The Effect of Productivity on Employment and Its Implication
: Evidences from Korean Industry-level Data

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Abstract

There are a number of previous studies regarding the effects of productivity on employment. In this sense, while investigating the effects of productivity on employment, this paper also tests whether the effects have changed since 2000 in Korea. Basically, the empirical analysis is focused on the long-run relationship using cointegration between productivity and employment. In particular, the paper attempts to include the inter-industrial effects of productivity on employment in the empirical model. The empirical results provide the following two findings. Firstly, the aggregate effect of productivity on employment is significantly positive but it has decreased since 2000. Secondly, the each inter-industrial effects of productivity on employment are significantly positive but it has decreased after 2000. However, intra-industrial effects of productivity after 2000 do not change significantly.

JEL Classification: C22, C23, D24, E24
Key words: Total Factor Productivity, Employment, (Panel) Cointegration, Period Effect

1. Introduction

The development of technology improves the efficiency of the production process and increases the competitiveness of the commodity produced. Considering an open economy, technology raises price and quality competitiveness of domestic goods in the international market. Therefore, technology innovation is known to be one of the most essential factors in economic growth. However, there are two different views regarding the effects of technology on employment. A negative insight of technology on employment insists that a simple labor-saving technology innovation like the introduction of automated equipment increases value-added at the expense of unskilled labor. On the contrary, technology innovation in some industries causes ultimate growth in the industry, and subsequently requires more employment. This is the income effect of technology innovation. Furthermore,
technology innovation in some industries has positive spillover effects on other industries, stimulating growth and bringing about positive inter-industrial effects of the technology.

These two insights with regards to the technology effect on employment have been cited in various literatures. First, with the negative aspects, Gali (1999) shows that positive technology innovation is possible to reduce total work hours in the short run at U.S., using VAR (Vector Autoregression) model. Francis and Ramsey (2005) and Basu, Fernald, and Kimball (2006) also suggest that an aggregate technology shock can reduce the use of labor, investment and real interest rates, even in the short run. And Canova, Lopez–Salido, and Michelacci (2007) suggest that a possible reason for this mechanism is “search friction” in the labor market. Kim, Choi, and Lee (2007) investigate the effects of labor productivity shocks on employment in aggregate, manufacturing, services, ICT, and non–ICT industries using 1993–2006 data in Korea. They show that a productivity shock in an industry reduces employment capacity of the industry in the short run, but the positive transmission effects of productivity on employment exist from non–ICT innovation to ICT employment. Choi and Lee (2008) provide that employment was reduced, especially for unskilled workers, by technological development and globalization during the years 1991–2007 in Korea. They estimate that the reduction amounted close to 11,000 job positions as an annual average. Kim (2008b) insists that the technology innovation in Korea has had a labor saving feature. As empirical evidence, he demonstrates a negative relationship between productivity and employment using panel model with 1993–2007 data.

However, some studies show that the technology effects on employment can be positive. The idea is based on the theory of RBC (Real Business Cycle), of which technology innovation increases employment as well as production. Related past studies are summarized by Christiano et al. (2003) and Uhlig (2004). Kim (2001) provides that there has been no significant employment reduction effect in Korea since 1970 using the empirical method of Gali (1999). Using the same empirical method of Gali (1999), Kang (2006) also shows that the effects of technology innovation on employment can be different across industries. The effects were significantly positive in manufacturing, but insignificant in services.

This paper investigates the effect of productivity on employment and also tests whether the effect has changed since the year 2000. The reasons to choose the year 2000 are two: firstly to control the financial crisis2) and secondly to consider

2) After Korean Economy suffered a financial crisis in 1997 mainly due to collapse in the foreign exchange market, significant efforts as a whole to overcome it had been carried. In the line with these efforts, Stanley Fischer - the first deputy managing director of the International Monetary Fund (IMF) - announced officially at Aug. 2000 that the IMF completed the final review of Korea
the discourse about jobless growth during the 2000s. In particular, the paper attempts to include the studies on inter-industrial effect of productivity on employment. The initiative of considering inter-industrial effect of productivity starts from Kim and Kim (2008) which investigates the effect of total factor productivity on investment and employment and shows two different empirical results by model specification; the effect was positive using national level data, but was negative using industry panel data.

We have outlined the purpose of the paper and related studies in this first section. In the second section, the data for the empirical analysis is described. Section III and section IV show the empirical model specifications for analysis and the subsequent results. Section V provides the conclusion and implications from the empirical results.

2. Data Description

It is not simple to define the level of technology within a general or common standard. However, a number of past studies use total factor productivity (TFP) as a proxy variable for this (Burnside et al, 1998; Basu, Fernald, and Kimball, 2006; Kim, 2008a, 2008b). Based on the definition of total factor productivity (TFP), TFP accounts for the effect in total output which is not caused by other inputs like labor or capital. Under independence between TFP and other inputs in production, TFP can be considered as a type of technology in an economy.3)

The sample period is for the years 1970-2009 at an aggregate level and is for the years 1980-2009 at an industry level. The discrepancy of starting point is due to the data restrictions in industry level. The industrial classification for 9 industries is organized based on consistency in handling labor, capital, and output data. The industries are as follows − (i) Agriculture Forestry and Fishery, (ii) Mining and quarrying; Manufacturing, (iii) Electricity, gas, and water supply, (iv) Construction, transportation and storage, (v) Wholesale and retail trade, (vi) Information and communication, (vii) Accommodation and Food service activities, (viii) Financial and insurance, real estate, and business service activities, (ix) Other personal and social service activities. Among nine industries, five industries, (v)-(ix), are classified as a service industry.4) For the estimation of TFP, a

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1 Program. In the reason, the year 2000 is selected as a base year to compare two periods − before and after crisis.
2 Alternatively, labor productivity can be considered to measure technology. However, with respect to this endogeneity problem, the use of TFP has an advantage.
3 The TFP in service industry is calculated using each subtotal of labor, capital stock, and output among the five industries, (v)-(ix).
growth accounting method is applied using data – net capital stock, total hours worked, and compensation rate for each input and so on. The data source is the Bank of Korea\(^5\) and the Statistics Korea\(^6\). All variables for employment and TFP are used after taking natural logarithm. The source of DATA is reported in Table C of Appendix.

Usually, TFP can be calculated by growth accounting method (Solow, 1957) which computes the rate of technology progress using the contributions of inputs on economic growth.\(^7\) The description for the method is from neoclassical economic model. Let’s start the Cobb–Douglas production function \( Y = AL^\alpha K^\beta \), where \( \alpha + \beta = 1 \) which is homogenous degree 1 and is a function of traditional inputs – labor \( (L) \) and capital \( (K) \). The specification of the production function with natural logarithm is following

\[
\ln(Y) = \ln(A) + \alpha \ln(L) + \beta \ln(K)
\]

where, \( Y \), \( L \), and \( K \) are a production (value added)\(^8\), a labor and a capital stock. \( \alpha \) and \( \beta \) are the labor share and the capital share of production, respectively. And \( \alpha + \beta = 1 \). TFP is \( A \). That is, a production is composed of the intangible factor, TFP, as well as the tangible inputs – a labor and a capital. Hence, the TFP level with natural logarithm is \( \ln(A) = \ln(Y) - \alpha \ln(L) - \beta \ln(K) \).

The production function can be transformed into the following equation which is converted along with growth accounting method.

\[
g_Y = g_A + \alpha g_L + \beta g_K
\]

where, \( g_Y \), \( g_A \), \( g_L \), and \( g_K \) are the growth rates in a production, a TFP, a labor and a capital, respectively.

Because the growth accounting method is based on the growth rate, TFP level is also obtained using the growth rate of TFP after fixing the initial value of TFP level. The initial value of TFP can be calculate the above production function

\(^5\) Refer website http://ecos.bok.or.kr/

\(^6\) Refer website http://kosis.kr/abroad/abroad_01List.jsp

\(^7\) Instead of the calculation method used in this paper, one may consider another approach to get TFP. It can be the econometric method by estimating TFP using an econometric model. For the econometric estimation of TFP, refer to Serot (1993) or Yeaple and Golub (2007).

\(^8\) In order to get TFP, a production can be used as a value added or as a gross output. Two applications have all both merits and demerits. For the comparison between them, refer to Nordhaus (2008), Tuomi (2004), Timmer et al. (2007), OECD (2001), and so on.
using the following each economic variable.

The input shares of production\(^9\) are transformed using Tornqvist method and then applied.\(^{10}\) Briefly speaking each input share of production is used as the two period average share of the input in nominal production. These input shares can be considered as a Divisia index which is a moving weight based on averages of adjacent points in time. Therefore, the growth rate of TFP is the residual which is the difference of the weighted average of input growth rates from the growth rate of production. This TFP is called as the Solow residual.

For estimating TFP, Kim (2004) and Kim and Bae (2004) apply such data at an aggregate level while Kim and Kim (2008a) use the data in the classification of 9 industries. Data and estimation process for TFP are as follows.

Capital stock is used as the concept of a net capital stock\(^{11}\) at a constant price and is estimated based on the national wealth statistics from the Statistic Korea. That is, capital stock is used by the fixed tangible capital among a produced capital, except for the animals & plants and the suspense account of construction. There are two considerations for the use of the statistics. First, its frequency of announcement was 10 years until 1997 based on actual measurement or survey. Missing values between actual measurements are interpolated using the adjusted depreciation rate is calculated using consumptions of fixed capital in the national account from the Bank of Korea and capital stocks surveyed actually in the national wealth statistics from the Statistics Korea. Secondly, even if the data from the national wealth statistics have been announced annually after 1997, it provides only a tangible fixed capital in a produced asset for an aggregate level and provides just a produced asset for an industry level. Therefore, the net capital stocks after 1997 are calculated based on he fixed tangible capital at an aggregate level. Also for an industry level, the net capital stocks are estimated using the growth rates of produced capital and the year 1997 value of a net capital stock which is actually measured. Consequently, the estimation method of a net capital stock is summarized such as a benchmark year method (BTM) before 1997 at both - an aggregate and an industry level. After the year 1997, a net capital stock at an aggregate level is a fixed tangible capital but the net capital stock at an industry level is estimated using a perpetual inventory method.

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9) Compensation rates of inputs

10) The advantages in use of Tornqvist index are explained in Timmer et al. (2007). It also cites Diewert (1976)

11) According to the OECD, the definition of net capital stock is “Net capital stock is the sum of the written-down values of all the fixed assets still in use is described as the net capital stock; it can also be described as the difference between gross capital stock and consumption of fixed capital” - http://stats.oecd.org/glossary/detail.asp?ID=1752.
Labor is calculated based on the Economically Active Population Survey from the Statistic Korea. In order to measure labor input, the total hours worked is used after multiplying the number of employees and average hours worked. The labor share of production is based on the data from the Bank of Korea. However, it is adjusted by assuming that the compensation of nonwage employees is a half of that of wage employees.

Also, employment is applied for two kinds of variables, the number of employees and total hours worked.

### 3. Empirical Model and Estimation Procedure

In this paper, the empirical analysis focuses on the long-run relationship between productivity and employment. Note that what is tested is whether the relationship has changed or not, and that it is assumed that employment is a function of productivity.\(^{12}\)

The empirical models can be classified by considering the inter-industrial effect. The first model focuses on the intra-industrial effect of productivity in an industry on its employment. For this analysis, a panel co-integration model (Pesaran and Smith, 1995; Pesaran, Shin, and Smith, 1999) with 9 industry data panels is used. The second model considers and includes the possibility of an inter-industrial effect of productivity in certain industries on employment in other industry, as well as the intra-industrial effect of productivity on employment. Both model specifications are discussed below, in detail.

#### 3.1 Model without Inter-industrial Effect

Model 1 considers the intra-industrial effect of technology innovation on employment. The basic model specification is as follows.

\[
L_{i,t} = \alpha_i TFP_{i,t} + \epsilon_{i,t} \tag{3.1}
\]

\[
L_{i,t} = \alpha_i TFP_{i,t} + \delta TFP_{i,t}D^T + \epsilon_{i,t} \tag{3.1}'
\]

where \(L_{i,t}\) is employment in industry \(i\) at time \(t\). Employment is applied as two alternatives, the number of employees and total hours worked. \(TFP\) is a total

\(^{12}\) In this specification, a control variable like GDP is not appropriate because of the endogeneity problem. Gali(1999) also uses only two variables - a labor productivity and a labor - in VAR model.
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factor productivity, which is a proxy variable for technology. Industry $i$ includes 9 industries. Data sample has an annual frequency and covers a period from 1980 to 2009. $D^{i}$ is a period dummy variable which shows the period effect after 2000. $\alpha_{i}$, $\delta$ are the coefficients and $\epsilon_{i,t}$ is residuals.

Equation (3.1) ignores the possibility of a period effect, of which the effect of productivity in industry $i$ on its employment may change after 2000. In contrast with that, equation (3.1)' considers the possibility of a period effect through the significance test for coefficient $\delta$.

Model 1 is estimated using a panel co-integration model (Pesaran and Smith, 1995; Pesaran, Shin, and Smith, 1999). As they proposed, the co-integrating relationships will be chosen between two different methods, MG (Mean Group) and PMG (Pooled Mean Group) based on the Hausman test. The model 1 shows the cointegrating relationship which is derived from ARDL (AutoRegressive Distributive Lag) dynamic panel specification in Pesaran, Shin, and Smith (1997, 1999). Let the following ARDL specification.

$$ y_{i,t} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=1}^{q} \delta_{ij} X_{i,t-j} + \mu_{i} + \xi_{i,t} $$

where, $i(=1,...N)$ and $t(=1,...T)$ are the panel group and time. $X_{i,t}$ is the vector of explanatory variable ($K \times 1$). $\delta_{ij}, \lambda_{ij}$ and $\mu_{i}$ are coefficient vector ($K \times 1$), coefficient scalar, and individual specific effect.

After the ARDL specification is transformed the following panel error correction form, the cointegrating vector, $(y_{i,t-1} - \theta_{i}^{*} X_{i,t})$, becomes main concern in this paper.

$$ \Delta y_{i,t} = \phi_{i}(y_{i,t-1} - \theta_{i}^{*} X_{i,t}) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij} \Delta X_{i,t-j} + \mu_{i} + \xi_{i,t} $$

where, $\phi_{i} = -(1 - \sum_{j=1}^{p} \lambda_{ij})$, $\theta_{i} = \sum_{j=0}^{q} \delta_{ij}/(1 - \sum_{k} \lambda_{ik})$, $\lambda_{ij}^{*} = -\sum_{m=j+1}^{p} \lambda_{im}$, $\delta_{ij}^{*} = -\sum_{m=j+1}^{q} \delta_{im}$

Firstly the MG model supposes fully heterogeneous coefficients across panels, and so estimates of $N$ separate regressions by panel. The estimation results are reported as an un-weighted average of the estimated coefficient of individual

$D^{i} = \begin{cases} 1, & \text{if } t \geq 2000 \\ 0, & \text{Otherwise} \end{cases}$
Hence, this MG model has an advantage because no cross panel restrictions are imposed. In contrast with MG, the PMG imposes homogenous long-run coefficient restrictions but assumes the heterogeneous short-run coefficients across panels. That is, there is a restriction in the long-run equation, only. Of course, if the true model imposes heterogeneity the estimators from PMG will be inconsistent estimators. However, the estimators from MG will be consistent. Otherwise, PMG estimators will be consistent and efficient, but the MG estimator will be consistent only. This PMG model is an intermediate model between MG and DFE (Dynamic Fixed effect). The DFE model is also a model on the opposite extreme against MG because the DFE imposes a homogenous restriction on all coefficients including long-run coefficients, the adjustment coefficient, and short-run coefficients. A special case of the DFE model is the static fixed effect (SFE) model. In order to choose an appropriate estimator model between MG and PMG, the Hausman test is used. The DFE model is not considered because it is related to the simultaneous equation bias which is not considered in this paper. A panel unit root test and panel co-integration test are employed for verifying the existence of the long run relationship.

For the panel unit root test, five test statistics are employed. The null hypothesis in LLC (Levin, Lin and Chu, 2002), and t-stat (Breitung, 2000) is the existence of a unit root under the assumption of common unit root process. The null hypothesis in W (Im, Pesaran, and Shin, 2003), ADF–Fisher & PP–Fisher (Fisher, 1932; Maddala and Wu, 1999; Choi, 2001) is existence of a unit root under the assumption of individual unit root process.

### 3.2 Model with Inter-industrial Effect

Unlike model 1, model 2 includes an inter-industrial effect of technology innovation on employment, implicitly. Empirical model 2 is estimated using aggregate TFP and employment instead of industry panel data. When aggregate level data is used, the model includes two effects—the inter-industrial effect of TFP and the intra-industrial effect of TFP on employment. That is, it is possible for the productivity of certain industry to have spillover effect on employment capacity of other industries.

<Model 2>

\[ L_t = \alpha_0 + \alpha_1 TFP_t + \epsilon_t \]  

14) Assuming fully homogenous coefficients across panels, it will be a pooled regression.
where $L_t$ and $TFP_t$ are employment (the number of employees or total hours worked) and total factor productivity as an aggregate at time $t$. The dummy variable $D^T$ is the same as in Model 1. Equation (3.2)' considers the possibility of a change in the effect of TFP on employment. But equation (3.2) does not.

Here, $\delta$ shows whether the total effect of TFP on employment changed since 2000, but does not provide any information about the possibility of changes in the inter-industrial effect. Model 3 considers this possibility.

Empirical model 3 expresses the inter-industrial effect on employment compared with model 2. Model 3 focuses on the productivity effects in two areas, manufacturing and services. The reasons for using two industries rather than eight more specific industries are to consider inter-industrial effect directly. The sample is not large enough to consider nine industries separately.17)

Where $L_t$ and $TFP_t$ are employment (the number of employees or total hours worked) and total factor productivity as an aggregate at time $t$.

$$L_t = \alpha_0 + \alpha_1 TFP_t + \delta TFP_t D^T + \epsilon_t \quad (3.2)'$$

and total factor productivities in industry $k$ and other industry $l$ ($k, l = m; \text{ manufacturing, s; services & } k \neq l$). Similarly to the above models, equation (3.3) and (3.3)' determine whether to consider possibility of period effect or not.

The estimations for model 2 and model 3 follow a two-step procedure for co-integration (Engle & Granger, 1987) using FMOLS method. The Engle-Granger two step procedure for co-integration requires that the variables in the empirical model are non-stationary. When the linear combination of the non-stationary variables make them stationary, the relationship is known as co-integration, which is a long-run relationship. In particular, model 3 is estimated by industry $k$, separately.18) The coefficients - $\delta$, $\delta_1$, and $\delta_2$ - which show the period effect of

17) Alternatively, the inter-industrial effect of productivity on employment in some industry can be applied using weighted average of productivities in other industries. However, this paper focuses only on manufacturing and services.

18) The necessary conditions for joint estimation such as SUR (Seemingly Unrelated Regression) to
productivity on employment are mainly focused on their signs and significance. The estimator from FMOLS uses a semi-parametric correction to remove the endogeneity problem (Phillips and Hansen, 1990). Before estimating the model, both tests, the unit root test and co-integration test, are required for verifying the existence of long run relationship.

\[\text{Table 3.1} \text{ Results of Panel Unit Root Test}\]

<table>
<thead>
<tr>
<th></th>
<th>Employment</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The number of employees</td>
<td>Total hours worked</td>
</tr>
<tr>
<td>Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLC</td>
<td>2.477</td>
<td>1.504</td>
</tr>
<tr>
<td>t-stat</td>
<td>3.749</td>
<td>3.124</td>
</tr>
<tr>
<td>W</td>
<td>3.816</td>
<td>2.716</td>
</tr>
<tr>
<td>ADF-Fisher</td>
<td>4.337</td>
<td>8.823</td>
</tr>
<tr>
<td>PP-Fisher</td>
<td>4.408</td>
<td>5.992</td>
</tr>
<tr>
<td>The First Difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLC</td>
<td>-10.303***</td>
<td>-10.186***</td>
</tr>
<tr>
<td>t-stat</td>
<td>-7.146***</td>
<td>-8.758***</td>
</tr>
<tr>
<td>W</td>
<td>-8.971***</td>
<td>-8.954***</td>
</tr>
<tr>
<td>ADF-Fisher</td>
<td>98.876***</td>
<td>98.227***</td>
</tr>
<tr>
<td>PP-Fisher</td>
<td>98.514***</td>
<td>123.439***</td>
</tr>
</tbody>
</table>

# of obs 270 (1980~2009, 9 panels)

Note: a) *, **, and *** indicate statistical significance at the 10%, 5%, and 1% test levels, respectively.

b) The basic assumption is existence of constant and trend in the test equation of each variable.

be better than separate regression estimation are if: (i) There is contemporaneous correlation between errors. (ii) The values of the explanatory variables are not same in both equations. The empirical model violates the second requirement. Also, the contemporaneous correlation coefficient between estimated residuals is less than 0.5.

19) The empirical results using FMOLS is consistent with those using OLS.
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4. Empirical Results

4.1 Model without Inter-industrial Effect

The empirical results in this section are based on model 1, which includes the effects of productivity on employment disregarding the inter-industrial effect and considers the change in the effect after 2000, using 9 industry panels and annual data for the period 1980–2009.

First, employment and TFP are all verified as I (1) processes from the panel unit root test (See Table 1). Also, the panel co-integration test result supports the existence of co-integration. The test statistic, based on the Maddala and Wu (1999) provide that there is (at least) one co-integrating vector between both variables (See Table 2). This means that a long-run relationship between productivity and employment exists.

In order to select the appropriate panel co-integration specification between MG and PMG, the Hausman test is used. The test statistics are shown in "Haus" in Table 3. The Hausman test statistics cannot reject the pooling of the long-run parameters. The estimated Hausman statistics are 0.01, 8.13, 0.00, 1.08 and are distributed through a chi-square distribution. Recall that the PMG estimator requires that the long-run coefficients be equal across all panels. The test results provide that the PMG estimator, the efficient estimator under the null hypothesis, is preferred.20)

The empirical results for model 1 using PMG are as follows.

First, employment in one industry decreases significantly with increased

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20) If the criterion for the model selection between MG and PMG is at the 5% significance level, the estimation [2] in Table 3 will be applied by MG. When the MG estimation is used for [2] in Table 3, the coefficients ($\delta$) for the period effect becomes insignificantly negative. Others are similar.
productivity (TFP) in that industry. It is common for estimations to use two applications for employment, the number of employees and total hours worked. When the number of employees is used for employment, the coefficients of TFP are -2.494 on the assumption of no period effect and -2.541 on the assumption of period effect. Both are statistically significant (See [1] and [2] in Table 3). Also, the coefficients in the estimations using total hours worked for employment are also significantly negative, -4.495 and -5.295 (See [3] and [4] in Table 3).

Secondly, the role of productivity in an industry in determining its employment worsened posterior to 2000. The coefficient (δ) for the period effect are all significantly negative, -0.350 and -0.805 (See [2] and [4] in Table 3).

These empirical results consider only the internal industry effect of productivity on employment. Hence, we need to consider the inter-industrial effect of productivity. This means that productivity in one of the industry have effects on employment in another industry.

4.2 Model with Inter-industrial Effect

Here, the empirical results for model 2 and model 3 are discussed in turn. Both models are differentiated from model 1 by considering the inter-industrial effect of productivity on employment, both implicitly and explicitly. Model 2 includes the inter-industrial effect using aggregate national level data but does not show that
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explicitly. Compared with model 2, model 3 configures to the inter-industrial effect directly in the specification. That is, it is assumed that employment in both manufacturing and services is determined by the level of technology in the other as well as its own technology.

Before estimation, stationarity in each variable is tested by unit root tests - an augmented Dickey–Fuller (ADF)\(^{21}\) and a Phillips–Perron (PP)\(^{22}\) test. Based on the results of unit root tests, employment – the number of employees and total hours worked – and TFP turn out to be all I (1), which are non-stationary in the level but are stationary after the first difference (See Table 4). Also, according to the results of the Engle–Granger (1987) test, a co-integrated relationship is significant for each specification (See \textit{E-G coint test} in <Table 3.5>).

\textbf{<Table 3.4> Results of Unit Root Test - time series}

<table>
<thead>
<tr>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate level</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>Employment</td>
<td>TFP</td>
</tr>
<tr>
<td>(L_1)</td>
<td>(L_2)</td>
</tr>
<tr>
<td>ADF</td>
<td>-1.063</td>
</tr>
<tr>
<td>PP</td>
<td>-1.028</td>
</tr>
</tbody>
</table>


Note: 1) *, **, and *** indicate statistical significance at 10%, 5%, and 1% test levels, respectively.
2) A basic assumption is existence of constant and trend in the test regression.

The empirical results for model 2 show that employment increases with the level of technology – TFP – in the aggregate. However, the influence of productivity on employment decreases after 2000 because the coefficients indicating the period effects, \(\delta_s\), are all significantly negative. The coefficients for TFP are 1.062 using employees and 1.043 using total hours worked, but the coefficients for the period effects of the 2000s are -0.584 and -1.015 in both applications for employment – the number of employees and total hours worked (See \textit{All} column in <Table 3.5>.)

\(^{21}\) Dickey & Fuller(1979), Said & Dickey (1984)
\(^{22}\) Phillips & Perron(1988)
### Table 3.5: Estimation Results of Model 2 and Model 3 (FMOLS)

<table>
<thead>
<tr>
<th></th>
<th>Model 2</th>
<th></th>
<th>Model 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aggregate level</td>
<td>The number of employees</td>
<td>Total hours worked</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$L_1$</td>
<td>$L_2$</td>
<td>$L^M_1$</td>
<td>$L^S_1$</td>
</tr>
<tr>
<td>TFP</td>
<td>1.062</td>
<td>1.043</td>
<td>0.32</td>
<td>0.884</td>
</tr>
<tr>
<td></td>
<td>(1.934)</td>
<td>(14.349)</td>
<td>(-4.704)</td>
<td>(13.056)</td>
</tr>
<tr>
<td>TFP$^M$</td>
<td>-0.32</td>
<td>0.884</td>
<td>-0.336</td>
<td>0.842</td>
</tr>
<tr>
<td></td>
<td>(-4.704)</td>
<td>(13.056)</td>
<td>(-3.834)</td>
<td>(12.765)</td>
</tr>
<tr>
<td>TFP$^S$</td>
<td>2.191</td>
<td>0.829</td>
<td>1.786</td>
<td>0.630</td>
</tr>
<tr>
<td></td>
<td>(15.832)</td>
<td>(6.427)</td>
<td>(10.079)</td>
<td>(4.657)</td>
</tr>
<tr>
<td>TFP $\cdot$ $D^T$</td>
<td>-0.584</td>
<td>-1.015</td>
<td>-0.572</td>
<td>-0.451</td>
</tr>
<tr>
<td></td>
<td>(-2.006)</td>
<td>(-2.755)</td>
<td>(-1.740)</td>
<td>(-1.274)</td>
</tr>
<tr>
<td>TFP$^M$ $\cdot$ $D^T$</td>
<td>0.481</td>
<td>-0.572</td>
<td>0.451</td>
<td>-0.755</td>
</tr>
<tr>
<td></td>
<td>(1.740)</td>
<td>(-2.006)</td>
<td>(1.274)</td>
<td>(-2.727)</td>
</tr>
<tr>
<td>TFP$^S$ $\cdot$ $D^T$</td>
<td>-0.430</td>
<td>-0.192</td>
<td>-0.430</td>
<td>-0.240</td>
</tr>
<tr>
<td></td>
<td>(-3.380)</td>
<td>(-0.193)</td>
<td>(-2.875)</td>
<td>(-0.256)</td>
</tr>
<tr>
<td></td>
<td>(67.957)</td>
<td>(81.279)</td>
<td>(47.423)</td>
<td>(53.181)</td>
</tr>
<tr>
<td>$D^T$</td>
<td>-1.900</td>
<td>-3.385</td>
<td>-1.796</td>
<td>-1.177</td>
</tr>
<tr>
<td></td>
<td>(-2.241)</td>
<td>(-2.933)</td>
<td>(-4.065)</td>
<td>(-3.241)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.972</td>
<td>0.942</td>
<td>0.977</td>
<td>0.960</td>
</tr>
<tr>
<td>$D-W$</td>
<td>0.584</td>
<td>0.583</td>
<td>0.490</td>
<td>0.472</td>
</tr>
<tr>
<td></td>
<td>(-2.937)</td>
<td>(-2.937)</td>
<td>(-2.622)</td>
<td>(-2.504)</td>
</tr>
</tbody>
</table>

Note: 1) The parenthesis () is the t statistic, and *, **, and *** are significance levels of 10%, 5%, and 1%.

2) Test statistic of co-integration, ['E-G coint test'], is obtained from Engle and Granger(1987) method under assumption of neither constant nor trend in ADF test.

3) Each estimation uses a heteroskedasticity & autocorrelation consistent covariance (Newey and West, 1987).

The empirical results for model 3 also have meaningful implications (See <Table 3.5>).

The inter-industrial effects of productivity on employment are significantly positive in both industries during the 1990s. The estimated values of the coefficient $\alpha_2^m$ which show the effects of productivity of services on employment in manufacturing are 2.191 using the number of employees and 1.786 using total hours worked. Also, the values of coefficient $\alpha_2^s$ which indicate the effect of productivity in manufacturing on employment in services are 0.884 using the number of employees and 0.842 using total hours worked. These provide that the positive inter-industrial effect of productivity on employment is significant during
However, those positive inter-industrial effects decreased after 2000. The empirical results show that both $\delta_1$ and $\delta_2$ are all significantly negative. Recall that $\delta_1$ is the period effect of productivity in services on manufacturing employment. Similarly, $\delta_2$ indicates the period effect of manufacturing productivity on services employment. According to applications for employment as the number of employees and the total hours worked, the values of $\delta_1$ are -3.600 and -3.701, with all significance. Also the values of $\delta_2$ are -0.572 and -0.725, both of which are significant.

These results have important implications for the role of productivity. Firstly, employment increases with productivity, at an aggregate level. However, the effect of productivity on employment decreased with the start of the 2000s. Secondly, a decrease in the effect of productivity appears to have root in the weakening of the inter-industrial effect of productivity on employment.

5. Implications

This paper investigated the effects of productivity in employment using three empirical models – model 1 without considering inter-industrial effect and models 2–3 addressing inter-industrial effect. In each model, it was tested to determine whether the effect in employment changed after 2000.

When the effects of productivity on employment within an industry are assessed, employment decreases with increased productivity and its effect has deteriorated since 2000. The empirical results of model 1 using a panel co-integration analysis shows the findings in 9 industries on average. This implies that technology innovation has taken on a labor-saving role instead of a labor-increasing – a labor-friendly – one. However, a change of productivity in a certain industry is possible to have an effect on employment changes in other industries, via income or substitution effects. Hence, model 2 and model 3 include studies on inter-industrial effect. Model 2 uses a national level of data for including an implicit inter-industrial effect of productivity on employment. Also, model 3 shows these effects explicitly using two industries.

The empirical results of model 2 and 3 provide the following three findings and implications.

Firstly, the aggregate effect of productivity on employment is significantly

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23) As mentioned above, both industries cover 9 industries in the previous panel analysis. The use of this simple classification is for preventing the estimation results result from losing reliability.
positive but its effect has decreased since 2000. When the effect is tested using national level data to include the inter-industrial effect of productivity, i.e. model 2, the empirical results provide a significantly positive effect of productivity on employment.

Secondly, the inter-industrial effect of productivity on employment is significantly positive. The empirical result in model 3 considers both manufacturing and service industries and provides that the long-run relationships between productivity in one industry and employment in another industry are significantly positive. That is, employment in manufacturing (services) increases with productivity in services (manufacturing). It is possible that the innovative capability of a sector is affected by technology innovation in other sectors, along with a degree of utilization and its efficiency. This positive effect brings about an increase in profit and thus more employment. For example, when production in manufacturing increases with an innovation in a sales technique in the service industry, it can be considered as a positive inter-industrial effect of productivity on employment.

Thirdly, the positive inter-industrial long-run relationship between productivity and employment decreased after 2000 due to the simple decline of the inter-industrial effect of productivity on employment. According to the empirical results for model 2, an additional effect of productivity on employment during the 2000s was significantly negative. Also, the empirical results for model 3 show that the positive effect of productivity in manufacturing (services) on employment in services (manufacturing) decreased significantly. There are three possible reasons for reduction in the inter-industrial effect. First, the employment increasing effect from introducing technology in other sector may have disappeared. Second, the change in investment behavior has weakened the inter-industrial effect. Park (2008) provides that investment behavior by firms in Korea changed after 2000 into concentrating on financial assets rather than on real assets. This trend of investment seems to hinder acceptance of new technology from other sector as well as further development of own productivities. Lastly, an increase of economic uncertainty appears to make firms more careful in using technology from other industries.

In concluding remarks, we note that the empirical models in this paper do not explicitly include a spillover effect of productivity. Additional research is needed. However, this study makes its contribution in that it considers the inter-industrial effect of productivity on employment using three models.

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Appendix

<Graph A> The Trend of Employment (Aggregate level, the Number of Employees)

<Graph B> The Trend of Employment (Aggregate level, the Total Hours Worked)

<Graph C> The Trend of TFP (Aggregate level)
### Table A: Summary Statistics of Variables (Level) used in Empirical Estimation

<table>
<thead>
<tr>
<th>Industry level (1980–2009)</th>
<th>Aggregate level</th>
<th>IND01</th>
<th>IND02</th>
<th>IND03</th>
<th>IND04</th>
<th>IND05</th>
<th>IND06</th>
<th>IND07</th>
<th>IND08</th>
<th>IND09</th>
<th>IND10</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(L) Stdev</td>
<td></td>
<td>0.272</td>
<td>0.333</td>
<td>0.160</td>
<td>0.317</td>
<td>0.322</td>
<td>0.332</td>
<td>0.264</td>
<td>0.724</td>
<td>0.407</td>
<td>0.369</td>
</tr>
<tr>
<td>ln(LT) Stdev</td>
<td></td>
<td>0.242</td>
<td>0.390</td>
<td>0.885</td>
<td>0.141</td>
<td>0.317</td>
<td>0.322</td>
<td>0.291</td>
<td>0.705</td>
<td>0.372</td>
<td>0.313</td>
</tr>
<tr>
<td>ln(TFP) Stdev</td>
<td></td>
<td>0.293</td>
<td>0.297</td>
<td>0.346</td>
<td>0.418</td>
<td>0.326</td>
<td>0.120</td>
<td>0.378</td>
<td>0.129</td>
<td>0.106</td>
<td>0.049</td>
</tr>
</tbody>
</table>

### Table B: The Growth Rates of Employments and TFPs (%)

<table>
<thead>
<tr>
<th>Industry level (1980–2009)</th>
<th>Aggregate level</th>
<th>IND01</th>
<th>IND02</th>
<th>IND03</th>
<th>IND04</th>
<th>IND05</th>
<th>IND06</th>
<th>IND07</th>
<th>IND08</th>
<th>IND09</th>
<th>IND10</th>
</tr>
</thead>
<tbody>
<tr>
<td>L All</td>
<td></td>
<td>2.292</td>
<td>-3.579</td>
<td>-5.810</td>
<td>0.900</td>
<td>2.676</td>
<td>2.439</td>
<td>3.865</td>
<td>2.573</td>
<td>7.622</td>
<td>4.625</td>
</tr>
<tr>
<td>LT All</td>
<td></td>
<td>1.880</td>
<td>-4.219</td>
<td>-6.656</td>
<td>0.394</td>
<td>2.888</td>
<td>1.768</td>
<td>3.432</td>
<td>1.824</td>
<td>7.364</td>
<td>4.121</td>
</tr>
<tr>
<td>2000–2009</td>
<td></td>
<td>0.087</td>
<td>-4.566</td>
<td>-1.918</td>
<td>-2.064</td>
<td>3.301</td>
<td>-0.067</td>
<td>3.302</td>
<td>-1.568</td>
<td>3.166</td>
<td>3.265</td>
</tr>
<tr>
<td>TFP All</td>
<td></td>
<td>2.476</td>
<td>3.838</td>
<td>0.538</td>
<td>4.538</td>
<td>3.330</td>
<td>1.448</td>
<td>3.286</td>
<td>1.856</td>
<td>0.953</td>
<td>1.217</td>
</tr>
<tr>
<td>1970–1980</td>
<td></td>
<td>1.837</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990–2000</td>
<td></td>
<td>2.064</td>
<td>4.470</td>
<td>4.266</td>
<td>5.330</td>
<td>3.879</td>
<td>-1.910</td>
<td>4.360</td>
<td>0.624</td>
<td>-2.772</td>
<td>0.081</td>
</tr>
<tr>
<td>2000–2009</td>
<td></td>
<td>2.304</td>
<td>4.816</td>
<td>-6.032</td>
<td>3.965</td>
<td>0.803</td>
<td>2.383</td>
<td>0.339</td>
<td>2.244</td>
<td>-0.462</td>
<td>0.915</td>
</tr>
</tbody>
</table>

Note: 1) The all sample periods (All) in the aggregate level and the industry level are 1970–2009 and 1980–2009.
2) "L", "LT", and "TFP" are the number of employees, the total hours worked, and the total factor productivity.
3) IND10 is for service industry. For other industries out of IND01–IND10, refer the section II.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Content</th>
<th>Official Title of Statistics</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Value added</td>
<td>National account</td>
<td>Bank of Korea</td>
</tr>
<tr>
<td>Labor</td>
<td>the number of employees</td>
<td>Economically Active Population Survey</td>
<td>KOSIS</td>
</tr>
<tr>
<td></td>
<td>hours worked</td>
<td>Economically Active Population Survey</td>
<td>KOSIS</td>
</tr>
<tr>
<td>Labor compensation</td>
<td>compensation of employees (wage)</td>
<td>National account</td>
<td>Bank of Korea</td>
</tr>
<tr>
<td></td>
<td>compensation of employees (nonwage)</td>
<td>Employed persons by occupation</td>
<td>KOSIS</td>
</tr>
<tr>
<td>Capital</td>
<td>(net) Capital stock</td>
<td>National wealth</td>
<td>KOSIS</td>
</tr>
</tbody>
</table>
Reference


