Regional Disparity of Productivity and the Factors in Japanese Industries

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Abstract

This study examined productivity change and the factors in Japan using a data set consisting of 47 prefectures over the period from 1990 to 2009. The data set was comprised of one output and five inputs for overall industries in Japan, that is, amount of gross real product as an output, and intermediate input, number of employees, private capital stock, social capital stock and final energy consumption as five inputs. Using the data set, we measured Hicks-Moorsteen-Bjurek (HMB) productivity change index and decomposed the productivity change into three factors, technical change effects, efficiency change effects and scale change and input and output mix effects. In the process of calculating the HMB productivity index, this study applied a data envelopment analysis (DEA) to measure distance functions. From the results, this study indicated regional disparity once expanded toward 2005 and 2006, but after the years it drastically decreased in parallel with an economic downtown. From the decomposition analysis, we found that the economic downturn and the resulting decrease in regional disparities were mainly attributed to the negative impact due to the technical change component.

Keywords: productivity change, Japanese regional industries, regional policy

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Introduction

Japanese economy experienced higher growth in the 1980s, when the economy achieved 4.4% annual growth rate of real GDP on average. However, it shifted to the so-called "lost decade" under the severe stagnation in the 1990s after the burst of bubble economy. Due to the stagnation, the average annual growth rate went down to 1.5% on average, and the growth rate further decreased in the 2000s, which indicated 0.6% annual growth rate of real GDP on average.

Until recently, the Japanese economy continued to suffer from a long-term stagnation. The economy experienced decreasing price levels and higher unemployment rates for more than a decade. Under such an economic downturn, Abe's Liberal Democratic Party took office after the winning of the Lower House general election at the 16th of December 2012, advocating the rebuilt of the crisis-ridden Japanese economy. The economic policy is called "Abenomics."

There are three pillars of the Abenomics. They are effective uses of fiscal policy and financial policy, and promotion of growth strategy in private sectors. In particular, productivity improvement plays an important role for the growth strategy in private sectors, because productivity growth is an inevitable source and a driver of economic development. Therefore, to suggest effective policy for the growth strategy by improving the productivity of the economy, it is necessary for us to measure the productivity growth and find specific factors that influence the growth. In addition, examining regional disparities of economic growth is important for regional policy in Japan.

The purpose of this study is to investigate the productivity of the Japanese regional economy from 1990 to 2009 using a data set consisting of 47 prefectures, and find if the regional disparity of the productivity has grown during the period. Barro and Sala-i-Martin (1995) recognized regional disparity in labor productivity in Japan from cross-section analysis. Meanwhile, Kawagoe (1999) and Togo's (2002) results based on time-series analyses are critical to the discussion. Particularly, Togo's (2002) analysis, which examined time trends in regional disparities of labor productivity for the period from 1985 to 1997, does not account for the existence of productivity convergence. This study revisits the discussion of productivity convergence and examines the productivity change in Japan using an updated data set. Further, we conduct a decomposition analysis to clarify the sources of the productivity growth in Japan during this period.

The reminder of this article is organized as follows. The methodology section provides a brief description of HMB productivity index and its decomposition. The model section specifies the HMB productivity index using mathematical expressions. The data section explains descriptive statistics of data on industries for 47 prefectures. The last section concludes this study and discusses remaining issues.

Methodology

This study applies a decomposition analysis of HMB productivity index that was proposed by Nemoto and Goto (2005). The HMB productivity index can be decomposed into four components, and the decomposable property is ideal for the purpose of disentangling the sources of productivity growth. Those four components are technical change component (TC), efficiency change component (EC), scale change component (SC) and input and output mix effects (ME).

The HMB productivity index is capable of assessing the relative importance of the factors as sources of fluctuations in productivity and has preferable property for the decomposition compared to the other popular productivity index. In particular, Törnqvist productivity index does not have an efficiency change component because it presumes the optimizing behavior of a producer. Malmquist productivity index can assess inefficiency, but it is not indicative of scale change because it is well defined only when technology exhibits constant returns to scale. Meanwhile, the HMB index provides an integrated framework in which the productivity change is fully decomposed into four components.

Model

The HMB productivity index is defined by combining Malmquist output change and input change indexes. The Malmquist indexes are based on the distance function. The Malmquist output change index that measures aggregate output change from the period t to $t+1$ is described as follows;

$$M_y^{t+1,t} = \left\{\frac{D_o^t(x^t,y^{t+1})D_o^{t+1}(x^{t+1},y^{t+1})}{D_o^t(x^t,y^t)D_o^{t+1}(x^{t+1},y^t)}\right\}^{1/2},$$

where the output-oriented distance function is defined as

$$D_o^t(x,y) \equiv min\{\delta|(x,y/\delta) \in \Omega^t\}.$$

Here Ω^t is the production possibility set consisting of any technically feasible pair of inputs and outputs at the period t. When $D_o^t(x,y) \leq 1$, the output-oriented distance function measures technical efficiency, and $D_o^t(x,y) = 1$ indicates full efficiency in the sense that more outputs cannot be obtained without increasing inputs.

Similarly, Malmquist input change index that measures change from the period t to $t+1$ is given by

$$M_x^{t+1,t} = \left\{\frac{D_i^t(x^{t+1},y^t)D_i^{t+1}(x^{t+1},y^{t+1})}{D_i^t(x^t,y^t)D_i^{t+1}(x^t,y^{t+1})}\right\}^{1/2}.$$

The input-oriented distance function is defined as

$$D_i^t(x,y) \equiv max\{\delta|(x/\delta,y) \in \Omega^t\},$$

where $D_i^t(x,y) \geq 1$ implies that the input-oriented distance function measures technical efficiency, and $D_i^t(x,y) = 1$ indicates full efficiency in the sense that inputs cannot be reduced further without decreasing the outputs.

Using the above two indexes, the HMB productivity index is defined by Bjurek (1996) as the ratio of the Malmquist output change to the input change indexes as follows;

$$HMB^{t+1,t} = M_y^{t+1,t} / M_x^{t+1,t}.$$

Since $M_y^{t+1,t}$ and $M_x^{t+1,t}$ measure changes in outputs and inputs, taking logarithms yields their proportionate changes. Thus, $\ln HMB^{t+1,t}$ measures the proportionate productivity change for the period t to $t+1$, which comprises of four components: technical change, $TC^{t+1,t}$, efficiency change, $EC^{t+1,t}$, scale change, $SC^{t+1,t}$, and input and output mix effects, $ME^{t+1,t}$. In other words, the proportionate change in productivity index and the proportionate changes in the four components are summarized below.

$$\ln HMB^{t+1,t} = \ln TC^{t+1,t} + \ln EC^{t+1,t} + \ln SC^{t+1,t} + \ln ME^{t+1,t}.$$

TC captures effects from a temporal shift of the production frontier. The production frontier changes its position in response to various shocks arising from technical advances, investment in infrastructure, and changes in the economic environment concerning production. Therefore, *TC* can be called as supply shocks.

EC measures effects arising from a deviation of actual production point from the production frontier. There are two major sources of efficiency change. (1) Variations in input utilization rates induced by demand shocks, arising from changes in exports, autonomous domestic expenditures, and fiscal policy. These are nationwide shocks. (2) Changes in managerial efficiency that are caused by idiosyncratic shocks confronted by industries.

SC measures effects of returns to scale. If technology exhibits increasing (decreasing) returns to scale, the economy will become more (less) productive by an expansion of the production scale.

Finally, *ME* will be observed if there is a change in the sectoral composition of the economy over industries that differ in terms of productivity growth. *ME* is excluded from the scale effects because *ME* is measured along a fixed ray of input and output combination for the decomposition analysis of the HMB productivity index. This is a unique feature of productivity decomposition analysis in this study. On the other hand, changes from input and output mix effects are compounded with the pure scale change in the conventional TFP analysis.

This study uses Data Envelopment Analysis (DEA) to measure distance functions. DEA is a holistic method to measure efficiency of firms, industries, and other decision-making units (DMUs). That is, Nemoto and Goto (2005) used a parametric approach to measure the distance function, while this study uses a non-parametric approach that can avoid a specification of production function. Among the various formulations of DEA model, this study applies radial DEA model.

Mathematical symbols to express production factors are summarized as follows:

(a) $X_j = \left(x_{1j}, x_{2j}, \dots, x_{mj}\right)^T > 0$: a column vector of m inputs of the j-th DMU ($j = 1, \dots, n$), and
(b) $Y_j = \left(y_{1j}, y_{2j}, \dots, y_{sj}\right)^T > 0$: a column vector of s outputs of the j-th DMU ($j = 1, \dots, n$),

where the superscript "*T*" indicates a vector transpose. The inequality (>) implies that the relationship is applied to all components of the three column vectors.

In addition to the above production factors, which are given to us as an observed data set, this study uses the following symbols which are unknown to us and are measured by applying DEA:

(c) $d_i^x \geq 0$: an unknown slack variable of the i-th input ($i = 1, \dots, m$),
(d) $d_r^y \geq 0$: an unknown slack variable of the r-th output ($r = 1, \dots, s$),
(e) $\lambda = (\lambda_1, \dots, \lambda_n)^T$: an unknown column vector of "intensity" or "structural" variables,
(f) ε: a small number to be prescribed by a DEA user.

The input oriented radial DEA model used in this study is described as follows;

$$
\begin{array}{lll}
\text{Minimize} & \xi + \varepsilon\left[\sum_{i=1}^{m} R_i^x d_i^x + \sum_{r=1}^{s} R_r^y d_r^y\right] & \\
\text{s.t.} & \sum_{j=1}^{n} x_{ij}\lambda_j + d_i^x = \xi x_{ij} & (i = 1, \dots, m), \\
 & \sum_{j=1}^{n} y_{ij}\lambda_j - d_r^y = y_{rj} & (r = 1, \dots, s), \\
 & \sum_{j=1}^{n} \lambda_j = 1, & \\
 & \lambda_j \geq 0\ (j = 1, \dots, n), \xi\text{: URS}, d_i^x \geq 0\ (i = 1, \dots, m), d_r^y \geq 0\ (r = 1, \dots, s). &
\end{array}
$$

The output oriented radial DEA model used in this study is described as follows;

$$
\begin{array}{lll}
\text{Maximize} & \xi + \varepsilon\left[\sum_{i=1}^{m} R_i^x d_i^x + \sum_{r=1}^{s} R_r^y d_r^y\right] & \\
\text{s.t.} & \sum_{j=1}^{n} x_{ij}\lambda_j + d_i^x = x_{ij} & (i = 1, \dots, m), \\
 & \sum_{j=1}^{n} y_{ij}\lambda_j - d_r^y = \xi y_{rj} & (r = 1, \dots, s), \\
 & \sum_{j=1}^{n} \lambda_j = 1, & \\
 & \lambda_j \geq 0\ (j = 1, \dots, n), \xi\text{: URS}, d_i^x \geq 0\ (i = 1, \dots, m), d_r^y \geq 0\ (r = 1, \dots, s). &
\end{array}
$$

Both models produce an efficiency measure, which is described as follows;

$$1 - \left(\xi^* + \varepsilon\left[\sum_{i=1}^{m} R_i^x d_i^{x*} + \sum_{r=1}^{s} R_r^y d_r^{y*}\right]\right),$$

where asterisks indicate optimal value of variables obtained from solving the models, and R is a weight given to each slack variable. R is calculated based on maximum and minimum values of each input and output data.

Data

This study uses a data set of regional industries at the level of 47 prefectures in Japan over the period from 1990 to 2009 (20 periods). The data set aggregates all industry sectors in manufacturing and non-manufacturing industries into a national total statistics. The data set is comprised of one output and five inputs. The output is a gross product in real terms, and five inputs consist of intermediate input, number of employees, private capital stock, social capital stock and final energy consumption. Table 1 provides descriptive statistics of data.

Table 1: Descriptive statistics of data

Statistics	Gross product	Intermediate input	Number of employees	Private capital stock	Social capital stock	Final energy consumption
Avg.	19,962,756	8,898,717	1,329,486	21,209,427	16,276,676	262,751
Max.	174,850,215	83,209,622	8,785,204	170,473,914	72,474,451	1,333,681
Min.	3,186,866	1,213,080	289,970	2,576,761	3,821,977	34,509
S.D.	26,120,081	11,752,210	1,425,974	25,033,049	13,543,344	259,589

Note: Gross product, intermediate input, private capital stock and social capital stock are measured in one million Japanese Yen. Final energy consumption is measured in tera-joule.

Empirical Results

Table 2 presents HMB productivity indexes of nine regions, regional averages and changes of the index or the value of lnHMB from 1991 to 2009. The nine regions are summarized from 47 prefectures, because such aggregation is often used for discussions of regional policy issues. Figure 1 depicts the trend of HMB productivity index on average for each region and total (nation-wide) average of the index.

Table 2: HMB productivity index and its change for nine regions

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Hokkaido	1.008	0.993	1.008	0.975	0.991	0.994	0.989	1.005	0.995	1.018
Tohoku	0.981	0.978	0.991	0.997	0.977	0.993	0.999	1.004	0.996	1.014
Kanto	0.964	0.965	0.991	0.984	0.985	0.998	0.953	0.975	0.994	1.019
Chubu	0.988	0.980	0.997	0.982	0.996	1.009	0.992	0.994	0.998	1.036
Kinki	0.998	0.981	1.004	0.993	1.003	1.017	0.991	0.994	1.017	1.045
Chugoku	1.003	0.986	0.991	1.003	1.000	1.004	0.991	0.979	1.007	1.033
Shikoku	0.993	0.987	1.003	0.999	1.006	0.988	0.987	1.008	1.008	1.021
Kyushu	0.985	0.985	0.996	0.991	0.992	0.999	0.998	1.008	0.994	1.025
Okinawa	0.941	0.981	0.990	0.945	0.972	0.980	0.977	0.993	0.958	1.021
Avg.	0.986	0.980	0.996	0.990	0.993	1.002	0.987	0.994	1.000	1.028
HMB change	-0.014	-0.020	-0.004	-0.010	-0.007	0.002	-0.013	-0.006	0.000	0.028
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	Avg.
Hokkaido	1.0090	0.9969	1.0311	1.0095	0.9990	1.0102	1.0074	0.9872	0.9771	1.0001
Tohoku	0.9938	1.0029	1.0161	1.0226	1.0491	1.0778	1.0392	1.0334	0.9574	1.0064
Kanto	0.9717	1.0179	1.0297	1.0090	1.0183	1.0195	1.0167	0.9926	0.9592	0.9928
Chubu	0.9893	1.0211	1.0197	1.0203	1.0374	1.0086	1.0126	0.9795	0.9371	0.9999
Kinki	0.9836	1.0397	1.0413	1.0333	1.0340	1.0501	1.0110	0.9915	0.9556	1.0096
Chugoku	1.0066	1.0122	1.0155	1.0188	1.0259	1.0249	0.9999	0.9830	0.9578	1.0022
Shikoku	1.0023	1.0238	1.0365	1.0034	1.0132	1.0324	1.0006	1.0077	0.9744	1.0049
Kyushu	0.9820	1.0206	1.0303	1.0171	1.0532	1.0223	1.0137	1.0098	0.9506	1.0038
Okinawa	1.0021	1.0048	1.0241	1.0188	1.0097	1.0094	1.0117	0.9971	0.9932	0.9910
Avg.	0.9890	1.0194	1.0268	1.0185	1.0332	1.0311	1.0140	0.9979	0.9552	1.0022
HMB change	-0.0111	0.0192	0.0265	0.0183	0.0327	0.0306	0.0139	-0.0021	-0.0459	0.0020

From Table 2 and Figure 1, we find that Japanese economy experienced increasing productivity toward 2005 and 2006, although there are temporal up and down variations through the period, then it significantly decreased after the years. Regional disparity of productivity change once became larger along with the productivity growth, but it diminished after the years in parallel with the economic downturn.

In particular, Tohoku and Kinki was two regions that revealed higher productivity growth over the period, which are 1.0096 and 1.0064 in HMB productivity index on average. On the other hand, Kanto, which includes Tokyo metropolitan area, was less than average with 0.9928. Since regional aggregation dilutes characteristics of each prefecture, the result does not deny higher productivity arising from extensive resource concentration in Tokyo metropolitan area, as often indicated in regional policy debates.

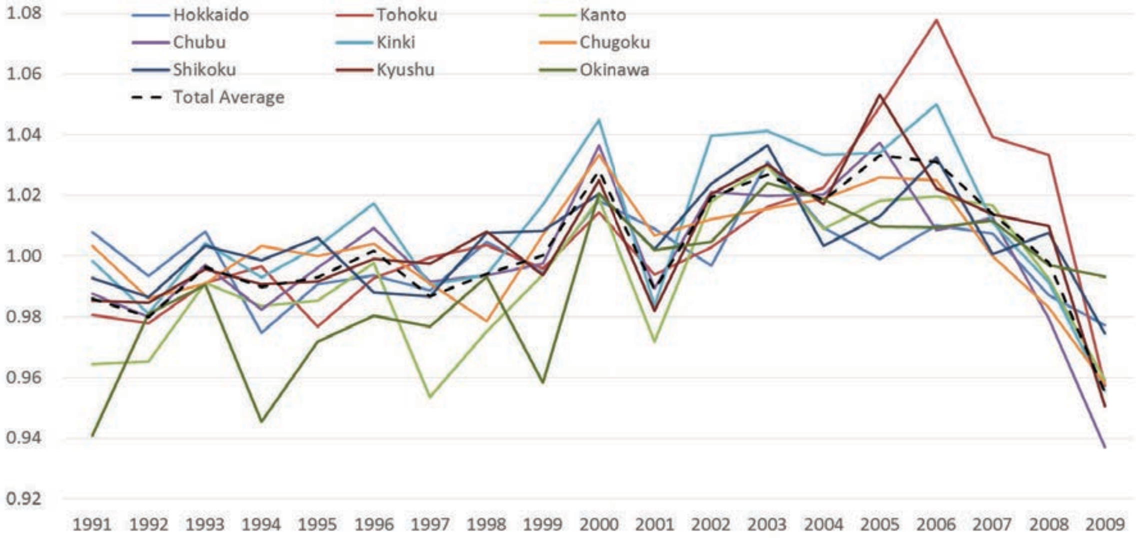

Figure 1: Trend of HMB productivity index from 1991 to 2009

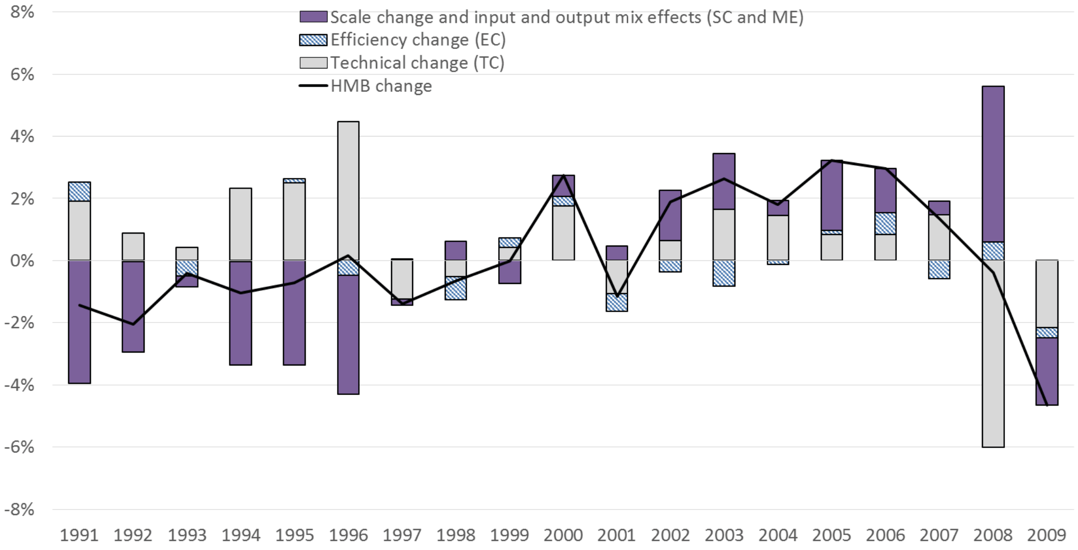

Figure 2: Decomposition of HMB productivity change from 1991 to 2009

Figure 2 presents the trend of HMB productivity change in percentage and results of the decomposition from 1991 to 2009. It should be noted that this study integrates SC and ME into one factor because of a reason for calculation.

This study summarizes three findings from the decomposition results. First, *TC* contributed to the productivity growth over the period, with the exception of a few years such as observed in negative impacts in 2008 and 2009. Second, *SC* and *ME* provided negative influences to productivity growth in the 1990s, but it changed to give positive impacts after the 2000s. Third, contribution of efficiency change to productivity growth was small over the period. That is, influences from supply shocks are more important to improve productivity growth in Japan compared to the demand shocks. Therefore, investment in infrastructure is critically important for Japanese economy, which supports shift in production frontier arising from technical advances. In addition, pursuing advantages produced from economies of scale would be a effective regional policy for higher productivity growth.

Conclusion

This study examined productivity change and the factors in Japan using a data set consisting of 47 prefectures over the period from 1990 to 2009. Using the data set, we measured HMB productivity change index and decomposed the productivity change into three factors, technical change component, efficiency change component and scale change and input and output mix effects. To measure the HMB productivity index, this study applied DEA. From the results, this study indicated regional disparity once increased toward 2005 and 2006, but after the years the regional differences drastically decreased in parallel with an economic downtown. From the decomposition analysis, we found that the economic downturn was mainly attributed to the negative impact due to the technical change component, and it influenced across a wide region of Japanese economy. These findings give us an idea that it is important for productivity growth in Japanese regional economy to promote technological advances that is realized by effective investment in infrastructure.

There are two tasks that should be overcome in future. First, HMB productivity index is capable of decomposition into four components. However, this study decomposed the productivity change only to three components due to calculation issues. Thus, this study does not separate input and output mix effects from scale change component. To complete the decomposition analysis by fully utilizing the virtue of HMB productivity index, this study needs to conduct additional calculations of DEA efficiency using different combinations of output and inputs. Second, the period covered in this study is from 1990 to 2009, but it needs to be further extended to examine recent policy effects of Abenomics. This is important because Japanese economy is recovering from the "lost two decades," after the bubble economy. These are two remaining tasks of this study.

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