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The impact of defense expenditure on economic productivity in OECD countries

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ABSTRACT

Evaluating the effects of defense spending on macroeconomic performance and, in particular, on economic productivity is a critical issue. This study integrates Malmquist productivity index (MPI) with bootstrapping to establish statistical inferences that provide a complete, effective analysis of the impact of defense expenditure on economic productivity between 1993 and 2009 for Economic Co-operation and Development member countries. The findings indicate that the average MPI with defense expenditure is higher than that without defense expenditure. Additionally, region based productivity analysis indicates that the appropriate allocation of defense expenditure can increase regional economic productivity effectively across Asia, Oceania and Europe. Moreover, the results further prove that the effective defense expenditure strategies undertaken by government are important for improving economic productivity of countries. The integrated methodology approach applied in this study can be used for further similar studies.

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1. Introduction

Defense expenditure is part of government's fiscal strategy to ensure the strength of the economy and national security. Defense expenditure comes from national finance that receives revenue through the redistribution of household incomes. Therefore, the scale of defense expenditure is limited by national finance conditions. Generally, if national finance is in good condition, the scale of defense expenditure is potentially larger. The status or condition of national finance is ultimately limited by the level of economic development. Faster economic development produces a higher growth rate and results in the availability of more resources for defense expenditure. DeGrasse (1993) showed that defense expenditure provides and creates job opportunities, increases workers' buying power, introduces greater demand, and boosts economic growth. Benoit (1978) argued that increasing military expenditure can promote economic growth and improve the quality of human capital through education. Particularly in underdeveloped countries, military industry fosters technological intensity in other industries such as aerospace industry.

Military industry has a positive impact on a country's development through network infrastructure development, such as the development of infrastructure (highways, airports, harbors, and telecommunication technologies), and ultimately boosts economic growth. Therefore, defense expenditure provides internal and external security and safety for a country's citizens, and creates a worldwide environment for trade and investment opportunities. Furthermore, the defense economics literature argued that the evaluation of military spending as necessary to manage changing markets and encourage investments and innovations is eventually to ensure the safety of people and property from internal and external threats (Dunne et al., 2005). That is, in the long term, defense expenditure provides national security and boosts economic growth (Ram, 1996).

However, Deger and Smith (1983) argued that increasing defense expenditure may hinder economic growth. Sivard (1996) also showed that defense expenditure excludes other economic activities, such as public education and healthcare. Safdari et al. (2011) showed an insignificant effect of military expenditure on economic growth in developing countries (Iran and Saudi Arabia), but in industrialized countries (South Korea and Malaysia), military expense and economic growth have a one-way or two-way correlation effect. To extend the scope of research, Chang et al. (2011) incorporated economic development perspective across countries to analyze the possible relationships between military expenditure and economic growth. The result identified that the crowding-out effect of military spending in turn would lead to ensuing economic slowdown. Using the Feder–Ram and military Keynesian Models to examine the link between defense expenditure and economic growth, Wijeweera and Webb (2012) further indicated that the national economic growth is dependent upon the political decision of the government for recognition. Pieroni (2009) also highlighted a weak substitution of defense

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expenditure on aggregate consumption. Regardless of the negative or positive impact of defense expenditure on economic growth, the core value of defense expenditure is to ensure national security and protect a nation from external threats (Feridun et al., 2011).

The spatiotemporal background and characteristics (resources and geographical location) of a country, level of external threats, and level of internal political stability affect defense expenditure and economic growth. Countries with high defense expenditure do not necessarily experience economic recession. A country with low defense expenditure may not experience high economic growth. However, economic growth is a key factor influencing the supply of defense expenditure. Therefore, the impact of defense expenditure on economic productivity and the strategic issues behind it is a significant issue for further discussions. Maintaining the optimal size of government spending by including practical decompositions of military spending into private sector expenditure such as consumption and investment is the best way to achieve economic growth (d'Agostino et al., 2011).

The Organization for Economic Co-operation and Development (OECD)[3] was founded to assist member countries to maintain advantages in economy, education, and society. The organization provides advice and numerous reports for creating farsighted national policies. The OECD promotes the development of developed and developing countries, emphasizes the establishment of robust economic systems, improves free trade mechanisms in the market, and provides member countries with a think tank for policy-making, as well as a platform for information exchange (e.g., Ministers' conferences and professional forums). In the upcoming era of the global village, "internalization" and "involvement in international affairs" are crucial factors for all governments to increase competitive capability.

Therefore, this study investigates the impact of national defense on economy by taking OECD member countries as research subject units. A majority of previous studies have mainly conducted longitudinal analyses of defense, economy, and other factors for "a single country" or "across countries" (e.g., unemployment rate, political factors, or budget deficits) without exploring the impact of defense expenditure on economic productivity. This study uses the Malmquist productivity index (MPI) of data envelopment analysis (DEA) to measure the economic productivity changes of numerous countries across several periods. However, the disadvantage of traditional MPI is that it cannot provide statistical inferences. Therefore, we integrate MPI with bootstrapping to establish statistical inferences that provide a complete, effective analysis of the impact of defense expenditure on economic productivity between 1993 and 2009 for OECD member countries.

This paper measures the macroeconomic performance of OECD countries by moderating unwanted externalities of economic growth using panel data between 1993 and 2009, and comparing efficiency changes in productivity. In this study, performance is defined by a country's capability to provide citizens with wealth and less defense expenditure. Based on the economic theory of production, productivity is generally defined as the efficiency of inputs (e.g., capital and labor) being transformed into outputs (e.g., gross domestic product, GDP) through production. Defense expenditure is added and the analysis is repeated to determine changes in productivity performance.

MPI measures productivity changes by considering panel data (Caves et al., 1982a,b; Lo and Lu, 2009). Malmquist (1953) first proposed a quantity index that can be used to construct the productivity indexes, as ratios of input or output distance functions. This method was applied by Färe et al. (1994a,b) to analyze productivity growth of OECD countries by considering labor and capital as inputs and GDP as an output. Numerous reasons for the popularity of MPI exist. First, the index demands less data because it does not require information on cost or revenue shares to aggregate inputs and outputs. Second, MPI has the advantage of simpler computation compared with other productivity indices. Finally, the bootstrap estimation procedure allows the construction of confidence intervals for DEA-based Malmquist indices of productivity and their decompositions of efficiency changes. The bootstrap estimation procedure can determine whether differences between two or more estimates are statistically significant. Simar and Wilson (1999) have also discussed the bootstrap approach which has the advantage of allowing for the inclusion of random errors while making it possible to obtain statistical properties of the efficiency estimates.

The remainder of this paper is organized as follows: Section 2 introduces an estimation methodology, including techniques that address the MPI and bootstrapping. Section 3 introduces the sample and data collection. Section 4 presents the empirical results and analysis. Finally, the conclusion is discussed.

2. Methodology

2.1. Measuring productivity change: the Malmquist productivity index (MPI)

MPI was first introduced by Malmquist (1953), and has been studied and further developed by several authors in the nonparametric framework, such as examples illustrated in Caves et al. (1982a,b) and Färe et al. (1994a,b). It is an index that represents the total factor productivity (TFP) growth of a decision-making unit (DMU), and reflects progress in efficiency, and progress or regress of the frontier technology between two periods in the multiple inputs and multiple outputs framework. Fig. 1 shows the MPI measures using a single output (Y) and two inputs (X1 and X2) for country A. MPI under constant returns to scale (CRS) for technology indicates a rise in potential productivity as the technology frontier shifts from period 1 t to 2 t. Efficiency change (EC) and technological change (TC) shown in Fig. 1 are represented by the distance functions.

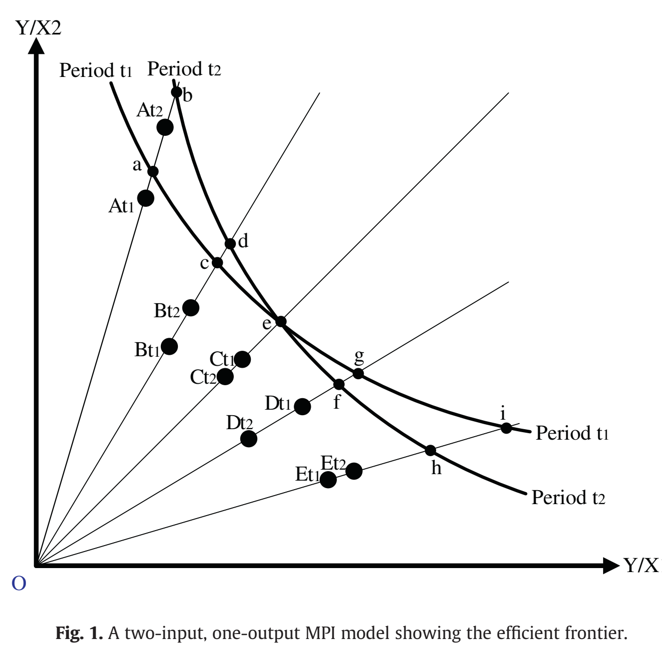

Fig. 1. A two-input, one-output MPI model showing the efficient frontier.

The country's productivity level is less than what is feasible under each period. Furthermore, it does not require input and output prices and it is likely to compute productivity only with information on quantity. MPI measures the changes in TFP and is calculated as a product of EC (efficiency change) and TC (technical efficiency change) in Eq. (1). An MPI value is greater than one which indicates productivity growth, whereas an MPI value is less than one which indicates a decline in productivity. Additionally, increases in either of the two MPI components are also associated with values greater than one, and any declines are associated with values less than one.

$$\mathrm{MPI} = \left[\frac{D^{t_2|t_2}}{D^{t_1|t_1}}\right] \times \left[\frac{D^{t_1|t_2}}{D^{t_2|t_2}} \times \frac{D^{t_1|t_1}}{D^{t_2|t_1}}\right]^{\frac{1}{2}} = \mathrm{EC} \times \mathrm{TC}. \tag{1}$$

MPI distance functions are calculated using linear programs similar to DEA. Benefits of using a DEA-type efficient frontier technique include non-reliance on price information; organizations must be assumed to be efficient. The linear programs, $D^{t_1|t_1}$, $D^{t_2|t_2}$, $D^{t_2|t_1}$ and $D^{t_1|t_2}$, are as follows.

As an example, assume that there are $j = 1,\ldots,n$ countries that produce $r = 1,\ldots,q$ outputs $Y_k^{t_1} = (y_{1k}^{t_1}, y_{2k}^{t_1}, \ldots, y_{qk}^{t_1})$ using $i = 1,\ldots,p$ inputs $X_k^{t_1} = (x_{1k}^{t_1}, x_{2k}^{t_1}, \ldots, x_{pk}^{t_1})$ at each period $t = t_1, t_2$. Input-orientated DEA-type linear programs with constant returns to scale (CRS) are summarized in Eqs. (2)–(5). Eqs (2)–(3) represent the cases where a datum point observed in a period is compared to the production technology (frontier) for that period. Similarly, data points are compared to the technology of the previous period in Eqs. (4)–(5). Eqs. (2)–(5) must be solved once for each country in each pair of adjacent time periods.

$$\begin{aligned} D^{t_1|t_1} &= \underset{\theta,\lambda}{Min}\,\theta \\ st - y_{rk}^{t_1} &+ \sum\nolimits_{j=1}^{n} \lambda_{kj}^{t_1} y_{rj}^{t_1} \geq 0,\ r = 1,\ldots,q, \\ \theta x_{ik}^{t_1} &- \sum\nolimits_{j=1}^{n} \lambda_{kj}^{t_1} x_{ij}^{t_1} \geq 0,\ i = 1,\ldots,p, \\ &\theta, \lambda_{kj}^{t_1} \geq 0. \end{aligned} \tag{2}$$

$$\begin{aligned} D^{t_2|t_2} &= \underset{\theta,\lambda}{Min}\,\theta \\ st - y_{rk}^{t_2} &+ \sum\nolimits_{j=1}^{n} \lambda_{kj}^{t_2} y_{rj}^{t_2} \geq 0,\ r = 1,\ldots,q, \\ \theta x_{ik}^{t_2} &- \sum\nolimits_{j=1}^{n} \lambda_{kj}^{t_2} x_{ij}^{t_2} \geq 0,\ i = 1,\ldots,p, \\ &\theta, \lambda_{kj}^{t_2} \geq 0. \end{aligned} \tag{3}$$

$$\begin{aligned} D^{t_2|t_1} &= \underset{\theta,\lambda}{Min}\,\theta \\ st - y_{rk}^{t_1} &+ \sum\nolimits_{j=1}^{n} \lambda_{kj}^{t_2} y_{rj}^{t_2} \geq 0,\ r = 1,\ldots,q, \\ \theta x_{ik}^{t_1} &- \sum\nolimits_{j=1}^{n} \lambda_{kj}^{t_2} x_{ij}^{t_2} \geq 0,\ i = 1,\ldots,p, \\ &\theta, \lambda_{kj}^{t_2} \geq 0. \end{aligned} \tag{4}$$

$$\begin{aligned} D^{t_1|t_2} &= \underset{\theta,\lambda}{Min}\,\theta \\ st - y_{rk}^{t_2} &+ \sum\nolimits_{j=1}^{n} \lambda_{kj}^{t_1} y_{rj}^{t_1} \geq 0,\ r = 1,\ldots,q, \\ \theta x_{ik}^{t_2} &- \sum\nolimits_{j=1}^{n} \lambda_{kj}^{t_1} x_{ij}^{t_1} \geq 0,\ i = 1,\ldots,p, \\ &\theta, \lambda_{kj}^{t_1} \geq 0. \end{aligned} \tag{5}$$

2.2. Bootstrap in Malmquist productivity index

The bootstrap method introduced by Efron and Tibshirani (1993) is a general resampling procedure f for estimating the distributions of statistics based on independent observations, and has been studied and further developed by several authors in the nonparametric framework, such as Caves et al. (1982a,b) and Färe et al. (1992, 1994).

As a deterministic model, MPI does not explicitly model random error terms, and the overall deviation from the frontier is interpreted as inefficiency. However, MPI accuracy may be affected by sampling variation. In the input-oriented model, efficiency estimates might be biased toward higher scores (i.e., approaching one), whereas efficiency estimates in the output model might be biased downward if the countries that determine the frontier are not contained in the sample. Attention to sampling noise in the efficiency estimates is increasing in relevant literature, although previous studies about country efficiency typically ignore this problem.

Bootstrap methodology is the only approach that can be employed to investigate the sampling variability of MPI point estimates by correcting the bias inherent in the MPI procedure and providing confidence intervals (Simar and Wilson, 2000a) in multi-output or multi-input cases. The bootstrapping procedure relies on repeating the parameter estimation with data resampled by mimicking the data generation process, which in this case is the process generating the efficiency scores. The observed distribution is taken to be an estimate of the true distribution (Brümmer, 2001).

The smoothed homogeneous bootstrap method and the procedure proposed by Simar and Wilson (1998, 2000b) were applied. The bandwidth parameters were selected according to the normal reference rule (Simar and Wilson, 2000b), and 3000 bootstrapping iterations were performed. Ninety-five percent confidence intervals were constructed using bootstrapping. Simar and Wilson (2007) have discussed these issues. For the MPI approach, the complete bootstrap algorithm is summarized by the following steps:

Step 1 From the original data set χ_n, compute $\hat{\theta}_k^t$ using Eq. (6) for each observation (x_{ij}^t, y_{rj}^t), $r = 1,\ldots,q;\ i = 1,\ldots,p;\ j = 1,\ldots,n; t = t_1, t_2$.

$$\hat{\theta}_k^t = Min\{\theta_k | y_k^t \leq \sum\nolimits_{j=1}^{n} \lambda_{kj}^t y_{rj}^t; \theta_k x_{ij}^t \geq \sum\nolimits_{j=1}^{n} \lambda_{kj}^t x_{ij}^t; \quad \theta_k > 0, \lambda_j^t \geq 0,\ k = 1,\ldots,n\}. \tag{6}$$

Step 2 Using the smooth bootstrap method, generate a random sample of size n from $\hat{\theta}_k^t (k = 1,\ldots,n, t = t_1, t_2)$ to obtain $\theta_1^{t^*},\ldots,\theta_n^{t^*}$. The smoothed bootstrap steps are summarized as follows:

- Generate $\tau_1^{t^*},\ldots,\tau_n^{t^*}$ by selecting replacements from the set D_{2n}^t, $t = t_1, t_2$.

$$D_{2n}^t = \left\{\hat{\theta}_1^t,\ldots,\hat{\theta}_n^t,\ \left(2-\hat{\theta}_1^t\right),\ldots,\left(2-\hat{\theta}_n^t\right)\right\} \tag{7}$$

- Select a value for h. Silverman (1986) shows an optimal value for bivariate data by setting $h = (4/5n)^{-1/6}$ because this study uses a bivariate normal kernel scaled to possess an identical shape as the data.
- For $k = 1,\ldots,n, t = t_1, t_2$, compute $\theta_k^{t^*}$

$$\theta_k^{t*} = \begin{cases} \gamma_k^t & \text{if}\,\gamma_k^t \leq 1 \\ 2-\gamma_k^t & \text{otherwise} \end{cases}, \tag{8}$$

where $\varepsilon_k^{t^*}$ is a random deviant drawn from the standard normal and $\gamma_k^t = (1+h^2)^{-1/2}(\tau_k^{t^*} + h\varepsilon_k^{t^*} - \sum_{k=1}^{n}\tau_k^{t^*}/n) + \sum_{k=1}^{n}\tau_k^{t^*}/n$.

Step 3 Repeat step 2 B times to provide for $k = 1,\ldots,n$ a set of bootstrap samples $\chi_b{}^* = \{(x_{ikb}^{t^*}, y_{rk}^{t^*}) |\ k = 1,\ldots,n,\ b = 1,\ldots,B\}$, where $\left(x_{ikb}^{t*} = \left(\hat{\theta}_k^t/\theta_{kb}^{t*}\right)x_{ikb},\ y_{ikb}^{t*} = y_{ikb}\right)$, $k = 1,\ldots,n$, $t = t_1, t_2$, $b = 1,\ldots,B$.

Step 4 The distance functions, $\{\hat{D}_{kb}^{t_1|t_2*}, \hat{D}_{kb}^{t_2|t_2*}, \hat{D}_{kb}^{t_1|t_2*}, \hat{D}_{kb}^{t_2|t_1*}\}_{b=1}^{B}$, between t_1 and t_2 are measured to obtain bootstrap estimates for each country $k = 1,\ldots,n$. These estimates can then be used to construct bootstrap estimates $\left\{\widehat{\mathrm{MPI}}_{kb}^{*}(t_1, t_2)\right\}_{b=1}^{B}$,

$\widehat{EC}^*_{kb}(t_1,t_2)$, and $\widehat{TC}^*_{kb}(t_1,t_2)$, where ($k=1,\ldots,n$ and $b=1,\ldots,B$) corresponds to Eqs. (2)–(5), respectively, by replacing the true distance function values in Eqs. (2)–(5) with their corresponding bootstrap estimates. Hall (1986) suggested setting $B=1000$ to ensure adequate coverage of the confidence intervals.

Step 5 Estimate the confidence intervals for each observed country. From this procedure, the construction of confidence intervals can be based on bootstrap percentiles (Simar and Wilson, 1998). However, the MPI, EC, and TC estimators must be corrected for bias, and this introduces additional noise (Simar and Wilson, 2000a). Simar and Wilson (2000b) proposed a procedure that automatically corrects bias. As an example, consider a set of bootstrap estimates for the MPI of country k: $\left\{\widehat{\mathrm{MPI}}^*_{kb}(t_1,t_2)\right\}_{b=1}^{B}$. The EC and TC indices can be analyzed similarly by changing MPI to EC or TC, as noted below. For a $(1-\alpha)$ percent confidence interval, it starts from the following probability:

$$\Pr\left(-\mathrm{a}_\alpha \le \widehat{\mathrm{MPI}}_k(t_1,t_2) - \mathrm{MPI}_k(t_1,t_2) \le -\mathrm{b}_\alpha\right) = 1-\alpha, \tag{9}$$

where $\mathrm{MPI}_k(t_1,t_2)$ denotes the real productivity score of the kth country. Because the distribution $(\widehat{\mathrm{MPI}}_k(t_1,t_2) - \mathrm{MPI}_k(t_1,t_2))$ can be approximated by the distribution $(\widehat{\mathrm{MPI}}^*_k(t_1,t_2) - \widehat{\mathrm{MPI}}_k(t_1,t_2))$, a_α and b_α can be estimated using the following probability:

$$\Pr\left(-\hat{a}_\alpha \le \widehat{\mathrm{MPI}}^*_k(t_1,t_2) - \widehat{\mathrm{MPI}}_k(t_1,t_2) \le -\hat{b}_\alpha\right) = 1-\alpha. \tag{10}$$

Finding $\hat{\mathrm{a}}_\alpha$ and $\hat{\mathrm{b}}_\alpha$ involves sorting the values $(\widehat{MPI}^*_{kb}(t_1,t_2) - \widehat{MPI}_k(t_1,t_2))$ for $b=1,\ldots,B$ in ascending order, and then deleting $((\alpha/2)\times 100)$ percent of elements at both ends of the sorted list. The variables $-\mathrm{a}_\alpha$ and $-\mathrm{b}_\alpha$ are equal to the end points of the truncated array, with $\mathrm{a}_\alpha \le \mathrm{b}_\alpha$. Thus, the estimated $(1-\alpha)$ percent confidence interval for $\mathrm{MPI}_k(t_1,t_2)$ of the kth country is:

$$\widehat{MPI}_k(t_1,t_2) + \hat{\mathrm{a}}_\alpha \le \mathrm{MPI}_k(t_1,t_2) \le \widehat{MPI}_k(t_1,t_2) + \hat{\mathrm{b}}_\alpha \tag{11}$$

3. Data selection and description

This study primarily examines the impact of defense expenditure on economic productivity in OECD countries. MPI is used to measure economic productivity and investigate four data items, "defense expenditure," "GDP," "capital," and "labor force" (the definitions of input and output items and descriptive statistics are shown in Table 1), for 32 countries. These items are used as variables and the correlations between them are examined.

This study extracts a total of 512 annual data from the 32 countries between 1993 and 2009. A world frontier is constructed from the data from a specific country. In the analysis without defense expenditure impacts, there are two inputs and one output. Capital and labor forces comprise the inputs, and GDP is the output for a specific country. The data of our multiple comparisons are obtained from the World Bank. Transformed defense expenditure is also added to the model. The defense expenditure data were obtained from the Stockholm International Peace Research Institute.

Macroeconomic performance is evaluated according to a country's ability to maximize desirable GDP output and minimize defense expenditure. Summary statistics of these inputs and outputs are shown in Table 2. Fig. 2 shows that the average value for overall defense expenditure increased significantly between 1994 and 1998, and that variation among countries increased after 2000. Therefore, investigating the impact of defense expenditure on economic productivity has become an essential topic.

4. Empirical results and discussion

4.1. Productivity change with/without defense expenditure

Using MPI, the average cumulative changes of 32 OECD countries' productivity with/without defense expenditure are shown in Fig. 3, with 1993 as the base year. The overall productivity growth with/without defense expenditure increased steadily from 2000 to the end of the sample period. The productivity growth without defense expenditure is less than the productivity growth with defense expenditure for every year. The gap between these two trends seems to be widening each year. In 2009, the difference was approximately 7.45%.

Further comparisons considering defense expenditure among countries are displayed in Table 3. On the left side, MPI without defense expenditure of the total sample is 1.010, with 25 OECD countries' indices exceeding unity, implying that these had positive production growth. Ireland had the highest productivity growth, followed by Norway, Turkey, Israel and USA. Table 3 also indicates an increase in MPI (on average, 1.0% per year) driven more by technological progress than technical efficiency.

The computation was repeated after adding the transformed defense expenditure data. The average MPI is shown on the right side of Table 3, with a defense expenditure total sample mean of 1.015. Among the 32 OECD countries, Ireland, Norway and Turkey rank higher regardless of

Table 1
Descriptions of input and output variables in MPI model.

Variables	Unit	Description
GDP (output)	US$ millions	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.
Capital (input)	US$ millions	Gross capital formation (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.
Labor (input)	Million population	Total labor force comprises people ages 15 and older who meet the International Labor Organization definition of the economically active population.
Defense expenditure (input)	US$ millions	A military budget (or military expenditure), also known as a defense budget, is the amount of financial resources dedicated by an entity (most often a nation or a state), to raising and maintaining an armed forces.

Data source: (1) World Bank Group (1993–2009) (2) Stockholm International Peace Research Institute(1993–2009). (3) International Monetary Fund (1993–2009).

Table 2
Descriptive Statistics for Inputs and Outputs.

Pearson Correlations	GDP	Capital	Labor	Defense Expenditure
GDP	1.000			
Capital	0.969	1.000		
Labor	0.955	0.903	1.000	
Defense expenditure	0.924	0.939	0.850	1.000

Year	Output data		Input data					
	GDP		Capital		Labor		Defense expenditure	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1993	647,708.6	1,371,542.5	137,202.4	293,789.5	16.0	25.8	26,794.2	77,864.5
1994	692,070.2	1,471,784.2	149,335.0	319,886.1	16.2	26.2	25,715.6	73,185.1
1995	760,584.9	1,572,415.2	166,418.0	346,025.5	16.3	26.5	24,669.9	69,218.6
1996	766,006.7	1,574,878.3	166,241.4	338,554.9	16.5	26.8	24,123.0	65,532.8
1997	754,548.8	1,610,349.0	164,971.8	343,431.7	16.7	27.3	24,034.9	65,164.2
1998	761,363.2	1,657,088.7	164,161.9	345,618.6	16.9	27.6	23,833.6	63,695.5
1999	800,588.1	1,773,973.2	173,012.1	373,686.0	17.1	27.9	24,099.2	63,855.2
2000	817,183.6	1,878,776.9	180,106.2	402,224.8	17.2	28.2	24,636.5	66,240.6
2001	809,365.0	1,897,204.7	167,643.6	374,529.3	17.3	28.3	24,761.0	66,757.7
2002	845,890.8	1,946,966.9	168,117.1	366,806.7	17.5	28.5	26,544.8	74,785.2
2003	950,223.9	2,052,586.7	189,614.9	385,988.1	17.6	28.6	28,454.6	84,987.7
2004	1,057,804.3	2,196,226.6	217,759.9	431,471.6	17.8	28.7	29,856.6	92,528.4
2005	1,116,454.3	2,313,774.0	234,536.8	465,878.1	18.0	29.0	30,648.5	96,851.0
2006	1,178,266.2	2,429,591.2	253,964.0	493,615.9	18.2	29.4	31,090.1	98,289.5
2007	1,291,666.3	2,560,505.7	277,205.8	495,644.9	18.4	29.7	31,657.5	100,827.8
2008	1,370,891.3	2,634,570.8	285,286.6	475,938.8	18.6	30.0	33,227.6	108,261.7
2009	1,285,930.7	2,592,037.9	226,701.9	387,900.1	18.7	30.0	35,190.1	116,972.6

Note: SD stands for "standard deviation."

defense expenditure. The average MPI with defense expenditure (MPI-D) is higher than that without defense expenditure, and so is the TC index. The relationship coefficient between MPI and MPI-D is 0.908. Therefore the appropriate allocation of defense expenditure can increase national economic productivity effectively.

In summary, overall productivity for MPI-D is greater than that for MPI without defense expenditure, indicating that defense expenditure had an impact on increasing economic productivity during the study period. For example, through collaboration with the defense industry, a country can provide and create job opportunities, increase workers' purchasing power, and boost economic growth by increasing demand. Furthermore, through education, a country can improve the quality of human capital, infrastructure (highways, airports, harbors, and information technologies) can be developed, military and private enterprises can complement each other and achieve a combined effect, and civilian industry can be upgraded through the development of defense industry. For example, defense technology can be privatized, converting investments into products and creating economic benefits. Civilian industry can be assisted to upgrade technologies through technology transfer, and private sectors can be encouraged to participate in defense construction. This enhances the progress of technology, moves the efficiency frontier (efficient frontier) forward, and ultimately boosts the growth of national economic productivity.

4.2. Regional productivity changes

The results in the previous section show that defense expenditure as included in the MPI-D can boost economic productivity. Next, OECD countries are divided into three regions for examination. Because threats faced by countries are primarily from intra-regional competition or resource preemption, we used the concept of region as a basis for analysis. First, we analyze the productivity change presented in Fig. 4.

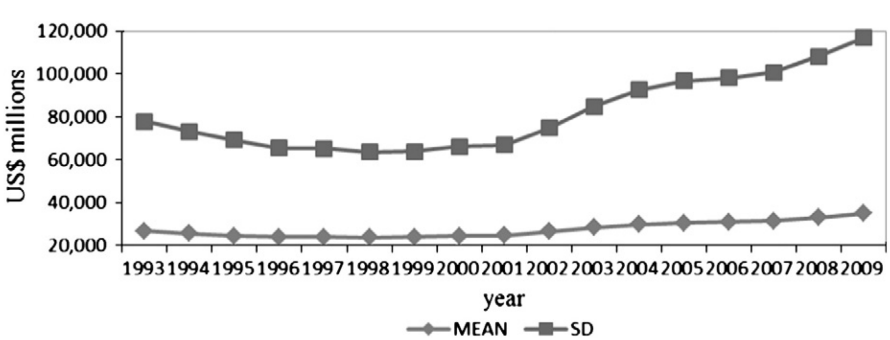

Fig. 2. Mean and standard deviation (defense expenditure).

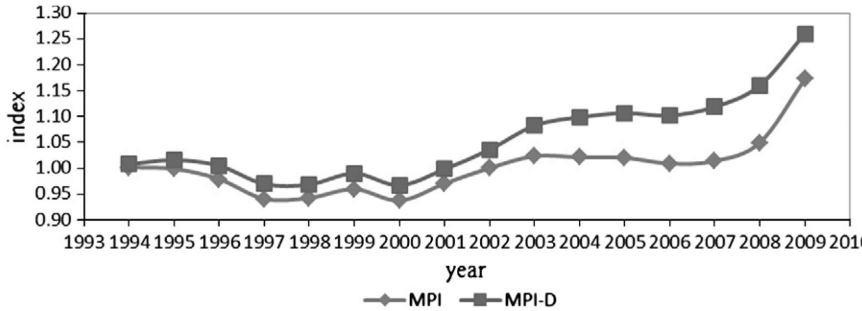

Fig. 3. Cumulative change in the MPI.

The results show that productivity changes in Europe (MPI-E) are significantly less than those in the Americas (MPI-A), as well as Asia and Oceania (MPI-A&O). MPI-A was lower than MPI-A&O prior to 2000 and greater than MPI-A&O after 2000. This increase in productivity may have resulted from an increase in arms sales in the United States.

Fig. 5 shows consistency in TC among continents despite small variations in some years. This indicates that each continent combines defense industry into industrial development effectively and improves production technology. The modernization of defense technology affects the defense industry and improves production technology for the whole economy.

Finally, Fig. 6 shows that EC in Europe (EC-E) is significantly less than in the Americas (EC-A), as well as Asia and Oceania (EC-A&O). Because the ratios of defense expenditure to GDP in European countries are lower than the Americas, Asia, and Oceania, utilization

Table 3
Decomposition of MPI without/with defense expenditure by country.

Country	Average annual change without defense expenditure			Average annual change with defense expenditure		
	Malmquist index (MPI)	Technical change (TC)	Efficiency change (EC)	Malmquist index (MPI-D)	Technical change (TC-D)	Efficiency change (EC-D)
Americas						
Canada	0.994	1.009	0.985	1.007	1.025	0.982
Chile	1.021	1.005	1.016	1.021	1.005	1.016
Mexico	0.996	1.006	0.990	1.007	1.007	1.000
USA	1.025	1.027	0.998	1.025	1.027	0.998
Mean	1.009	1.012	0.997	1.015	1.016	0.999
Asia and Oceania						
Australia	1.000	1.010	0.990	1.001	1.013	0.989
Israel	1.028	1.014	1.014	1.028	1.014	1.014
Japan	1.003	1.024	0.980	1.009	1.028	0.981
Korea, South	1.023	1.010	1.013	1.018	1.014	1.004
New Zealand	1.011	1.009	1.002	1.033	1.037	0.996
Mean	1.013	1.013	1.000	1.018	1.021	0.997
Europe						
Austria	1.014	1.022	0.992	1.021	1.030	0.991
Belgium	1.011	1.021	0.991	1.018	1.027	0.992
Czech Rep.	1.014	1.006	1.008	1.020	1.011	1.009
Denmark	1.014	1.019	0.995	1.019	1.024	0.995
Estonia	1.020	1.007	1.013	1.009	1.009	1.000
Finland	1.004	1.012	0.993	1.012	1.019	0.993
France	1.007	1.019	0.988	1.008	1.020	0.988
Germany	1.013	1.018	0.995	1.015	1.021	0.994
Greece	1.013	1.006	1.007	1.013	1.006	1.007
Hungary	0.994	1.006	0.988	1.000	1.011	0.989
Ireland	1.040	1.040	1.000	1.043	1.043	1.000
Italy	1.009	1.017	0.992	1.012	1.020	0.991
Netherlands	1.016	1.021	0.995	1.018	1.023	0.995
Norway	1.037	1.036	1.002	1.037	1.036	1.002
Poland	0.983	1.005	0.978	0.985	1.006	0.979
Portugal	1.007	1.006	1.001	1.008	1.007	1.001
Slovak Rep.	0.974	1.006	0.968	0.986	1.006	0.980
Slovenia	0.985	1.002	0.983	0.996	1.014	0.983
Spain	0.997	1.009	0.988	1.014	1.030	0.984
Switzerland	1.000	1.012	0.988	1.011	1.023	0.988
Sweden	1.020	1.027	0.993	1.026	1.027	0.999
Turkey	1.036	1.005	1.031	1.034	1.003	1.031
UK	1.014	1.010	1.004	1.014	1.010	1.004
Mean	1.010	1.014	0.995	1.014	1.019	0.995
Total mean	1.010	1.014	0.996	1.015	1.019	0.996

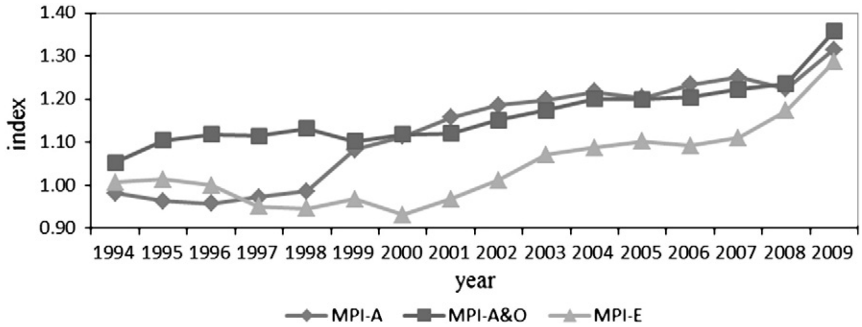

Fig. 4. Cumulative change in the MPI for three regions.

efficiency in Europe is relatively lower than other continents. The Americas had lower efficiency in defense expenditure utilization than Asia and Oceania, except for the years 1999, 2006, and 2009. However, the Americas experienced greater EC and overall stability in 2009, indicating that defense expenditure could assist overall industrial development and boost economic growth. Additionally, the greatest reduction of EC from 2008 to 2009 resulted from the global financial crisis, as well as the subprime lending crisis in the United States that negatively affected economies worldwide.

Although the overall performance of Europe is worse than other continents, changes in various European indices are lower than other continents. Because Europe was the origin of the industrial revolution and has experienced significant financial loss from two world wars, Europe began to combine politics and economics to defend against the powerful United States and avoid a third tragedy. Additionally, the economic unity of the European Union is strong because no natural boundary exists between European countries (Life Science, 2010). Because Europe's social welfare expenditure ratio is higher than other continents, the defense expenditure in Europe is more stable than other continents. In the Americas, Asia, and Oceania, the consistency of development levels among countries is lower. The overall performance of the Americas is boosted by the United States' role as a primary supplier of arms and its deployment of soldiers in several countries. Various economic indices fluctuate significantly in Asian countries because of a greater potential for conflict, and a significant difference in political environments, religious backgrounds, and wealth gaps.

4.3. Statistical inferences in the Malmquist productivity index

Maintaining the assumption of constant returns to scale, this study applied the discussed bootstrap methods to obtain bias and variance estimates, and to test for significant differences from unity, with the *B* value set at 2000. Additionally, an asterisk (*) is used to indicate cases where the indices are significantly different from unity (0.05). Results for the original and bootstrap estimates are presented in Appendices A–C.

Examining changes in efficiency shows that "Mexico" is efficient in all time periods, as indicated by unity values for EC between all successive pairs of years (see Appendix A). Three countries had statistically insignificant changes in all but one pair of years (Austria, Norway and Sweden). Only 174 (40.5%) of the 430 EC estimates shown in Appendix A differ significantly from unity. The TC index in Appendix B shows that the bootstrap results support the MPI statements regarding TC. This study shows that between 2000 and 2001, as well as 2008 and 2009, most countries experienced technical progress. The results show that the TC estimates are statistically non-significant at the 0.05 level between 1998 and 2000 in all. TC estimates between 2006 and 2007 are statistically non-significant at the 0.05 level, except for 2 instances.

The productivity change results (see Appendix C) generally support MPI statements. This study found productivity gains in 312 cases and productivity losses in 192 cases, whereas this research identified significant (at 0.05) gains in 279 cases, and significant (at 0.05) losses in 175 cases; 90.1[(279+175)/(312+192)] percent of the estimates shown in Table 4 differ significantly from unity at the 0.05 level.

In summary, the bootstrap method corrects inherent MPI bias, and is a suitable method for checking whether bias-correction increases mean-square errors. Confidence intervals are essential for interpreting MPI estimates. As with any estimator, it is insufficient to determine if the MPI estimator indicates an increase or decrease in productivity; the goal is to determine if the indicated changes are statistically significant. The bootstrap procedure allows researchers to make these distinctions.

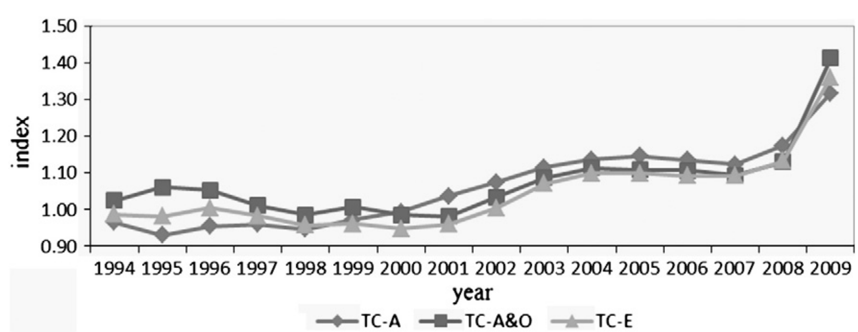

Fig. 5. Cumulative change in the technical change for three regions.

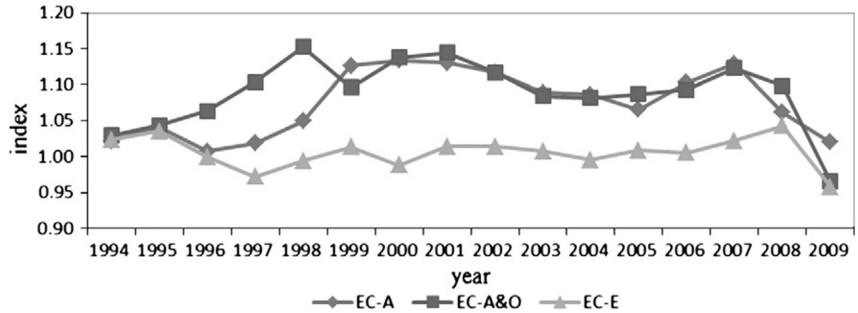

Fig. 6. Cumulative change in the efficiency change for three regions.

5. Conclusion

This study applied MPI and the bootstrap methods to explore the impact of defense expenditure on economic productivity of OECD countries. The results show that the productivity measured in terms of MPI-D was higher than that is measured in terms of MIP for OECD countries during the period examined (1993–2009). From a regional economic development view, the overall productivity in the Americas is superior to other continents such as Asia, Oceania and Europe. This means that the United States' arms sales boosts its own defense industry and strongly foster Americas' overall productivity. Conversely, European countries have adopted defense-cutting budget annually since the end of World War II and even after the establishment of the European Union (EU). That is, this study also indicates the weak link between defense expenditure and economic productivity examined in the EU members. The effective defense expenditure strategies employed to improve economic productivity can be concluded as follows.

Firstly, by implementing “defense resources privatization” policy aimed at improving defense industrial base technology and self-reinforcing cycle of economic prosperity, the whole society benefits from which the defense resources can be directly or indirectly undertaken by domestic arms weapon manufacturers. Organizing resources of private and public sectors, government can achieve defense autonomy, improve national defense technology, boost the economy, and create jobs. Furthermore, private sectors are encouraged to serve and invest in the national security field for exploiting the synergies that can result from integration of the research and development (R&D), production, and maintenance elements of the weapons and equipment and general military based supply activities. To reallocate defense resources from short-term military capabilities to long-term military potential, expand domestic privatization, and enhance economic development in private sectors, government should consider three principles for future defense production: 1) reduce self-sponsored programs and business in the military industry; 2) reduce foreign procurement; and 3) increase the budget for privatization.

Secondly, by undertaking “industrial cooperation” projects, government can impose an obligation on a foreign contractor under a government procurement project to execute certain industrial or commercial activities such as local investment, local procurement, technology transfer, etc. Such obligation is particularly stipulated in procurement project concerning national defense, transportation and power generation. This approach aimed at fostering domestic industrial improvements and revitalizing long-term economic prosperity through economical procurement or purchase contracts, promoting industrial competitiveness in global markets, and ensuring independent and autonomous equipment and facility maintenance (Dowdy, 1999). Six action plans are undertaken for the strategy of private investment promotion as follows: 1) technology transfer; 2) research and development collaboration; 3) domestic investment; 4) personnel training; 5) assistance to expand international trade and marketing; and 6) domestic procurement.

Thirdly, recent trends and intense international competition require countries to reform industrial structure quickly, conduct industrial collaboration, complement each other's technology and production advantages, and relax or revise technology protection, export, and R&D investment policies. Countries should also collaborate with numerous countries that have strong defense industries base in the fields of tactical missiles, ground weapons, aircraft, shipbuilding, and satellites, to reduce the production cost, improve quality, and reinforce negotiation positions in international competition (Dowdy, 1999; Neal and Taylor, 2001).

Finally, successful defense management will require better coordination and cooperation between government and industry and between the executive units. Finding a winning strategy acts on the role of economic security for most households and national security is needed (Pieroni, 2009).

Table 4
Original MPI and bootstrapping MPI.

	Malmquist productivity index (MPI)			Efficiency change (EC)			Technological change (TC)		
	>1	=1	<1	>1	=1	<1	>1	=1	<1
Original MPI	312	8	192	211	82	219	311	3	198
Bootstrapping MPI	279	8	175	77	4	97	162	2	88

Note: This table is extracted from Appendices A–C.

Appendix A. Changes in efficiency, 32 OECD countries. Numbers greater than one indicate improvements (constant returns to scale)

Country	Year															
	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009
Australia	0.979	0.978	1.014	1.084*	0.937	0.970	1.051	1.066	0.940	0.906*	1.012*	1.043	1.007	1.028*	0.977*	0.858*
Austria	0.970	1.015	1.024	0.957	1.029	0.922	0.974	1.046	0.998	0.955	1.012	1.044	1.018	0.962	1.003	0.937*
Belgium	1.004	1.020	0.961	0.990	1.017	0.976	0.928	1.058	1.036*	0.981	0.987	0.984	0.990	1.020	0.944*	0.977*
Canada	0.962	1.059*	0.995	1.010	0.991	0.978	1.089	1.021*	0.926	0.938	0.952	1.017	1.003	1.021*	0.994	0.797*
Chile	1.157*	1.024*	0.923	0.970*	1.102*	1.312*	0.953*	0.955*	1.022*	1.005	1.070	0.897*	1.128	1.041*	0.745*	1.076
Czech Rep.	0.963*	0.985*	0.934*	1.085	1.148	1.068*	0.916*	1.003*	1.005*	1.030	0.993	1.064*	1.006*	1.050	1.129	0.812*
Denmark	1.000	1.000	0.987	0.970*	1.013	1.022	0.927	0.999	0.998	1.015	1.005	1.002	0.960	1.031	1.014	0.991*
Estonia	0.967	0.988*	1.091*	0.904*	1.001	1.056*	0.924*	0.995*	0.829*	0.957*	0.995	1.000*	0.923*	1.009*	1.298*	1.135*
Finland	1.012	1.077	0.931	0.936*	1.024	1.030	0.968	1.040*	0.988	0.968	0.987	0.979	1.040*	1.013	1.003	0.902*
France	0.968	1.033	0.980	0.992	1.003	0.975	0.953	0.991*	1.027*	0.995*	0.985	0.998	0.991	0.999	0.979*	0.945*
Germany	1.004	1.027	0.976	0.978	1.008	0.975	0.960	1.085	1.077*	0.977	1.015	1.009	1.000	1.000	1.000	0.831*
Greece	1.133*	1.093	0.923	0.968*	1.005	0.966	0.939	0.983*	1.028	0.896*	1.103*	1.132	0.986	0.988	0.973	1.038
Hungary	0.960	1.114*	0.886	0.934*	0.967	1.094*	0.960*	1.081*	0.984*	0.980*	0.936*	1.048	1.071*	1.166*	1.050	0.692*
Ireland	1.000	1.000	1.000	1.000*	1.000	0.975	0.990	1.036*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Israel	1.057	1.052*	0.998	1.073*	1.030	0.984	1.102	0.981*	1.039*	1.036*	1.009*	0.930*	1.062	1.001	0.965*	0.923*
Italy	1.010	0.969	1.016	1.011	1.015	0.981	0.980	0.988*	0.968	1.003*	1.007	1.029	0.988	1.029*	1.010	0.870*
Japan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.925	0.957	0.983	0.993	0.939	1.031*	1.022	0.860*
Korea, South	1.048	1.029	1.014	1.009	1.283*	0.875*	1.009*	1.015	0.957*	0.958*	0.993	1.026*	1.045	1.031*	0.923*	0.910*
Mexico	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Netherlands	0.987	1.045	0.943	0.982	1.019	0.997	0.993	1.015*	1.042*	0.999	1.012	1.034	0.988	1.019	0.996	0.868*
New Zealand	1.063	1.008	1.071	1.022	0.971*	0.927*	1.028*	0.967*	1.019*	0.997*	0.992	1.031	0.974	1.049	1.002*	0.843*
Norway	0.969	1.003	1.037	1.017*	0.921	1.078	1.008	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Poland	0.937*	1.021*	0.866*	0.875*	1.000	1.012	1.043	1.171*	1.074*	0.973	0.944	1.035*	0.955*	0.896*	1.074	0.842*
Portugal	1.030	1.023	0.957	0.905*	1.015	0.981	1.043*	1.008*	1.033	1.076*	0.979	1.011	1.066*	1.051	0.982	0.880*
Slovak Rep.	1.255*	0.909*	0.693*	0.976*	1.093	1.230*	1.087*	0.874*	0.983*	1.157*	0.934*	0.936*	1.119	1.026	0.992*	0.647*
Slovenia	1.004	0.976*	0.984	0.992	1.016	0.958	1.022*	1.016*	0.983	0.929*	0.910*	1.046	0.975	0.988*	1.000*	0.937*
Spain	1.002	1.034	1.026	0.968	1.021	0.929	0.959	1.020*	0.953	0.997	0.988	1.022	0.916*	1.020	1.048	0.863*
Sweden	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.828*
Switzerland	1.000	1.000	1.000	1.000	1.000	1.000	0.917	1.028	1.020	0.984	1.013*	0.969	0.987	1.043*	1.032	0.994*
Turkey	1.333*	0.902	1.002	0.960*	1.214*	1.179*	0.917*	1.176*	0.970	0.980*	0.922*	0.963	0.943*	1.069	0.946*	1.133
UK	1.022	1.046	0.981	0.963*	1.002	1.035	1.020	1.000	1.000	1.000	0.996	1.004	1.000	1.000	1.000*	1.000
USA	0.968	0.993	0.953	1.064*	1.029	1.002	0.983	1.014	1.003*	0.958	0.968*	1.010	1.008	1.034*	1.022	0.970*

Note: Single asterisks (*) denote significant differences from unity at 0.05.

Appendix B. Changes in technology, 32 OECD countries. Numbers greater than one indicate improvements (constant returns to scale)

Country	Year															
	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009
Australia	1.015	1.023*	1.051	0.957	0.989	0.993	0.965	1.007*	1.031*	1.045*	1.027*	0.992*	0.995*	1.004*	1.050	1.064*
Austria	1.042	1.050	0.974	0.974	0.985	1.073	0.982	0.993*	1.084	1.102*	1.066	0.988	1.039	1.043*	1.041	1.059*
Belgium	1.040	1.070*	1.028	0.938	0.991	1.001	0.995	0.989	1.060*	1.100*	1.058*	1.015	1.032*	1.022*	1.050	1.051*
Canada	1.007	0.968*	1.045	0.982	0.983	1.038	0.965	0.995*	1.083	1.073*	1.045*	0.982	1.014	1.000*	1.013	1.228*
Chile	0.937*	0.927	1.036	1.019*	0.935*	0.981	1.004	1.031*	0.993*	1.021*	0.985*	1.007	0.961*	0.960*	1.097	1.222
Czech Rep.	0.937*	0.927	1.041	1.015*	0.935*	0.981	1.004	1.009*	1.034*	1.023*	0.998*	1.007	0.965*	0.971*	1.004*	1.401*
Denmark	1.016*	1.037*	1.029	0.945	0.987	1.005	1.006	1.018*	1.038*	1.099*	1.043*	1.014*	1.003*	1.005*	1.057	1.094*
Estonia	0.956*	1.002*	0.942*	0.966	1.009	1.027	0.956	1.015*	1.054	1.037*	1.021*	0.976	0.967*	0.968*	1.005*	1.289*
Finland	0.973*	1.010*	1.041	0.986	0.978	1.021	0.958	0.989*	1.084	1.072*	1.039*	0.993*	0.994*	1.011*	1.037*	1.139*
France	1.033	1.032	1.041	0.964	0.981	1.001	0.973	1.025*	1.034*	1.051*	1.012*	0.989*	0.999*	1.011*	1.056	1.121*
Germany	1.041	1.070	1.028	0.941	0.994	1.007	0.973	1.000*	1.042*	1.038*	1.005*	1.004	0.967*	0.981*	1.010*	1.274*
Greece	0.937*	0.928	1.035	1.019*	0.935	0.981	1.004	1.023*	1.013*	1.025*	0.988*	1.007	0.961*	0.960*	1.097	1.218
Hungary	0.937*	0.927	1.036	1.019*	0.952	0.982	0.980	1.010*	1.038*	1.023*	1.017*	0.970	0.968*	0.966*	1.003*	1.435*
Ireland	0.974*	0.984*	0.987*	0.981	0.994	1.047	0.992	0.998*	1.098	1.194	1.086	1.019	1.061	1.115	1.068	1.112
Israel	1.005*	1.017	1.037	0.947	0.989	0.996	0.967	1.024*	1.027*	1.021*	0.985*	1.007	0.961*	0.960*	1.097	1.219*
Italy	1.014*	1.023*	1.054	0.951	0.989	0.998	0.971	1.020*	1.031*	1.066*	1.019*	0.987*	0.999*	1.012*	1.036	1.176*
Japan	1.076	1.061	0.903	0.941	0.947	1.110	1.035	0.921	1.090	1.085	1.056*	0.991	1.042	0.978*	1.002	1.268*
Korea, South	1.013	1.043*	0.985*	0.979	0.959*	0.981	0.961	1.014*	1.053	1.032*	1.007*	0.987	0.969*	0.983*	1.008*	1.282*
Mexico	0.891	0.943*	0.977	1.071	1.037	1.073	1.087	1.103	1.046	1.000	1.039	1.053	0.989	0.981	1.024	0.844
Netherlands	1.041	1.044*	1.036	0.947	0.988	1.002	0.985	1.009*	1.045*	1.075*	1.029*	0.981	0.994*	1.007*	1.031*	1.177*
New Zealand	1.008	1.035*	0.986	0.978	0.986	1.033	0.960	1.015*	1.066	1.073*	1.050*	0.997	1.031	1.012*	1.012	1.420*
Norway	1.040	1.060	1.017	0.928*	1.014	0.989	1.048	1.033	1.064	1.124	1.057*	1.080	1.048	1.046*	1.114	0.928
Poland	0.937*	0.928*	1.036	1.019*	0.935*	0.981	0.975	1.012*	1.033*	1.024*	0.993*	1.007	0.959*	0.969*	1.008*	1.342*
Portugal	0.937*	0.927*	1.036	1.019*	0.954	0.997	0.963	1.014*	1.041*	1.023*	1.001*	1.007	0.959*	0.964*	1.016*	1.294*
Slovak Rep.	0.937*	0.928*	1.035	1.019*	0.939*	0.981	0.977	1.011*	1.041*	1.023*	1.003*	0.982	0.968*	0.974*	1.003*	1.339*

Appendix B (*continued*)

Country	Year															
	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009
Slovenia	0.937*	0.951	1.024	0.980	0.987	1.038	0.980	1.022*	1.057	1.048*	1.035*	0.969	0.966*	0.973*	1.002	1.289*
Spain	1.017	0.990*	1.001*	0.977	0.983	1.041	0.972	0.995*	1.083	1.095*	1.059*	0.991	1.037	1.041*	1.027	1.187*
Sweden	0.987*	1.018*	1.059	0.982*	0.966	1.010	0.957	0.990*	1.068	1.077*	1.050*	0.983	1.004*	1.005*	1.010	1.225*
Switzerland	1.056	1.105	0.985	0.903	1.003	0.990	1.032	0.992	1.070	1.143*	1.057*	1.033	1.021*	1.001*	1.048	1.022*
Turkey	0.937*	0.928*	1.035	1.019*	0.935*	0.981	1.004	1.122*	0.904*	1.021*	0.985*	1.007	0.961*	0.962*	1.046	1.252
UK	0.945*	0.938*	1.035	1.019*	0.943	0.981	0.995	1.008	1.029*	1.036*	1.003*	0.997	0.987*	0.991*	1.063	1.213
USA	1.018 *	1.016	1.051	0.949	0.988	1.016	1.035	1.043	1.028*	1.054	1.010*	0.990*	0.999*	1.018*	1.046	1.194*

Note: Single asterisks (*) denote significant differences from unity at 0.05.

Appendix C. Changes in productivity, 32 OECD countries. Numbers greater than one indicate improvements (constant returns to scale)

Country	Year															
	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009
Australia	0.994*	1.000*	1.066*	1.038*	0.926	0.964*	1.015*	1.073*	0.969*	0.947*	1.039*	1.035*	1.002*	1.032*	1.025*	0.913*
Austria	1.010*	1.066*	0.997*	0.932*	1.014*	0.989	0.957*	1.039*	1.082	1.052*	1.080*	1.032	1.057	1.004*	1.044*	0.993*
Belgium	1.044*	1.091*	0.988*	0.929*	1.008*	0.977*	0.924	1.047*	1.097*	1.079*	1.045*	1.000*	1.022*	1.043*	0.991*	1.027*
Canada	0.968*	1.025*	1.040	0.992	0.974	1.015*	1.051*	1.015	1.003*	1.007*	0.995*	0.999*	1.018*	1.022*	1.007*	0.978*
Chile	1.084*	0.949*	0.956*	0.988*	1.031*	1.287*	0.956*	0.984*	1.015*	1.026*	1.053*	0.903*	1.084*	1.000*	0.817*	1.314*
Czech Rep.	0.902*	0.914*	0.972*	1.101*	1.073*	1.048*	0.919*	1.012*	1.039*	1.054*	0.992*	1.071*	0.971*	1.020*	1.134*	1.138*
Denmark	1.016*	1.037*	1.015	0.916*	1.000*	1.027*	0.932*	1.016*	1.035*	1.115*	1.048*	1.017*	0.963*	1.036*	1.072*	1.084*
Estonia	0.925*	0.990*	1.028*	0.874*	1.010*	1.085*	0.884*	1.010*	0.873*	0.992*	1.016*	0.976*	0.893*	0.977*	1.305*	1.464*
Finland	0.984*	1.088*	0.970	0.923*	1.002*	1.052*	0.927	1.029	1.071*	1.038*	1.026*	0.972*	1.034*	1.024*	1.040*	1.028*
France	1.000*	1.066*	1.021	0.957*	0.984*	0.976*	0.927	1.016*	1.062*	1.046*	0.997*	0.987*	0.990*	1.011*	1.034*	1.060*
Germany	1.045	1.099*	1.003*	0.920*	1.002*	0.981	0.934*	1.085*	1.122*	1.015*	1.019*	1.014	0.967*	0.981*	1.010*	1.059*
Greece	1.061*	1.014*	0.955*	0.986*	0.940*	0.948*	0.943*	1.006*	1.041*	0.919*	1.090*	1.140*	0.948*	0.949*	1.067*	1.264*
Hungary	0.899*	1.033*	0.918*	0.951*	0.921*	1.074*	0.941*	1.092*	1.021*	1.002*	0.952*	1.017*	1.037	1.127*	1.054*	0.994*
Ireland	0.974*	0.984*	0.987*	0.981*	0.994*	1.021*	0.982*	1.034*	1.098	1.194	1.086*	1.019*	1.061*	1.115*	1.068*	1.112*
Israel	1.062*	1.069*	1.035*	1.017	1.018	0.980*	1.065*	1.004	1.067*	1.058	0.993*	0.936*	1.021*	0.961*	1.059*	1.125*
Italy	1.024*	0.991*	1.071*	0.961	1.003*	0.979*	0.951*	1.008*	0.998*	1.069*	1.026*	1.015*	0.987*	1.042*	1.046*	1.023*
Japan	1.076*	1.061*	0.903	0.941*	0.947*	1.110*	1.035*	0.921*	1.008	1.038*	1.039*	0.985	0.979*	1.009*	1.024*	1.090*
Korea, South	1.062*	1.074*	1.000*	0.988*	1.231*	0.858*	0.969*	1.030*	1.008*	0.989*	0.999*	1.013*	1.012*	1.014*	0.930*	1.166*
Mexico	0.891*	0.943*	0.977*	1.071*	1.037*	1.073*	1.087*	1.103*	1.046*	1.000*	1.039*	1.053*	0.989*	0.981*	1.024*	0.844
Netherlands	1.028*	1.091*	0.977*	0.929	1.007*	0.999*	0.978	1.024*	1.088*	1.074*	1.041*	1.015*	0.983*	1.026*	1.027*	1.021*
New Zealand	1.071*	1.043*	1.056*	0.999*	0.957*	0.958*	0.987*	0.981*	1.086*	1.069*	1.042*	1.027*	1.004	1.062*	1.014*	1.197*
Norway	1.007*	1.063*	1.054*	0.944*	0.933*	1.066	1.056	1.033	1.064*	1.124	1.057*	1.080*	1.048*	1.046*	1.114*	0.928*
Poland	0.878*	0.947*	0.897*	0.891*	0.935*	0.993*	1.017	1.185*	1.109*	0.996*	0.937*	1.042*	0.916*	0.868*	1.083*	1.130*
Portugal	0.965*	0.949*	0.991*	0.922*	0.968*	0.979*	1.005*	1.022*	1.076*	1.101*	0.981*	1.018*	1.022*	1.013*	0.998*	1.139*
Slovak Rep.	1.176*	0.844*	0.718*	0.994*	1.026*	1.207*	1.062*	0.884*	1.023*	1.184*	0.937*	0.919*	1.083*	1.000*	0.996*	0.866*
Slovenia	0.940*	0.929*	1.008	0.973*	1.003*	0.994*	1.001*	1.038	1.039*	0.974*	0.942*	1.014*	0.942*	0.961*	1.002*	1.209*
Spain	1.019	1.023*	1.027	0.946*	1.004*	0.968*	0.933*	1.015*	1.033*	1.092*	1.046*	1.013*	0.950*	1.062*	1.076*	1.025*
Sweden	0.987*	1.018*	1.059*	0.982*	0.966*	1.010	0.957	0.990*	1.068*	1.077*	1.050*	0.983*	1.004*	1.005*	1.010*	1.014*
Switzerland	1.056*	1.105*	0.985*	0.903*	1.003*	0.990	0.946*	1.020	1.091	1.124*	1.071*	1.001*	1.008*	1.044*	1.082*	1.016*
Turkey	1.248*	0.837*	1.038*	0.978*	1.136*	1.156*	0.921*	1.319*	0.876*	1.001*	0.908*	0.970*	0.906*	1.028*	0.990*	1.419*
UK	0.966*	0.981*	1.016*	0.981*	0.945*	1.015*	1.016*	1.008*	1.029*	1.036*	0.998*	1.001*	0.987*	0.991*	1.063*	1.213*
USA	0.986*	1.008*	1.001*	1.010*	1.017*	1.018*	1.017*	1.058*	1.032*	1.009*	0.977*	0.999*	1.007*	1.053	1.069*	1.158

Note: Single asterisks (*) denote significant differences from unity at 0.05.

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