kalimantan was stagnant, with negative TFPCH both before and after the crisis.

Table 5.5 The trends of TFPCH before and after the crisis

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Riau</td>
<td>+</td>
<td>-</td>
<td>North Sulawesi</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Jambi</td>
<td>+</td>
<td>&gt;+</td>
<td>Maluku</td>
<td>+</td>
<td>&gt;+</td>
</tr>
<tr>
<td>South Sumatera</td>
<td>+</td>
<td>&gt;+</td>
<td>Papua</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>West Java</td>
<td>+</td>
<td>&gt;+</td>
<td>NAD</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>East Nusa Tenggara</td>
<td>+</td>
<td>&gt;+</td>
<td>Bengkulu</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Central Kalimantan</td>
<td>+</td>
<td>-</td>
<td>East Kalimantan</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: (+) means positive productivity growth, (-) means negative productivity growth, (>+) means productivity growth was increasing and positive
Source: Author’s own calculation

Uncommon trends imply that the regions do not fulfil both high productivity growth in the period before the economic crisis and decreased (but still remained positive) after the economic crisis.
5.5.3 Productivity Growth Based on Economic Development Stages


Based on the data available in the period of study, the productivity growth of these periods can be seen in Table 5.6. The table shows that the Indonesian economy experienced negative productivity growth in two stages (1985-1987 and 1994-2001). In both periods, TECCH and TFPCH deteriorated. The reason is clear that the classification of people economy includes a period of crisis in 1997-1999. One can therefore conclude the crisis period will mostly be characterized by technical change and productivity growth deterioration.

In the other two stages (conglomeration and transitional economy), productivity growth was positive and dominated by efficiency change. The most interesting result was the positive sign of TECCH in the conglomeration economy phase. Although in this period efficiency change was still the main driver of productivity growth, technical change improvement must be noticed as a special achievement in this stage. This result

\textsuperscript{71} In this sub section the classification from Emil Salim, Mubyarto and Noer Soetrisno will be used. Mostly this classification is based on Mubyarto (2000, pp. 222). Prof. Dr. Emil Salim was the Minister of Environment in the Soeharto era and he is also a professor at the University of Indonesia. Prof. Dr. Mubyarto has been famously known as the one who introduced the people based economy and he was professor at University of Gajah Mada. Dr. Noer Soetrisno was the Director General of Research and Development Ministry of Cooperatives, Small and Medium Enterprises in the period 1998-1999 and was Secretary to the Ministry of Public Housing in the period 2005-2008

\textsuperscript{72} Until 1978 the classification was named by Emil Salim, until 2001 the stage was named by Mubyarto and the last period (2001-2009) was named by Noer Soetrisno. These classification and their complete explanations can be seen in Soeistrino (2004) and Mubyarto (2000, pp. 222).
raises a question of whether the conglomeration economy was good for technological development in Indonesian regions.

Lasserre (1993) concluded that the conglomeration period in Indonesia was characterized by a new stage of industrial development. This stage was supported by a concentration of financial and human resources in several Indonesian conglomerates. Lassere (1993) also found that this diversified conglomerates supported the export-oriented manufactures in Indonesia by focusing their activities on a number of key industries and by adopting international strategy. This could be the reason why the Indonesian technical change, which is mainly supported by technology adoption, was positive in this phase.

**Table 5.6 Productivity growth by Indonesian development stages**

<table>
<thead>
<tr>
<th>Period</th>
<th>Classification</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-1987</td>
<td>Economy of apprehension</td>
<td>1.0349</td>
<td>0.9624</td>
<td>0.9960</td>
</tr>
<tr>
<td>1987-1994</td>
<td>Conglomeration economy</td>
<td>1.0240</td>
<td>1.0021</td>
<td>1.0261</td>
</tr>
<tr>
<td>1994-2001</td>
<td>People economy</td>
<td>1.0412</td>
<td>0.9575</td>
<td>0.9969</td>
</tr>
<tr>
<td>2001-2009</td>
<td>Transitional economy</td>
<td>1.0566</td>
<td>0.9578</td>
<td>1.0120</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

In the previous subsection, it was found that in the period 2004-2010, which covers some years of the phase of transition, productivity growth was lower than that in the periods before the economic crisis. Similarly, the table also reveals that this period showed a lower productivity growth than the conglomeration economy. As its name suggests, the transitional economy phase was characterized by the changes of Indonesian economic foundations through the changes of UUD 1945, the implementation of decentralization policy and the different economic strategies of
various governments\textsuperscript{73}. The argument of Okamoto and Sjoholm’s (2001) in the previous sub-section could also be the reason behind the lower productivity growth of this phase than that of conglomeration economy phase.

5.6 The Results of Sequential DEA-MPI

From the conventional and fixed base year DEA-MPI estimation results, it is clear that one of the problems facing Indonesian regional economies is negative technical change. This means that Indonesian regional economies were not supported by innovation as a source of productivity growth and hence economic growth. Although Java-Bali and Sulawesi were characterized by positive TECCH and dominated by this factor, they cannot support the national performance since national productivity growth was dominated by efficiency change. Despite the economic reasons, negative technical change may also be a consequence of the methods used in the estimation process which allows for technical regress. As discussed in the data and method section, some scholars prefer to employ sequential DEA-MPI for productivity growth estimation which does not allow for technical change deterioration\textsuperscript{74}.

Table 5.7 reveals the results of sequential DEA-MPI estimation. There were four regions (NAD, Riau, Central Kalimantan and East Kalimantan) experienced productivity deterioration. The highest TFPCH was shown by East Nusa Tenggara, followed by DKI Jakarta, Central Sulawesi, North Sulawesi, South Kalimantan and Bali. Among the regions experiencing positive productivity growth, 11 regions reveal productivity growth above 2 per cent, five regions between 1.5 per cent and 2 per cent and six regions below 1.5 per cent.

\textsuperscript{73} UUD 1945 stands for Undang-Undang Dasar 1945 (Indonesia’s 1945 constitution). The Article 33 UUD 1945 about whether it is relevant for the current and future Indonesian economy was debatable in this transition period. The different economic vision, namely, dual track strategy (in the Megawati Sukarnoputri presidential era, 2001-2004) and triple track strategy (in SBY presidential, 2004-2009) was also part of this period. The new era of independency of BI (Indonesian central Bank) was also part of debatable issue in this period.

\textsuperscript{74} see section 5.2 and section 5.3
Based on islands, on average, Sulawesi was the island with the highest productivity growth (2.06 per cent) followed by Java-Bali (1.89 per cent), Manupa (1.79 per cent), Sumatera (0.68 per cent) and Kalimantan (0.64 per cent). Most of the regions experienced TFPCH above national average (61.54 per cent) while only Kalimantan and Sumatera Islands recorded TFPCH below national growth. Table 5.7 also reveals that productivity growth of Indonesian regions was dominated by efficiency change when the estimation is based on sequential frontier. The dominance of efficiency change can also be seen among the island average. Sulawesi experienced the highest TECCH growth (0.36 per cent) followed by Java-Bali (0.28 per cent) and Manupa (0.26 per cent). Sumatera had the lowest TECCH among other regions.

**Table 5.7 Sequential DEA-MPI by regions**

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
<th>REGIONS</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAD</td>
<td>0.9650</td>
<td>1.0026</td>
<td>0.9676</td>
<td>West Kalimantan</td>
<td>1.0093</td>
<td>1.0028</td>
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<td>1.0187</td>
<td>1.0035</td>
<td>1.0222</td>
</tr>
<tr>
<td>Riau</td>
<td>0.9925</td>
<td>1.0009</td>
<td>0.9934</td>
<td>East Kalimantan</td>
<td>0.9929</td>
<td>1.0014</td>
<td>0.9943</td>
</tr>
<tr>
<td>Jambi</td>
<td>1.0185</td>
<td>1.0026</td>
<td>1.0211</td>
<td>Kalimantan (rank 5)</td>
<td>1.0039</td>
<td>1.0025</td>
<td>1.0064</td>
</tr>
<tr>
<td>South Sumatera</td>
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<td>1.0014</td>
<td>1.0044</td>
<td>North Sulawesi</td>
<td>1.0194</td>
<td>1.0033</td>
<td>1.0228</td>
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<tr>
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<td>South Sulawesi</td>
<td>1.0148</td>
<td>1.0038</td>
<td>1.0186</td>
</tr>
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<td>Sumatera (rank 4)</td>
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<td>South East Sulawesi</td>
<td>1.0124</td>
<td>1.0039</td>
<td>1.0163</td>
</tr>
<tr>
<td>DKI Jakarta</td>
<td>1.0234</td>
<td>1.0016</td>
<td>1.0251</td>
<td>Sulawesi (rank 1)</td>
<td>1.0170</td>
<td>1.0036</td>
<td>1.0206</td>
</tr>
<tr>
<td>West Java</td>
<td>1.0089</td>
<td>1.0022</td>
<td>1.0111</td>
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<td>1.0210</td>
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<td>1.0270</td>
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<td>DI Yogyakarta</td>
<td>1.0158</td>
<td>1.0029</td>
<td>1.0188</td>
<td>Maluku</td>
<td>1.0065</td>
<td>1.0035</td>
<td>1.0100</td>
</tr>
<tr>
<td>East Java</td>
<td>1.0126</td>
<td>1.0029</td>
<td>1.0155</td>
<td>Papua</td>
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<td>1.0009</td>
<td>1.0127</td>
</tr>
<tr>
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<td>1.0036</td>
<td>1.0222</td>
<td>Manupa (rank 3)</td>
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<td>1.0026</td>
<td>1.0179</td>
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<td>Java-Bali (rank 2)</td>
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<td>1.0028</td>
<td>1.0189</td>
<td>Total</td>
<td>1.0107</td>
<td>1.0026</td>
<td>1.0133</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation
Comparing the total average with the regional average, there are three groups (Sulawesi, Java and Manupa) that exhibited TECCH above total average\textsuperscript{75}. This finding supports the previous finding that the east development zone including Sulawesi, Kalimantan and Manupa plays an important role in determining the economic growth performance of Indonesia. It was also supported by the fact that their TECCH, on average, was higher than in the west regions (Sumatera and Java-Bali).

The yearly average also shows the existence of technical change discontinuity (Figure 5.4). Most parts of the line chart in this figure are flat denoting that TECCH is equal to one. This means that in most years there was neither deterioration nor an improvement of technical change. A high level of improvement in technical change occurred in 1989 (3.02 per cent and in 1991 (2.64 per cent). This achievement was not continued in the subsequent years. Although there was positive TECCH in 1993, 2004 and 2007, the improvement was under 0.5 per cent. In other word, no significant technological improvement took place in the period of study.

\textbf{Figure 5.4} Annual TECCH by sequential frontier

\begin{center}
\includegraphics[width=\textwidth]{figure54}
\end{center}

Source: Author’s own calculation

\textsuperscript{75} Manupa in five digit TECCH was 1.00264 while total was 1.00257
Several interesting trends can be seen in the sequential frontier estimation when the data are segmented into the east and west development zone (Table 5.8). Firstly, a regional average shows that all west regions experienced TECCH above one compared to only one region (East Kalimantan) in the east. Secondly, the east was characterized by TFPCH being dominated by technical change. Thirdly, on average productivity growth of the east deteriorated. Fourthly, the flat trend (neither deterioration nor improvement) of technical change mostly occurred in the east. The last is that the ranking of the best performance changes in all of the regions. Bali displayed the best performance in the west with productivity growth at 2.89 per cent followed by Central Java (2.78 per cent) and Lampung (2.73 per cent). In the east, three best performers were displayed by Papua (1.19 per cent), East Nusa Tenggara (0.94 per cent) and Central Sulawesi (0.43 per cent).

Table 5.8 Sequential frontier of west-east groups

<table>
<thead>
<tr>
<th>Regions</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
<th>Regions</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
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<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
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<tr>
<td>NAD</td>
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<tr>
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<td>1.0000</td>
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</tr>
<tr>
<td>Riau</td>
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<td>Central Kalimantan</td>
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<td>1.0013</td>
<td>1.0000</td>
<td>1.0013</td>
</tr>
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<td>1.0039</td>
<td>1.0273</td>
<td>Central Sulawesi</td>
<td>1.0043</td>
<td>1.0000</td>
<td>1.0043</td>
</tr>
<tr>
<td>DKI Jakarta</td>
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<td>1.0189</td>
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<td>0.9884</td>
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<td>West Java</td>
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<td>1.0000</td>
<td>0.9800</td>
</tr>
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<td>Central Java</td>
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<td>1.0278</td>
<td>Maluku</td>
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<td>1.0000</td>
<td>1.0013</td>
</tr>
<tr>
<td>DI Yogyakarta</td>
<td>1.0202</td>
<td>1.0061</td>
<td>1.0265</td>
<td>Papua</td>
<td>1.0119</td>
<td>1.0000</td>
<td>1.0119</td>
</tr>
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<td>East Java</td>
<td>1.0181</td>
<td>1.0060</td>
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<td>East</td>
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<td>1.0169</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s own calculation
These findings confirm that the west still leads in technological development since the growth of technical change was relatively higher and continuous in the period of study (Figure 5.5). Almost all regions in the east on average experienced neither improvement nor deterioration (except East Kalimantan) of technical change implying that technological development was unchanged. Although productivity growth in the east was characterized by technical progress, TFPCH was deteriorated. This implies that technical change was associated with the low level of technology. The conclusion based on this trend is that the technical change discontinuity observed at the national level was influenced by the discontinuity in the east regions.

**Figure 5.5** Annual TECCH of west-east regions

![TECHH graph](image)

Source: Author’s own calculation

### 5.7 Comparing the Approaches

Comparing conventional and fixed base year DEA-MPI shows slightly different features. The annual average TFP improvement of conventional approach (1.07 per cent) was lower than fixed base year (1.25 per cent). However, both approaches share similar patterns of TFPCH, which deteriorated in the first year of the study period.

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76 The methodology comparison will use the results of productivity growth at the national level (the average of productivity growth at the regional level)
increased in 1987-1996, decreased in 1997-1999 and increased again in 2000-2009. As mentioned previously, the only difference in the trend was in 2010, with fixed base year showing progress while the conventional exhibited negative growth. These different signs were caused by different estimation methods. Conventional DEA-MPI compares the year 2009 and 2010 while fixed base year compares the year 1985 to 2010.

Comparing the islands’ geometric means, the two methods showed similar trends. The best performer in the fixed base year approach was Sulawesi followed by Java-Bali and Manupa. In the conventional approach, Java-Bali exhibited the highest progress followed by Manupa and Sulawesi. The geometric mean of the islands’ TFP can be seen in Table 5.9.

### Table 5.9 TFPCH ranked by island

<table>
<thead>
<tr>
<th>Island</th>
<th>Fixed base year</th>
<th>Conventional approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TFP Growth</td>
<td>Rank</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Sumatera</td>
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</tr>
<tr>
<td>Java-Bali</td>
<td>1.774</td>
<td>2</td>
</tr>
<tr>
<td>Kalimantan</td>
<td>0.500</td>
<td>5</td>
</tr>
<tr>
<td>Sulawesi</td>
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<td>1</td>
</tr>
<tr>
<td>Manupa</td>
<td>1.765</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

Figure 5.6 shows how average productivity growth differs between the two methods. The figure shows that the lines stay with a similar trend. Bengkulu is an exception which exhibited negative TFP growth using conventional DEA-MPI but positive TFP growth using sequential DEA-MPI. The figure also shows that the conventional method showed a high TFPCH in most regions. The sequential method
displayed a high TFPCH in Lampung, West and East Nusa Tenggara, North Sulawesi and South and South East Sulawesi. However, the national growth shows that sequential approach produces a higher growth (1.33 per cent) than the conventional method (1.07 per cent). The similar trends can also be observed in TECCH while the EFFCH of the conventional approach exhibited higher growth (4.25 per cent) than the sequential approach (1.07 per cent).

**Figure 5.6** TFPCH estimated by conventional and sequential DEA-MPI

Grouping the regions into Sumatera, Java-Kalimantan and BNSMP (Bali, Nusa Tenggara, Sulawesi, Maluku and Papua) can provide deeper insight into the differences among the methods\(^7\). Figure 5.7 shows that the gap between TFPCH among the methods is higher in Sumatera and similar in Java-Kalimantan and BNSMP. The more

\(^7\) These groups is based on the basic principle of national connectivity in which use Indonesian sea lane of communication (SLoC), namely, Indonesian Archipelagic sea lines (Alur Laut Kepulauan Indonesia/ALKI) except for Bali. This group has also been used as a basis of cluster in MP3EI.
variations can be seen in TECCH and EFFCH. TECCH using sequential was higher than that using conventional. Figure 5.7 further show that the line chart of efficiency change of sequential index is far below the line chart of conventional DEA-MPI.

**Figure 5.7** Group DEA-MPI with two different methods

Source: Author’s own calculation

### 5.8 Conclusion

The study of productivity growth at the regional level in Indonesia provides valuable insight into the country’s regional development. It fills the gap in the literature on regional productivity growth in the country by employing a DEA-MPI technique and decomposing productivity growth into its components. This topic becomes important in
the processes of the implementation of decentralization policy in which regional
governments have more authority to manage their own regions and hence need more
data, information and analysis at a regional level.

The estimation results in this study indicate that Indonesian productivity growth, represented by the average of its regional productivity growth, was positive in the period 1986-2010. This result was very strong since the three methods employed in this study all displayed a positive result. The dominant factor of this growth was efficiency change indicating that the catch-up process occurred in the Indonesian regions. This catch-up process was found to be very reliable since the efficiency change was positive over the years of study except in the years 1991, 1999 and 2002. This study also found that there was technical progress discontinuity in Indonesia. Technical change deteriorated over the study period and only exhibited a positive sign in some years. Although the results of sequential DEA-MPI show a positive technical change as a consequence of its technical assumption, discontinuity was observed. Technical change using sequential DEA-MPI was mostly equal to one in the period of study, indicating neither an improvement nor deterioration.

The estimation results show that the trends of productivity growth were similar in some regions and different in others. This difference can also be observed when the data were segmented into east and west development zones. The east development zone exhibited negative productivity growth. This indicates that there are disparities in productivity growth performance between Indonesian regions.

A specific pattern of regional productivity growth was found by analysing productivity growth by islands. The study found that Indonesian provinces can be categorized into three different groups of island: positive productivity growth dominated by technical change (Java-Bali and Sulawesi), positive productivity growth due to efficiency change (Sumatera and Manupa) and negative productivity growth
(Kalimantan). The estimation of productivity growth by island also showed that the best performance in productivity growth was not shown by the developed regions such as Java-Bali but by Sulawesi. This spatial productivity growth estimation also reveals that there were different structures of productivity growth in Indonesian regions, which meant that the trends of productivity growth at the national level cannot be used to describe the trends of productivity growth at the regional level.

The estimation of productivity growth based on different time periods shows a similar pattern at the national and the regional level. The trends were increasing and positive during the period 1987-1996, decreasing in the period covering the crisis period (1997-1999) and increasing and positive with lower growth after the recovery periods (starting in the year 2000). When the TFP growth was estimated based on Pelita, Manupa exhibited TFP growth above national growth in all the Pelita periods. In contrast, Sumatera was always below the national growth. There were two groups of regions that displayed positive productivity growth in the period covering economic crisis (1994-1999), namely Sulawesi and Manupa. Despite this regional specific pattern, there were interesting findings in this exercise, namely, the productivity growth in the last period (2004-2010) was significantly lower than the previous period (0.65 per cent vs 1.75 per cent). This is interesting since the last period was several years after the implementation of decentralization policy and was remarked as having a constitutional government as due to direct general election.

Overall, the estimation of TFP growth over time reveals that productivity growth estimates can help identify the stages of Indonesian economic development including the boom and bust periods. This conclusion has also been supported by the results of productivity growth based on Indonesian development stages. Productivity growth was negative in the economy of apprehension stage and people economic stage. The reason is clear since in both periods the economic environment of Indonesia was unstable and
characterized by economic recession. However, the estimation results based on this classification also reveal that in the conglomeration economy Indonesia experienced positive technical change.
Appendix to Chapter 5

Table A5.1 Conventional and fixed base year DEA-MPI of west-east groups

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>Conventional</th>
<th>Fixed base year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EFFCH</td>
<td>TECCH</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
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<tr>
<td>NAD</td>
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</tr>
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</table>

Source: Author’s own calculation
Table A5.2 Yearly productivity change by island (Conventional DEA-MPI)

<table>
<thead>
<tr>
<th>Regions</th>
<th>Sumatera</th>
<th>Java-Bali</th>
<th>Kalimantan</th>
<th>Sulawesi</th>
<th>Manupa</th>
<th>Total</th>
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Source: Author’s own calculation
### Table A5.3 Yearly technical change by island (Conventional DEA-MPI)

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Source: Author’s own calculation
6.1 Introduction

Regional productivity growth estimates in the previous chapter employed three different approaches of DEA-MPI. These methods assume that the Indonesian regions share the same production technology and therefore the approaches don’t take into account the heterogeneity of Indonesian regions. In reality, different units of analysis like firms, regions or countries have different production technologies and it is plausible to classify them into different groups in order to estimate their productivity growth. The difference in production technology can be caused by regional specific factors such as geographical and demographic structures, culture, financial systems, comparative advantages, and policy implementations. The validity of the productivity growth estimation can be improved by incorporating these regional specific factors associated with different production technologies.

Hill (1995) argued that although firms exist in the same industry, they are not guaranteed to have the same production function. Different firms and hence regions are bounded by different choices of production technology. O’Donnell et al. (2008) concluded that because of different choices of production technology the regions combine their inputs and outputs in different ways. Hayami and Ruttan (1970) explained this difference in production functions using the concept of metaproduction. Battese, et al. (2004) adopted this concept in the productivity growth estimation and estimated a metafrontier in the form of the stochastic metafrontier-MPI. Oh and Lee (2010) combined the metafrontier approach with the MPI by adding a group factor to the global MPI proposed by Pastor and Lovell (2005). The Oh and Lee (2010)
metafrontier MPI used DEA to estimate the productivity index. Therefore the metafrontier DEA-MPI in their study involves the estimation of group frontiers enveloped by a global frontier.

This chapter attempts to estimate Indonesian metafrontier DEA-MPI over the period of 26 years from 1985-2010. Metafrontier is broken down into efficiency change within groups, best practice change within groups and technological gap change. It attempts to explore several questions. Specifically, what is the pattern of the Indonesian productivity growth estimated by different grouping? Are these results are consistent with the results of the conventional approach? Are the dominant factors of productivity growth similar among regions? What is the pattern of technology gaps among Indonesian regions?

To gain more insight into the results of regional productivity growth estimated by the proposed method, the comparison of metafrontier DEA-MPI estimates and their components between Indonesian regions and China’s regions will be conducted. This comparison aims to investigate the different variations of regional productivity growth in the two countries, to explore whether Indonesia’s and China’s regional productivity growth follow the same pattern and to differentiate the dominant factors behind productivity growth in each country.

The rest of the chapter is organized as follows. Section 6.2 presents a literature review. Section 6.3 describes the methods and data used in this study. The next section discusses the empirical results of regional productivity growth estimates. Section 6.5 compares regional productivity growth in Indonesia and China. The last section concludes the chapter.
6.2 Literature Review

Pastor and Lovell (2005) proposed a global MPI which uses global frontier from all periods of observable data as a benchmark. They also explained that this index satisfies circularity and linear programming infeasibility\textsuperscript{78}. They explained that this index allows technical regress and can perform a single measure of productivity growth. Therefore they concluded that the global MPI may solve the problem of linear programming infeasibility found in fixed base year DEA-MPI proposed by Berg et al. (1992) and the circularity problem in the sequential index proposed by Shestalova (2003).

Krisnasamy and Ahmed (2009) used metafrontier DEA-MPI to estimate the productivity growth of 26 OECD countries for the period 1980-2008. They grouped the countries based on geographical proximity. Three groups were formed, namely, the Americas, Asia-Pacific, and Europe. They found that Asian countries showed higher technical progress with respect to OECD technology, while European regions exhibited a lower rate of technical progress with respect to OECD technology. For American regions, they found that the catch up to the OECD technology was very slow in the early period of study (1985-1988).

Oh and Lee (2010) proposed a metafrontier DEA-MPI to estimate productivity growth which was constructed by introducing the intertemporal production set (Tulkens and Eeckaut, 1995a) into the global Malmquist production set explained by Pastor and Lovell (2005). By using the proposed method, productivity growth can be decomposed into efficiency change, best practice change and technological gap change\textsuperscript{79}. The method was applied to the 58 countries in the period 1970-2000. They found that Asian countries showed the highest productivity growth followed by America and Europe. African countries experienced the lowest productivity growth in the period of study.

\textsuperscript{78} The circularity and infeasibility are two requirements underlying the index method and are not discussed further in this chapter. For more details, see Frisch (1936) and Xue and Harker (2002)

\textsuperscript{79} This decomposition will be discussed in the method and data section
The highest technological gap change was shown by European countries meaning that they were taking the leadership in technological development. They also observed that the catch up process displayed in Asian countries could help these countries converge with world technology leaders.

Chen et al. (2009) employed the generalized metafrontier DEA-MPI to compare costal and non-coastal regions of China over the period 1996-2004. They found that technical change was the dominant factor of China’s regions while technical efficiency had an adverse effect. They concluded that the existence of regional inequality in terms of productivity growth performance among China’s regions did exist. On average, this study shows that China’s coastal regions experienced higher productivity growth than non-coastal regions in the period of study. In addition they concluded that the productivity growth of western regions could be improved through China’s Western Development policy since scale efficiency change in this region was positive.

Oh (2010) utilized the metafrontier DEA-MPI-Luenberger index to estimate and decompose productivity growth of 46 countries between 1993 and 2003. The countries were grouped into the Americas, Asia and Europe. Unlike the metafrontier DEA-MPI, the metafrontier DEA-MPI-Luenberger index includes CO₂ emissions as an undesirable output. This makes it possible to measure environmentally sensitive productivity growth despite the common productivity growth components (efficiency change, technical change and technological gap change). He found that there were divergence trends among the Americas, Asia and Europe in terms of environmentally sensitive productivity. Europe was found to be a technology leader while Asian countries were better at efficiency change.

Sang-Mok et al. (2013) estimated productivity growth and its components in 31 of China’s provinces in the period 1995-2008. They divided China’s regions into three groups, namely the eastern, western and central regions. They found that there were
differences between group and global index estimates. They also concluded that ignoring these differences could give spurious results for productivity growth estimation. They found that China’s eastern regions were the regions that were close to the global frontier and other regions were far from the global frontier. They also found that the dominant factor of productivity growth in the western and central regions was efficiency change while the dominant factor of productivity growth in the eastern regions was technical change.

At a sectoral level, there have been several studies employing metafrontier DEA-MPI to estimate productivity growth. Kabir and Khan (2010) applied the metafrontier concept to estimate technical efficiency and the technological gap of biogas plants in difference regions in Bangladesh. The data used were based on a field survey in 2009. They found that there were no visible differences of technological gap change among the regions included in the study.

Matawie and Assaf (2008) compared metafrontier based on DEA and stochastic frontier analysis (SFA) in the healthcare food service industry in Australia. They used two group data sets which were 42 hospitals from the states of New South Wales (NSW) and Victoria (group 1) and 48 hospitals from the Western Australia, South Australia and other states (group 2). They found that there were no significant differences between the two approaches in terms of the ranking of efficiency. The technological gap ratio between the two methods was also similar.

Sang-Mok and Moon-Hwee (2012) analysed technical efficiency, technological gaps and productivity growth of the manufacturing industries in Korea and China for the period 2000–2004. They used metafrontier DEA-MPI approaches by differentiating the productivity growth into ‘with pollution variables and ‘without pollution variables’. They found that in terms of efficiency, China’s manufacturing industry showed a higher rate compared to Korea however in terms of productivity the Korean manufacturing
industry experienced higher productivity growth than China. Therefore, they concluded based on their estimation results that the Korea manufacturing industry was more sustainable than China.

Liao and Lien (2012) estimated efficiency and technology gap change of Asia-Pacific Economic Cooperation (APEC) integrated telecommunications operators during the time period from 2001 to 2008. They used metafrontier DEA-MPI and found that there was no guarantee that the operators with a high level of revenue will have a high level of efficiency and a low gap to metafrontier technology. However a group of operators with a high penetration rate show a higher efficiency change and a small gap to the metafrontier technology compared to the ones that had a low penetration rate.

In the Indonesian case, to the best of the author’s knowledge there has been no study that employs a simple metafrontier DEA or metafrontier DEA-MPI in estimating productivity growth either at an aggregate level or a sectoral level. A study by Battese et al. (2004) employed metafrontier SFA to examine garment firms in five different regions of Indonesia over the period 1990 to 1995. Other studies employing DEA-MPI were mentioned in previous chapters but none of them used the metafrontier DEA-MPI approach.

6.3 Methods and Data

6.3.1 Methods

The metafrontier DEA-MPI framework used in this study is the one that was proposed by Oh and Lee (2010). It is the combination of the metafrontier framework of O’Donnell et al. (2008) and the global frontier framework of Pastor and Lovell (2005). The former explored the relation between group frontier and metafrontier and the latter discussed a single contemporaneous and global frontier. The graphical illustration of the two frameworks can be seen in Figure 6.1. Oh and Lee (2010) extended Pastor’s and
Lovell’s (2005) framework by adding the term group frontier into panel 6.1b. However they used the term intertemporal frontier rather than group frontier which was proposed by Tulkens and Eeckaut (1995a). Therefore there are three steps in the mathematical formulation of the metafrontier DEA-MPI in this study. The first is the contemporaneous DEA-MPI, followed by the intertemporal DEA-MPI and the last is the global frontier DEA-MPI.

Figure 6.1 Comparing metafrontier concepts

\[ M^C(x^{i_{t+1}}, y^{i_{t+1}}, x^t, y^t) = \frac{D^i_o(x^{i_{t+1}}, y^{i_{t+1}})}{D^i_o(x^t, y^t)} \]  

(6.1)

The symbols in Equation 6.1 are similar to the Equation 3.20. \( M^C \) is the contemporaneous Malmquist index, \( D^i_o(x^{i_{t+1}}, y^{i_{t+1}}) \) is the output distance function at time

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80 The graphical illustration of Oh and Lee (2010) can be seen in Figure 6.2
t+1 with technology at time t, and $D_o^t(x^t, y^t)$ is the output distance function at time t with time t technology.

The second step is the formulation of the intertemporal index by constructing a single production set from the whole time period of the production plan of the group. The contemporaneous frontiers of the group of DMUs are enveloped by an intertemporal frontier of that group of DMUs. Suppose the contemporaneous reference technology set of group $C_j$ is $P_{C_j}$ then the intertemporal set will be

$$P_t^I = P_{C_j}^1 \cup P_{C_j}^2 \cup \ldots \cup P_{C_j}^T$$

From this formulation the intertemporal Malmquist indices can be formed as

$$M^I(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}$$

(6.2)

where $M^I$ is the intertemporal Malmquist index of a particular group and $D_0^{t+1}(x^{t+1}, y^{t+1})$ and $D_0^t(x^t, y^t)$ are the output distance function in time $t+1$ and time $t$ of the intertemporal frontier of the group respectively. By a simple multiplication, the intertemporal index can be decomposed as

$$M^I(x^{t+1}, y^{t+1}, x^t, y^t) = D_0^{t+1}(x^{t+1}, y^{t+1}) x \left[ \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \frac{D_0^t(x^t, y^t)}{D_0^t(x^t, y^t)} \right]$$

$$M^I(x^{t+1}, y^{t+1}, x^t, y^t) = D_0^{t+1}(x^{t+1}, y^{t+1}) x \left[ \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \frac{D_0^t(x^t, y^t)}{D_0^t(x^t, y^t)} \right]$$

$$M^I(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{TE^{t+1}}{TE^t} x \frac{BPG^{t+1}}{BPG^t}$$
Equation 6.3 shows that the intertemporal DEA-MPI can be broken down into efficiency change (EFFCH) and best practice change (BPC). The efficiency change is explained in Chapter 3 while the BPC is the ratio of the best practice gaps (BPG) in time $t+1$ and time $t$. The BPG was introduced in Pastor and Lovell (2005) and is also used by Oh and Lee (2010). As the ratio of the output oriented distance function of intertemporal frontier over the contemporaneous frontier, the BPG measures the gap between the intertemporal frontier and the contemporaneous frontier. The closer the value of the BPG to one (zero), the smaller (bigger) the gap of the contemporaneous frontier and intertemporal frontier.

The ratio of the BPG at time $t+1$ and at time $t$ is equal to BPC which is greater than one if the BPG of time $t+1$ is greater than the BPG at time $t$. The value of BPC being greater than one results in an outward shift of the contemporaneous frontier. Consequently, the gap between the contemporaneous and intertemporal frontiers becomes smaller. This is also the reason why Oh and Lee (2010) mentioned that the BPC is similar to the technical change component in conventional DEA-MPI since both of them represent the shift of the frontier. Similarly, if the value of technical change is less than one, it indicates technical regress or an inward shift of the frontier.

The last step in the metafrontier DEA-MPI estimation is the global index, which is based on the global production frontier. The intertemporal frontier is enveloped by this global frontier in which $P^G = P^t_1 \cup P^t_2 \cup \ldots \cup P^t_j$ where $P^G$ is the global production set and $P^t$ is the intertemporal production set. Following Oh and Lee (2010) the global DEA-MPI can be written and decomposed as follows

$$M^G(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D^G(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}$$ (6.4)
\[ M^G(x^{t+1}, y^{t+1}, x^t, y^t) = D_{o}^{t+1}(x^{t+1}, y^{t+1}) \times \frac{D_{o}(x^t, y^t)}{D_{o}^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \]

\[ M^G(x^{t+1}, y^{t+1}, x^t, y^t) = D_{o}^{t+1}(x^{t+1}, y^{t+1}) \times \frac{D_{o}(x^t, y^t)}{D_{o}^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \]

\[ M^G(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_{o}^{t+1}(x^{t+1}, y^{t+1})}{D_{o}(x^t, y^t)} \times \frac{D_{o}(x^t, y^t)}{D_{o}^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \times \frac{D_{o}(x^t, y^t)}{D_{o}(x^t, y^t)} \]

\[ M^G(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{TE^{t+1}}{TE^t} \times \frac{BPG^{t+1}}{BPG^{t}} \times \frac{TGR^{t+1}}{TGR^t} \]

\[ M^G(x^{t+1}, y^{t+1}, x^t, y^t) = EFFCH \times BPC \times TGC \quad (6.5) \]

The first two components of Equation (6.5) are efficiency change and best practice change, which is the same as in Equation (6.3). The new term from the global DEA-MPI are the technological gap change (TGC) and the technological gap ratio (TGR). The TGC is the ratio of the TGR at time \( t+1 \) over the TGR at time \( t \). The TGR represents the gap between the intertemporal (group) frontier and the global frontier. The value of the TGR is between one and zero and the closer the value to one (zero) the lower (bigger) the gap between the intertemporal and global frontier. This means that the value of TGC being greater than one represents an outward shift of the intertemporal (group) frontier toward the global frontier showing the production technology improvement of the group frontier relative to the global production technology. TGC being less than one represents an inward shift of the intertemporal (group) frontier
relative to the global frontier. These movements can be analysed as technological improvement and the technological regress of the unit of analysis. Oh and Lee (2010) stated that the analysis of TGC among groups can show the technology leadership of the leading group (group with the highest TGC) compared to other groups (group with lower TGC).

The graphical illustration of the metafrontier concepts by Oh and Lee (2010) are the combination of panel a (6.1a) and panel b (6.1b) in Figure 6.1. The combination of the two can be seen in Figure 6.2.

Given $D^t_o(x^t, y^t) = \frac{oa_{1,t}}{ob_{1,1}}$ and $D^{t+1}_o(x^{t+1}, y^{t+1}) = \frac{oa_{2,2}}{ob_{2,2}}$ then

$$EFFCH = \frac{D^{t+1}_o(x^{t+1}, y^{t+1})}{D^t_o(x^t, y^t)} = \frac{oa_{2,2}}{oa_{1,1}} \frac{ob_{2,2}}{ob_{1,1}}$$

$$BPG^t = \frac{oa_{1,1}}{oa_{1,1}} \frac{ob_{1,1}}{oc_i} = \frac{ob_{1,1}}{oc_i}$$ and $$BPG^{t+1} = \frac{oa_{2,2}}{oa_{2,2}} \frac{ob_{2,2}}{oc_2} = \frac{ob_{2,2}}{oc_2}$$

and

$$BPC = \frac{BPG^{t+1}}{BPG^t} = \frac{ob_{2,2}}{ob_{1,1}} \frac{oc_2}{oc_i} \frac{ob_{2,2}}{ob_{2,2}} = \frac{ob_{2,2}}{ob_{2,2}}$$

$$TGR^t = \frac{oa_{1,1}}{oa_{1,1}} \frac{od_{1}}{oc_i} = \frac{oc_i}{od_1}$$ and $$TGR^{t+1} = \frac{oa_{2,2}}{oa_{2,2}} \frac{od_2}{oc_2} = \frac{oc_2}{od_2}$$

As a result

$$TGC = \frac{TGR^{t+1}}{TGR^t} = \frac{oc_2}{od_2} \frac{od_1}{oc_i}$$
To estimate metafrontier DEA-MPI, there are six linear programming problems of distance functions that have to be resolved (Oh and Lee, 2010). The distance functions are $D_o^t(x^{t'}, y^{t'})$, $D_o^t(x^{t+1}, y^{t+1})$, $D_o^t(x^{t'}, y^{t'}/D_o^t(x^{t'}, y^{t'}))$, $D_o^t(x^{t+1}, y^{t+1}/D_o^{t+1}(x^{t+1}, y^{t+1}))$, $D_o^G(x^{t'}, y^{t'}/D_o^G(x^{t'}, y^{t'}))$ and $D_o^G(x^{t+1}, y^{t+1}/D_o^G(x^{t+1}, y^{t+1}))$. The two first problems are explained in sub section 3.5.1, Chapter 3. To estimate the intertemporal distance function, Oh and Lee (2010) computed the linear programming problem as follows

$$\left\{ D_o^t(x^h, y^h / D_o^h(x^h, y^h)) \right\}^{t+1} = \max \theta^t$$

where $h=t, t+1$

Subject to

$$\sum \lambda_j^h y_{ij} = \theta^t y_{ij} \quad r=1,2,\ldots,s$$

$$\sum \lambda_j^h x_{ij}^h \leq x_{ij}^h \quad i=1,2,\ldots,m$$

$$\lambda_j^h \geq 0 \quad j=1,2,\ldots,n$$
where \( i \) is the number of outputs, \( i \) is the number of inputs, \( j \) is the number of DMUs in the group, \( \lambda \) is an intensity variable and \( \theta^l \) is the solution of the problems.

To estimate global distance function, Oh and Lee (2010) used the linear programming as follows

\[
\left\{ D_o^G(x^h, y^h / D_o^b(x^h, y^b)) \right\}^{-1} = \max \theta^G \quad \text{where} \ h=t, \ t+1
\]

Subject to

\[
\sum \gamma_j^h y_{ij}^h \geq \theta^G \theta_j^h y_{ij}^h \quad r=1,2,\ldots,s
\]

\[
\sum \gamma_j^h x_{ij}^h \leq x_{ij}^h \quad i=1,2,\ldots,m
\]

\[
\gamma_j^h \geq 0 \quad j=1,2,\ldots,n
\]

where \( r \) is the number of outputs, \( i \) is the number of inputs, \( j \) is the number of DMUs in the group, \( \gamma \) is an intensity variable and \( \theta^G \) is the solution of the problems.

### 6.3.2 Data and Grouping

The data used in this study includes two inputs and one output for 26 Indonesian provinces and 31 Chinese provinces and covers the period of 1985-2010. The output data used is the gross regional product (GRP). Employment and capital stock by province are utilized as input factors. Data for GRP and capital stock are expressed in the 2000 constant prices. Indonesian data is the same with the data used in the previous chapter. These data are explained in Chapter 4 and summarized in the appendix to Chapter 4. China’s regional capital stock data, labour and GRP are taken from Wu (2009)\(^{81}\).

For comparison purposes, the Indonesian data are divided into three groupings\(^{82}\). The first is based on the GRP level (GRPL)\(^{83}\). The GRP of Indonesian provinces in


\(^{82}\) Grouping in this study refers to the way to form the group and group is part of the grouping

\(^{83}\) This grouping is similar to Iyer et al. (2006) which used income level as a basis of grouping
2010 are ranked from the highest to the lowest level. The 26 provinces are divided into three groups with the first group involving nine provinces (West Java, DKI Jakarta, East Java, Central Java, Riau, North Sumatera, East Kalimantan, South Sumatera and South Sulawesi). The GRP level of this group is between $5.6 \times 10^{13}$ and $4.10 \times 10^{14}$ (rupiah), which is categorized as the high GRP level group. The second group (the medium GRP level group) includes West Sumatera, Lampung NAD, Papua, South Kalimantan, West Kalimantan, Bali, North Sulawesi and Yogyakarta. Their GRP is ranged from $2.1 \times 10^{13}$ to $3.9 \times 10^{13}$ (rupiah). The third group is the low GRP level group including West Nusa Tenggara, Central Kalimantan, Jambi, Central Sulawesi, East Nusa Tenggara, South East Sulawesi, Bengkulu and Maluku. The GRP range of this last group is between $7 \times 10^{12}$ and $2 \times 10^{13}$ (rupiah).

The second grouping is based on the development zones which are used in the previous chapter, namely, the west and east groups. The west includes Sumatera, Java and Bali while the east includes Sulawesi, Kalimantan, Nusa Tenggara, Maluku and Papua. The last grouping is the one that will also be used as the basis of comparison with China. There are three considerations for this grouping, namely Indonesian archipelagic sea lines (Alur Laut Kepulauan Indonesia (ALKI)), MP3EI and balanced samples\textsuperscript{84}. Therefore, the main consideration of this grouping is geographical proximity. Commonly the studies that used geographical proximity classify the units of analysis on the basis of location such as continents, islands and territories marked\textsuperscript{85}. As a result Indonesia will be compared to China in a group of three regions. The three groups are Sumatera (regions in the left side of ALKI I line as the west part), Java-Kalimantan latter called JK (regions between ALKI I and ALKI II lines as the central part) and Bali,
Nusa Tenggara, Sulawesi, Maluku and Papua (BNSMP) as the third (regions in the right side of ALKI II line as the east part). Figure 6.3 shows the division of the ALKI.

**Figure 6.3** ALKI of Indonesian regions

In relation to MP3EI this grouping is relevant since the first group is the first corridor of MP3EI as a “centre for production and processing of natural resources and as nation’s energy reserves”. The second group is the combination of the Java and Kalimantan corridors which combines the centres of national industry, mining and energy. The last group is characterized as the center of agriculture production, plantation, fisheries, tourism and food support. This is the reason why Bali, which is geographically a member of the second ALKI group, (with Kalimantan and Java) is here classified to be in the third block since in the six corridors of MP3EI, Bali is in the same group as Nusa Tenggara to support the tourism development zones. This grouping also represents the west-east development zones, particularly the last group which is mostly part of the east development zone. The provinces are divided almost evenly among the

Source: Indonesia’s map is author’s own elaboration (using ArcGIS 10.0)
three groups, namely, eight provinces in the Sumatera group, nine provinces in the Java-Kalimantan group and nine provinces in the BNSMP group.

China’s regions have been divided into three development zones which are based on the classification of the United Nations Industrial Development Organization’s (UNIDO) classification in its technical report in 2005. The eastern cluster of China includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. Central China involves Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan. The west includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.

Figure 6.4 China’s map


6.4 Indonesian Productivity Growth with Different Groupings

6.4.1 Productivity Growth across Regions

Table 6.1 shows the results of the metafrontier DEA-MPI. On average, the TFP growth of Indonesian regions was 1.31 per cent in the period of study with average efficiency

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86 For further explanation see UNIDO (2005b, pp.11)
change within groups 1.56 per cent, 2.06 per cent and 2.54 per cent for ALKI, GRPL and west-east grouping respectively. On average, the BPC deteriorated in all groupings with rates – 1.15 per cent, -0.89 per cent and -1.86 per cent for ALKI, GRPL and west-east grouping respectively. In the ALKI grouping, BNSMP was observed to have the highest TFP growth followed by JK and Sumatera. In the GRPL grouping, the low level of GRP group was the best performer followed by the medium GRP level group and regions with a high level of GRP. The last grouping (west-east) shows that eastern Indonesia has better productivity growth performance than the western part.

Table 6.1 Productivity growth estimates by different groupings

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Regions</th>
<th>EFFCH</th>
<th>BPC</th>
<th>TFPCH</th>
<th>Rank TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>ALKI</td>
<td>Sumatera</td>
<td>1.0350</td>
<td>0.9759</td>
<td>1.0063</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>JK</td>
<td>1.0100</td>
<td>0.9848</td>
<td>1.0130</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>BNSMP</td>
<td>1.0042</td>
<td>1.0035</td>
<td>1.0193</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1.0156</td>
<td>0.9885</td>
<td>1.0131</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GRPL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>1.0143</td>
<td>0.9830</td>
<td>1.0111</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>1.0409</td>
<td>0.9859</td>
<td>1.0131</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>1.0053</td>
<td>1.0064</td>
<td>1.0153</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1.0206</td>
<td>0.9911</td>
<td>1.0131</td>
<td></td>
</tr>
<tr>
<td></td>
<td>West-East</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>1.0373</td>
<td>0.9794</td>
<td>1.0118</td>
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</tr>
<tr>
<td></td>
<td>East</td>
<td>1.0117</td>
<td>0.9838</td>
<td>1.0147</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1.0254</td>
<td>0.9814</td>
<td>1.0131</td>
<td></td>
</tr>
</tbody>
</table>

Note: The index in the table is the geometric mean of the groups and the total is the geometric mean of all provinces.

Source: Author’s own calculation

The trends of BPC show an interesting feature in particular when the BPC of ALKI is compared with the trends of TECCH in Table 5.3. In ALKI grouping only BNSMP showed technical progress (BPC>1). In Table 5.3, the average of Bali Island, Sulawesi Island and NMP Islands was also exhibit technical progress (TECCH>1). This trend simply explains that technical progress is strongly consistent according to both conventional and metafrontier DEA-MPI for Bali, Sulawesi and NMP Islands. The

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87 It was explained in the sub section 6.3.1 that both BPC and TECCH represent a shift of the frontier.
consistency of the results from the two methods can also be observed from the technical regress shown by Sumatera and Kalimantan Island. However for Java Island the estimation results that display technical progress are much more dependent upon the group of the islands to which they belong.

Table 6.1 shows that the BPC of the low GRP level group is greater than one. This was supported by the BPC of some provinces in this group such as Jambi (1.0089), West Nusa Tenggara (1.0086), East Nusa Tenggara (1.0035), Central Kalimantan (1.0084), Central Sulawesi (1.0105), South Sulawesi (1.0047) and Maluku (1.0066) (Table 6.2). Only Bengkulu in this group recorded a BPC value of one. However, when some of these regions were grouped using different kinds of grouping techniques they exhibited BPC less than one. This can be seen in Table 6.2 in which Jambi, Bengkulu, East Nusa Tenggara, Central Kalimantan and Maluku show BPC less than one in ALKI grouping. Based on these results one can conclude that in the case of Indonesia, the grouping of the units of analysis affects the results of BPC and hence the ranking of the productivity growth performance[^88].

Comparing efficiency change, Sumatera exhibits the highest growth in the ALKI grouping. However, similar to the results of the conventional approach in Table 5.3, the highest EFFCH of Sumatera cannot support Sumatera to be the best performer in productivity growth. This can also be observed in the case of the medium GRP level group (GRPL grouping) and the west (west-east grouping). Both groups show a relatively high EFFCH but lower TFPCH than other groups. The estimation results show that in the Indonesian case, BPC is the factor that supports the high growth of productivity. Table 6.1 shows this premise. The positive improvement of BPC of BNSMP (in ALKI grouping) and low level GRP group (in GRPL grouping) and the

[^88]: This conclusion is very strong in the case of Indonesian regions. To check this, different kinds of groupings namely DFC-MPI and MP3EI were conducted by the author and the same conclusion was drawn in the case of Java, Bali and Sulawesi (see the appendix to this chapter).
better performance of BPC of the east group than that of the west (in west-east grouping) support their high TFPCH.

The better productivity growth performance of the eastern group (1.47 per cent) than that of the western regions (1.18 per cent) was supported by the results in the ALKI grouping in which, on average, Sulawesi, Maluku, Nusa Tenggara and Papua (as part of the eastern regions) showed a relatively higher productivity growth than regions in the western part, e.g. Sumatera. Six regions of the east also contributed to the low GRP level group being the best performer in GRPL grouping. These empirical findings show the strategic position of eastern Indonesia in national development. The Indonesian government encouraged this strategic role of the eastern regions through the President Decree number 13/2000 (amended by the President Decree number 44/2002). This regulation tries to promote more equal development among Indonesian regions.

Table 6.2 shows the estimation results among provinces in three different groupings. Since the TFPCH is the result of the metafrontier approach in which the global frontier is applied in all groupings, its values are the same for each province in every grouping technique (columns 5, 9 and 13). The interesting results can be seen in the best performer of TFPCH of the west and east regions. In the east group, East Nusa Tenggara displayed the best performance, whilst for the west it was shown by DKI Jakarta. The former includes lagging underdeveloped regions while the later has leading developed regions. We can argue that this is a sign of productivity convergence in the east and productivity divergence in the west.

The table also reveals that most of the Indonesian provinces (73.08 per cent in ALKI, 76.92 per cent in GRPL and 80.77 per cent in west-east) are good at the catch up as reflected by the EFFCH greater than one. Two regions, NAD and East Kalimantan, showed EFFCH equal to one in the three grouping techniques indicating no efficiency

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89 President decree 13/2000: the establishment of the East Indonesian Development Board.
90 Whether and how this policy affect the regional performance could be an interesting exercise for future research.
change. Two regions which are members of the ALKI and west-east groupings, Central Kalimantan and South East Sulawesi, experienced negative EFFCH. These regions are not good at catch up. However their BPC was greater than one when they are part of the GRPL grouping, meaning that there was technical progress in the regions.

The results of the BPC of the metafrontier DEA-MPI vary among the three groupings. There were six provinces in the ALKI grouping, seven provinces in MP3EI and one province in the west-east that experienced technical progress. For Bali, Sulawesi and Papua Islands in the ALKI grouping, their BPC followed the trends in Table 5.3, which showed BPC > 1 except for South East Sulawesi (In Table 5.3 South East Sulawesi’s TECCH > 1 but in ALKI grouping its BPC = 1). Of the seven regions in the GRPL grouping that showed BPC>1, four of them (East Nusa Tenggara, Central Sulawesi, South East Sulawesi and Maluku) were consistent with the result in Table 5.3 (their TECCH were >1). The trends of BPC in the west-east groupings are similar to Table A5.1 in which only Jakarta displayed technical progress. This finding supports the previous conclusion that in the case of the Indonesian regions the estimation of technical progress or regress is very sensitive to the classification of the regions in the grouping process.
## Table 6.2 Productivity growth estimated by different groupings and regions

<table>
<thead>
<tr>
<th>Regions</th>
<th>ALKI</th>
<th></th>
<th></th>
<th></th>
<th>GRPL</th>
<th></th>
<th></th>
<th></th>
<th>WEST-EAST</th>
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<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
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<td>(7)</td>
<td>(8)</td>
<td>(9)</td>
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<td>(11)</td>
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<td>0.9650</td>
<td>2</td>
<td>1.0000</td>
<td>0.9807</td>
<td>0.9650</td>
<td>1</td>
<td>1.0000</td>
</tr>
<tr>
<td>North Sumatera</td>
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<td>1.0467</td>
<td>0.9807</td>
<td>1.0186</td>
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<td>1.0248</td>
<td>0.9831</td>
<td>1.0044</td>
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</table>

Source: Author’s own calculation
The comparison of Tables 6.2 and 5.3 in the previous paragraph has implications for regional development planning on the basis of cluster, corridors or development zones. Based on this comparison the planner can compare the results of BPC of metafrontier DEA-MPI and TECCH of the conventional DEA-MPI estimated by different grouping. This comparison can also be used to analyse productivity growth of the current corridors of MP3EI by comparing BPC of metafrontier DEA-MPI estimated on the basis of MP3EI grouping with other kinds of groupings. To provide empirical evidence, metafrontier DEA-MPI are estimated with groupings based on the findings in Table 5.3. The results are compared with those of metafrontier DEA-MPI with MP3EI base groupings (see the appendix).

6.4.2 Productivity Growth over Time

Yearly results of metafrontier can be seen in Figure 6.5. The figure shows that Indonesian regions experienced productivity improvement throughout the period of study except in 1986 and 1997-1999. Efficiency change had a similar trend with TFPCH that an upswing occurred over the years except in the year 1991 (GRPL), 1992 and 1996 (ALKI), 1998-1999 (all grouping), 2002 (all grouping) and 2004 (west-east). Unlike productivity growth and efficiency change, the trend of BPC was mostly characterized by deterioration except in 1988 (GPRL), 1991 (all grouping), 1992 (ALKI), 1993 (west-east), 1995-1996 (ALKI), 1999 (all grouping), 2002 (all grouping) and 2004 (all grouping). Overall the yearly trends of metafrontier DEA-MPI are very similar to the trends of the conventional and fixed base year DEA-MPI in Chapter 591.

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91 In some years the trends discussed in this section are the same as the trends observed in the findings according to the conventional and fixed base year methods. For a comparison, see section 5.4 and Table 5.1.
Figure 6.5 Yearly EFFCH, BPC and TFPCH metafrontier

Source: Author’s own calculation
In the five-year interval, the common trend can be observed among the three groupings (Table 6.3). The first trend is that the efficiency change improved by more than one per cent in the periods (2001-2005 and 2006-2010) in all of the groupings. The second trend is that the lowest efficiency change was in the period of ACE (1996-2000), except for GRPL, for which it was in the period 2006-2010. The third is that the best performance of BPC and TFPCH occurred in the second period (1991-1995), except for GRPL’s BPC which exhibited its best performance in the period 2001-2005. The Indonesian economy experienced technical progress in the period 1991-1995 (based on ALKI and GRPL groupings) and in the period 2001-2005 (based on GRPL grouping).

**Table 6.3 Productivity growth estimated by different groupings in different periods**

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<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
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<td>1.0231</td>
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<td>1.0231</td>
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<td>1.0231</td>
<td>1.0110</td>
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<td></td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

92 The five-year interval in this chapter is different to the Pelita discussed in the previous chapter. In this chapter the five year trend are computed based on the average of the five year estimation results. This is why the periods show different interval to the Pelita used in the previous chapter. The purpose of this scenario is to see the productivity in the business cycle of Indonesian economy.
Within the groups, similar to the findings in the previous sub-section, Sumatera was leading in efficiency (Table 6.4). This cluster exhibits efficiency improvement along the yearly interval in the ALKI grouping. BNSMP is the only group which exhibited efficiency change deterioration in the second period. JK and BNSMP (ALKI), high GRP group and the east (west-east) are the groups with negative EFFCH in the crisis period (1996-2000). Sumatera, medium and low GRP level groups showed EFFCH to be greater than one in the crisis period.

**Table 6.4 Productivity growth in different groups and different periods**

<table>
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<tr>
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<th>GRPL</th>
<th>West-East</th>
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</thead>
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<td>BNSMP</td>
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<td>2001-2005</td>
<td>0.9775</td>
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<td>1996-2000</td>
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<td>2001-2005</td>
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<td></td>
<td>2006-2010</td>
<td>1.0042</td>
<td>1.0127</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

There are variations in the trend of BPC among groups but the most interesting one is that at the early period (1986-1990) Sumatera, BNSMP, medium and low GRP level group and the west experienced positive BPC. However in the subsequent periods Sumatera’s BPC was always negative. JK and the east showed positive BPC only in the period of 2001-2005. From this trend one can conclude that the good performance of
BNSMP was mostly affected by Bali and Sulawesi. This can be seen from the good performance of Sulawesi when this island became an independent group (in DFC-MPI grouping, see the appendix) and also the inclusion of Bali in the NMP group (in MP3EI grouping, see the appendix). The east was expected to follow the trends of BPC of Bali or Sulawesi but the effect of Kalimantan seems likely to play a dominant role in determining the BPC of the east93.

In terms of TFPCH, all groups exhibited improvement in all periods but the crisis period, except the medium GRP group which also showed TFPCH deterioration in the period 2006-2010. In relation to Indonesian economic development, the BNSMP might benefit from the fast rise of the Indonesian economy in the high economic growth period (1986-1996) since in the two periods (1986-1990 and 1991-1996) this group exhibited high productivity growth (2.24 per cent and 4.49 per cent respectively). The medium GRP level group showed a similar trend with BNSMP in the first two periods. Despite high TFPCH in the first two periods, the low GRP level group might also benefit from the recovery period after 2000 with TFPCH 3.40 per cent (2001-2005) and 2.31 per cent (2006-2010).

In general the comparison of productivity growth overtime can be seen in three specific periods. These are the periods of high productivity growth (1991-1995), productivity growth downturn of (1996-2000) and recovery from economic crisis (2001-2005 and 2006-2010). The latest trend was similar to the estimation result in conventional DEA-MPI that productivity growth of the group is positive in the first period of recovery from the economic crisis (2001-2005) but with a lower growth rate than that in the period 1991-1995 except for the Sumatera group and low GRP level group. The low growth of productivity in the period 2001-2010 found in the conventional DEA-MPI estimated by Pelita in the previous chapter was mostly affected

93 The TECCH of Kalimantan was less than one in Table 5.3 and its BPC was also less than one in MP3EI (see appendix)
by the second period of recovery from economic crisis (2006-2010) shown in Table 6.4\textsuperscript{94}.

6.4.3 Technological Gap Change

The technological gap is the opportunity deviation to acquire science and technology between the people as a whole and people as individual entities (UNCSTD, 2006). Therefore, the persistence of this will affect the diversity of sectoral development either at a regional or national level. The technological gap can also be viewed by looking at the advantage of backwardness, in which the catch-up process allows the lagging regions or countries to grow faster than the leading ones (Abramovitz, 1986). Based on these propositions, we now seek to explore whether or not the technological gap and its consequences persist in Indonesian regions.

According to the conventional approach, the technological gap can be perceived as the difference in productivity performance in terms of technical change. Two findings of the conventional approach in Chapter 5 should be mentioned. The first is that TFPCH was dominated by technical change in Java-Bali, while other regions except Sulawesi were dominated by efficiency change. This implies that there is a technology gap between developed and underdeveloped regions in Indonesia. Conformably, the developed region (Java-Bali) has an advantage in technological development that supports their technical change improvement and hence productivity growth. Secondly, the dominant factor of technical change in Sulawesi, as one of the underdeveloped regions, can be recognized as an example of the advantage of backwardness. That both the conventional and sequential approaches showed that TECCH, and hence TFPCH, of Sulawesi was the highest among the islands.

\textsuperscript{94} This period was mentioned in the previous chapter as the period after the implementation of decentralization policy and the most constitutional government era as a result of a direct general election.
demonstrates that the lagging regions grow faster in terms of technological development than the leading regions.

Unlike the conventional approach, the metafrontier approach directly measures the technological gap by capturing the change of the gap between group frontier and global frontier in two time periods as explained in the method and data section. Table 6.5 shows the technological gap change of four grouping scenarios of Indonesian regions. From the ALKI grouping, JK has the highest technological gap change followed by the BNSMP. The estimation results in the GRPL grouping exhibit that the high GRP group was found as a leader in technological development. The west-east grouping showed that the east zone had TGC greater than one while the west experienced TGC less than one. This is one of the signs that the eastern part of Indonesia may be the country’s technology leader in the future.

**Table 6.5** TGC in three grouping scenarios

<table>
<thead>
<tr>
<th>Grouping I (ALKI)</th>
<th>TGC</th>
<th>Grouping II (GRPL)</th>
<th>TGC</th>
<th>Grouping III (West-East)</th>
<th>TGC</th>
</tr>
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<td>JK</td>
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<td>Medium</td>
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<td>East</td>
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<td>BNSMP</td>
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<td>Low</td>
<td>1.0035</td>
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<td></td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

Sumatera’s TGC played a dominant role in causing the TGC of the west to be less than one\(^{95}\). This must be a concern of policy makers in Indonesia. As a “centre for production and processing of natural resources and as nation’s energy reserves” in MP3EI, the evaluation regarding the technology development in the regions has to be considered. In the second grouping, the BPC of the high GRP level group which was far

\(^{95}\) Other islands that are part of the west group namely Java and Bali showed TGC more than one in MP3EI grouping (see appendix)
above one showed that the income level may affect the leadership of regions in technological development. However this premise does not hold true in the case of the medium GRP level group when compared to the low GRP group. In the Indonesian case the low GRP group experienced BPC > 1 while the medium GRP group showed BPC < 1.

Yearly trends of the TGC can be seen in Figure 6.6. It reveals that most of the TGC in the three scenarios was located above the border line (TGC = 1) except for the GRPL grouping. It implies that there were dynamic changes in the leadership in Indonesian regions during the period of study. In the beginning of the period we can observe TGC below the borderline implying on average most regions lagged behind and most of the group frontier shifted inwards with respect to the global frontier. In all scenarios TGC peaked in 1995 and becomes lower overtime in particular after the year 1998. TGC being lower than one can mostly be observed in the GRPL grouping after 1998. This means that most of the group frontiers in Indonesia experienced an inward shift after economic crisis.

**Figure 6.6 Yearly trends of TGC in different groupings**

Source: Author’s own calculation
6.4.4 Technological Gap Ratio

It is premature to conclude that the good performance of technological gap change will boost the region to catch up with the global frontier. Some literature reminds us that the catch up process is not a global phenomenon. The global frontier applied in exploring the technology gap change gives a direction of the trends of the regions in relation to the national frontier. Therefore information regarding the technical gap ratio needs to be examined to accompany the analysis of TGC.

Table 6.6 shows the TGR of regions in different groups of estimation. Sumatera exhibited the highest TGR. JK has TGR more than 0.5 implying both regions are relatively closer to the frontier when compared to the BNSMP, which shows TGR under 0.5. In the GRPL grouping, the medium GRP group was closer to the frontier than other groups. The low GRP group was lagging behind and showed a similar trend with BNSMP with a TGR far below one. TGR determines how close the group is to the global technology frontier. Therefore it should be interpreted in conjunction with the technical gap change. This is because Equation (6.5) explained that the technology gap change is derived from technology gap ratio in time t+1 over time t. The finding here implies that some groups experienced TGC greater than one but with TGR far below one. This is observed in the case of the BNSMP group, the low GRP group and the east group. These groups were far from the global technology but they experienced an outward shift of the group frontier. In other words, the shift of these group frontiers to decrease their gaps between group and global technology may be significant but this shift is started from the technological stage that was far lagging behind global technology.
Table 6.6 TGR in three grouping scenarios

<table>
<thead>
<tr>
<th>Grouping I (ALKI)</th>
<th>TGR</th>
<th>Grouping II (GRPL)</th>
<th>TGR</th>
<th>Grouping III (West-East)</th>
<th>TGR</th>
</tr>
</thead>
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<td>(3)</td>
<td>(4)</td>
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<td>(6)</td>
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<tr>
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<td>0.6839</td>
<td>West</td>
<td>0.8661</td>
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<tr>
<td>JK</td>
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<td>Medium</td>
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<td>East</td>
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<td>BNSMP</td>
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<td>Low</td>
<td>0.3091</td>
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</tr>
</tbody>
</table>

Source: Author’s own calculation

Table 6.6 shows that the TGR of Sumatera was the highest among the islands meaning that, on average, the regions are closer to the frontier technology than others. However these regions lost the power to speed up their technological development, represented by the negative value of technological gap change. Similarly in the GRPL grouping, the medium GRP group exhibited TGC less than one but its TGR was the highest in the group implying its closeness to the frontier. This is a good example of the process of catch up to the technology frontier as explained in Howit and Mayer-Foulkes (2005) the closer the countries or regions get to the frontier, the lower the growth rate of the productivity. The TFPCH of Sumatera in Table 6.1 confirmed this. Sumatera was the lowest among groups. The TFPCH of the medium GRP group was also lower than that of the low GRP group.

6.5 Comparing Indonesia and China

6.5.1 Productivity Growth Comparison

To compare Indonesia’s and China’s regional productivity growth, this section used the ALKI grouping of Indonesian regions while the grouping for China is based on the three development zones of UNIDO. To make the groupings comparable, the group

\[96\] This was explaining in sub-section 6.3.2.
was named as west, central and east based on geographical proximity. Sumatera was associated with the west, JK was classified as the central and the east involves BNSMP.

The estimation results can be seen in Table 6.7. Both China and Indonesia exhibited productivity growth improvement. On average, the improvement of China’s regions (0.50 per cent annually) was lower than the Indonesian regions (1.31 per cent annually). Indonesian TFPCH was formed by the positive TFPCH of all zones and China’s was the combination of positive in the west-east and negative in the central regions. The table also informs us that China experienced technical progress in two regions (west and east) while Indonesia exhibited technical progress in the eastern region. In total China experienced 0.27 per cent technical progress and Indonesia showed technical change deterioration -1.15 per cent. It means that China’s regions were characterized by innovation while Indonesia was better at catch up, with the ability to improve efficiency. This result is contrary to the classification of the World Economic Forum by whom both Indonesia and China were categorized as efficiency driven countries.

**Table 6.7** Efficiency, best practice change and productivity growth in Indonesia and China

<table>
<thead>
<tr>
<th>Country</th>
<th>Regions</th>
<th>Metafrontier</th>
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<th></th>
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<td>BPC</td>
<td>TFPCH</td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>West</td>
<td>1.0018</td>
<td>1.0090</td>
<td>1.0036</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td>1.0020</td>
<td>0.9952</td>
<td>0.9998</td>
<td></td>
</tr>
<tr>
<td></td>
<td>East</td>
<td>1.0011</td>
<td>1.0014</td>
<td>1.0104</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1.0016</td>
<td>1.0027</td>
<td>1.0050</td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>West</td>
<td>1.0350</td>
<td>0.9759</td>
<td>1.0063</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td>1.0100</td>
<td>0.9848</td>
<td>1.0130</td>
<td></td>
</tr>
<tr>
<td></td>
<td>East</td>
<td>1.0042</td>
<td>1.0035</td>
<td>1.0193</td>
<td></td>
</tr>
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<td>Total</td>
<td>1.0156</td>
<td>0.9885</td>
<td>1.0131</td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s own calculation
Table 6.8 presents the results of the productivity growth estimation using the metafrontier approach. On average, most of China’s regions (83.87 per cent) experienced productivity growth with the exception of Anhui, Henan, Hubei, Chongqing and Tibet. Three regions showed productivity growth of more than 2 per cent, these being Guangdong (2.76 per cent), Hainan (3.22 per cent), and Gansu (2.18 per cent). Three other regions showed TFPCH of more than 1.5 per cent, namely, Tianjin (1.58 per cent), Sichuan (1.65 per cent) and Qinghai (1.90 per cent). It is noted that Qinghai is part of the west cluster.

Table 6.8 also reveals that all regions in China’s eastern group experienced productivity growth. This is reasonable since these regions are the most developed region in the country. In addition, the two regions with the best performance (greater than two per cent) were also shown by regions located in the east coastal area. In Indonesia, most of the regions (84.61 per cent) experienced positive TFPCH with the exception of only four regions. Eleven regions (West Sumatera, Jambi, Lampung, DKI Jakarta, Central Java, South Kalimantan, Bali, West Nusa Tenggara, East Nusa Tenggara, North Sulawesi and Central Sulawesi) experienced TFPCH growth greater than 2 per cent.

The best performance in productivity growth in Indonesian regions was recorded in the relatively under-developed regions (third group) that are associated with the east development zone. This region was also the only one to have a BPC greater than one. Only six regions among the twenty-six provinces showed a BPC greater than one. However, this positive BPC cannot affect all the estimation results since TFPCH is dominated by efficiency change. The average of the three clusters also demonstrates that efficiency change recorded the best growth. This is consistent with the conclusion that TFPCH is dominated by efficiency changes. 73.08 per cent of the regions experienced better growth of efficiency than growth of technical change in Indonesia.
These empirical findings again confirm the premise that Indonesia was an efficiency driven country in the period of study.

**Table 6.8** Efficiency change, best practice change and productivity growth by provinces

<table>
<thead>
<tr>
<th>Province</th>
<th>EFFCH</th>
<th>BPC</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
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<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>NAD</td>
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<td>0.9728</td>
<td>0.9650</td>
</tr>
<tr>
<td>North Sumatera</td>
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<td>0.9807</td>
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</tr>
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<td>0.9819</td>
<td>1.0219</td>
</tr>
<tr>
<td>Riau</td>
<td>1.0000</td>
<td>0.9918</td>
<td>0.9931</td>
</tr>
<tr>
<td>Jambi</td>
<td>1.0502</td>
<td>0.9737</td>
<td>1.0212</td>
</tr>
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<td>South Sumatera</td>
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<tr>
<td>West</td>
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<td>0.9759</td>
<td>1.0063</td>
</tr>
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<td>DKI Jakarta</td>
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<th>TFPCH</th>
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<tr>
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<td>1.0018</td>
<td>1.0090</td>
<td>1.0036</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation
In China the most developed zone is the east which recorded the highest TFPCH among the Chinese zones (1.04 per cent). In Indonesia, the east is regarded as the least developed zone although in this study the regions demonstrated an astonishing TFPCH that reached 1.93 per cent. The Indonesian case confirms that the backward regions would grow faster than the leading regions, one of the so-called advantages of backwardness (Nelson and Phelps, 1966)\(^7\). The estimates also show that the relatively developed regions in Indonesia (west and central) have negative BPC and less developed regions exhibit positive BPC. The Chinese experience however, shows that the advanced regions grow faster than the lagging regions, which may be a sign of regional divergence. China’s economic development zones seem to show a common feature that more developed regions exhibit positive technical change since they benefit from advanced technological development. However the relative advantage of backwardness can still be observed in the case of the western zone since its BPC is positive and the highest among the zones. This polarized China’s regions into two typical development zones in which catch-up occurs between the west (lagging regions) and the east (leading regions) and divergence appears between the east and central regions. These advantages of backwardness and development polarization signify that unbalanced development has been a problem in both China and Indonesia.

To understand regional productivity growth over time, the yearly estimation results are also analysed. The estimation results in a specific timeframe in both countries are summarized in Table 6.9. The table reveals that Indonesia started with relatively high productivity growth in the first period (1986-1990) but this decreased in the period 1991-2000 and then it performed better in the last period (2001-2010). The BPC of Indonesia was less than one over the periods. Before 1990 China’s TFPCH was dominated by efficiency change implying the country was efficiency driven. This trend

\(^7\) Nelson and Phelps (1966) formalized the idea of advantages of backwardness which is originally proposed in Gerschenkron (1962, pp.6-10). The advantage of backwardness in this case refers to catch up process in which backward regions grow faster than leading regions.
changed a decade later, with continuing domination by BPC. There was a jump in the growth of BPC from negative 2.58 per cent in the first period (1986-1990) to 1.05 per cent in the second period (1991-2000), which might be due to the impact of the success in technological development.

Table 6.9 clearly shows how the countries’ performance was very much different. China’s performance was much stronger following the crisis, which depicts confidence in its technology trajectory (TFPCH after crisis was higher than before crisis). In contrast, after economic crisis Indonesia experienced lower growth than the pre-crisis period although it was still showing positive TFPCH growth. Indonesian BPC also deteriorated after the downturn while China showed technical progress after the crisis. This empirical result indicates that the impact of the crisis was very high in Indonesia compared to China. Therefore this indirectly influenced the time of recovery, which was relatively longer in Indonesia. The results of Table 6.9 (column 3) are also similar to the conclusion of Wu (2003) who found that the efficiency change of China’s economy was characterized by wide variations overtime. The EFFCH of Indonesia was better than that of China and displayed positive growth in all periods. However, the source of efficiency change might well differ markedly between the two countries and could be affected by many other factors.

The above-mentioned findings under the metafrontier approach imply that the growth of productivity components plays a role in distinguishing the different experience of the two countries. The faster average growth of China’s regions supports the common consensus about the important role that technical progress plays in promoting economic growth. Higher TFP growth is accompanied by technical progress. However, the results of estimation show that both technical progress and efficiency changes among the zones are different for both countries. While there is technical progress in the west and east of China, that trend cannot be observed in the west and
east of Indonesia. These different trends can also be detected in efficiency change and overall total factor productivity growth performance.

Table 6.9 Indonesia's and China's productivity growth

<table>
<thead>
<tr>
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<th>Periods</th>
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<th>BPC (2)</th>
<th>TFPCH (3)</th>
</tr>
</thead>
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</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>2001-2010</td>
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<td>1.0095</td>
<td>1.0083</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1.0016</td>
<td>1.0027</td>
<td>1.0050</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1986-1990</td>
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<td></td>
<td>1991-2000</td>
<td>1.0024</td>
<td>0.9916</td>
<td>1.0077</td>
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<tr>
<td></td>
<td>2001-2010</td>
<td>1.0259</td>
<td>0.9870</td>
<td>1.0170</td>
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<tr>
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<td>Total</td>
<td>1.0156</td>
<td>0.9885</td>
<td>1.0131</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Periods</th>
<th>EFFCH (1)</th>
<th>BPC (2)</th>
<th>TFPCH (3)</th>
</tr>
</thead>
<tbody>
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<td>China</td>
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<tr>
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<tr>
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<td>Before Crisis (&lt;1997)</td>
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<td>After Crisis (&gt;1999)</td>
<td>1.0278</td>
<td>0.9854</td>
<td>1.0168</td>
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</tbody>
</table>

Source: Author’s own calculation

Unbalanced development in the two countries is a significant problem. This is very similar to the case of China and India (Wu, 2008b). Wu mentioned that unbalanced development is the main problem of the regional economies in these countries. Consequently, it can be argued that regional cooperation in terms of knowledge transfer and new technology adoption may be relatively weak. Thus, both countries share similarities in promoting balanced development in the less developed regions. China has implemented the “west development” program, while Indonesia may have to rethink its emphasis on the eastern development.

6.5.2 Differences in Distance to Frontier

In relation to the distance to the frontier, Verspagen (1991) considered two phases, pre-catch up and post-catch up. The country that is far from the frontier characterized by the
pre-catch up phase will benefit from spillover effects rather than from intrinsic learning capabilities. When the country arrives at the post-catch up phase, internal ability plays a major role in maintaining the country at the frontier. The findings in the preceding section show that the main factor that differentiates Indonesia and China is their respective rate of technical change. This technical change represents innovation and can be attributed as a shift in frontier technology. This shift can be an outward shift, which closes the gap between the group and global frontiers. The inward shift works the other way around. The shift of production technology is represented by technological gap change and the gap between production technologies is measured by technological gap ratio in the metafrontier DEA-MPI.

Figure 6.7 shows the technological gap change in Indonesia and China. The figure shows that most of Indonesian TGC was above the borderline (TGC=1) and vice versa for China. The figure also depicts that the TGC of China lay below the borderline after the economic crisis (after 1997) with the average rate -0.063 per cent (before 1997 it was 0.24 per cent) and the Indonesian TGC also considerably decreased in this period with the average rate 0.42 per cent (before 1997 it was 1.5 per cent). This trend implies that the gap between the group frontier and global frontier was larger after the economic downturn in the two countries.

**Figure 6.7 Comparing TGC between Indonesia and China**

Source: Author’s own calculation
At the regional level, among the three development zones in both countries, the most developed regions exhibited TGR close to the frontier (Table 6.10). In China, the east is almost in the frontier with TGR 0.9433. In Indonesia, the west’s and central’s TGR is more than 0.5, meaning that the regions are relatively close to the frontier which differs from the east’s TGR (0.3085).

The difference between the two countries is very clear. TGR of China’s regions is on average closer to the frontier than that of Indonesian regions. This can be seen from the less developed regions (west regions) in China showing a TGR of more than 0.7, compared to the less developed regions (the east) of Indonesia. In total the average of TGR in China is 0.82 compared to 0.55 in Indonesia. It can be argued that the distance to the frontier is the main difference between the two countries.

In Indonesia, it was found that the west region showed negative TGC with high TGR. In a dynamic analysis this finding could be explained as follows. The negative TGC means that the shift of the group frontier was slower than the global frontier. However, the east shows a relatively high TGC (1.16 per cent) with low TGR, meaning that the shift of the group frontier was faster than the global frontier.

**Table 6.10** TGC and TGR in Indonesia and China

<table>
<thead>
<tr>
<th>Development Zone</th>
<th>TGC/TGR</th>
<th>China</th>
<th>Indonesia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>West</td>
<td>TGC</td>
<td>0.9929</td>
<td>0.9963</td>
</tr>
<tr>
<td></td>
<td>TGR</td>
<td>0.7357</td>
<td>0.8563</td>
</tr>
<tr>
<td>Central</td>
<td>TGC</td>
<td>1.0026</td>
<td>1.0185</td>
</tr>
<tr>
<td></td>
<td>TGR</td>
<td>0.7850</td>
<td>0.6455</td>
</tr>
<tr>
<td>East</td>
<td>TGC</td>
<td>1.0080</td>
<td>1.0116</td>
</tr>
<tr>
<td></td>
<td>TGR</td>
<td>0.9433</td>
<td>0.3085</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation
The comparison of regions between the west and the east of Indonesia confirms the common assumption that the closer to the frontier the regions or countries are, the slower its productivity growth. However, this is incorrect for the central regions including Java and Kalimantan. In contrast to the east, the central regions relatively closer to the frontier and have high TGC, meaning that even though they are close to the global frontier, they still grow relatively faster. It can be assumed that this group, particularly Java, can maintain its faster growth to catch up with the global frontier. This trend can also be observed in the central and eastern regions of China while western China followed the similar trend with western Indonesia.

6.6 Conclusion

The results in empirical studies are to some extent dependent upon the choice of the methods by the researchers. Following this argument, to estimate the regional productivity growth of Indonesia, the method that takes into account the heterogeneity of the regions has to be considered. Therefore this chapter used metafrontier as an estimation technique, which assumes that different regions have different technology frontiers. Several important results are found from the metafrontier DEA-MPI in Indonesian regions. On average, Indonesian regional productivity growth was 1.31 per cent in the period of study with the highest growth shown by the BNSMP group (in ALKI grouping), the low GRP group (in GRPL grouping) and the eastern group (in west-east grouping). The productivity growth improvement of the groups was dominated by efficiency change, except in the low GRP group which was dominated by technical progress. Two groups showed BPC greater than one, which were BNSMP (in ALKI grouping) and the low GRP group (in GRPL grouping). It was found that the eastern part of Indonesia plays a strategic role in the country’s productivity performance. This was exhibited by the high productivity growth of this group (the east in the west-east group). The empirical results also reveal that it was BPC that affected
the group to become the best performer in productivity growth rather than efficiency change. The high efficiency change of Sumatera, medium GRP group and the west cannot help them become the best performers in TFPCH.

The estimation results show that in the case of Indonesian regions BPC and the ranking of productivity growth performance are sensitive to the grouping technique employed in the metafrontier DEA-MPI. The change of BPC from greater than one to less than one was observed when the regions were grouped in different groupings. The groupings made in this study can also be used as an input for regional development planning on the basis of cluster, corridors or development zones in Indonesia. Java-Bali and Sulawesi can be formed in the same cluster since they revealed consistent technical change both in conventional and metafrontier DEA-MPI. Sumatera with high TGC and low TGR can be classified as one cluster or corridor as in the MP3EI. Nusa Tenggara, Kalimantan, Maluku and Papua may be best classified in the same cluster since they showed the second best performance in the DFC-MPI grouping.

The results of the metafrontier approach are different from conventional and sequential approaches in some directions. The first is the improvement of TFPCH in metafrontier (1.31 per cent), which showed better performance than conventional (1.07 per cent) but lower than sequential approach (1.33 per cent). Both in sequential and conventional approaches, aggregate productivity growth is shown as the combination of improvement in the west and deterioration in the east, but in the metafrontier approach it is the accumulation of productivity growth of the west, central and the east. Technical change in the conventional approach was negative in all the development zones but in the metafrontier approach the east zone showed positive best practice change (equivalent to technical change).

The metafrontier approach can show the technological gap between regions in a way that cannot be done by other approaches. The most important part of this is that
Sumatera lost its leadership, showing negative technological gap change, while the east showed positive TGC and may take the lead in national technological development in the near future. The Java regions, as the most developed regions, still show a positive technological gap change but are not the best performers over all.

However the high TGC of the east zone was not followed by high TGR. This meant that the region was still far below the frontier. Sumatera and Java regions show a high TGR implying that both regions are close to the frontier. This trend is in line with the common belief that the closer to the frontier the regions are, the lower their growth, since more is needed to shift the frontier further. In reality the case of Sumatera may also be caused by failure to upgrade the existing technology. Therefore the frontier shift is very slow in this region as shown by the negative technological gap change.

In comparison with China, there is evidence that most of the regions in the two countries experienced productivity growth improvement. However, on average China’s productivity growth was dominated by technical change while Indonesia productivity growth was dominated by efficiency change. The structure of productivity growth among groups in the two countries is also different. Indonesia was characterized by the advantage of backwardness while China regions were polarized.

China was dominated by technical change in the period 1991-2000 and 2001-2010 and by efficiency change in the period 1986-1990. Indonesia was found to have been dominated by efficiency change in the period 1986-1990, 1991-2000 and 2001-2010. China showed better productivity growth performance after the Asian economic crisis while Indonesia experienced positive growth with a lower rate than before the Asian economic crisis.

Indonesia’s technological gap change was higher compared to China’s but the TGR of China was higher than that of Indonesia. This implies that China’s regions were closer to their national frontier compared to Indonesian regions. As a result, the TGC of
Indonesia, particularly in the east, was far higher than China’s regions. This comparison means that the closer to the global frontier the regions are, the lower the growth. This different structure has affected economic development in the two countries. China’s metafrontier results show that its economy gained from both efficiency and technical progress since both of them showed improvement. Indonesia only gains from efficiency change and experiences negative technical progress.
Appendix to Chapter 6

To show the sensitivity of the change in BPC because of grouping, two new groupings are formed. The first is based on the finding from the spatial pattern of productivity in the conventional DEA-MPI estimation (Table 5.3) and we shall call it a dominant factor of conventional Malmquist productivity index (DFC-MPI). As a result, Java-Bali and Sulawesi (JBS), which exhibit productivity growth dominated by technical change, are classified in the same group. Regions in Sumatera that show productivity growth dominated by efficiency change are arranged in the same group and the last group contains regions also dominated by efficiency change, including Nusa Tenggara, Kalimantan, Maluku and Papua (NKMP).

The second grouping is based on MP3EI’s corridors. There are six corridors in MP3EI. The first corridor is Sumatera (8 provinces) as a “centre for production and processing of natural resources and as nation’s energy reserves”. The second corridor is the Java economic corridor (5 provinces) as a “driver for national industry and service provision”. The third is the Kalimantan (4 provinces) economic corridor as a “centre for production and processing of national mining and energy reserves”. The fourth is the Sulawesi economic corridor (4 provinces) as a “centre for production and processing of national agricultural, plantation, fishery, oil & gas, and mining. The fifth is the Bali – Nusa Tenggara economic corridor (3 provinces) as a “gateway for tourism and national food support”. The last is the Papua – Maluku economic corridor (2 provinces) as a “centre for development of food, fisheries, energy, and national mining” (Coordinating Ministry for Economic Affair Republic of Indonesia, 2011, pp.46). For the small number of provinces in the group, the last two corridors are grouped into one group. The last grouping is based on the common development zones which are west and east. The west includes Sumatera, Java and Bali and the rest belong to the east zone (Tables A6.1 and A6.2).
Table A6.1 Productivity growth estimated by different groupings

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Regions</th>
<th>EFFCH</th>
<th>BPC</th>
<th>TFPCH</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>1.0154</td>
<td>0.9897</td>
<td>1.0131</td>
<td></td>
</tr>
<tr>
<td>DFC-MPI</td>
<td>Sumatera</td>
<td>1.0350</td>
<td>0.9759</td>
<td>1.0063</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Java-Bali-Sulawesi</td>
<td>1.0022</td>
<td>1.0057</td>
<td>1.0196</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>NKMP</td>
<td>1.0126</td>
<td>0.9837</td>
<td>1.0120</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1.0154</td>
<td>0.9897</td>
<td>1.0131</td>
<td></td>
</tr>
<tr>
<td>MP3EI</td>
<td>Sumatera</td>
<td>1.0350</td>
<td>0.9759</td>
<td>1.0063</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Java</td>
<td>1.0002</td>
<td>1.0007</td>
<td>1.0185</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Kalimantan</td>
<td>1.0036</td>
<td>0.9840</td>
<td>1.0062</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Sulawesi</td>
<td>0.9993</td>
<td>1.0094</td>
<td>1.0202</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>BNMP</td>
<td>1.0016</td>
<td>1.0047</td>
<td>1.0187</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1.0114</td>
<td>0.9925</td>
<td>1.0131</td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s own calculation

Table A6.2 Productivity growth estimated by different groupings and provinces

<table>
<thead>
<tr>
<th>Regions</th>
<th>DFC-MPI</th>
<th>MP3EI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cluster</td>
<td>EFFCH</td>
</tr>
<tr>
<td>NAD</td>
<td>1</td>
<td>1.0000</td>
</tr>
<tr>
<td>North Sumatera</td>
<td>1</td>
<td>1.0467</td>
</tr>
<tr>
<td>West Sumatera</td>
<td>1</td>
<td>1.0460</td>
</tr>
<tr>
<td>Riau</td>
<td>1</td>
<td>1.0000</td>
</tr>
<tr>
<td>Jambi</td>
<td>1</td>
<td>1.0502</td>
</tr>
<tr>
<td>South Sumatera</td>
<td>1</td>
<td>1.0248</td>
</tr>
<tr>
<td>Bengkulu</td>
<td>1</td>
<td>1.0542</td>
</tr>
<tr>
<td>Lampung</td>
<td>1</td>
<td>1.0600</td>
</tr>
<tr>
<td>DKI Jakarta</td>
<td>2</td>
<td>1.0000</td>
</tr>
<tr>
<td>West Java</td>
<td>2</td>
<td>1.0000</td>
</tr>
<tr>
<td>Central Java</td>
<td>2</td>
<td>1.0036</td>
</tr>
<tr>
<td>DI Yogyakarta</td>
<td>2</td>
<td>1.0040</td>
</tr>
<tr>
<td>East Java</td>
<td>2</td>
<td>1.0003</td>
</tr>
<tr>
<td>Bali</td>
<td>2</td>
<td>1.0047</td>
</tr>
<tr>
<td>West Nusa Tenggara</td>
<td>3</td>
<td>1.0119</td>
</tr>
<tr>
<td>East Nusa Tenggara</td>
<td>3</td>
<td>1.0251</td>
</tr>
<tr>
<td>West Kalimantan</td>
<td>3</td>
<td>1.0021</td>
</tr>
<tr>
<td>Central Kalimantan</td>
<td>3</td>
<td>0.9983</td>
</tr>
<tr>
<td>South Kalimantan</td>
<td>3</td>
<td>1.0141</td>
</tr>
<tr>
<td>East Kalimantan</td>
<td>3</td>
<td>1.0000</td>
</tr>
<tr>
<td>North Sulawesi</td>
<td>2</td>
<td>1.0076</td>
</tr>
<tr>
<td>Central Sulawesi</td>
<td>2</td>
<td>1.0095</td>
</tr>
<tr>
<td>South Sulawesi</td>
<td>2</td>
<td>1.0000</td>
</tr>
<tr>
<td>South East Sulawesi</td>
<td>2</td>
<td>0.9925</td>
</tr>
<tr>
<td>Maluku</td>
<td>3</td>
<td>1.0169</td>
</tr>
<tr>
<td>Papua</td>
<td>3</td>
<td>1.0333</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.0154</td>
<td>0.9897</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation
The explanation of reference 88, section 6.4.1

In the metafrontier estimation results, the effect of grouping on the BPC can be seen in the MP3EI. The inclusion of Bali in NMP in the MP3EI grouping supports the finding in Table 5.3 in which Nusa Tenggara, Maluku and Papua experienced technical progress on average. The separation of the JBS group in DFC-MPI into Java, Sulawesi and BNMP groups in MP3EI affected the ranking of performance particularly in the Java Island. In DFC-MPI this island was part of the best performing group but in MP3EI this island was ranked third in terms of productivity growth. Based on these results one can conclude that in the case of Indonesia, the grouping of the units of analysis affects the results of BPC and the ranking of the productivity growth performance.

Analysing BPC to form a development cluster

One example to form a new development cluster is that Central Java and DI Yogyakarta can be categorized as centers for technological development and innovation, if they are developed as similar corridors with other provinces in the JBS (like DFC-MPI grouping) rather than when they are grouped with other provinces in Java only (like MP3EI). This is because when they are grouped in the JBS they displayed technical progress while in the MP3EI they experienced technical regress. This should be of consideration in regional development planning on the basis of cluster, corridors or development zones in Indonesia. In other words, the results of this study may provide a better classification of Indonesian regional economic corridors.
CHAPTER 7
PRODUCTIVITY CONVERGENCE IN INDONESIAN REGIONS

7.1 Introduction

Productivity convergence has been investigated and analysed in many countries at various levels. The investigations vary in terms of methods, data used, period of study and coverage. The main objective of the studies is to explore whether low productivity regions catch up with high productivity regions and what factors can close the gap between them. The existence of a gap between low and high productive regions requires economic policy to promote convergence. Barstelman and de Groot (2004) argued that to close the technological gap, technology diffusion from technology leading countries to the lagging countries is crucial.

This chapter aims to examine productivity convergence in Indonesian regions. It differs from others in two ways. First, this study analyzed the productivity convergence by employing both parametric and nonparametric approaches. Second, unlike previous studies that commonly analyse productivity growth and convergence by comparing regions within a country, this study will compare productivity convergence in Indonesian regions with that in China. This comparison will enrich the understanding of regional productivity convergence in Indonesia.

This study will answer several questions. Does productivity convergence exist in Indonesian regions? What is the source of convergence among Indonesian regions? Are there any specific differences between Indonesian productivity convergence and that in China? To answer these questions, the conventional DEA-MPI will be used to estimate productivity growth. To test productivity convergence and its sources, the tripartite productivity growth decomposition as seen in Maudos et al. (2000b) will be conducted. Panel data analysis will be used to test absolute beta and conditional productivity
convergence. The structure of the rest of the chapter is as follows. The next section is a literature review followed by method and data issues. Section four presents the analysis of sigma convergence. Section five provides the results of the absolute beta and conditional convergence tests. Section six examines the sources of productivity convergence and the last section is the conclusion.

7.2 Literature Review

The early studies on productivity convergence can be found in Abramovitz (1986), Baumol (1986), Dowrick and Nguyen (1989) and Wolff (1991), among others. The studies analysed the role of productivity in the convergence process. They argued that the main driver of productivity growth is technology advancement. The countries categorized as followers who learn by modification from the technology leaders. This process supports the follower countries to grow faster than the advanced countries. Other literature concerning productivity convergence includes Bernard and Jones (1996) and Fare et al. (2006, 2007). The former investigated the difference in trends of productivity convergence among sectors and the latter examined productivity convergence incorporated by productivity growth decompositions.

Taskin and Zaim (1997) investigated productivity convergence by employing productivity components in their analysis. By regressing initial per capita income and productivity components, Taskin and Zaim (1997) found that efficiency change is the source of convergence while technical change is the source of divergence. They also concluded that analysing productivity convergence without decomposing its components might not be a better technique to test productivity convergence.

Maudos et al. (2000b) examined productivity convergence of OECD countries over the period of 1975-1990. Productivity growth was decomposed by DEA-MPI into efficiency and technical changes. The decomposition of productivity growth into the accumulation of input per worker was done by tripartite decomposition. They regressed
each of the tripartite decomposition components against the logarithm of the initial labour productivity level to test the sources of convergence or divergence. They found that there was convergence among OECD counties due to the accumulation of input per worker and technical change as sources of divergence.

Leonida et al. (2004) tested the productivity growth convergence among 20 Italian regions over the period 1970-1995. They divided the regions into North-West, North-East, Centre and South regions. They regressed the components of productivity growth estimated by the DEA-MPI approach (EFFCH, TECCH and TFPCH) against the GRP per worker as an independent variable using panel data fixed effects. The model also incorporated the nonlinear form of convergence by adding GRP per worker square as the independent variable. The finding was that the productivity convergence exists among Italian regions and was mainly driven by efficiency change.

Unlike Leonida et al. (2004), Piacentino and Vassalo (2011) used kernel distribution to test productivity growth convergence in Italian regions. Despite decomposing productivity growth into technical change, efficiency change and capital input change, they also looked at the contribution of human capital to productivity growth. They used Italian regional data over the period 1982-2000. They found that there was a divergence trend among Italian regions in the form of regional polarization. The source of this divergence was identified to be efficiency change, which is in contrast to Leonida et al. (2004) who found that efficiency change was the source of Italian regional convergence. Piacentino and Vassalo (2011) also found the important role of human capital in regional productivity.

Badunenko and Tochkov (2010) examined regional productivity growth determinants and convergence of India, China and Russia over the period 1993-2003. They used nonparametric approach to decompose productivity growth components by the means of quadripartite decomposition in the three countries. They discussed the
regional productivity distributions for China, Russia and India and analysed the existence of convergence or divergence. They found that some regions in India and China reached a certain level of catch up due to capital accumulation while in Russia they found the existence of convergence due to efficiency change.

Kumar and Managi (2012) tested the convergence in Indian regions by using income per capita, lag of efficiency level, physical capital, human development index and public investment as the determinants of productivity growth. They used data at the Indian state level for the period 1993-2005. They divided the regions into low, middle and high-income states. They found that convergence exists among Indian states, however they did not examine the sources of this convergence and whether it was due to efficiency or technical change.

Tochkov and Yu (2013) examined regional productivity convergence in China over the period 1978–2006. They employed distribution dynamics, transition probability matrix and multinomial logit regression model to analyse the effect of labor productivity growth in three sectors (primary, secondary and tertiary) on regional disparities. They found that there was divergence in primary and tertiary sectors with tendency bimodal distribution in productivity. The secondary sector was found to be less polarized among the regions. They also observed that research and development spending, human capital, and infrastructure are the sources of divergence whilst physical capital and international trade are the sources of convergence.

Convergence in Indonesia was studied by Wibisono (2005) by using provincial data from 1984-2000. The author concluded that there was a close relationship between regional productivity growth and regional inequality. Resosudarmo and Vidyattama (2006) worked with panel data of per capita income from 1993-2002. They proposed that there is conditional convergence in per capita income among regions in Indonesia. A dynamic approach of convergence in Indonesia is employed by Firdaus and Yusop
(2009). They considered convergence in Indonesia between 1983 and 2003 by using a dynamic panel data approach, and pointed out that the prevailing convergence process in Indonesian regions is at a relatively slow speed.

In the Indonesian case, to the author’s best knowledge, the study of this chapter is the first of its kind to study Indonesian regional productivity convergence. The comparison with China to gain more insight into policy implications for Indonesian regions also makes this study a valuable addition to cross country productivity analysis.

7.3 Methods and Data

7.3.1 Absolute Beta Convergence

The method used to test convergence hypothesis in this chapter follows Taskin and Zaim (1997) and Leonida et al. (2004). A similar method was also used by Maudos et al. (2000b). The difference between them is that the former used panel data while the latter employed cross section data. Their method is based on the non-parametric approach of decomposition of productivity growth into efficiency change and technical change. These two components can also be related to labour productivity in a tripartite decomposition in which labour productivity is broken down into efficiency change, technical change and capital deepening (input factor). Therefore they tested the convergence hypothesis by using each of these components as a dependent variable against initial income per capita (Taskin and Zaim, 1997) or initial labour productivity (Maudos et al., 2000b and Leonida et al., 2004). The mathematical form of their model to test absolute beta convergence is as follows

\[ \text{MPI}_i = \alpha + \beta \text{LP}_{i_t} + \epsilon_{it} \]  

(7.1)
where \( \alpha \) and \( \beta \) are parameters, \( MPI_{it} \) is MPI or its components of regions \( i \) in period \( t \), \( LP_{it_0} \) is initial labour productivity level and \( \varepsilon_i \) is the error term. To test conditional beta convergence the model becomes

\[
MPI_{it} = \alpha + \beta LP_{it_0} + \gamma Z_{it} + \varepsilon_{it}
\]  

(7.2)

where \( Z_{it} \) is a vector of explanatory variables. In the case of the Indonesian regions the inclusion of regional specific factors would improve the validity of the test of convergence since it allows for heterogeneity among regions. Equation (7.2) also means that the convergence test considers province specific effects in the estimation process, which is very important for Indonesian regions characterized by regional diversifications. Two regional specific factors are used, namely, human development index (HDI) and the share of export plus import to the GRP. The former represents human capital and the latter is commonly used as a trade indicator.

The panel data analysis that allows for the inclusion of the initial productivity level to be the independent variable follows the method proposed by Islam (1995). The panel is constructed by taking the average of several time spans of study periods while the initial year is obtained from the initial year of each interval. Leonida et al. (2004) divided their total period of study into five year time spans while Rath and Madheswaran (2010) used three year intervals. Di Liberto et al. (2008) used both five year intervals and three year intervals. In this chapter, the absolute beta convergence uses five year time spans while the conditional beta convergence employs three years intervals due to data constraints.

To estimate the model, three approaches are commonly used, namely, pooled least square, fixed effect and random effect. The first approach does not account for the time invariant regional specific effects. This approach assumes that the error term (\( \varepsilon \)) is individually and identically normal distributed. The error term is also assumed
independent of cross sectional regions. The use of this approach may lead to bias and inconsistency in the estimation results due to not taking into account of time invariant regional specific effects. Therefore in this chapter the fixed and random effect models are employed. The Hausman test will be presented to choose the preferred model among the two.

7.3.2 Tripartite Decomposition

To introduce the tripartite decomposition, accordingly to Figure 3.4 in Chapter 3, the following relation is derived (Maudos et al., 2000b)

\[
\begin{bmatrix}
\frac{y_{t+1}'}{y'_t} - \frac{y'_{t+1}}{y_t'}
\end{bmatrix}^{1/2} = \begin{bmatrix}
0e & 0f
\end{bmatrix}^{1/2}
\]

\[(7.3)\]

where \(y'_t\) is the vector of outputs projected by technology in time \(t\). From Figure 3.4, one can determine that

\[
\frac{y_{t+1}'}{y'_t} = \frac{0d}{0a}
\]

The term \(\frac{0d}{0a}\) can be drawn from the multiplication of Malmquist index and Equation (7.3), that is,

\[
\begin{bmatrix}
\frac{y_{t+1}'}{y'_t} - \frac{y'_{t+1}}{y_t'}
\end{bmatrix}^{1/2} \cdot M_a(x^{t+1}, y^{t+1}, x', y') = \begin{bmatrix}
0d / 0e & 0d / 0f
\end{bmatrix}^{1/2} \cdot \begin{bmatrix}
0e & 0f
\end{bmatrix}^{1/2}
\]

or

\[
\begin{bmatrix}
\frac{y_{t+1}'}{y'_t} - \frac{y'_{t+1}}{y_t'}
\end{bmatrix}^{1/2} \cdot M_a(x^{t+1}, y^{t+1}, x', y') = \frac{0d}{0a}
\]

Therefore

\[
\frac{y_{t+1}'}{y'_t} = M_a(x^{t+1}, y^{t+1}, x', y') \cdot \begin{bmatrix}
\frac{y_{t+1}'}{y'_t} - \frac{y'_{t+1}}{y_t'}
\end{bmatrix}^{1/2}
\]

\[(7.4)\]

or
\[
\frac{y_{t+1}^i}{y_t^i} = \text{EFFCH} \times \text{TECH} \times \text{KACC} \quad (7.5)
\]

The first and the second term of Equation (7.5) were explained in the previous chapters. The new term, KACC, is the contribution of the accumulation of inputs per worker (Maudos et al., 2000b). The reason why KACC represents the accumulation of inputs per worker can be explained as follows. It is commonly known that the observed output level at any point in time equals the potential output time efficiency index (Maffezzoli, 2006).

\[
Y_t^i = \theta^i \hat{Y}(K_t^i, L_t^i)
\]

or

\[
y_t^i = \theta^i \hat{y}(k_t^i) \quad \text{where} \quad y_t^i = Y_t^i / L_t^i \quad \text{and} \quad \hat{y}_t^i = \hat{Y}_t^i / L_t^i
\]

The relative change of labour productivity in two time periods can be formulated as

\[
\frac{y_{t+1}^i}{y_t} \equiv \frac{\theta_t^{i+1} \hat{y}_t^{i+1}(k_t^{i+1})}{\theta_t^i \hat{y}_t^i(k_t^i)} = \frac{\theta_t^{i+1}}{\theta_t^i} \times \frac{\hat{y}_t^{i+1}(k_t^{i+1})}{\hat{y}_t^i(k_t^i)} \quad (7.6)
\]

Equation (7.6) is the decomposition of labour productivity into tripartite as in Equation (7.4) or (7.5). Labour productivity therefore can be decomposed into efficiency change (the first term of Equation (7.6)), technical change (the second term of Equation (7.6)) and the last part of Equation (7.6) as the effect of capital deepening. However the decomposition in Equation (7.6) is based on the technical change of capital-labour ratio in the second period and the movement along the frontier in the first period. The alternative decomposition with a different basis period of technical change (in time t of capital-output ratio) and a different basis period of production frontier (time t+1) can be written as
As explained in Chapter 3, the difficulty in choosing the reference technology to estimate MPI was solved, by using the geometric mean of two time references (time $t$ and $t+1$) as proposed in Fare et al. (1994). Therefore Equations (7.6) and (7.7) can be written as

$$
\frac{y^{t+1}}{y^t} = \frac{\theta^{t+1}}{\theta^t} \frac{\hat{y}^{t+1}(k^{t+1})}{\hat{y}^t(k^t)} = \frac{\theta^{t+1}}{\theta^t} \frac{\hat{y}^{t+1}(k^t)}{\hat{y}^t(k^t)}
$$

(7.7)

which is equivalent to Equation (7.5) that can be written as

$$
\frac{y^{t+1}}{y^t} = \text{EFFCH} \times \text{TECCH} \times \text{KACC}
$$

(7.9)

The analysis of convergence will follow the steps of Maudos et al. (2000b). To use the tripartite productivity growth decomposition, five steps are involved:

$$
\text{LPCH}_i = \alpha + \beta \log \text{LP}_{p_i} + u_i
$$

(7.10)

$$
\text{EFFCH}_i = \alpha_{\text{EFFCH}} + \beta_{\text{EFFCH}} \log \text{LP}_{p_i} + u_{\text{EFFCH}_i}
$$

(7.11)

$$
\text{TECCH}_i = \alpha_{\text{TECCH}} + \beta_{\text{TECCH}} \log \text{LP}_{p_i} + u_{\text{TECCH}_i}
$$

(7.12)

$$
\text{TFPCH}_i = \alpha_{\text{TFPCH}} + \beta_{\text{TFPCH}} \log \text{LP}_{p_i} + u_{\text{TFPCH}_i}
$$

(7.13)

$$
\text{KACC}_i = \alpha_{\text{KACC}} + \beta_{\text{KACC}} \log \text{LP}_{p_i} + u_{\text{KACC}_i}
$$

(7.14)

98 To make it easy to understand the symbol of labour productivity ($y$) which is equal to $Y/L$ is changed to LP (labour productivity) in this formulation. This symbol is used to avoid confusion with the symbol in the derivation of the index and to make it consistent with the symbol of labour productivity (LP) in Chapter 3.
where $\log LP_{i0}$ is the logarithm of the initial labour productivity level as the independent variable. The dependent variable is the annual rate of growth of labour productivity (LPCH) in Equation (7.10), the average efficiency change (EFFCH) in Equation (7.11), the average technical change (TECCH) in Equation (7.12), the average of TFP growth (TFPCH) in Equation (7.13), and the average contribution of the accumulation of inputs per worker (KACC) in Equation (7.14). From this equation, the following equalization has to be fulfilled

$$\beta = \beta_{EFFCH} + \beta_{TECCH} + \beta_{KACC} \quad \text{or} \quad \beta = \beta_{TFPCH} + \beta_{KACC} \quad (7.15)$$

### 7.3.3 Data

The data used in this study are the same as the data used in the previous chapter both Indonesia and China. The labour and GRP data explained in Chapter 4 are used to compute labour productivity. The MPI and its components are obtained from the conventional DEA-MPI estimated in Chapter 5. The HDI data available in the years 1996, 1999, 2002 and 2004-2010 can be accessed in Indonesian CBS (BPS Statistics of Indonesia) website. The data of regional imports and exports are obtained from the GRP of Provinces in Indonesia by expenditure. For the absolute beta convergence, there are five data points to estimate Equation (7.1) since the period of study is 25 years and divided by five for each time span. For conditional beta convergence, there are also five data points which are based on the average of the year 1995-1997, 1998-2000, 2001-2003, 2004-2006 and 2007-2010. Due to data constraints, the HDI of the first three years uses the middle years as a representative of average while the last two years uses the average of the year in the interval.
7.4 Sigma Convergence

There are many ways to define convergence and they also turn up in different methods and technical frameworks. Two prominent convergences are convergence in per capita income and productivity. The former has been widely explored empirically compared to the latter. The former also receives attention in the growing development of neoclassical growth theory. In this section, the sigma and absolute convergence will be tested for Indonesian regions. The effect of regional specific factors will also be examined in the conditional beta convergence. Finally, tripartite decomposition is applied to examine the impact on labour productivity of MPI components.

For the sigma convergence test, the simple indicator is the coefficient of variation (CV). This indicator is simply the standard deviation divided by mean value. In the case of labour productivity, CV is calculated as follows

\[
CV = \sqrt{\frac{\sum_{i=1}^{n} (LP_{it} - \overline{LP})^2}{n \overline{LP}^2}}
\]  

(7.16)

where \(LP_{it}\) is the labour productivity of region \(i\) in time \(t\) and \(\overline{LP}\) is the average of labour productivity for period \(t\). \(n\) is the number of regions. A decreasing trend of CV indicates \(\sigma\)-convergence and an increasing trend indicates \(\sigma\)-divergence.

A kernel density function can also be used to assess the tendency of convergence by comparing the range of the variation in the curve. A small range means small variation indicating convergence and large range implies divergence because of more variation. Like other relative indicators, both of these indicators will be meaningful in the comparison over time or among different groups of units of analysis.

Islam (2003) categorized seven dichotomies of convergence (1) Convergence within an economy vs. convergence across economies; (2) Convergence in terms of growth rate vs. convergence in terms of income level; (3) Beta (\(\beta\)) convergence vs. sigma (\(\sigma\)) convergence; (4) Unconditional (absolute) convergence vs. conditional convergence; (5) Global convergence vs. local or club-convergence; (6). Income-convergence vs. total factor productivity (TFP)-convergence; (7) Deterministic convergence vs. stochastic convergence.
Figure 7.1 (left hand panel) exhibits the coefficient of variation of regional labour productivity in Indonesia during the period 1985-2010\textsuperscript{100}. Overall the graph shows the presence of sigma convergence. Productivity convergence among Indonesian regions was strong in the period 1985-1998. In this period the CV decreased from 1.38 to 1.04, which accounted for 25 per cent. This means that the disparity in labour productivity in this period in Indonesian regions exhibited decreasing trends.

Figure 7.1 Coefficient of variation: GRP per worker in Indonesian regions, 1985-2010

![Coefficient of Variation Graph]

Source: Author’s own calculation

Figure 7.1 also show that there was a slight upward trend of CV in the period 1998-2004. This period was the period of economic reform in Indonesia, which was characterized by significant changes in the country\textsuperscript{101}. The different regional foundations may affect the ability of regions to improve their productivity in rapid change environments in this period, which in turn increased disparity among regions.

---

\textsuperscript{100} The figure in the right hand side is presented for comparability purposes since some literature also used the logarithm of labour productivity to estimate coefficient of variation. Both of the graphs in the case of Indonesian showed a similar trend.

\textsuperscript{101} These changes have been explained in Chapter 5.
The CV fell to its low value in 2005 onward. Comparing the year 1985 to 2010, it was a clear downward trend of CV. This meant that, over all there was strong evidence of labour productivity convergence in Indonesian regions. The figure on the right hand side, which is based on the logarithm of labour productivity, also shows a similar trend.

Another approach that can be used to analyse the convergence is the kernel density distribution. Kernel density approach is a nonparametric technique which can be used to analyse the distribution of the data over some periods. Figure 7.2 shows the distribution of the kernel density of labour productivity of Indonesian regions in 1985 and 2010. The trend of the figure moved from left to the right between 1985 and 2010 indicating productivity improvement in the period of study. The higher peak in the middle of the curve in the year 2010 means that more regions approached the means of labour productivity, which is the sign of convergence. In other words, the mode of the distribution in 2010 is higher than in 1985.

**Figure 7.2 Initial and final distribution of labour productivity**

Source: Author’s own calculation
This trend supports the finding in the CV from Figure 7.1. However it is a left move in the right tail of Figure 7.2. This could be because some regions experienced divergence trend. The high coefficient correlation of initial and final labour productivity (0.9291) indicates that high productivity regions still experienced high productivity and vice versa. This also means that the general downward trend of regional disparities showed in Figure 7.1 may involve increasing disparities of some of the Indonesian regions, particularly regions with high labour productivity level. This may be one of the possible explanations of the small peak in the right tail of the graph.

Figure 7.3 exhibits the kernel density curve of efficiency change in Indonesian regions. The graph clearly shows that there were multi peaks of efficiency change in the 1986 curve. The trend moved from multi peaks in 1986 to single peak in the 2010 curve meaning that it was a shift from multimodal to unimodal distribution. The distribution of efficiency change in 1986 may follow the multi peak convergence of Quah (1997) that prominently came to be known as the convergence club.

**Figure 7.3** Initial and final distribution of efficiency change

![Kernel density curve of efficiency change](image)

Source: Author’s own calculation
The range of the curve also shifts from a wide range in 1986 towards a small range in 2010. The small range of the bell curve implies that more efficiency change scores gather around the mean. The trend suggested the presence of convergence during the period. However, the kernel density curve indicate shift of the probability mass towards the left, from 1986 to 2010. This move implies that Indonesian regions decrease their ability to catch up to the frontier. The left shift is observed more in the right tail, an indication that some regions that had high efficiency scores in 1986 recorded low efficiency scores in 2010.

The technical change density curves in 1986 and 2010 (Figure 7.4) exhibit vast differences. In the initial year the density graph exhibits a small bell shape with three peaks. At the end of the period, the density curve moves towards a high level with four peaks. The probability mass of technical change was higher in 2010 than that in 1985. However the peak of the density distribution in 2010 is greater than that in 1985. These indicate that club convergence may exist in terms of technical change in Indonesian regions.

**Figure 7.4 Initial and final distribution of technical change**

Source: Author’s own calculation
Productivity change density curves move from multimodal in 1986 towards an unimodal in 2010 (Figure 7.5). The 1986 productivity change density distribution is more widely spread than the 2010 density distribution. This suggests that there was a decreasing variation in labour productivity change in the period of study, and hence supports sigma convergence.

**Figure 7.5** Initial and final distribution of productivity change

![Kernel density curves for productivity growth](image)

Source: Author’s own calculation

### 7.5 Absolute Beta and Conditional Convergence

Taskin and Zaim (1997) argued that a study of productivity convergence without looking at productivity growth components may arrive at spurious conclusions. Following this argument some studies tested the existence of productivity convergence by incorporating its components (see, Taskin and Zaim (1997), Maudos et al. (2000b), Leonida et al. (2004), Mahmood and Afza (2008), among others). Similar exercises are conducted and the results can be seen in Table 7.1.

The panel data regression of productivity growth components shows a negative sign of the coefficient of the independent variable (initial labour productivity). The
Hausman test implies that the random effect is preferred to the fixed effect for the EFFCH model. For TECCH and TFPCH the fixed effect is preferable to the random effect. These findings conclude that the absolute beta convergence could be found in Indonesian regions.

Table 7.1 Absolute beta convergence

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FE</td>
<td>RE</td>
<td>FE</td>
</tr>
<tr>
<td>Intercept</td>
<td>1.051</td>
<td>1.056</td>
<td>1.005</td>
</tr>
<tr>
<td></td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
</tr>
<tr>
<td>Initial LP</td>
<td>-5E-10</td>
<td>-8E-10</td>
<td>-2E-09</td>
</tr>
<tr>
<td></td>
<td>(0.528)</td>
<td>(0.000)**</td>
<td>(0.001)**</td>
</tr>
<tr>
<td>R²</td>
<td>0.1766</td>
<td>0.1766</td>
<td>0.0471</td>
</tr>
<tr>
<td>Hausman</td>
<td>0.1500</td>
<td>15.4900</td>
<td>13.1700</td>
</tr>
<tr>
<td></td>
<td>(0.6990)</td>
<td>(0.0001)**</td>
<td>(0.0003)**</td>
</tr>
</tbody>
</table>

Note: p values are given in parentheses. ** (*) statistical significance at 1 (5) per cent.
Source: Author’s own calculation

The conditional convergence uses the formulation of Equation (7.2) with provincial exports plus imports (trades) share to total GRP and the Human Development Index (HDI) as the region specific factors. Based on the output in conditional convergence (Table 7.2), there is similar tendency for absolute convergence. All MPI components confirm the existence of convergence, except for technical change in the random effect model. Looking at the region specific factors, trade share has an insignificant effect on the convergence path in Indonesian regions. Elmslie and Milberg (1996) argued that regions could be characterized by the specialization of zero or positive feedback goods. If regions specialize in zero feedback goods, there will be little
effect on productivity improvement since investment mostly absorbs low skill workers and involves standard technology.

Table 7.2 Conditional convergence

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.362</td>
<td>0.798</td>
<td>1.358</td>
</tr>
<tr>
<td></td>
<td>(0.001)**</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
</tr>
<tr>
<td>Initial LP</td>
<td>-3E-09</td>
<td>-2E-09</td>
<td>-4E-09</td>
</tr>
<tr>
<td></td>
<td>(0.202)</td>
<td>(0.000)**</td>
<td>(0.034)**</td>
</tr>
<tr>
<td>HDI</td>
<td>0.0106</td>
<td>0.0041</td>
<td>-0.0046</td>
</tr>
<tr>
<td></td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.002)**</td>
</tr>
<tr>
<td>EIGRP</td>
<td>0.0279</td>
<td>0.0177</td>
<td>-0.0254</td>
</tr>
<tr>
<td></td>
<td>(0.373)</td>
<td>(0.302)</td>
<td>(0.352)**</td>
</tr>
<tr>
<td>R²</td>
<td>0.1947</td>
<td>0.238</td>
<td>0.0973</td>
</tr>
<tr>
<td></td>
<td>(0.0000)**</td>
<td>(0.0154)**</td>
<td>(0.0001)**</td>
</tr>
</tbody>
</table>

Note: p values are given in parentheses. ** (*) statistical significance at 1 (5) per cent.
Source: Author's own calculation

The significant effect of HDI confirms the common finding that human capital contributes to convergence. However the negative impact of HDI on technical change is debatable. It may reflect the phenomena of lop-sidedness of Ranis and Stewart (2000), i.e., weak HDI performance but strong economic growth or good HDI performance but weak economic growth. Their empirical test concluded that Indonesia is HDI-lopsided meaning that the high performance of HDI ends up with a low level of economic growth.

7.6 Sources of Convergence

Tables 7.3 and 7.4 provide the estimation results of the sources of productivity convergence of Indonesia in the period 1985-2010 in comparison with China. This
comparison is needed to see whether these two economies share a similar convergence trend. In total there is a convergence of labour productivity in Indonesian regions while China exhibits tendencies of divergence. The concern of greatest interest is the sources of convergence. In Indonesia, efficiency change is the source of convergence as well as input factors. However, only efficiency is statistically significant while input factors are not statistically significant. Productivity growth as a source of convergence was significant with a rate of convergence almost similar to the common role (2 per cent). The most interesting result is that technical change is the significant source of divergence in Indonesia.

**Table 7.3** Indonesian regional convergence in labour productivity and its sources

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>LPCH</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
<th>KACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.2402</td>
<td>1.3712</td>
<td>0.8175</td>
<td>1.1723</td>
<td>1.0641</td>
</tr>
<tr>
<td></td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
</tr>
<tr>
<td>Initial LP</td>
<td>-0.0309</td>
<td>-0.0473</td>
<td>0.0219</td>
<td>-0.0232</td>
<td>-0.0071</td>
</tr>
<tr>
<td></td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.001)**</td>
<td>(0.011)*</td>
<td>(0.263)</td>
</tr>
<tr>
<td>R²</td>
<td>0.606</td>
<td>0.8043</td>
<td>0.3704</td>
<td>0.2415</td>
<td>0.0520</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.5896</td>
<td>0.7961</td>
<td>0.3442</td>
<td>0.2099</td>
<td>0.0125</td>
</tr>
</tbody>
</table>

Note: p values are given in parentheses. ** (*) statistical significance at 1 (5) per cent.
Source: Author’s own calculation

The Indonesian trends could support the findings of conventional DEA-MPI in which the dominant factor of productivity growth is efficiency change. The divergence of technical change in Indonesia can be explained if we refer to the results of DEA-MPI estimates by province and west-east segmentation (see Chapter 5). In the west east group, only Jakarta experienced technical progress. This result indicates the advantages of Jakarta as a capital city, which leads to technological development.
Table 7.4 shows that in China there was productivity divergence in the period 1985-2010 indicated by a positive sign of initial labour productivity coefficient when labour productivity growth and TFPCH are used as dependent variables. The sources of convergence are efficiency change and capital accumulation while technical change is significantly the source of divergence. The insignificance of initial labour productivity in LPCH could be one of the reasons to explore further the existence of other factors that play different roles in relation to the labour productivity convergence in China. The divergence of technical change could be observed in the case of China’s central regions, which show negative technical change while the two other regions exhibit progress. The divergence of productivity growth was indicated by the faster growth of TFP in the most developed east regions compared to the west and central regions (see Chapter 6).

Table 7.4 China’s regional convergence in labour productivity and its sources

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>LPCH</th>
<th>EFFCH</th>
<th>TECCH</th>
<th>TFPCH</th>
<th>KACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.0465</td>
<td>1.0616</td>
<td>0.4993</td>
<td>0.5613</td>
<td>1.5091</td>
</tr>
<tr>
<td></td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
</tr>
<tr>
<td>Initial LP</td>
<td>0.0077</td>
<td>-0.0102</td>
<td>0.0895</td>
<td>0.0793</td>
<td>-0.0758</td>
</tr>
<tr>
<td></td>
<td>(0.500)</td>
<td>(0.330)</td>
<td>(0.000)**</td>
<td>(0.000)**</td>
<td>(0.001)**</td>
</tr>
<tr>
<td>R²</td>
<td>0.0158</td>
<td>0.0327</td>
<td>0.715</td>
<td>0.4171</td>
<td>0.3255</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>-0.0181</td>
<td>-0.0007</td>
<td>0.7052</td>
<td>0.3970</td>
<td>0.3022</td>
</tr>
</tbody>
</table>

Note: p values are given in parentheses. ** (*) statistical significance at 1 (5) per cent.
Source: Author’s own calculation

It is clear that there are different sources of productivity convergence in the Indonesian and Chinese regional economies. In Indonesia the efficiency change is the significant source of convergence while in China it was capital accumulation. The finding of China is similar to Tochkov and Yu (2013) who conclude that one of the
sources of convergence among Chinese provinces is physical capital\textsuperscript{102}. The two countries also differ in terms of labour productivity and multifactor productivity convergence. In Indonesia the labour productivity shows significant convergence while in China it was insignificant, suggesting that conditional convergence may explain further analysis of labour productivity for Chinese regions. The multifactor productivity (TFPCH) in Indonesia showed a convergence trend while China experienced divergence. However both of the countries follow the findings of Maudos et al. (2000b) in which the technical change is the source of the divergence among regions.

7.7 Conclusion

This chapter investigates productivity convergence in Indonesian regions. The comparison of the sources of productivity convergence between Indonesia and China is also conducted. The results show that there was productivity convergence in Indonesia in the period of study. The decreasing value of the coefficient of variation and the negative coefficient of the initial labour productivity variable in the productivity growth and its components regression models indicate absolute beta convergence. The existence of productivity convergence is also supported by conditional convergence that employs HDI and trade as the regional specific factors. This conditional convergence test shows that the effect of HDI was positive while the effect of trade was insignificant.

The convergence of Indonesian regions was due to efficiency change between 1985 and 2010. Technical change was the source of divergence. In China, TFPCH was the source of divergence and technical change showed a divergence effect. Capital accumulation in China was the factor behind its regional productivity convergence.

\textsuperscript{102} Tochkov and Yu (2013) found that physical capital and international trade are the main factor of convergence among Chinese provinces.
CHAPTER 8
CONCLUSION

Productivity studies at the national level in Indonesia have been documented extensively. These studies only consider national level data and provide useful information on national productivity performance over time. Regional productivity growth is under documented in the literature. As a result, many aspects of regional productivity growth i.e., its determinants, regional disparity and other important information remain unexplored.

Gardiner et al. (2004) noted that productivity at the regional level is a representation of regional competitiveness which regional economic development policy should reflect. They suggested that the information of regional productivity performance should support policy implementation in alleviating the gap between high and low productivity regions. However few studies have deeply investigated productivity growth at the regional level particularly in Indonesia. A lack of analysis on regional productivity growth is a significant obstacle to reshaping regional development planning and hence regional policy implementation on the basis of productivity performance. This study fills this gap by estimating and analyzing regional productivity growth in Indonesia. The estimation of the capital stock data, productivity growth performance and productivity convergence is the focus of this thesis.

The main findings in this thesis could provide useful policy implications for the improvement of Indonesian development planning both at the national and regional level. This study also contributes to the literature on Indonesian regional productivity growth and convergence by providing productivity estimation using the most up to date data. This chapter first summarizes the major findings of the study then discusses the policy implications, followed by discussion of the future research.
8.1 The Main Findings

8.1.1 Capital Stock Estimates

In the absence of official data of capital stock at a regional level in many countries, researchers have used regional capital formation data (Margono et al., 2004) or capital expenditure data of state governments (Rao et al., 1999) as a proxy for regional capital stock to estimate regional productivity growth. In order to avoid using a proxy of regional capital stock data, this study employed the perpetual inventory method to estimate Indonesian regional capital stock data (in Chapter 4).

The estimation results show that the growth of capital stock has followed the three different phases of Indonesian economic development, namely, the rapid growth, the crisis period and the recovery period. The growth rate reached the peak in the period 1991-1995 (7.81 per cent), decreased to 5.34 per cent in the period 1996-2000, reached the lowest growth in the period 2001-2005 (3.28 per cent) and increased steadily to 4.61 per cent in the last period (2006-2010). Regional share of capital stock over the national total is consistent with the finding of Tadjoedin et al. (2001). The average shares are significantly bigger (more than 3 per cent) in the advanced and resource-rich regions. To gain more insight, the data are plotted with GRP and regional development index. It was found that most of Java’s provinces were located in the quadrant of the high GRP level, a high regional development index and a high level of capital stock. In addition, regions with a high regional development index do not always fall into the regions with a high level of capital stock.

The data are compared to Sigit’s (2004). It is found that if the capital stock data estimates used the same depreciation rate as Sigit (2004) did, the difference between the data in this study and Sigit’s data becomes less than 5 per cent. The difference becomes more than 5 per cent but still less than 10 per cent if different depreciation rate are used. Domazlicky and Weber (2006) stated that the choice between different methods of
regional capital stock estimation is not clear since the true capital stock at a regional level is unknown. Therefore they argued that it is premature to conclude that one method is superior to other methods.

To check the stability of the data estimate, simple sensitivity analysis is conducted. It was found that the data estimated by PIM is more stable than those by the SSM. The fluctuation of the real value of the PIM series is smaller than those of the SSM series. The shares of labour and capital in the SSM model have a significant impact on the change of real values of capital stock. There is no agreement about the depreciation rate in the case of Indonesian regions. Sigit’s (2004) used a 3 per cent depreciation rate to estimate national capital stock data. Schundeln (2013) estimated the depreciation rate to be between 8 per cent and 14 per cent by using Indonesian manufacturing data. In a cross-countries study, Bu (2006) found a 2 per cent depreciation rate in 1996-1997 and 7 per cent in 1997-1998 for Indonesia. One can take the average of the lowest rate from these studies such as 2 per cent (Bu, 2006), 8 per cent (Schundeln, 2013), 3 per cent (Sigit, 2004) and 6 per cent (SSM). The average of all these rates is 4.75 per cent, which is very close to the 5 per cent, which is used by Wibisono (2005) and this study.

8.1.2 Regional Productivity Growth Estimate

Chapter 5 estimated productivity growth of Indonesian regions by three different approaches, namely conventional DEA-MPI, fixed based year DEA-MPI and sequential frontier DEA-MPI. In the case of Indonesian regions these approaches are new since previous studies only used growth accounting to estimate Indonesian productivity growth. These approaches do not need to assume functional forms of production functions and that all the units of analysis are efficient. The use of these approaches also makes it possible to decompose productivity growth into its components, namely technical change and efficiency change. Fare et al. (1997) showed that the information
of these productivity growth components is equally important as productivity growth estimation itself is.

The three sets of estimates agree that Indonesian regions experienced productivity growth at more than one per cent in the period of study. These positive results are similar to the results of productivity growth at a national level in the study by Van der Eng (2010) who found TFP growth in Indonesia was at 0.6 per cent (1951-2008), Krisnasamy and Ahmed (2008) who found it to be 1.62 per cent (1993-2006) and recently the Conference Board (2013) which found it to be 0.78 per cent (2010-2012).

The patterns of the national productivity (aggregate regions) are different to the structures of the regional productivity growth. The first difference is that the national data showed positive productivity growth but at the regional level five regions experienced negative productivity growth. The positive productivity growth also cannot be observed in the eastern regions (west-east data segmentation) which revealed productivity growth deterioration in the period of study while the western regions experienced positive growth. The results by islands also show that Kalimantan Island experienced negative growth which differs from the national trend. Another difference is that the dominant factor of productivity at a national level is efficiency change and all the regions experienced technical change deterioration while at the regional level, the estimation based on islands shows that Java-Bali and Sulawesi were dominated by technical change.

The yearly results show that Indonesian regions were good in catch up indicating that the regions were characterized by positive efficiency change and technical regress. Based on the productivity growth components, Indonesian regions can be divided into three different groups, namely positive productivity growth dominated by technical change (Java-Bali and Sulawesi), positive productivity growth due to efficiency change (Sumatera and Manupa), and negative productivity growth
(Kalimantan). This indicates that there are disparities in productivity growth performance in Indonesian regions.

Similar to capital stock estimation, productivity growth based on different time periods shows a positive upward trend in the period 1987-1996, a negative downward trend in the period covering the crisis period (1997-1999) and a lower positive growth after the recovery periods (starting in the year 2000). Productivity growth in the last period (2004-2010) was significantly lower than that in the previous period (1.75 per cent in the period 1999-2004 compared to 0.65 per cent in the period 2004-2010). This is interesting since the last period covers several years of national reform (decentralization and democratization). Czap and Nur-tegin (2011) concluded that gradual reforms were superior to the radical reforms in the long term since the gradual reforms supported high productivity growth.

8.1.3 Metafrontier Estimates

The results of metafrontier (in Chapter 6) are different from the conventional and sequential approaches in some directions. The average productivity growth estimated by metafrontier is 1.31 per cent, which was higher than those by the conventional and fixed base year but lower than that by the sequential approach. According to the metafrontier approach, the western, central and eastern group of regions experienced productivity improvement while according to other approaches the west showed improvement and the east exhibited productivity growth deterioration. Technical change according to the conventional approach was negative in all development zones but the metafrontier results show that the east zone had positive best practice change (equivalent to technical change). The empirical results also revealed that it was BPC underlying the group’s best performance in productivity growth, rather than efficiency change. This is similar to the argument that technical progress is the source of sustainability in economic growth.
The technical gap change from this approach also showed very interesting trends. The high technological gap change in the east was not followed by the high technological gap ratio. This implies that the regions were far below the global frontier and the high TGC reflects the advantage of backwardness rather than an improvement toward innovation. Sumatera, which had TGC of less than one, was very close to the frontier (high TGR). As a developed region it is reasonable that this region was close to the frontier, but the TGC value of less than one points to an upgrading failure in technological advancement.

To gain an understanding of whether productivity growth performance of Indonesian’s regions is different from other countries, Indonesia is compared to China. Indonesia’s regional productivity growth was higher than that of China but was dominated by efficiency change, while China’s regional productivity growth was dominated by technical change. Another finding, which is the most important factor behind the Indonesia-China differences, is that high efficiency in Indonesian regions was not supported by an improvement in technical change. China, however, benefited from the improvement of efficiency change, which is followed up by an improvement in technical change. These factors could be responsible for the better performance of China’s productivity growth in the crisis period and the country’s innovation, competitiveness, and standard of living. China’s TGC is small compared to Indonesia, but its TGR is higher meaning that China’s regions were closer to their national frontier than Indonesian regions.

8.1.4 Productivity Convergence

Chapter 7 examines productivity convergence in Indonesia. The chapter tests the productivity convergence by investigating the existence of sigma, absolute beta and conditional beta convergence of Indonesian regions. The comparisons of the sources of productivity convergence between Indonesia and China are also conducted.
Three convergence tests, namely sigma, absolute beta and conditional beta convergence, support the existence of productivity convergence in Indonesian regions. The existence of productivity convergence is supported by the importance of HDI as a regional specific factor in Indonesia. The positive impact of HDI is consistent with the studies that explain the important role of human capital in economic development (Lucas, 1988; Ranis and Stewart, 2000). The insignificant impact of openness may raise some questions regarding the structure of trade in Indonesian regions. If imports and exports of the regions contain zero feedback goods (Elmslie and Milberg, 1996), then the impact of trade on the production process and hence productivity improvement is small, since investment may mainly absorb low skill workers and standard technology.

In Indonesia, efficiency change as the sources of productivity convergence in the period of study. This differs from China which showed a divergence trend of productivity growth. The findings for China in this study are different from that of Jiang (2012) who found productivity convergence in the period 1984-2008 in China’s regions. However, the convergence test shows capital accumulation as the source of China’s productivity convergence. Both countries share a similar trend in which technical change acts as a source of divergence. If technical change is associated with the manufacturing industry sector then the conclusion of the divergence of productivity growth in this study confirms the conclusion of Bernard and Jones (1996) who found that the manufacturing sector is the source of divergence.

8.2 Policy Implications and Suggestions for Future Research

8.2.1 Policy Implications

This section discusses policy implications at both national and regional levels. Most of Indonesian regions showed productivity improvement and on average, regional productivity growth in the period of study was positive (more than one per cent). Different patterns of productivity growth performance are observed among Indonesian
regions. This disparity could be the main concern for the Indonesian government in promoting balanced development (between east and west). The finding that the east regions play a strategic role in affecting regional productivity also suggests that investing in these regions might be a more promising strategy to improve regional productivity growth and hence national performance. As suggested by Broersma and van Dijk (2008) investing in less congested regions might be preferred from both the regional and national point of view.

The negative sign of technical change in Indonesian regions requires a policy that simultaneously supports productivity growth in general and technology development in particular. Indonesia needs to focus on technological development which is associated with innovation (Fare et al. 1997). Regional innovation systems are needed to support knowledge transfer and technology diffusion at the regional level. There are many different systems. Indonesia could choose the one that is appropriate with its background and culture. The choices would affect the implementation of this system.

Technology gaps are the most important driver of Indonesian regional productivity growth (metafrontier approach) and the sources of regional disparity in Indonesia. Verspagen (1991) used the model of technological gap dynamics to explain the catch up process between North and South countries. He concludes that there were two driving forces that influenced the ability of the country to catch up with the technology frontier: the intrinsic learning capability and the initial technological gap. In relation to the Indonesian regions the regions with a high level of initial technological gap and a high intrinsic learning capability, will have a greater possibility to catch up with the frontier technology and vice versa. In relation to Verspagen (1991), there are two phases, which have to be considered by the Indonesian regions, which are the pre-catch up phase and post-catch up phase. In the pre-catch up phase, education and
infrastructure are the main factors to be improved and hence the domain of government policy. In the post-catch up phase, the lagging regions have to be able to reach the same standard of research and development as the leading regions.

Policy makers have to provide better economic development policy for the lagging or backward regions. Regional development aid for backward regions may be one of the solutions. Another way to support the lagging regions is by getting the role of science right (Woo and Hoo, 2010). Getting the role of science right in Indonesian regions case was explained by Woo and Hoo (2010) as science-led growth in which the university at the province level played a significant role in expanding and upgrading agricultural, scientific and technical faculties to support the province or regions within a province. Partnership between businesses and universities and more aid for research and development as well as entrepreneurship should be the top priority for Indonesian regional development.

8.2.2 Suggestions for Future Research

This study used the same rate of depreciation of 0.05 in estimating capital stock at the regional level. Therefore estimating capital stock by using a different depreciation rate in different provinces might improve the variability of the results (Wu, 2009).

This study did not incorporate the undesirable outputs in the estimation process. Estimating Indonesian regional productivity growth by considering undesirable outputs might show different variation in regional performance. In addition, as environmental issues have become prominent recently, the estimation of regional productivity growth performance, which covers undesirable outputs, could present promising results to measure the environmental sensitivity of productivity growth. The presence of green GDP and hence GRP may be in line with this purpose. Therefore, the implementation of Luenberger DEA-MPI in the Indonesian case is suggested for future research and further examination of regional productivity growth.
The analysis of regional productivity convergence at sectoral level by estimating transition probabilities matrix and incorporating productivity growth determinants as a source of convergence could be of particular interest to be explored for future research (Tochkov and Yu, 2013). This investigation may extent productivity convergence analysis in Indonesian regions for sectoral planning purposes in the era of decentralization.
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