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Aggregate Productivity Growth in Korean Manufacturing: The Role of Young Plants

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I measure aggregate productivity growth in manufacturing between 1995 and 2013 as defined by Petrin and Levinsohn (2012). I decompose aggregate productivity growth into technical efficiency improvements, resource reallocations, and net entry effects. I find that aggregate productivity growth slows down after 2004 and that the rapid drop in technical efficiency growth contributed most to the decline. In this paper, I focus on the role of young plants with regard to productivity growth of Korean manufacturing. I show that young plants account for nearly half of APG (48%), while their value-added share is 14 percent on average between 1995 and 2013. I find that productivity growth at young plants has been declining for the last ten years. The lower growth of continuing young plants contributes to this trend. These results stress the important role of young plants in aggregate productivity growth and imply that understanding the dynamics of young plants is necessary to form effective start-up policies.

Key Word: Aggregate productivity growth, Productivity, Reallocation, Young plants
JEL Code: L6, L26, O47

I. Introduction

Manufacturing firms in Korea are exposed to competition with developed countries, including Germany, Japan, and the United States, in innovative products and services. They are also competing with Chinese firms in both domestic and foreign markets at a time when China is experiencing rapid growth in Korea's flagship industries. This paper studies aggregate productivity growth in Korean manufacturing over the past two decades and investigates the sources of productivity growth.

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Aggregate productivity can increase when plants increase their technical efficiency by developing or adopting new technologies, implementing process innovations, or improving their management system. However, without an increase in technical efficiency at plants, aggregate productivity can increase when resources are reallocated to a business with a higher market value. On the other hand, this also means that aggregate productivity can decrease when allocative efficiency decreases. Whether the decline in aggregate productivity is attributable to the stagnation of technical efficiency growth or to the decline in allocative efficiency is important when considering policies to maintain competitiveness. In this paper, I study the role of plant-level technical efficiency improvements, resource reallocations, and the net entry of plants in aggregate productivity growth.

I use plant-level data from the annual Mining and Manufacturing Survey provided by Statistics Korea to measure aggregate productivity growth in manufacturing between 1995 and 2013. I adopt the description of Petrin and Levinsohn (2012) (PL) of aggregate productivity growth (APG), where APG is defined as the change in aggregate final demand net of the change in expenditures on labor and capital. First, I need to estimate plant-level technical efficiency in order to estimate the contributions of plant-level technical efficiency improvements, resource reallocations, and the net entry of plants to APG. I apply the estimation method of Wooldridge (2009), which is a modified version of that by Levinsohn and Petrin (2003), to estimate the elasticity parameters of inputs in the production function. The elasticity parameters are estimated for every 82 three-digit industry.

The measured APG of the manufacturing industry is 5.7 percent on average between 1995 and 2013. During this period, technical efficiency growth is 4.3 percent on average, making the main contribution to APG. Resource reallocation also contributed positively by adding 1.2 percent to APG on average during the period. Net entry added 0.3 percent to APG on average. Over the period, APG shows a declining trend after peaking at a growth rate of 11 percent in 2004. I find that the main driver of the decline is the sharp decrease in technical efficiency growth. Moreover, despite the fact that the effect of resource reallocation increased APG after the 2008 global financial crisis, technical efficiency growth fell sharply causing APG to decline. Similar to the pattern found in the manufacturing industry, most of the two-digit industries in manufacturing experienced a slowdown in APG. However, the contribution of technical efficiency and reallocation differed across industries. APG was negative in recent years in the cases of the Basic Metal Products and Other Transport Equipment industries, where the necessity of industrial restructuring was strongly urged to strengthen competitiveness.

There are recent papers which apply the same measure of APG from Petrin and Levinsohn (2012) to study the effects of resource allocation and technical efficiency growth on APG. Petrin, White and Reiter (2011) find a 2.2% rate of APG on average in the U.S. manufacturing industry between 1976 and 1996. They show that resource reallocation effects contributed mainly to APG. For manufacturing in Japan, Kwon, Narita and Narita (2015) show that resource reallocation effects decreased in the 1990s and impacted APG negatively during the late 1990s.

Several studies used alternative measures of aggregate productivity growth for the Korean manufacturing industry. These measures define aggregate productivity

growth based solely on plant-level technical efficiency. Baily, Hulten and Campbell (1992) (BHC) and Foster, Haltiwanger and Krizan (2001) are examples of studies which use this measure. Hahn (2003) finds that plant entries and exits account for 45 percent of manufacturing productivity growth during the 1990-95 cyclical upturn and for 65 percent during the 1995-98 downturn. He also shows that resource reallocation contributed negatively during the 1990-95 upturn but positively during the 1995-98 downturn. Ahn (2006) finds a large role of the net entry of plants at a similar magnitude to APG between 1990 and 2003. The measured contribution of net entry is sensitive to the length of the period in the analysis because the longer the period, the higher the number of plants which are counted as entering and exiting. The measured contributions of technical efficiency, reallocation, and net entry to APG in these papers are different from the results of this paper. These differences are not only the result of the different periods of analysis but are also due to the methods applied to measure APG. When I estimated APG using the method devised by BHC, I found that the levels of variance in the reallocation effects and net entry effects are large for the BHC measure. Moreover, BHC resource reallocation effects were negative while PL resource reallocation effects were positive on average throughout the period. These findings imply the necessity of a cautious approach when studying the roles of technical efficiency, reallocation, and net entry, as the results depend on how APG is defined.

Among the many sources of the decline in APG, this paper focuses on productivity growth at young plants. Young plants contribute substantially to the creation of jobs and in creating value-added. Recent research has uncovered the importance of the role of a firm's age. For example, Haltiwanger, Jarmin, and Miranda (2013) find that surviving young firms show considerably higher growth rates than mature firms. Haltiwanger, Jarmin, Kulick and Miranda (2016) find that young firms undergoing high growth contribute to job creation and output growth disproportionately more relative to their share in employment and output. Both papers analyze the U.S. economy using data that covers firms and plants in the U.S. private sector.

For the Korean economy, Pyo, Hong, and Kim (2016) and Cho, Chun, Kim, and Lee (2017) study the roles of age and size on job creation. Both papers utilize Census on Establishment data, which covers all establishments. Pyo, Hong, and Kim (2016) find while controlling for firm size that younger firms show higher net job growth rates. Cho, Chun, Kim, and Lee (2017) show that establishment births explain the majority of job creation among small businesses, which themselves account for the majority of job creation. However, they find no systematic relationship between age and job creation, except with regard to births. In this paper, I study the role of young plants on productivity growth in the Korean manufacturing sector.

The role of young plants can be found in many important outcomes. However, the share of young plants in Korean manufacturing has been declining over the past two decades. The proportion of young plants dropped from 45% in 1995 to 28% by 2013, while the shares in employment and value-added both dropped in a similar fashion. As a result, the average age of manufacturing plants has increased over the last twenty years. This declining pace of dynamism is likely to have affected the decline of APG. Section IV measures the productivity growth of young plants and

identifies the causes of the decline. Furthermore, I analyze the contribution of young plants in high-tech manufacturing industries.

To quantify the impact of young plants on APG, I define young plants as plants aged up to five years old and aggregate the contribution of each young plant to APG. First, I show that young plants account for nearly half of APG (48%), while their share with regard to value-added is 14 percent on average between 1995 and 2013. During the same period, small plants with less than 300 employees represent 36 percent of APG while their share of value-added is 47 percent. Second, productivity growth of young plants shows less variation than that associated with APG and increases APG during economic recessions. Third, productivity growth of young plants has been declining for the last ten years and has thus not boosted productivity growth as much during that time.

The declining growth rate of young plants may have resulted from fewer entries or from the lower growth rates of young plants. When I decomposed the effects of young plants into the effects of entries and the effects of continuing young plants, I found that the effects of young plants were reduced mainly due to lower growth rates of continuing young plants. The growth rates of continuing young plants are lower in the most recent ten years than in the previous ten years. This period corresponds to the period during which the Korean government implemented active start-up support policies and greatly increased the budget size for the policies. It is necessary to understand the business dynamics when designing an effective start-up policy.

Moreover, I find that the APG of the high-tech industry decreased in the last three years, while the effects of young plants on productivity growth in the high-tech industry were sharply reduced over the last three years. This is linked to the sharp decline in the APG of manufacturing in the last three years, as the APG of the high-tech industry accounts for major part of APG overall. High-tech industries are among those focused on by the government, which considers them an engine of future growth. Fewer entries and lower growth rates of plants in these industries could limit productivity growth in the manufacturing industry.

This study has a few limitations regarding the data used to measure APG and the effects of young plants. I use plant-level data from 1995 to 2013 from the annual Mining and Manufacturing Survey provided by Statistics Korea. This survey covers all establishments with ten or more employees. The majority of plants have fewer than ten employees, and their impacts are not measured. With regard to these young plants which are more likely to start their business with fewer than ten employees, the effects of these plants can be underestimated relative to their actual role. Nevertheless, gross output produced from the plants covered in the survey accounts for 87% of the gross output of manufacturing in 2012, where the gross output data is obtained from the national input-output table from the Bank of Korea.

Another limitation is that the unit of analysis is at the establishment level and not at the firm level. When an existing firm establishes a new plant to expand its business, the plant is considered as young given that it was created at that point, with the age of the existing parent firm disregarded. Thus, some of the effects of young plants come from new plants established by existing firms. However, an establishment-level analysis has the advantage of having well-defined units of

businesses with employees. A firm-level analysis can contain effects coming from acquisitions and mergers, thus blurring the relationship between firm growth and age.

The next section introduces the methodology used to measure APG and how this data was decomposed. It also explains the plant-level data. Section III presents the results. Section IV discusses the productivity growth of young plants. Section V concludes the paper.

II. Measuring Aggregate Productivity Growth

A. *Aggregate Productivity Growth*

I use the definition of aggregate productivity growth (APG) by Petrin and Levinsohn (2012) (PL) to measure aggregate productivity growth in the Korean manufacturing industry between 1995 and 2013. APG is defined as the change in aggregate final demand net of the change in the expenditures on labor and capital. Plant-level data is utilized to construct the APG measure. Any changes in each plant's technical efficiency or in a reallocation of inputs across plants contribute to APG according to this definition.

In addition to this method, there are other methods which can be used to measure APG, for instance by aggregating individual plants' productivity, as was done by BHC. They measure APG according to the change in the weighted average of plant-level technical efficiency. Numerous papers which measure APG in the Korean manufacturing industry are based on these methods (e.g., Hahn, 2003; Ahn, 2006; Rhee and Pyo, 2015). Petrin and Levinsohn (2012) discuss the problems which can arise when measuring APG with the BHC method.

One problem is that APG can increase in some cases when using the BHC method while aggregate output decreases due to the reallocation of inputs across plants. These cases can arise if the value of the additional output net of the increased cost of input decreases while the inputs are reallocated across plants. BHC reallocation effects can be positive in these cases if inputs are reallocated to plants with higher levels of technical efficiency, as the definition by BHC of reallocation effects uses only technical efficiency as weights to the change in input. The definition of reallocation effects in APG uses the differences between the marginal product and the unit cost of the input as weights to the change in input.

Another problem is that the estimated effects of the reallocation of inputs are excessively large and various. This problem stems from the large dispersion of the estimated technical efficiency among plants. Petrin and Levinsohn (2012) overcome these problems by defining APG and reallocation effects such that APG decreases when there is a loss in output and reallocation effects capture the difference in the value of the marginal product and input cost. In this paper, I apply both methods, PL and BHC, using micro-level data pertaining to Korean manufacturing to study the roles of technical efficiency and reallocation in APG. The results from the two methods are compared.

APG represents the change in the aggregate final demand net of the change in the expenditures on inputs. It is expressed by the following equation,

(1) $$APG \equiv \sum_i P_i dY_i - \sum_i \sum_f W_{if} dX_{if},$$

where dY_i is the change in the final demand of plant i's output, and P_i is the price of the output. dX_{if} denotes the change in plant i's primary input f, and W_{if} is the unit price of the input. Labor and capital can be considered as primary inputs. The time index is suppressed for convenience.

There is no available data with which to distinguish how much of each plant's output is spent on final demand. The growth accounting identity requires aggregate final demand to be equal to aggregate value-added,

(2) $$\sum_i P_i Y_i = \sum_i VA_i,$$

where VA_i is the value-added of plant i.

The growth accounting identity is utilized to express APG, as follows:

(3) $$APG = \sum_i dVA_i - \sum_i \sum_f W_{if} dX_{if}$$

Here, dVA_i is the change in the value-added of plant i.

Using Eq. (3), APG is calculated by aggregating the value-added and expenditure on inputs by individual plants. Given the way in which APG is defined, we can measure each plant's contribution to APG and analyze the effects of a group with particular characteristics.

PL represents the decomposition of APG into its technical efficiency and reallocation components. Kwon, Narita, and Narita (2015) undertake a further decomposition of APG into the technical efficiency effect (TE), resource reallocation effect (RE) and net entry effect (NE). I use their decomposition of APG and the following notations for each component:

(4) $$APG_t = TE_t + RE_t + NE_t$$

(5) $$TE_t = \sum_{i \in C_t} \overline{D}_{it} \Delta \ln A_{it}$$

Here, $\ln A_{it}$ is the log TFP of plant i. D_{it} denotes the Domar (1961) weight, which is equal to the gross output of plant i over the aggregate value-added. A bar over a variable indicates an average over two periods of time $\left(\overline{x}_{it} := \frac{x_{i,t-1} + x_{it}}{2} \right)$. C_t is the set of continuing plants which are active for year $t-1$ and year t.

The technical efficiency effect is the contribution to APG due to the changes in

plant-level technical efficiency. TE is the sum of the weighted plant-level technical efficiency, where the weight is the ratio of each plant's gross output to aggregate final demand. The plant-level technical efficiency estimate is obtained by estimating a production function. I use gross output production to consider a plant's usage of intermediate inputs in the estimation. It is natural to use a plant's gross output when weighting for this specification. Petrin and Levinsohn (2012) find a rationale for using the Domar weight from Hulten (1978), holding that the contribution of the plant-level technical efficiency gain is identical to additional output multiplied by the price of the output.

(6) $$RE_t = \sum_i RE_{ft} = \sum_f \sum_{i \in C_t} \overline{D}_{it} (\varepsilon_{if} - \overline{s}_{ift}) \Delta \ln X_{ift}$$

In this equation, ε_{if} is the elasticity of output with respect to input f, and s_{if} is the ratio of expenditures on input f to gross output of plant i. $\Delta \ln X_{ift}$ is the log change in input.

The difference between the marginal product and the unit cost of input f, i.e., $(\varepsilon_{if} - \overline{s}_{ift})$, is weighted to the change in input. Reallocation effects exist only when there is a difference between the two. Reallocation effects aggregate the changes in output due to the reallocation of inputs across plants. There is a gain in allocative efficiency when inputs move from plants with a lower marginal product to a higher marginal product relative to their unit cost of input.

(7) $$NE_t = \sum_{i \in E_t} D_{it} [1 - \sum_f s_{ift}] - \sum_{i \in X_{t-1}} D_{i,t-1} [1 - \sum_f s_{if,t-1}]$$

Here, E and X indicate the sets of entering and exiting plants, respectively.

Net entry effects capture the net output minus the net unit costs of the input according to the net entry of plants.

Compared to the APG measure and its decomposition as introduced in this section, I present the BHC measure of aggregate productivity growth and its decomposition. Petrin and Levinsohn (2012) provide a detailed discussion of the difference between these two methodologies. BHC define aggregate productivity by the weighted average of plant-level technical efficiency. Aggregate productivity growth is the change of the weighted average. Following Petrin and Levinsohn (2012), the BHC aggregate productivity growth is approximated with discrete data, as follows:

(8) $$BHC = \sum_i D_{it} \ln A_{it} - \sum_i D_{it-1} \ln A_{it-1}$$

Most empirical papers use labor or gross output shares as weights for technical efficiency. Petrin and Levinsohn (2012) used the Domar weight in the BHC measure to abstract from the difference in the technical efficiency effect using identical weights for both APG and BHC. In this paper, I used gross output shares

as weights in the BHC measure to compare APG with other empirical results under the BHC framework. Thus, I allow technical efficiency effects to differ across the two measures. The Domar weight equals the gross output share only when there is no intermediate input use. Because APG uses the Domar weight, technical efficiency growth in APG will be larger than the BHC technical efficiency growth when there is more intermediate input use.

The resource reallocation effect and net entry effect when using the BHC measure are expressed as follows:

$$\text{BHC } RE_t = \sum_{i \in C_t} \overline{\ln A_{it}} \; \Delta D_{it} \tag{9}$$

$$BHC \;\; NE_t = \sum_{i \in E_t} D_{it} \ln A_{it} - \sum_{i \in X_{t-1}} D_{it-1} \ln A_{it-1} \tag{10}$$

B. *Data and Estimation*

I utilize plant-level data from 1995 to 2013 from the annual Mining and Manufacturing Survey provided by Statistics Korea. Only the manufacturing sector is considered. The survey covers all establishments with ten or more employees. The survey classifies plants according to the five-digit Korean Standard Industry Classification (KSIC). KSIC was revised three times, from Rev. 6 to 9, during the period of analysis. I used concordance tables from Statistics Korea to match industries to KSIC Rev. 9.

The set of plants used in the analysis includes 52,391 plants in 1995, increasing to 64,332 plants in 2013. I compared the number of plants and the aggregates of gross output and employees respectively in the set with statistics on sectoral output and employee data in 2012 from the Bank of Korea. The set represents 17% of the number of plants, 87% in terms of gross output, and 72% in terms of employees. The coverage with regard to the number of plants is low because the majority of plants hire fewer than ten employees. However, relatively large plants account for most of the gross output and employees in the manufacturing industry.

I use information on the number of employees, gross output, capital stock, total expenditures on intermediate inputs, and wages from the survey. The expenditures on intermediate inputs include the costs of materials, fuel, electricity, water, and processing costs paid to subcontractors. I define capital stock as the sum of the average book value of the building structure, machinery, and transport equipment between the beginning and end of the year.

What we observe in the data are in nominal values. I calculated industry-level deflators at the two-digit level using gross output and intermediate input data both in nominal and real values from the productivity database of the Korea Productivity Center. Constructed deflators are gross output deflators and intermediate input deflators for 19 industries in manufacturing. I deflate the nominal value of each plant's gross output and expenditures on intermediate inputs using these deflators. Real value-added is defined as the real value of gross output minus the real value of expenditures on intermediate inputs. For capital stock, I constructed deflators for

building structures, machinery, and transport equipment using gross capital formation in national accounts in nominal and real values provided by the Economic Statistics System of the Bank of Korea. Real capital stock is the sum of the real values of each fixed asset. Real wage is obtained using the consumer price index (CPI) from the Bank of Korea.

These real values constructed from plant-level data are used to calculate APG and its decomposition in Eqs. (3)-(7). All terms in the equations except for technical efficiency (A_{it}) and the elasticity parameters (ε_{if}) are directly obtained from the data. I use the following gross output specification of the Cobb-Douglas production function,

$$\ln Q_{it} = \ln A_{it} + \varepsilon_{jK} \ln K_{it} + \varepsilon_{jL} \ln L_{it} + \varepsilon_{jM} \ln M_{it}, \tag{11}$$

where Q_{it} is the gross output of plant i, and K_{it}, L_{it} and M_{it} are the capital, employees, and intermediate inputs, i.e., the production inputs of plant i. ε_{jK}, ε_{jL}, ε_{jM} are coefficients in the estimation, representing the elasticities of each production input.

I estimate the elasticity parameters for all 82 three-digit industries using the estimation method by Wooldridge (2009). The method is based on Levinsohn and Petrin (2003), who use intermediate inputs to control the simultaneity problem arising from the correlation between unobserved productivity and the input level. Wooldridge (2009) proposes the use of a generalized method of moments (GMM) framework. He shows that the method is robust to the identification problem[1] that can arise when applying the two-step estimation method of Levinsohn and Petrin (2003). In this paper, I used one- and two-year lag variables of labor and intermediate inputs as instrumental variables. Once the elasticity parameters are estimated, Eq. (11) is used to calculate plant-level productivity.

III. Aggregate Productivity Growth

This section presents the measured aggregate productivity growth of the Korean manufacturing industry and its decomposition. I compare the baseline results from the PL method to the results from the BHC method. This section also reports APG and its decomposition for industries at the two-digit level.

A. *Aggregate Productivity Growth and its Decomposition*

Table 1 reports annual APG and its decomposition between 1995 and 2013. The average APG is 5.7 percent during this period. Technical efficiency effects account for a larger part of APG than resource reallocation effects and net entry effects.

Except for the rebounding growth rate after two economic crises of 1998 and 2009, APG declines from a peak of 11 percent in 2004. I divided the period from

[1]See the discussion of the identification problem in Ackerberg, Caves, and Frazer (2006).

TABLE 1—APG AND ITS DECOMPOSITION

Year	Aggregate productivity (APG)	Technical efficiency (TE)	Resource reallocation (RE)	Net entry (NE)
1996	10.9	9.6	1.7	-0.3
1997	5.9	3.8	2.9	-0.8
1998	-6.9	4.5	-10.6	-0.8
1999	19.8	14.6	4.6	0.7
2000	6.9	4.7	0.9	1.3
2001	2.6	2.5	-0.6	0.7
2002	8.8	5.5	2.4	0.8
2003	3.1	2.4	0.7	0.0
2004	11.0	13.4	-1.6	-0.8
2005	4.3	3.9	-2.0	2.3
2006	8.3	5.6	3.0	-0.3
2007	5.1	5.9	-2.3	1.5
2008	6.5	3.6	3.0	-0.1
2009	-2.5	-6.6	2.8	1.4
2010	9.1	4.2	3.7	1.2
2011	9.1	4.2	3.7	1.2
2012	0.8	-3.8	6.2	-1.6
2013	-0.4	-1.2	2.5	-1.8
’95-’13 Mean (s.d.)	5.7 (5.8)	4.3 (5.0)	1.2 (3.6)	0.3 (1.1)
’95-’04 Mean (s.d.)	6.9 (6.9)	6.8 (4.3)	0.04 (4.1)	0.1 (0.8)
’04-’13 Mean (s.d.)	4.5 (4.0)	1.8 (4.2)	2.3 (2.6)	0.4 (1.4)
’11-’13 Mean (s.d.)	0.2 (0.6)	-2.5 (1.3)	4.4 (1.8)	-1.7 (0.1)

Note: The growth rates for 2010 and 2011 are the average annual growth rate between 2009 and 2011.

Source: Author’s calculation from the Mining and Manufacturing Survey.

1995 to 2013 into the first ten years and the last ten years to compare the average growth rates for each period, finding that APG declined from 6.9 percent in the first ten years to 4.5 percent in the last ten years. The main reason for the decline comes from the rapid drop in the technical efficiency effects. Technical efficiency effects dropped from 6.8 percent in the first ten years to 1.8 percent in the last ten years. The 4.5 percent average rate of APG in the last ten years was mainly attributable to resource reallocation effects. For the more recent three years between 2011 and 2013, APG showed less than a 1 percent growth rate. Both technical efficiency effects and net entry effects made negative contributions to APG during this period.

Some recent work investigated the role of resource reallocation in industry-level productivity growth during recessions. Focusing on the U.S., Foster, Grim and Haltiwanger (2016) show that the role of reallocation in enhancing productivity was reduced during the Great Recession compared to the previous recession. Table 1 shows that resource reallocation effects helped to increase APG continuously in the five years after the global financial crisis. Despite the positive resource reallocation effects during this period, technical efficiency effects fell sharply, lowering APG.

Table 1 presents the baseline results from the PL method. Many papers (e.g., Hahn, 2003; Ahn, 2006) used annual Mining and Manufacturing Survey to measure aggregate productivity growth based on the BHC method. To show empirical differences between the PL method and the BHC method, I calculated BHC aggregate productivity growth using Eqs. (8), (9) and (10). I used gross output shares as weights. I present the empirical differences between PL and BHC in

Appendix A.

The results show that the degrees of variance in the reallocation effects and the net entry effects are large for the BHC measure. For nearly half of the twenty-year period, the resource reallocation effects of PL and BHC show opposite signs. On average, BHC resource reallocation effects were negative while PL resource reallocation effects were positive. The difference is large, particularly for years after 2008 global financial crisis. These findings suggest that the measured aggregate productivity growth and its decomposition into technical efficiency, reallocation, and net entry are sensitive to the method applied.

B. *Sectoral Productivity Growth and its Decomposition*

In this subsection, I study the contribution of each sector to APG in the manufacturing industry. I also study whether the source of the productivity growth differs across industries by calculating APG decompositions. Table 2 presents sectoral productivity growth and its decomposition for industries at the two-digit level. Using the given definition of APG, we can easily compute the contribution of each individual plant to APG. Sectoral productivity growth is defined by aggregating the contribution of each individual plant by sector. The weight in the aggregation is the Domar weight defined for industries at the two-digit level, i.e., the gross output of individual plants over sectoral value-added.

Table 2 lists the sectors according to the size of the average value-added share. The first column in Table 2 shows that sectoral productivity growth differs considerably across sectors. The designation Electronic Components, Computer, Radio, Television and Communication Equipment creates 21 percent of value-added on average in the manufacturing industry and shows the highest average growth rate. Among the top ten industries in terms of the value-added share, the lowest and the second lowest growth rates were found in the Basic Metal Products and Other Transport Equipment industries, where the necessity of industrial restructuring was strongly urged to strengthen competitiveness.

Looking at the average contribution of technical efficiency, reallocation and net entry, different sectors have different relative factors of productivity growth. Out of top ten value-added share industries, four industries (26, 24, 29, 22) make relatively large resource reallocation contributions, while the other six industries (30, 20, 10, 25, 31, 28) have larger contributions of technical efficiency.

Figures 3 and 4 show the sectoral productivity growth estimates and related components for industries 26 and 30, respectively. These two sectors account for 32 percent of value-added in the manufacturing industry. The factors that help to increase productivity growth stand in contrast between the two sectors. For industry 26, reallocation effects were positive for most years during the period of 1995-2013. The recent slowdown in productivity growth was affected by negative effects of technical efficiency. In contrast, technical efficiency effects were the main driver of productivity growth in industry 30 and negative reallocation effects decreased the productivity growth during the most recent four years.

TABLE 2—APG AND ITS DECOMPOSITION FOR INDUSTRIES AT THE TWO-DIGIT LEVEL

(UNIT: %)

Code (KSIC9)	Description	APG	TE	RE	NE	Value-added share
26	Electronic Components, Computer, Radio, Television and Communication Equipment	11.6	1.3	9.8	0.5	21.2
30	Motor Vehicles, Trailers and Semitrailers	6.9	13.0	-6.2	0.1	10.6
20	Chemicals and Chemical Products	4.1	4.5	-1.6	1.2	7.9
24	Basic Metal Products	1.5	-0.4	1.8	0.1	7.3
29	Other Machinery and Equipment	5.1	-10.0	14.4	0.7	7.1
10	Food Products	3.5	3.5	-0.1	0.1	5.0
25	Fabricated Metal Products	6.1	24.4	-19.0	0.6	4.8
31	Other Transport Equipment	2.1	11.2	-10.3	1.2	4.6
22	Rubber and Plastic Products	5.2	-6.4	11.3	0.2	4.2
28	Electrical Equipment	6.1	6.9	-1.0	0.2	4.0
23	Other Non-metallic Mineral Products	4.2	2.4	1.8	0.1	3.7
19	Coke and Refined Petroleum Products	1.1	6.5	-5.3	-0.1	3.6
13	Textiles	1.6	3.4	-1.4	-0.4	3.1
14	Wearing apparel and Fur Articles	4.3	8.0	-2.4	-1.4	2.3
17	Pulp, Paper and Paper Products	2.5	-0.1	3.0	-0.5	1.9
21	Pharmaceuticals, Medicinal Chemicals and Botanical Products	7.2	4.2	3.3	-0.4	1.8
11	Beverages	2.7	-2.8	5.7	-0.2	1.5
27	Medical, Precision and Optical Instruments, Watches and Clocks	10.0	5.0	3.8	1.3	1.1
12	Tobacco Products	-2.9	7.1	-7.5	-2.5	0.9
15	Leather, Luggage and Footwear	2.4	4.9	-1.3	-1.1	0.7
32	Furniture	3.5	-6.4	9.8	0.03	0.7
33	Other manufacturing	2.9	-0.4	4.0	-0.7	0.6
18	Printing and Reproduction of Recorded Media	4.3	3.5	-0.3	1.2	0.6
16	Wood and of Products of Wood	2.3	4.6	-1.4	-0.9	0.5

Note: The growth rates for 2010 and 2011 are the average annual growth rate between 2009 and 2011.

Source: Author's calculation from the Mining and Manufacturing Survey.

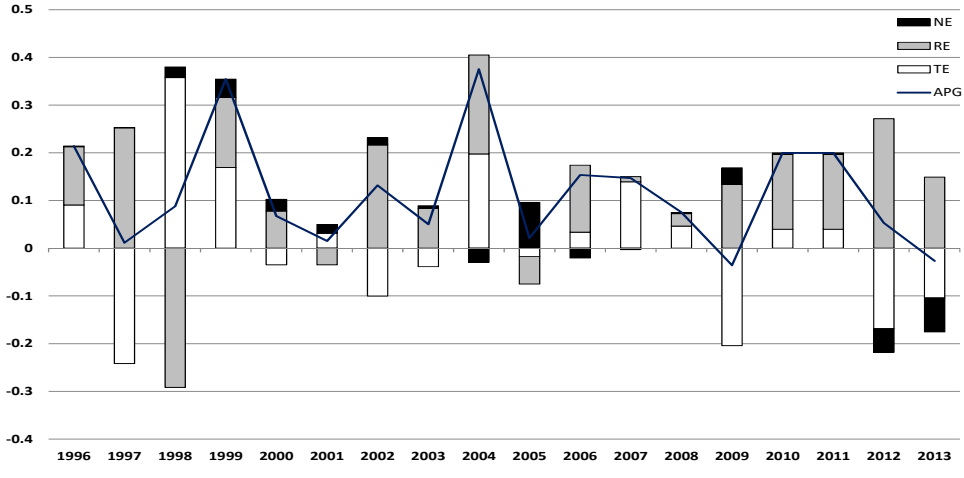


FIGURE 3. SECTORAL PRODUCTIVITY GROWTH AND ITS DECOMPOSITION (INDUSTRY 26)

Note: The growth rates for 2010 and 2011 are the average annual growth rate between 2009 and 2011.

Source: Author's calculation from the Mining and Manufacturing Survey.

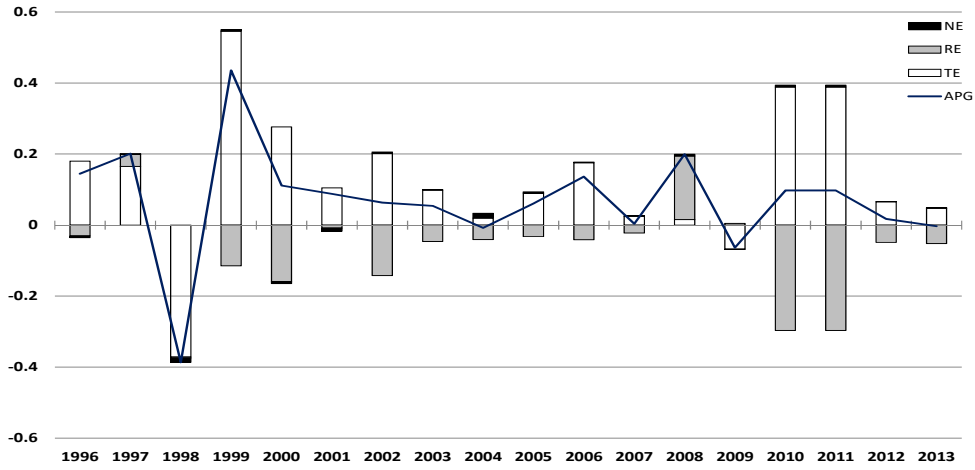


FIGURE 4. SECTORAL PRODUCTIVITY GROWTH AND ITS DECOMPOSITION (INDUSTRY 30)

Note: The growth rates for 2010 and 2011 are the average annual growth rate between 2009 and 2011.

Source: Author's calculation from the Mining and Manufacturing Survey.

IV. The Role of Young Plants in Aggregate Productivity Growth

This section empirically shows the role of young plants in aggregate productivity growth. Figure 5 shows the share of young plants (less than six years old) in terms of the number of plants, employment, and value-added for all plants with ten or more employees in the Mining and Manufacturing Survey. The share of young plants in the manufacturing industry shows a decline for all three variables over the last twenty years. The declining share of young plants is likely to have affected aggregate productivity growth.

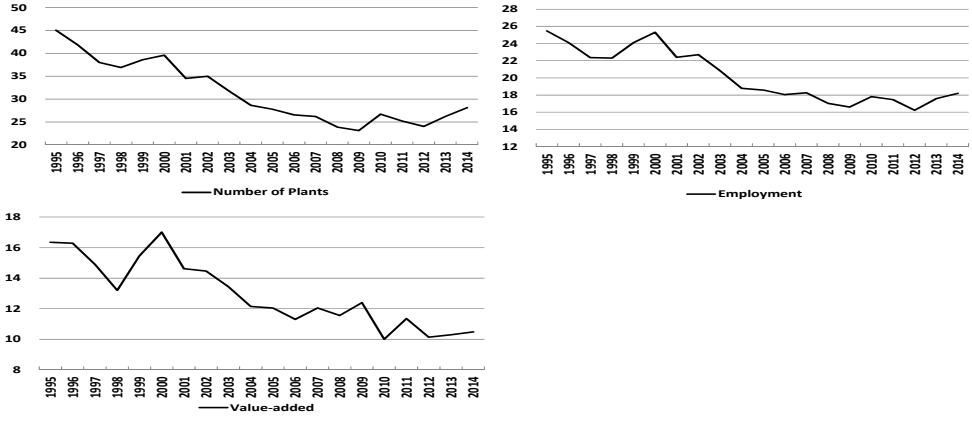


FIGURE 5. SHARE OF YOUNG PLANTS

Note: The graph shows the share of young plants (less than six years old) in terms of the number of plants, employment, and value-added.

Source: Author's calculation from the Mining and Manufacturing Survey.

A. *Young Plants' Contribution to Aggregate Productivity Growth*

In this section, I compute the contribution by young plants to aggregate productivity growth. I define young plants as plants up to age 5 in the baseline results. Results for young plants up to age 2 are presented to study the effects of start-ups. I use the establishment year information in the Mining and Manufacturing Survey to calculate plant ages. Using the definition of APG in Eq. (3), the contribution by young plants to APG (APG_{young}) is measured as follows:

$$APG_{young} = \sum_{i \in young_t} dVA_i - \sum_{i \in young_t} \sum_f W_{if} dX_{if} \tag{12}$$

The contribution of old plants to APG (APG_{old}) is defined correspondingly. APG is the sum of APG_{young} and APG_{old} .

Figure 6 shows the estimates of APG and the contributions by young and old plants for the period of 1995-2013. Table 3 reports the average of those estimates. There are three main findings regarding the role of young plants in aggregate productivity growth. First, the contribution of young plants to APG is much larger than their shares for value-added. Productivity growth by young plants accounts for nearly half of APG on average over the twenty-year period while their valued-added share is only 14 percent on average. Young plants show high growth in value-added relative to growth in input expenditures. Second, productivity growth of young plants shows much less variance than that of APG, and it increases APG during economic recessions. Third, young plants' productivity growth shows a decline over the last ten years. A decline is apparent for the last three years of the period of analysis. The last two columns in Table 3 decompose productivity growth by young plants into the growth of start-ups (age 0-2) and the growth of young plants (age 3-5). These results show that productivity growth declines in the last ten years for both start-ups (age 0-2) and young plants (age 3-5).

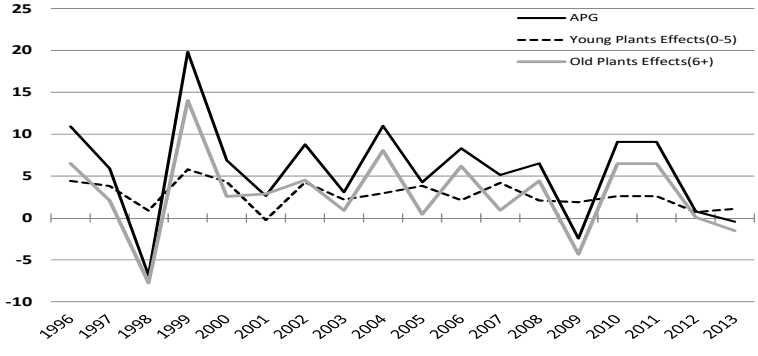


FIGURE 6. APG AND ITS DECOMPOSITION INTO DIFFERENT AGE GROUPS

Note: The growth rates for 2010 and 2011 are the average annual growth rate between 2009 and 2011.

Source: Author's calculation from the Mining and Manufacturing Survey

TABLE 3—APG AND ITS DECOMPOSITION INTO DIFFERENT AGE GROUPS

(UNIT: %)

	APG	Old Plants Effects (6+)	Young Plants Effects (0-5)	Young Plants Effects (0-2)	Young Plants Effects (3-5)	Young Plants Value-added share
’95-’13 Mean (s.d.)	5.7(5.8)	2.9(4.8)	2.8(1.5)	1.3(0.6)	1.5(1.2)	13.7(2.9)
’ 95-’04 Mean (s.d.)	6.9(6.9)	3.8(5.5)	3.2(1.8)	1.5(0.7)	1.6(1.4)	16.1(1.5)
’04-’13 Mean (s.d.)	4.5(4.0)	2.1(3.7)	2.3(1.1)	1.1(0.4)	1.3(0.8)	11.3(1.6)
’11-’13 Mean (s.d.)	0.2(0.6)	-0.7(0.8)	0.9(0.2)	0.6(0.2)	0.3(0.01)	10.2(0.1)

Source: Author’s calculation from the Mining and Manufacturing Survey.

TABLE 4—APG AND ITS DECOMPOSITION INTO DIFFERENT SIZE GROUPS

(UNIT: %)

	APG	Large Plants Effects	Small Plants Effects	Small & Young Plants Effects	Small Plants Value-added share
’95-’13 Mean (s.d.)	5.7(5.8)	3.6(4.2)	2.1(2.2)	1.6(0.8)	47.3(1.8)
’95-’04 Mean (s.d.)	6.9(6.9)	4.2(4.7)	2.8(2.7)	1.8(1.0)	47.2(2.0)
’04-’13 Mean (s.d.)	4.5(4.0)	3.1(3.4)	1.4(1.2)	1.4(0.4)	47.4(1.4)
’11-’13 Mean (s.d.)	0.2(0.6)	-0.8(0.6)	1.0(0.1)	1.4(0.5)	46.3(0.7)

Note: Large plants are those with equal to or more than 300 employees. Small and young plants are those with fewer than 300 employees and under six years old.

Source: Author’s calculation from the Mining and Manufacturing Survey.

To compare the size of the contribution from young plants to that of small plants, I compute the contribution of small plants to APG by applying Eq. (12) to plants with less than 300 employees. Table 4 presents the results. During the twenty-year period, small plants with less than 300 employees account for 36 percent of APG while their share in value-added is 47 percent on average. Productivity growth rates decline for both large and small plants in the last ten years, with a remarkably steep decline for large plants over the last three years.

The fourth column in Table 4 shows the productivity growth of young plants among the small plants. I find that young plants contribute to the majority of small plants’ productivity growth. I also find that the productivity growth of small and young plants did not decline much compared to the decline in APG. These results imply that the steep decline in the productivity growth of young plants was due to large and young plants.

B. *Continuing, Entering and Exiting Plants*

The declining productivity growth of young plants may have resulted from fewer entries or from the lower growth rates of young plants. Table 5 shows the decomposition of the productivity growth of young plants into the effects of net entries and the effects of continuing young plants. The productivity growth of young plants was reduced mainly due to the lower growth rates of continuing

TABLE 5—YOUNG PLANTS PRODUCTIVITY GROWTH

(UNIT: %)

	Young Plants Effects(0-5)	Young Plants Continuing	Young Plants Net entry
'95-'13 Mean (s.d.)	2.8(1.5)	1.8(1.3)	1.0(0.7)
'95-'04 Mean (s.d.)	3.2(1.8)	2.3(1.5)	0.9(0.6)
'04-'13 Mean (s.d.)	2.3(1.1)	1.3(0.8)	1.0(0.8)
'11-'13 Mean (s.d.)	0.9(0.2)	0.7(0.1)	0.2(0.1)

Source: Author's calculation from the Mining and Manufacturing Survey.

young plants. The recent ten-year period corresponds to the period when the Korean government implemented active start-up support policies and greatly increased the size of the budget related to these policies. These results imply certain policies can effectively increase aggregate productivity growth if those policies can help surviving start-ups to grow rather than focus only on increasing the number of start-ups.

C. *Plants Age and Productivity Dynamics*

Both the decrease in the growth rate of technical efficiency and the decrease in the share of young plants can be responsible for the slowdown in productivity growth by young plants. I investigate whether the changes in the technical efficiency of young plants or the changes in their shares have affected productivity growth. To this end, I compare the simple average and the weighted average of technical efficiency for each age group. Figure 7 shows the time-series unweighted mean of plant-level technical efficiency by age group during the period of 1995-2013. The values are relative to the mean of plants over 11 years old. At the beginning of the period, there was little difference in average productivity by age group. For the 0-2 age group, the productivity level drops relative to that of the oldest group during five years after the Asian financial crisis. From 2003, the relative productivity level of 0-2 age group increased, not showing a great difference relative to that of the oldest group until 2007. From 2008 onward, the relative productivity levels of young group of plants (the 0-2 and 3-5 age groups) exceed those of the oldest group. The relative slowdown in the productivity growth of old plants after the global financial crisis may account for this difference. It may also come from a selection effect, in that only highly productive young plants entered the market.

Despite the fact that the average productivity of young plants increased relative to that of old plants after 2008, their weighted average productivity rates did not increase. Figure 8 shows the weighted mean of plant-level technical efficiency by age group for each year using the Domar weight. The weighted mean of technical efficiency is larger for the older group, and the difference in magnitude is much greater for the weighted mean than for the unweighted mean. Relative productivity of young plants shows a decline over twenty years, reaching 5 percent of the oldest group since 2011. The decline was steeper for the 3-5 age group. These results imply that the declining share of young plants contributed to the decreased productivity growth of young plants.

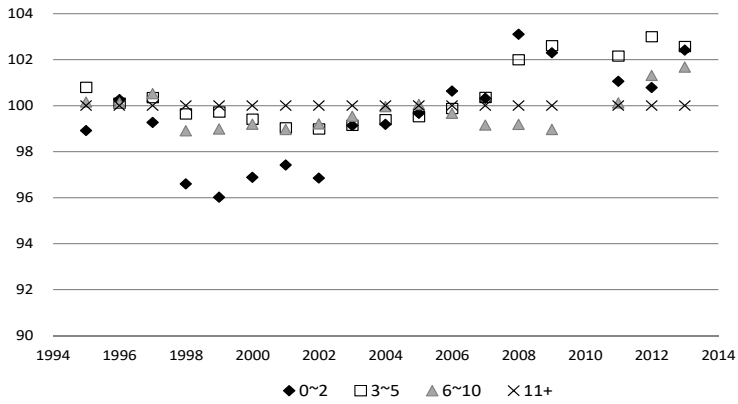


FIGURE 7. (UNWEIGHTED) AVERAGE PRODUCTIVITY BY DIFFERENT AGE GROUPS

Note: The graph shows the unweighted mean of plant-level technical efficiency. For each year, values are reported relative to the age group for plants older than 10.

Source: Author's calculation from the Mining and Manufacturing Survey

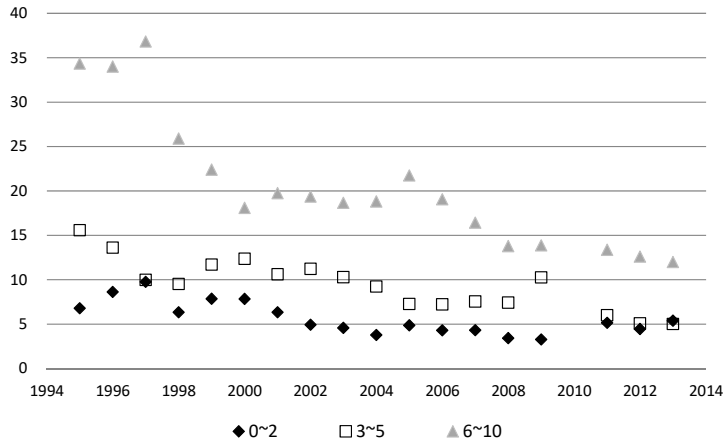


FIGURE 8. (WEIGHTED) AVERAGE PRODUCTIVITY BY DIFFERENT AGE GROUPS

Note: The graph shows the Domar-weighted mean of plant-level technical efficiency. For each year, values are reported relative to the age group for plants older than 10.

Source: Author's calculation from the Mining and Manufacturing Survey.

D. *Contribution of Young Plants in the High-Tech Industry*

In this section, I look at the productivity growth of the high-tech sector to determine whether the growth rates show the same pattern across sectors with different tech levels. I focus on the high-tech sector because this sector contributed most to productivity growth over the last twenty years. The high-tech sector is among those targeted by the Korean government in their recent policy goal of preparing for the 'Fourth Industrial Revolution'. I also analyze the contribution of

TABLE 6—APG AND ITS DECOMPOSITION INTO DIFFERENT TECH SECTORS

(UNIT: %)

	APG	High technology	Medium-high technology	Medium-low technology	Low technology
’95-’13 Mean (s.d.)	5.7(5.8)	2.9(1.9)	1.6(2.5)	0.8(1.6)	0.3(0.9)
’95-’04 Mean (s.d.)	6.9(6.9)	3.2(2.0)	2.0(3.2)	1.2(1.6)	0.5(1.2)
’04-’13 Mean (s.d.)	4.5(4.0)	2.6(1.8)	1.2(1.6)	0.5(1.6)	0.2(0.3)
’11-’13 Mean (s.d.)	0.2(0.6)	0.5(0.8)	0.1(0.2)	-0.5(0.5)	0.1(0.1)

Note: Industries (KSIC Rev. 9) are matched to the OECD (2011) tech level classification defined in the International Standard Industrial Classification (ISIC) Rev. 3.

Source: Author’s calculation from the Mining and Manufacturing Survey.

TABLE 7—YOUNG PLANTS’ PRODUCTIVITY GROWTH IN DIFFERENT TECH GROUPS

(UNIT: %)

	High technology	Medium-high technology	Medium-low technology	Low technology
’95-’13 Mean (s.d.)	1.0(0.9)	0.8(0.6)	0.6(0.3)	0.4(0.3)
’95-’04 Mean (s.d.)	1.1(0.9)	0.9(0.7)	0.6(0.4)	0.5(0.3)
’04-’13 Mean (s.d.)	1.0(0.9)	0.6(0.4)	0.6(0.2)	0.2(0.1)
’11-’13 Mean (s.d.)	-0.1(0.5)	0.2(0.3)	0.5(0.3)	0.3(0.1)

Note: Industries (KSIC Rev. 9) are matched to the OECD (2011) tech level classification defined in the International Standard Industrial Classification (ISIC) Rev. 3.

Source: Author’s calculation from the Mining and Manufacturing Survey.

young plants in high-tech manufacturing industries.

I follow Ahn (2006) when categorizing industries according to the intensity of the technology used in them. He used OECD methodology to classify industries into four sectors and studied productivity growth in each sector. The OECD uses the R&D investment share of value-added or output for technology intensity classification purposes. I match industries with the OECD (2011) technology intensity classification defined in the International Standard Industrial Classification (ISIC) Rev. 3. Table A2 in the appendix lists the industries for each technology classification based on KSIC Rev. 9.

Tables 6 and 7 report the decomposition of APG and young plants' productivity growth, respectively, into four sectors based on the technology intensity level. The higher the technology intensity is, the higher the productivity growth rate becomes. The two sectors of high technology and medium-high technology account for 80 percent of APG on average. I find that over the last three years, the productivity growth rates of high-tech industries decreased and that the productivity growth rates of young plants in high-tech industries declined sharply. This is associated with the sharp decline in the APG of manufacturing for the last three years given that high-tech industries account for a major portion of APG. High-tech industries are also among those targeted by government policies as an engine of future growth. Fewer entries and lower growth rates of plants in these industries could limit productivity growth in the manufacturing industry.

V. Concluding Remarks

In this paper, I adopted the method devised by Petrin and Levinsohn (2012) to measure aggregate productivity growth. I reported that both aggregate productivity growth and that the productivity growth of young plants decelerated over the last ten years, i.e., between 2004 and 2013. The findings in this paper stress the important role of young plants in aggregate productivity growth. Understanding the dynamics of young plants is necessary to form effective start-up policies. The Korean government implemented active start-up support policies and greatly increased the size of the budget over the past ten years. I discuss several policy implications based on the results of this study.

I found that productivity growth by young plants accounts for nearly half of APG on average over the twenty-year period, while their valued-added share is only 14 percent on average. In contrast, SMEs account for much less in terms of APG relative to their share. Though the role of young plants in creating jobs is not measured in this paper, recent studies (e.g., Pyo, Hong, and Kim, 2016; Cho, Chun, Kim, and Lee, 2017) find an important role of young firms in job creation in Korea. Many policies are oriented to support small and medium-sized enterprises (SMEs). When the goal of such policies is to help economic growth or to create jobs, policymakers must consider the important role of age.

Even when policies target young enterprises, they need to be designed based on an understanding of the dynamics of young plants. The results of this study show that productivity growth by young plants mostly occurs in plants up to three years old. The Korean government has already implemented policies to lower start-up costs, such as R&D support and government lending. It is advisable to check whether these resources are allocated to high growth establishments. Recent research (e.g., Haltiwanger, Jarmin, Kulick and Miranda, 2016) shows that only a small number of young firms grow rapidly and make a disproportionate contribution to growth. Understanding the characteristics of these high-growth young firms can help in the creation of selection criteria for government programs.

I also found that the decline in the productivity growth of young plants (age 4-5) contributed substantially to the decline in the productivity growth of young plants (age 0-5) over the last ten years. The Small and Medium Business Administration in Korea implemented a program starting in 2015 which supports young establishments between three to six years of age to increase their revenue. This program will be effective when it helps entrepreneurs to overcome difficulties stemming from market failures. This is true for other policies that support entrepreneurs as well.

Further analysis is needed to identify and measure difficulties that entrepreneurs and young establishments face when their start up their businesses and grow. I showed that the productivity growth rates of young plants in high-tech industries sharply declined over the last three years. Probing the reasons why young plants in high-tech industries could not grow can provide implications for Korean policies intended to foster a new growth engine.

APPENDIX

A. *Comparing APG to the BHC APG measure*

Table A1 and Figure A1 compare the BHC APG estimates to the (PL) APG estimates. The dots in Figure A1 are the growth rates of value-added. APG closely follows the growth rates of value-added because APG is defined as the growth rate of value-added minus the growth rate of expenditures on labor and capital. For many years, BHC APG is smaller than the APG estimates. On average, APG is approximately three times larger than BHC APG (5.7 versus 1.8).

TABLE A1—COMPARING APG AND ITS DECOMPOSITION TO THE BHC MEASURE

Year	APG	BHC APG	TE	BHC TE	RE	BHC RE	NE	BHC NE
’95-’13 Mean (s.d.)	5.7	1.8	4.3	1.7	1.2	-0.4	0.3	0.6
	(5.8)	(3.9)	(5.0)	(1.9)	(3.6)	(5.4)	(1.1)	(3.8)
’95-’04 Mean (s.d.)	6.9	2.5	6.8	2.7	0.04	0.4	0.1	-0.6
	(6.9)	(4.1)	(4.3)	(1.8)	(4.1)	(5.4)	(0.8)	(2.7)
’04-’13 Mean (s.d.)	4.5	1.2	1.8	0.6	2.3	-1.3	0.4	1.8
	(4.0)	(3.6)	(4.2)	(1.4)	(2.6)	(5.2)	(1.4)	(4.3)
’11-’13 Mean (s.d.)	0.2	-1.4	-2.5	-0.8	4.4	3.4	-1.7	-4.0
	(0.6)	(0.9)	(1.3)	(0.4)	(1.8)	(0.4)	(0.1)	(0.9)

Note: The growth rates for 2010 and 2011 are the average annual growth rate between 2009 and 2011.

Source: Author’s calculation from the Mining and Manufacturing Survey.

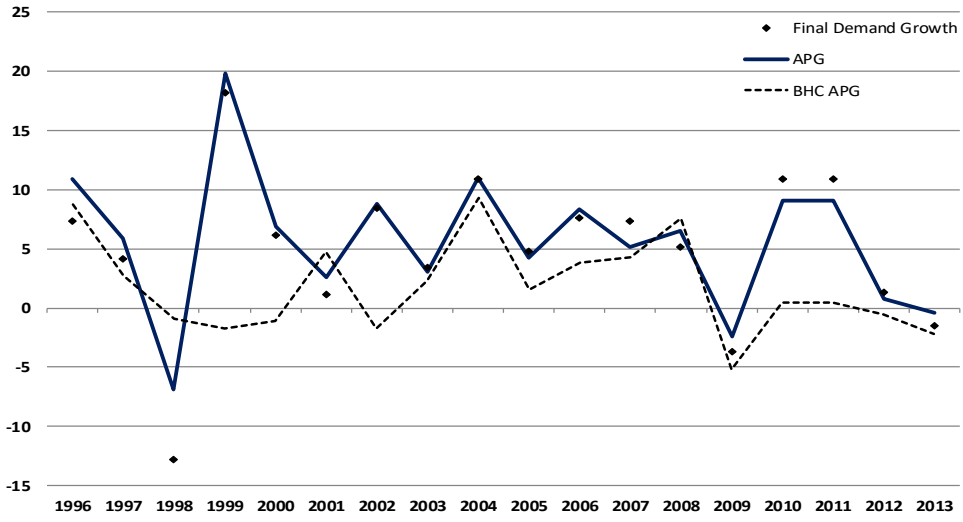


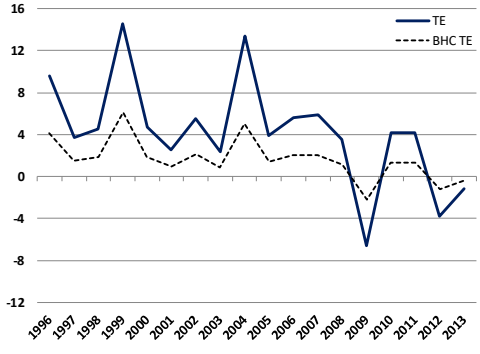
FIGURE A1. COMPARING APG (BASELINE) AND BHC APG

Note: The growth rates for 2010 and 2011 are the average annual growth rate between 2009 and 2011.

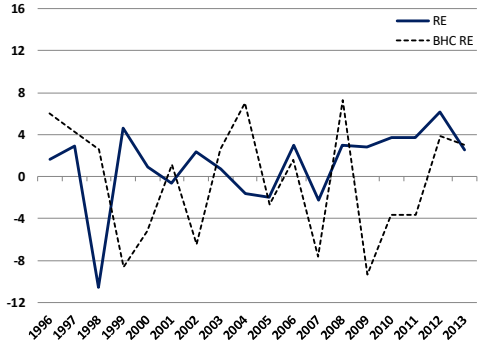
Source: Author’s calculation from the Mining and Manufacturing Survey.

A large part of the difference between the two measures is due to the different weights used in each measure. By definition, APG technical efficiency growth (TE) and BHC technical efficiency growth (BHC TE) differ only in terms of the weights used when aggregating technical efficiency growth. The estimated TE showed much larger growth at 4.3 percent on average than BHC TE, which showed 1.7 percent.

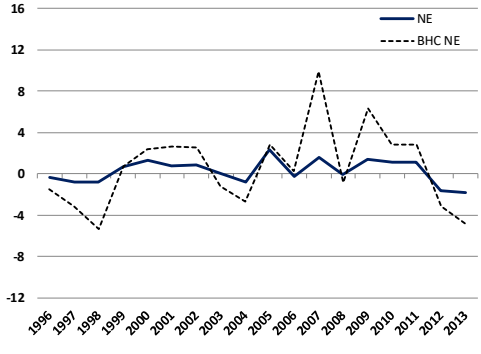
Figure A2 compares the estimates of the resource reallocation effects and net entry effects between the two methods. A few differences become apparent. First, BHC reallocation effects and BHC net entry effects show much larger degrees of variance than those of APG. Second, the estimates of resource reallocation effects frequently show opposite signs for a given year (for 9 years out of 20 years). For the years after the 2008 global financial crisis, reallocation effects were positive in APG, whereas BHC reallocation effects were negative. This comparison of the results shows that the estimates of APG and its components can differ remarkably depending on the method used.



TECHNICAL EFFICIENCY EFFECTS



RESOURCE REALLOCATION EFFECTS



NET ENTRY EFFECTS

FIGURE A2. COMPARISON OF THE APG DECOMPOSITION (BASELINE) AND BHC DECOMPOSITION

Note: The growth rates for 2010 and 2011 are the average annual growth rate between 2009 and 2011.

Source: Author's calculation from the Mining and Manufacturing Survey.

B. *Technology Classification of Industries*

Table A2 lists the industries for each technology classification based on KSIC Rev 9. Industries (KSIC Rev. 9) are matched with the OECD (2011) technology intensity classification as defined in the International Standard Industrial Classification (ISIC) Rev. 3.

TABLE A2— TECHNOLOGY CLASSIFICATION OF INDUSTRIES

Code	Description(KSIC9)	Code	Description(KSIC9)
	High-Technology Industries		Medium-High Technology Industries
21	Pharmaceuticals, Medicinal Chemicals and Botanical Products	20	Chemicals and chemical products
26	Electronic Components, Computer, Radio, Television and Communication Equipment	28	Electrical equipment
27	Medical, Precision and Optical Instruments, Watches and Clocks	29	Other Machinery and Equipment
2918	Office Machinery and Equipment	30	Motor Vehicles, Trailers and Semitrailers
313	Aircraft, Spacecraft and its Parts	312	Railway and Tramway Locomotives and Rolling Stock
		319	Other Transport Equipment
	Medium-Low-Technology Industries		Low-Technology Industries
19	Coke and Refined Petroleum Products	10	Food Products
22	Rubber and Plastic Products	11	Beverages
23	Other Non-metallic Mineral Products	12	Tobacco Products
24	Basic Metal Products	13	Textiles
25	Fabricated Metal Products	14	Wearing apparel and Fur Articles
311	Building of Ships and Boats	15	Leather, Luggage and Footwear
		16	Wood and of Products of Wood
		17	Pulp, Paper and Paper Products
		18	Printing and Reproduction of Recorded Media
		32	Furniture
		33	Other manufacturing

Source: OECD. 2011. "ISIC REV. 3 Technology Intensity Definition." OECD Publishing, Paris.

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Contributions of Public Investment to Economic Growth and Productivity†

By SUNGMIN HAN*

Whereas a large variety of previous studies show mixed results regarding the relationship between public investment and economic outcome, several studies have been conducted on related issues in Korea. The present study deals with the effect of public investment in Korea on economic growth and productivity. Using administrative data, it exploits three different methodologies: the total factor productivity approach, production function approach, and stochastic frontier production function approach. The results of this study show that public investment has a statistically significant effect on economic growth. However, it contributes little to enhance productivity. It is explained that there exists inefficiency of production in the Korean economy. These findings indicate that public investment has played a central role in the direct input factor and not in indirect role in Korea. Thus, it is necessary for public investment policies to concentrate on enhancing the efficiency of the Korean economy.

Key Word: Public Investment, Public Capital,
Total Factor Productivity, Production Function,
Stochastic Frontier Production Function
JEL Code: C13, D24, H41

I. Introduction

Since the 1970s, the Korean government has steadily made much effort to enhance the economy. Above all, the effort to expand public investment has been recognized as one of the key factors that led to the remarkable economic growth which occurred in Korea. The annual growth rate of fixed assets consequently exceeded 10% until the 1997 Asian financial crisis and afterwards recorded 5%. This leads to the questions of how much public investment affected

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economic growth and productivity in the Korean economy and whether these effects of public investment differ over time or by sector?

There has been long-standing debate over the role of public investment. It is commonly known that public investment promotes national economic growth, improves productivity, and contributes to the long-term development of nations as a productive factor in an economy. A large variety of previous studies, however, show mixed results regarding the relationship between public investment and economic outcome. These studies begin with questions about how much public investment contributes to economic growth, productivity and production cost reductions and investigate the differences in the productivity of public investment by sector, region or country (Aschauer, 1989; Hulten and Schwab, 1991; Holtz-Eakin, 1994; Evans and Karras, 1994; Bonaglia *et al*., 2001; A. Warner, 2014a). The underlying questions in these studies refer to the role of public investment and to the path by which it influences economic growth and improves productivity.

The role of public investment is in general twofold. As a direct element of production such as labor and capital, it can increase economic output. It can also play an indirect (or intermediate good) role to reduce inefficiency and transaction costs during the production process, with externalities (Kim and Kim, 2008; Lee, 2008). In other words, through different attributes of public investment, economic growth can be achieved by increasing input factors such as capital and labor as used for production or by improving efficiency overall. Thus, when analyzing the relationship between public investment and economic growth, it is crucial to separate the role of public investment.

For this reason, a large number of previous studies attempt to isolate the direct and indirect impacts of public investment. To observe the direct impact, output elasticity or marginal productivity is normally estimated with data on the real GDP of the country in question, or the output of private firms is assessed through a production function approach. Kim and Song (2013) analyze the marginal productivity of SOC capital stock by sector, including roads, railways, electricity and communication, and water supply and sewerage with administrative data from 1970 to 2014. The marginal productivity of each sector showed a decrease from 0.93 to 0.32 for private capital, from 0.8 to 0.15 for roads, from 1.5 to 0.5 for railways, from 0.8 to 0.26 for electricity and communication, and from 1.9 to 0.47 for the water supply and sewerage category. This implies that investment in the road sector is oversupplied while that in the water supply and sewerage sector is lacking. Shioji (2001) uses the convergence approach to analyze the effect of economic growth on the types of public capital in the US and Japan, reporting that the output elasticity of public capital ranged from 0.1 to 0.15.

On the other hand, the indirect impact of public investment can be estimated through a total factor productivity approach. Hulten and Schwab (1991) argue that the relationship between the growth rate of total factor productivity and public capital is limited. Aschauer (1989) reports that the output elasticity of public capital is 0.35, implying that public capital is closely related to productivity. On the other hand, Holtz-Eakin (1994) studies the influence of the accumulation of public capital on private firm productivity for 48 states in the United States. They report that it has a negative impact on private firm productivity, which means that there is little benefit related to productivity beyond direct supply (Evans and Karras,

1994). Bonaglia *et al.* (2001) analyze the effect of public infrastructure investment on total factor productivity, productivity and cost reductions using regional data from Italy from 1970 to 1994. It was reported that the effect of public investment varies by region. Overall, investment in public transportation, especially railways in the northern area and roads in the central-south region, largely contributes to an improvement in productivity. In Korea, Choi *et al.* (2012) analyze the productivity of public capital and the efficiency of spatial allocation by comparing the situation before and after decentralization. They report that the efficiency of spatial allocation worsens because public capital is oversupplied as compared with private capital after decentralization. It is interpreted that resource allocation is shifted from efficiency to equity. Lee (2008) emphasizes the classification of the effect by the production input factor and productivity in analyzing productivity. He claims that the most effective element to improve total factor productivity is to increase the economy of scale of firms.

As mentioned above, the results differ, with different findings showing a positive or negative relationship between public investment, productivity and economic growth. The main causes of these mixed results are discussed below. First, obtaining reliable data of public capital stock is limited. Second, the characteristics of the regions or countries in question are heterogeneous. Third, there are econometric issues, such as an endogeneity problem. It is thus an interesting challenge to take into account these issues when analyzing the effect of public investment.

In the past, it was generally true that the Korean government made great efforts to expand public investment to improve the efficiency of resource allocation. However, some doubts about the effectiveness of this strategy have been raised. The growth rate of total factor productivity in the manufacturing sector has continuously decreased since the 2000s (Korea Productivity Headquarters, 2013). Moreover, it was reported that the marginal productivity of SOC capital stock fell by more than 60% in 2013 compared to that in 1970 (Kim and Song, 2013). However, such phenomena are not limited to Korea. Productivity in most Asian countries is decreasing. It is often interpreted that the main cause of economic growth in Asian countries is not due to improvements in productivity but to increases in production input factors. Krugman (1994) warns that low productivity functions as a threat to economic growth in the future.

Although the ongoing debate about the role of public investment has not yet drawn concrete conclusions, it nonetheless concentrates on how to improve the economic growth and productivity of the country through public investment in the long run. It is clearly a question that should be asked regarding the Korean economy. Thus, at this point in time, it is judged that presenting a clear answer to this is important.

In this study, I examine how much public investment contributes to productivity improvements and to economic growth in the Korean economy. To investigate these effects, I use unique administrative data thus far unused in previous work, except for one study, and discuss econometric issues to overcome the problems which arose in previous studies. This may secure the reliability of the results. The main contribution of this research is that it considers various forms of public investment, such as R&D and human capital stock as well as SOC stock. Previous

studies in general focus on only SOC stock in their analysis of the effect of public investment. This approach only provides implications regarding how SOC capital stock affects economic outcomes. It will make it difficult to derive implications pertaining to the effect of public investment only with specific stocks. When we interpret public investment in a broad sense, public capital encompasses transportation assets, equipment assets, R&D assets and human assets as well. Thus, this study examines the effect of public investment overall by sector to derive more general implications. Moreover, to ascertain the effects of public investment on economic growth and productivity, three different methodologies are used. Through these analyses, this study attempts to find evidence that public investment improves productivity. If not, these causes are investigated. Finally, the study suggests implications regarding future direction of public investment for productivity improvements.

The remainder of the paper is as follows. Section II explains the conceptual framework of the role of public investment. Section III introduces data and methodology utilized for empirical analysis. Section IV presents the analysis results, and finally in Section V, it provides conclusions and future direction of public investment in Korea.

II. Theoretical Framework

In this study, public investment is defined as investment in public infrastructure, transportation facilities, machinery facilities, R&D and education. Each capital stock is utilized in the empirical analysis. The aim of this chapter is to see how each public investment affects economic growth and productivity. This can be explained as the role of public investment.

In general, the role of public investment can be divided into direct and indirect influences. A direct impact means that public investment acts as a direct component of production, such as labor or capital, and that it has a direct effect on production. The indirect impact is that it increases productivity by reducing inefficiency or by lowering transaction costs during the production process with externalities. This type can be explained by a general production function. Based on the Cobb-Douglas production function, the growth rate of TFP is derived (Hulten and Schwab, 1991).

$$\dot{A} = \dot{Q} - \alpha_1 \dot{L} - \beta_1 \dot{K} \tag{1}$$

Here, $\dot{A}$ is the TFP growth rate; Q is the output of the economy, which is the real GDP; L and K are labor input and private capital stock; $\dot{Q}$, $\dot{L}$, and $\dot{K}$ are the growth rate of each variable, respectively; and α_1 and β_1 correspondingly denote the labor and capital share. Although an economy in a country is also affected by public investment, in equation (1), public investment by the government is excluded. It is impossible to examine the role of public investment. Thus, it is necessary to transform the

production function on the assumption that public investment directly or indirectly affects economic growth $\left(Q = A(KG)F(L,K,KG)\right)$. Here, KG is public investment and KG under A implies the indirect effect. KG under the function F is the direct effect as a production factor. Moreover, A, implying technological progress or productivity improvements, can be classified into two categories: true technology progress $\bar{A}$ and productivity improvements due to public investment. Equation (1) is then transformed into equation (2), as follows,

$$\dot{\bar{A}} = \dot{Q} - \alpha_2 \dot{L} - \beta_2 \dot{K} - (\delta + \gamma)\dot{K}G, \tag{2}$$

where α_2 and β_2 are the elasticity of output, δ is the elasticity of public investment on technological progress, and γ denotes the elasticity of public investment to technological progress. If equation (2) is subtracted from equation (1), equation (3) can be derived using the following equation (Ferrara and Marcellino, 2000).

$$\dot{A} = \dot{\bar{A}} + (\alpha_1 - \alpha_2)\dot{L} + (\beta_1 - \beta_2)\dot{K} + (\delta + \gamma)\dot{K}G \tag{3}$$

In other words, this implies that the improvement in productivity can be explained by the growth rate of labor input, private capital stock, public capital stock and true technological progress, meaning that it is possible to distinguish productivity improvement from that by true technological progress or by an increase in capital stock. In this study, I examine the effect of the growth rate of public investment on productivity improvement based on equation (3). Productivity improvement by sector is also examined in order to determine the sectoral effect. However, in the sectoral analysis, the heterogeneity of the type of public investment may have different effects on economic growth or productivity in a different manner. Therefore, it is necessary to consider the characteristics of capital stock by sector in the analysis. For example, in the case of R&D, productivity can be influenced by direct innovations and by ripple effects through technology transfers. Likewise, education can impact productivity depending on the level of human capital, which leads to differences in economy growth. That is, it is necessary to identify the paths by which the effects work on productivity or economic growth by sector and to analyze them according to their characteristics. In order to do this, using a structural model is more appropriate. However, the structural interactions between related variables have not yet been studied in depth. Theoretically, it was reported that they are unclear (Lee, 2008). This is a limitation of this study, and additional research is needed in this area.

For this reason, in previous research, the differences between the paths were adjusted to differences in time, which generally affects the analysis. For example, Kwack and Lee (2006) conduct an analysis based on the same point in time to examine the relationship between educational spending, R&D expenditures and economic growth. Griffith *et al.* (2004) use the first-difference estimator to ascertain the effect of R&D investment on productivity. In other words, rather than classifying the paths of the effects by the types of public investment, as in various studies, these studies used the difference in the time lag to determine economic growth. The present study follows this approach.

III. Data and Estimation Strategy

A. *Data*

The conventional methodology to analyze the relationship between public investment and productivity is growth accounting. A production function approach is used to estimate output elasticity. To this end, labor and capital inputs are used as input factors, with real GDP used as an output factor. Relatively, labor input and GDP data can easily be obtained, but as pointed out in previous studies, researchers have had difficulties in obtaining reliable capital stock data in many countries.

In Korea, capital stock data were not properly constructed until 2013. Accordingly, it was difficult for individual researchers to utilize published capital stock data. However, since 2014, the Bank of Korea has been compiling five sets of statistical data: national income statistics, interindustry relationship tables, money flow tables, balance of payments statements, and national balance sheets. In the national balance sheets, a stock account that records the capital status at a certain point is presented, allowing more reliable data to be utilized. The capital stock data of the national balance sheet is utilized in this study.

The national balance sheet is divided into non-financial assets and financial assets/liabilities. The non-financial assets are divided into production assets and non-production assets. Production assets are divided into fixed assets and inventory assets, and fixed assets are divided into construction assets, equipment assets, and intellectual property assets. As described above, in this study, it is important to grasp the relationship between public investment and productivity; hence, a definition of public investment and the division of available capital stock should be done beforehand. I define public investment as investment related to governmental gross fixed capital formation, and available capital stock includes only durable and reproducible assets in the economy. In other words, according to these criteria, the assets available for this analysis can be regarded as a group consisting of non-financial assets, production assets, fixed assets, and construction assets; equipment assets; and intellectual property products assets. In detail, how public capital stock is divided is shown in Table 1.

Specifically, capital stock is divided into public infrastructure, transportation facilities, machinery equipment, and R&D. Public infrastructure is divided into non-residential buildings, transportation, water, electricity and communication, and

TABLE 1—CLASSIFICATION OF PUBLIC AND PRIVATE CAPITAL STOCK

	Public Infrastructure					Transportation/ Machinery Equipment			R&D / ICT
	Non-residential buildings	Transportation	Water	Electricity and Communi-cation	OTHERS	Automobiles	Transportation except automobile	Non-ICT	
Public Capital	K_{pub1}					K_{pub2}			K_{pub3}
Private Capital						K_{pri}			

Note: Roads, airports, railways, subways, and ports are classified as transportation facilities, and river and water sewage are classified as water resources. Other assets include agriculture and forestry, urban civil engineering, and other civil engineering assets.

other assets. In addition, transportation facilities, machinery and R&D assets are classified into private capital and public capital, and public infrastructure assets are considered only to be public capital. However, ICT assets among machinery assets are included as R&D assets in the empirical analysis and private capital is used as the sum of transportation facilities, machinery facilities and R&D assets.

Next, quarterly data from 1970 to 2015 are used in the empirical analysis, and Table 2 shows the summary statistics of the data used.[1] In Table 2, the average growth rate for public infrastructure among public capital stock (log level) is 0.18 to 0.25%, and that of the transportation facilities is 0.23%. The growth rate of ICT assets is higher than that of non-ICT assets. That of R&D assets is 0.32%, which is higher than those of the other assets in the public sector. For private capital, transportation facility assets, ICT assets, non-ICT assets, and R&D assets grow by 0.2%, 0.55%, 0.23% and 0.37%, respectively. The data of the real GDP and labor force population used here are from the National Statistical Office. The real GDP growth rate is 0.16%, and the growth rate of the labor force population is 0.06%.

In the last row in Table 2, the human capital index is presented. This index is used because educational investments form a major part of public investment, and the difference in human capital formed by the education investment affects economic growth and productivity. However, because information on human capital is not presented in the data from the Bank of Korea, I use the Penn World Table (PWT), which provides national account data for each country since 1950. PWT data provides country-specific economic statistics for research purposes at UC Davis in the United States.

The human capital index covered in this study is based on the average years of education and the educational performance of individuals over 25 years old. It is constructed according to the methodologies of Barro and Lee (1993) and Caselli (2005). In previous studies utilizing the human capital index, Barro and Lee (1993) use the average years of education, and Tallman and Wang (1994) divide the

[1]Because the data here are based on internal data from the Bank of Korea, this study reports only the growth rate of the log variables (the difference between the previous and the current year, $X_t\left(=lnX_t - lnX_{t-1}\right)$, instead of the level variable for the summary statistics.

TABLE 2—SUMMARY STATISTICS

	Mean	Std.	Min	Max
Public Capital				
Public Infrastructure				
Non-residential Buildings	0.1885	0.0904	0.0684	0.3996
Transportation Infrastructure	0.2307	0.1115	0.0389	0.4406
Water Infrastructure (Stream, Water Supply and Sewage)	0.2476	0.1639	0.0051	0.7273
Power and Communication Facilities	0.2202	0.1525	0.0060	0.5253
Others	0.2032	0.1175	0.0433	0.6854
Transport Equipment	0.2303	0.1779	0.0483	0.7977
Plant, Machinery and Equipment				
ICT Equipment	0.4325	0.4029	-0.1099	1.8747
Non-ICT Equipment	0.2941	0.2492	0.0434	1.0017
R&D	0.3190	0.1877	0.0585	0.7726
Private Capital				
Transport Equipment	0.2074	0.1762	-0.1228	0.7658
Plant, Machinery and Equipment				
ICT	0.5521	0.6886	0.0265	2.2121
Non-ICT	0.2334	0.1906	-0.0435	0.6921
R&D	0.3716	0.2488	0.1201	1.0855
Growth Rate of Real GDP (log)	0.1550	0.1053	-0.0846	0.4088
Growth Rate of Labor Force Population(log)	0.0609	0.0822	-0.3109	0.3335
Human Capital Index	2.855	0.485	1.977	3.594

population according to the education level. Mulligan and Sala-i-Martin (1995) use labor income, and Kim (1997) and Shim (2000) use the educational expenditure index. However, as in these studies, the use of the human capital index can be problematic if only a single index is used. As mentioned above, because PWT uses two variables to construct a human capital index, it is more suitable for this study. It provides human capital indexes for individual countries on a scale of 0~4, and the average of only human capital index in 144 countries is 2.1783. The average of only human capital index in Korea is 2.855, which is 30th among 144 countries.

B. *Estimation Strategy*

This chapter focuses on whether public investment contributes to productivity improvements and economic growth, and it expands the discussion on whether there is production inefficiency in the Korean economy. To do this, I investigate the effect of productivity improvements by resetting the empirical models based on equation (3). I examine the effects on economic growth and productivity through the production function and analyze the inefficiency of production through a stochastic frontier function. Moreover, the effect of public capital stock is investigated according to sector and time period.

Total Factor Productivity Approach

Unlike the single-factor productivity estimation method, total factor productivity

(hereinafter referred to as productivity) is used to measure the overall efficiency of production considering input factors overall. Technological advances that are not included in the single-factor productivity estimation approach are included. Total factor productivity analysis derived from residuals has an advantage in that it can measure the overall efficiency of the production function transfer and production process and deal with production costs, technological advances and equipment improvements.

As shown in equation (3), the growth rate of productivity can be explained by the growth rates of labor input, private capital stock, and public capital stock. In the empirical analysis, I examine how the growth rates of these variables can explain productivity improvements. Moreover, sectoral impacts are investigated by dividing the public capital stock into the sector. First, I derive TFP through the Cobb-Douglas production function $\left(Y = AF\left(L,K\right)\right)$, which is generally used to derive the growth rate of productivity.

$$\text{a} = \text{y} - \hat{\alpha} l - \hat{\beta} k \tag{4}$$

In this equation, lower case refers to the log level, a represents productivity, y is the real GDP, and l and k are the total labor supply and capital stock, respectively. $\hat{\alpha}$ and $\hat{\beta}$ are estimates of the elasticity of labor and capital.

Next, based on the estimated productivity, I examine how the growth rate of productivity can be explained by the growth rate of public capital stock. In order to enable an empirical analysis, I modify equation (3) by identifying factors that may cause productivity changes. Factors that may affect productivity growth are the productivity level and the capital stock level of the previous year. Thus, the model for the regression analysis considers the capital stock level and the growth rate simultaneously (Tatom, 1991). Moreover, the time trend variable is included as a control variable in the model. Finally, the equation for analyzing the effect of public capital stock on productivity improvements is as follows:

$$\begin{aligned} \Delta a_t = a_{t-1} + \sum_{i=1}^{j} \beta_{pub_{it-1}} k_{pub_{it-1}} + \beta_{pri_{t-1}} k_{pri_{t-1}} + \beta_{l_{t-1}} l_{t-1} + \\ \sum_{i=1}^{j} \beta_{pub_{it}} \Delta k_{pub_{it}} + \beta_{pri_t} \Delta k_{pri_t} + \beta_{l_t} \Delta l_t + \gamma \text{t} + \epsilon_t \end{aligned} \tag{5}$$

Here, Δa_t is the growth rate of productivity between the previous year and pertinent year, a_{t-1} is the level of productivity of the previous year, $k_{pub_{it-1}}$ is the level of public capital stock of the previous year, the subscript i denotes public capital stock by sector (e.g., public infrastructure, R&D/IT, human capital), $k_{pri_{t-1}}$ is the level of private capital stock, and l and t are correspondingly the labor force population and the time trend. $\Delta\left(=t-t-1\right)$ refers to the rate of change between the previous year and the pertinent year. One-year and two-year time differences are postulated in the regression analysis.

Production Function Approach

Next, I investigate the relationship between public investment and economic growth using the Cobb-Douglas production function via the same methodology used with the TFP approach. Similar to equation (5), the model includes the level and growth rate of capital stock. As control variables, the growth rate of labor force participation and the amounts of export variables are added because they can directly affect the real GDP. This implies that the higher the growth rate of labor force participation is in the economy, the greater the real GDP, and the more exports increase, the greater the real GDP becomes.

$$\begin{aligned}\Delta y_t = y_{t-1} + \sum_{i=1}^{j}\beta_{pub\_1}k_{pub\_1} + \beta_{pri_{t-1}}k_{pri_{t-1}} + \beta_{emp_{t-1}}emp_{t-1} + \\ \beta_{exp_{t-1}}exp_{t-1} + \sum_{i=1}^{j}\beta_{pub}\Delta k_{pub} + \beta_{pri_t}\Delta k_{pri_t} + \beta_{emp_t}\Delta emp_t + \\ \beta_{exp_t}exp_t + \gamma t + \epsilon_t\end{aligned} \tag{6}$$

Here, $\Delta y_t \left(= y_t - y_{t-1}\right)$ is the growth rate of the real GDP per capita between the previous year and the pertinent year, y_{t-1} is the level of real GDP per capita in the previous year, $k_{pub_{it-1}}$ is the level of public capital stock in the previous year, the subscript i is the public capital stock by sector (e.g., public infrastructure, R&D/IT, human capital), $k_{pri_{t-1}}$ is the level of the private capital stock, and emp and t are correspondingly the growth rate of labor force participation and the time trend. exp denotes the export amount. $\Delta\left(= t - t - 1\right)$ means the rate of change between the previous year and the pertinent year. One-year and two-year time differences are postulated in the regression analysis.

Stochastic Frontier Function Approach

The two preceding methods can provide answers as to whether public capital causes productivity improvements and affects economic growth. However, it is difficult to determine whether or not the production process of the entire economy is efficient. In order to determine whether there is inefficiency in production in the entire Korean economy, I use the stochastic frontier function. The stochastic frontier function approach consists of the step of estimating the parameters and the step of measuring the efficiency of production using parameters and residuals. The model for this is as follows (Aigner, Lovell, and Schmidt, 1977):

$$y_i = f\left(x_i, \beta\right) \cdot exp\left(v_i\right) \cdot exp\left(-u_i\right) \tag{7}$$

Here, y_i is the output variable, x_i is the production input factor, $exp(v_i)$ is a random error, the exogenous effect on the individual production unit, and $exp(-u_i)(u_i \geq 0)$ implies the level of technical inefficiency. In equation (7),

the remaining part (except for $exp(-u_i)$) indicates the stochastic production frontier, and the technical efficiency of individual production unit is expressed by equation (8).

(8) $$TE_i = \frac{y_i}{f(x_i, \beta) \cdot exp(v_i)} = exp(-u_i)$$

Because it is impossible directly to estimate u_i, $\hat{u}_l$ is generally derived via a Cobb-Douglas production function.

(9) $$\ln y_i = \beta_0 + \sum_j^k \beta_j \ln x_{ij} + v_i - u_i$$

Next, given that inefficiency implies a negative (-) factor, it is necessary to assume the distribution of u_i. In general, to make u_i positive, normal-half normal, normal-exponential, normal-truncated normal and normal-gamma distributions are assumed. In this study, the normal-half normal distribution, often used, is assumed. I modify the previous equation (6) to determine whether technological efficiency exists when considering public capital stock.

(10) $$\begin{aligned}\Delta y_t = y_{t-1} + \sum_{i=1}^{j} \beta_{pub_{it}} k_{pub_{it}} + \beta_{pri_{t-1}} k_{pri_{t-1}} + \beta_{emp_{t-1}} emp_{t-1} + \beta_{exp_{t-1}} exp_{t-1} + \\ \sum_{i=1}^{j} \beta_{pub_{it}} k_{pub_{it}} + \beta_{pri_t} \Delta k_{pri_t} + \beta_{emp_t} \Delta emp_t + \beta_{exp_t} exp_t + \gamma t + v_t - u_t\end{aligned}$$

Here, all of variables in equation (10) are identical to those in equation (6) except for the error terms assuming a normal distribution and indicating technical inefficiency in production. The overall error term is $\epsilon_t (= v_t - u_t)$, and v_t and u_t are assumed to be independent. Equation (10) can be estimated by the maximum likelihood method (MLE),

(11) $$\ln L = -\frac{n}{2} \ln 2\pi\sigma^2 + \sum \ln\left[1 - \Phi\left(\frac{\eta\lambda}{\sigma}\right)\right] - \frac{1}{2\sigma^2} \sum \ln\left[y - \beta_0 - \beta_x x\right]^2$$

Where $\eta = v - u$, $\lambda = \sigma_u / \sigma_v$ is the ratio of the standard error of technical inefficiency to the standard error, and the determination of technical inefficiency depends on the statistical significance of λ. In other words, if $\lambda = 0$, technological inefficiency does not exist, and if λ is statistically significant, technical inefficiency exists.

[2]This equation is expressed for simplicity because the dependent and independent variables of $y - \beta_0 - \beta_x x$ are identical to those in equation (10).

IV. Results

Total Factor Productivity Approach

The growth rate of TFP as derived through residuals can be estimated from equation (4). Based on this, the trend of the growth rate of productivity (log level) from 1970 to 2015 is shown in Figure 1. As shown in Figure 1, the rate of change in productivity has continued to increase and decrease, but in particular, the growth rate of productivity declined significantly in 1980 and 1998. This is the impact of the oil crisis in 1980 and the Asian financial crisis of late 1997. However, except for these crisis situations, the growth rate of productivity increases overall. This raises the question of how much public investment contributes to productivity change. To this end, I examine the effect of public capital stock and productivity on productivity improvement through equation (5).

Although this analysis uses quarterly data, the growth rate of all variables considered in the empirical analysis is calculated as the difference between the current year and the previous year $\left(\Delta t = t_0 - t_{-4}\right)$ and the difference between the current year and the two prior years $\left(\Delta t = t_0 - t_{-8}\right)$. Table 3 shows the effect of public capital stock on the productivity improvement, as calculated from the difference between the current year and the previous year.

Column (1) and (2) in Table 3 are the results obtained through the OLS (ordinary least squares) method. First, in column (1), there is a negative relationship between the level of productivity of the previous year, the level of private capital stock, and productivity improvement, but public capital stock and the human capital index are found to have a positive effect on productivity improvement. Moreover, the labor input variable shows no statistically significant effect on productivity improvement. Second, the growth rate of public capital stock is negatively

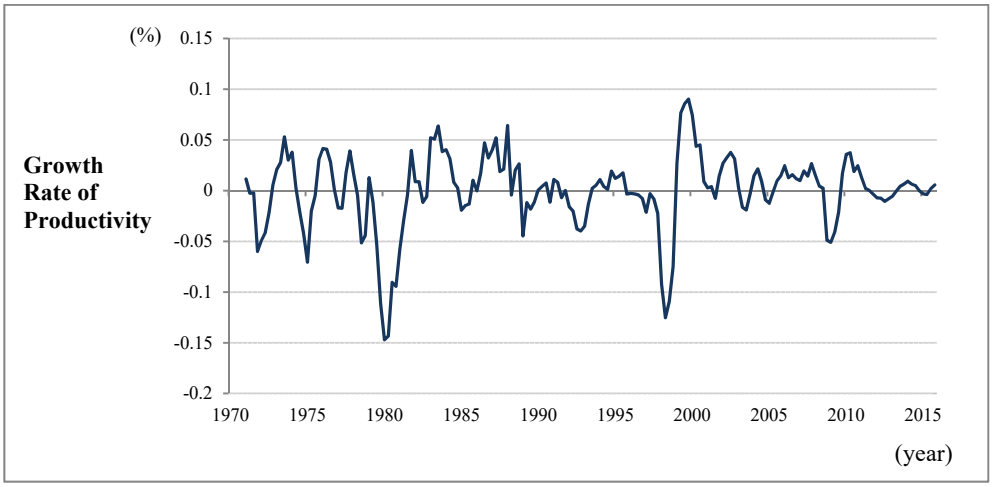

FIGURE 1. THE TREND OF THE GROWTH RATE OF PRODUCTIVITY

TABLE 3—THE EFFECT OF PUBLIC CAPITAL STOCK ON THE PRODUCTIVITY IMPROVEMENT (ONE-YEAR LAG)

	(1)	(2)	(3)	(4)
Productivity (a_{t-1})	-0.870***	-0.817***	-1.061***	-1.065***
	(0.071)	(0.073)	(0.072)	(0.074)
Public Capital (pub_{t-1})	0.188***	0.284***	-0.231	-0.217
	(0.061)	(0.073)	(0.194)	(0.193)
Private Capital (pri_{t-1})	-0.215***	-0.288***	-0.283**	-0.279**
	(0.042)	(0.050)	(0.131)	(0.132)
Human Capital (hc_{t-1})	0.565**	1.134***	3.684***	3.505***
	(0.238)	(0.294)	(1.248)	(1.262)
Labor Input (l_{t-1})	-0.018	-0.014	-0.090***	-0.090***
	(0.032)	(0.032)	(0.016)	(0.016)
Growth Rate of Public Capital Stock (Δpub_t)	-1.095***	-1.087***	0.264	0.263
	(0.335)	(0.335)	(0.377)	(0.380)
Growth Rate of Private Capital Stock (Δpri_t)	0.0831***	0.862***	0.327**	0.326**
	(0.114)	(0.112)	(0.145)	(0.145)
Growth Rate of Human Capital Stock (Δhc_t)	-3.802**	-4.375***	0.324	0.167
	(1.565)	(1.554)	(2.733)	(2.761)
Growth Rate of Labor Input (Δl_t)	0.114	0.241**	-0.063	-0.066
	(0.116)	(0.120)	(0.055)	(0.056)
(1985-2000)* Growth Rate of Public Capital Stock $(D_{85} \cdot \Delta pub_t)$		-0.389***		0.052
		(0.124)		(0.130)
(2000-2014)* Growth Rate of Public Capital Stock $(D_{00} \cdot \Delta pub_t)$		-0.728**		0.079
		(0.304)		(0.286)
Trend (t)	yes	yes	yes	yes
$D-W$ statistics	0.581	0.722	1.961	1.957
$Adj\ R^2$	0.600	0.618	0.573	0.567
N	176	176	176	176

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

correlated with the growth rate of human capital stock, while the growth rate of private capital stock is positive. In column (2), I use dummy variables[3] to examine whether the effects of changes in public investment on productivity improvements differ by period. The coefficients of all variables are not significantly different from those in column (1), and the effect of public capital on productivity improvement decreases over time. However, it is often reported that auto-correlation problems arise in time-series data and that it is difficult to derive consistent estimates without solving this problem. To verify this, the Durbin-Watson test is used in general. The test results here show that the Durbin-Watson statistic values (d) are 0.653 and 0.839[4], which indicates a serious autocorrelation problem in the model. Therefore, I use the Prais-Winsten method to solve this problem. This method is used to obtain an efficient estimator when covariance matrices are unknown when analyzing time-series data. Estimates can be obtained using the FGLS (Feasible GLS) method, similar to the Cochrane and Orcutt method, but the difference between them is that

[3]The entire period is divided into three sub-periods: from 1970 to 1984, from 1985 to 1999, and from 2000 to 2015. Table 3 includes the interaction of each time variable and the growth rate of public capital stock.

[4]The Durbin-Watson test statistic is obtained via $\Sigma(e_t - e_{t-1})^2 / \Sigma(e_t)^2$.

TABLE 4—THE EFFECT OF PUBLIC CAPITAL STOCK ON THE PRODUCTIVITY IMPROVEMENT (TWO-YEAR LAG)

	(1)	(2)	(3)	(4)
Productivity (a_{t-1})	-1.053***	-1.044***	-1.077***	-1.081***
	(0.074)	(0.073)	(0.075)	(0.081)
Public Capital (pub_{t-1})	-0.009	0.068	-0.179	-0.182
	(0.098)	(0.105)	(0.201)	(0.205)
Private Capital (pri_{t-1})	-0.091	-0.165**	-0.193	-0.19
	(0.066)	(0.071)	(0.146)	(0.149)
Human Capital (hc_{t-1})	1.064***	1.751***	2.683**	2.670**
	(0.308)	(0.416)	(1.224)	(1.302)
Labor Input (l_{t-1})	-0.042	-0.042	-0.088***	-0.088***
	(0.038)	(0.037)	(0.018)	(0.018)
Growth Rate of Public Capital (Δpub_t)	-1.750***	-1.778***	-0.496	-0.494
	(0.309)	(0.310)	(0.390)	(0.392)
Growth Rate of Private Capital (Δpri_t)	0.640***	0.640***	0.195	0.195
	(0.091)	(0.091)	(0.138)	(0.139)
Growth Rate of Human Capital (Δhc_t)	-3.955***	-4.861***	-0.346	-0.222
	(1.133)	(1.181)	(2.395)	(2.445)
Growth Rate of Labor Input (Δl_t)	-0.023	0.037	-0.114**	-0.113**
	(0.102)	(0.104)	(0.044)	(0.044)
(1985-2000)* Growth Rate of Public Capital $(D_{85} \cdot \Delta pub_t)$		-0.204**		0.012
		(0.079)		(0.073)
(2000-2014)* Growth Rate of Public Capital $(D_{00} \cdot \Delta pub_t)$		-0.437**		0.001
		(0.176)		(0.149)
Trend (t)	yes	yes	yes	yes
$D-W$ statistics	0.453	0.530	1.737	1.736
$Adj\ R^2$	0.754	0.761	0.571	0.566
N	172	172	172	172

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

this approach does not exclude the first observation (t=1). As a result, the Prais-Winsten method can solve the autocorrelation problem and obtain an efficient estimator.

Columns (3) and (4) are the results of the analysis using the Prais-Winsten method, which showed that the d-values of the Durbin-Watson test are 1.961 and 1.957, indicating that the autocorrelation problem is significantly mitigated. This implies that the results can be trusted. In column (4), I examine the effect of public capital stock over time using dummy variables, as in column (2), and the coefficients of all variables in column (3) and column (4) are similar overall. Therefore, only the results of column (4) are mentioned here.

Interestingly, after solving the autocorrelation problem, the changes in public capital stock and the growth rate do not have a statistically significant impact on productivity growth. On the other hand, the effect of human capital stock becomes much greater, and the increase in labor input does not have a positive effect on productivity improvement. In addition, the statistical significance of the growth rate of public capital stock over time is not determined. Therefore, it is necessary to examine whether this outcome is due to the calculation of the growth rate. This occurs because, in general, it is suggested that public capital needs a certain period

TABLE 5—THE EFFECT OF PUBLIC CAPITAL STOCK ON THE PRODUCTIVITY IMPROVEMENT BY PERIOD (ONE-YEAR LAG)

	(1)	(2)	(3)	(4)
Productivity (a_{t-1})	-1.061***	-1.000***	-1.100***	-0.985***
	(0.072)	(0.144)	(0.132)	(0.122)
Public Capital (pub_{t-1})	-0.231	-1.406***	-0.851	-0.145
	(0.194)	(0.442)	(0.592)	(0.276)
Private Capital (pri_{t-1})	-0.283**	-0.008	0.148	-0.991**
	(0.131)	(0.195)	(0.270)	(0.401)
Human Capital (hc_{t-1})	3.684***	1.091	3.237**	4.136
	(1.248)	(6.008)	(1.456)	(5.455)
Labor Input (l_{t-1})	-0.090***	-0.116***	-0.017	-0.062
	(0.016)	(0.029)	(0.061)	(0.070)
Growth Rate of Public Capital (Δpub_t)	0.264	-0.346	-2.027*	0.819
	(0.377)	(0.534)	(1.030)	(1.417)
Growth Rate of Private Capital (Δpri_t)	0.327**	0.341	1.101***	0.084
	(0.145)	(0.209)	(0.224)	(0.344)
Growth Rate of Human Capital (Δhc_t)	0.324	-3.387	0.626	0.485
	(2.733)	(5.579)	(4.963)	(2.175)
Growth Rate of Labor Input (Δl_t)	-0.063	-0.127	0.592**	0.648***
	(0.055)	(0.079)	(0.262)	(0.224)
Trend (t)	yes	yes	yes	yes
$D-W$ statistics	1.961	1.797	1.847	1.736
$Adj\ R^2$	0.573	0.542	0.793	0.694
N	176	56	60	60

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

of time to affect productivity. Therefore, the growth rate of all variables is derived from the difference between the current year and the two previous years, and this analysis using equation (5) again is presented in Table 4.

The results in columns (1) and (2) in Table 4 are derived by the OLS method, as in Table 3, and those in columns (3) and (4) use the Prais-Winsten method. In the analysis of the rate of increase according to a two-year time lag, the results are found to be generally similar to those in Table 3. The effects of public capital stock and the growth rate on productivity improvement are not statistically significant, and the signs of private capital and the labor input variable are identical. The sign of the coefficient of the human capital stock is also the same, and statistical significance is thus secured. In conclusion, Table 3 and Table 4 reveal that the level of public capital stock and its growth rate do not have a statistically significant effect on the improvement of economic productivity in Korea.

Next, in order to examine this more specifically, the time period is divided into the periods from 1970 to 1984, from 1985 to 1999 and from 2000 to 2015. The Prais-Winsten method is also used to solve the autocorrelation problem, as in the previous analysis. The time lag of the growth rate is one year, and these results are shown in Table 5.

Column (1) in Table 5 shows the results of the analysis of the entire period and is identical to column (3) in Table 3. Columns (2), (3) and (4) are the results of the analysis from 1970 to 1984, from 1985 to 1999, and from 2000 to 2015,

TABLE 6—THE EFFECT OF PUBLIC CAPITAL STOCK ON THE PRODUCTIVITY IMPROVEMENT BY SECTOR AND PERIOD (ONE-YEAR LAG)

	(1)	(2)	(3)	(4)
Productivity (a_{t-1})	-1.090*** (0.073)	-1.253*** (0.130)	-1.169*** (0.145)	-1.341*** (0.118)
Public Infrastructure (a_{-1})	0.141 (0.100)	-1.358*** (0.469)	-1.261* (0.640)	0.372 (0.250)
R&D/ICT $(tech_{-1})$	-0.139 (0.101)	-0.412* (0.212)	0.058 (0.251)	0.559* (0.312)
Other Public Capital (ex_tech_{-1})	-0.345*** (0.070)	-0.150* (0.082)	1.305 (0.897)	-1.966*** (0.383)
Private Capital (pri_{t-1})	-0.081 (0.080)	0.514** (0.193)	-0.552 (0.427)	0.407 (0.462)
Human Capital (hc_{t-1})	3.489*** (0.733)	4.675 (4.415)	-1.364 (3.395)	6.620 (4.694)
Labor Input (l_{t-1})	-0.089*** (0.018)	-0.121*** (0.030)	-0.013 (0.065)	-0.164** (0.071)
Growth Rate of Public Infrastructure (Δa_{-1})	0.724** (0.342)	0.210 (0.541)	-1.560 (0.937)	0.218 (1.275)
Growth Rate of R&D/ICT $(\Delta tech_{-1})$	-0.359** (0.138)	-0.964*** (0.272)	0.566* (0.323)	0.374* (0.206)
Growth Rate of Other Public Capital (Δex_tech_{-1})	-0.167 (0.110)	-0.154 (0.119)	0.545 (0.531)	-1.029*** (0.338)
Growth Rate of Private Capital (Δpri_t)	0.660*** (0.128)	0.596*** (0.188)	0.917*** (0.323)	0.945*** (0.341)
Growth Rate of Human Capital (Δhc_t)	0.176 (1.948)	-7.302 (4.952)	-4.884 (6.584)	-0.400 (1.566)
Growth Rate of Labor Input (Δl_t)	-0.049 (0.063)	-0.151* (0.085)	0.456* (0.251)	0.573*** (0.193)
Trend (t)	yes	yes	yes	yes
$D-W\ statistics$	1.780	1.827	1.858	1.707
$Adj\ R^2$	0.629	0.820	0.844	0.844
N	176	56	60	60

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

respectively. These results show that public capital stock does not have a positive effect on productivity improvement over the entire period, while human capital stock has a positive effect on productivity improvement over the entire period. This is consistent with previous findings which showed that the growth rate of public capital stock does not have a positive effect on productivity growth through a period analysis. However, if I investigate the sectoral effect of public capital stock on productivity improvement, the effect varies depending on the type of public capital stock. Public infrastructure, which accounts for most public investment, and R&D and IT stock, which have recently become more important, are analyzed to determine the effect of each type of public capital on productivity. Similar to the previous analysis, the Prais-Winsten method is used to ascertain the sectoral effect by period. Column (1) in Table 6 shows the results of the analysis of the entire period and columns (2), (3) and (4) are the results of the analysis from 1970 to

1984, from 1985 to 1999, and from 2000 to 2015, respectively. These results are shown in Table 6.

The growth rate of public infrastructure capital such as roads, railways, ports, water resources, and electricity and communication has a positive effect on productivity improvement. On the other hand, the growth rate of R&D and IT capital stock does not show a corresponding statistically significant positive effect. The growth rate of human capital stock is positive but not statistically significant. However, if I divide it by period, more interesting results are obtained. Although the positive effect of public infrastructure capital was not derived by period, the growth rate of R&D and IT capital stock has been positively influenced productivity growth since 1985.

In conclusion, the effect of public capital stock on the productivity improvement is limited in the Korean economy, but there is a difference in the effect on productivity by sector. In particular, the findings that R&D and IT capital stock have positively affected productivity improvement since the 1990s and that human capital has a positive effect on productivity improvement imply that in the future these will be the most important factors when setting the directions for public investment.

Production Function Approach

Next, I use equation (6) to examine the effect of public capital stock on economic growth in Korea. The analysis period, the growth rate and methodology are identical to those applied in the previous TFP approach. Prior to the analysis, this study utilizes quarterly data, implying that we should initially investigate the time-series characteristics of the variables included in the empirical analysis. The unit root test can be used to verify the stability of the variables. The Augmented Dickey-Fuller test (ADF test) is generally used for this purpose. Table 7 shows the tau statistics, which is the ADF test result for level and differential variables.

As shown in Table 7, while the hypothesis that the levels of the variables have the unit root cannot be rejected, the hypothesis that the first differential variables have the unit root is rejected at the 1% significance level. This implies that the I(1) process will be stabilized if the first-order differential variable is utilized, and it is appropriate to use the first-differential variables in the empirical analysis.

Table 8 presents the results after analyzing the effect of public capital stock on economic growth using Equation (6). Columns (1) and (2) are the results of the OLS

TABLE 7—UNIT ROOT TEST (ADF TEST)

	Level	First Difference
Real GDP	-1.341	-5.922***
Public Capital	-1.456	-4.610***
Private Capital	-2.143	-3.235**
Human Capital	-5.230***	-9.752***

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

TABLE 8—THE EFFECT OF PUBLIC CAPITAL STOCK ON THE ECONOMIC GROWTH (ONE-YEAR LAG)

	(1)	(2)	(3)	(4)
Real GDP (gdp_{t-1})	-0.635*** (0.071)	-0.509*** (0.074)	-0.871*** (0.073)	-0.838*** (0.075)
Public Capital (pub_{t-1})	0.625*** (0.074)	0.725*** (0.081)	0.668*** (0.114)	0.731*** (0.118)
Private Capital (pri_{t-1})	-0.163*** (0.037)	-0.281*** (0.047)	-0.110 (0.086)	-0.150* (0.089)
Human Capital (hc_{t-1})	0.091** (0.036)	-0.022 (0.045)	0.271*** (0.057)	0.214*** (0.064)
Labor Force Participation Rate (emp_{t-1})	-0.144 (0.146)	-0.197 (0.143)	-0.170 (0.176)	-0.182 (0.176)
Export (amount of export) (exp_{t-1})	0.017* (0.009)	0.025*** (0.009)	-0.001 (0.012)	-0.002 (0.012)
Growth Rate of Public Capital (Δpub_t)	0.391 (0.282)	0.400 (0.277)	0.954*** (0.340)	1.025*** (0.344)
Growth Rate of Private Capital (Δpri_t)	0.612*** (0.115)	0.499*** (0.114)	0.493*** (0.128)	0.476*** (0.128)
Growth Rate of Human Capital (Δhc_t)	-0.213 (0.239)	-0.011 (0.253)	-0.508 (0.308)	-0.543* (0.312)
Growth Rate of Labor Force Participation Rate (Δemp_t)	0.866*** (0.220)	1.086*** (0.235)	0.546** (0.220)	0.540** (0.220)
Growth Rate of Exports (Δexp_t)	0.061*** (0.013)	0.062*** (0.012)	0.036** (0.014)	0.033** (0.014)
(1985-2000)* Growth Rate of Public Capital ($D_{85} \cdot \Delta pub_t$)		-0.188* (0.105)		-0.191 (0.132)
(2000-2014)* Growth Rate of Public Capital ($D_{00} \cdot \Delta pub_t$)		-1.050*** (0.271)		-0.532* (0.279)
Trend (t)	yes	yes	yes	yes
$D-W$ statistics	0.653	0.755	2.011	2.003
$Adj\ R^2$	0.719	0.744	0.771	0.774
N	176	176	176	176

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

analysis. Given that the d-values from the Durbin-Watson test are very low, 0.653 and 0.755, and considering that a serious autocorrelation problem occurs in the model, the Prais-Winsten method is also applied to this analysis. The d-values of columns (3) and (4) are determined to be 2.011 and 2.003, respectively, indicating that the autocorrelation problem is significantly alleviated. As shown in column (3), the level of public capital stock and the growth rate of public capital stock have a positive impact on economic growth. In addition, the level of human capital stock and the growth rate of exports both have a positive impact on economic growth. Column (4) presents the results of the effect of public capital stock on economic growth over time. The coefficients in column (4) are nearly identical to those in column (3) and the growth rate of public capital stock is shown to decrease in the 2000s.

Similar to the previous analysis, these results can be argued considering that the effects of public capital on economic growth may occur at a certain time lag. Thus, in order to observe whether the results in Table 8 are due to the calculation of the

TABLE 9—THE EFFECT OF PUBLIC CAPITAL STOCK ON THE ECONOMIC GROWTH (TWO-YEAR LAG)

	(1)	(2)	(3)	(4)
Real GDP (gdp_{t-1})	-0.959*** (0.088)	-0.802*** (0.093)	-0.943*** (0.077)	-0.958*** (0.080)
Public Capital (pub_{t-1})	0.964*** (0.095)	1.014*** (0.121)	0.604*** (0.158)	0.658*** (0.168)
Private Capital (pri_{t-1})	-0.191*** (0.056)	-0.321*** (0.086)	-0.002 (0.116)	-0.033 (0.120)
Human Capital (hc_{t-1})	0.083* (0.049)	-0.004 (0.061)	0.308*** (0.081)	0.298*** (0.084)
Labor Force Participation Rate (emp_{t-1})	0.099 (0.207)	-0.045 (0.215)	-0.067 (0.213)	-0.094 (0.215)
Export (amount of export) (exp_{t-1})	0.041*** (0.013)	0.044*** (0.013)	-0.005 (0.015)	-0.005 (0.015)
Growth Rate of Public Capital (Δpub_t)	0.139 (0.283)	0.103 (0.313)	0.400 (0.342)	0.422 (0.348)
Growth Rate of Private Capital (Δpri_t)	0.450*** (0.105)	0.337*** (0.114)	0.321** (0.129)	0.313** (0.130)
Growth Rate of Human Capital (Δhc_t)	0.180 (0.228)	0.442* (0.261)	0.290 (0.271)	0.280 (0.276)
Growth Rate of Labor Force Participation Rate (Δemp_t)	0.580** (0.243)	1.060*** (0.263)	0.529** (0.235)	0.556** (0.237)
Growth Rate of Exports (Δexp_t)	0.051*** (0.015)	0.054*** (0.014)	0.035** (0.015)	0.033** (0.016)
(1985-2000)* Growth Rate of Public Capital ($D_{85} \cdot \Delta pub_t$)		0.001 (0.079)		-0.014 (0.066)
(2000-2014)* Growth Rate of Public Capital ($D_{00} \cdot \Delta pub_t$)		-0.535** (0.230)		-0.152 (0.165)
Trend (t)	yes	yes	yes	yes
$D-W$ statistics	0.529	0.566	1.718	1.731
$Adj\ R^2$	0.774	0.792	0.841	0.839
N	172	172	172	172

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

growth rate, Table 9 applies a two-year time lag to the growth rate of the variables.

The d-values in columns (1) and (2) in Table 9 are 0.529 and 0.566, respectively, which indicate that there is an autocorrelation problem. To correct this, I use the Prais-Winsten method, and these results are shown in columns (3) and (4). They are not significantly different from the results in Table 8. Although the statistical significance between the growth rate of public capital stock and economic growth has disappeared, the level of public capital stock has a positive effect on economic growth while the level of human capital is also found to be positively correlated with economic growth. Moreover, the statistical significance of the effect of public capital stock on the growth rate over time is shown to differ from that in Table 8.

However, it was also reported that in addition to the problem caused by the difference in the time lag, an endogeneity problem in the production function approach may occur. Holtz-Eakin (1994) adopted an IV method with using a second-difference variable to solve the endogeneity problem in production function equation with the first-difference variable. In this study as well, the model was

TABLE 10—THE EFFECT OF PUBLIC CAPITAL STOCK ON THE ECONOMIC GROWTH BY PERIOD (ONE-YEAR LAG)

	(1)	(2)	(3)	(4)
Real GDP (gdp_{t-1})	-0.871*** (0.073)	-1.037*** (0.118)	-0.946*** (0.129)	-0.658*** (0.112)
Public Capital (pub_{t-1})	0.668*** (0.114)	-1.494*** (0.522)	-0.794 (0.550)	0.103 (0.321)
Private Capital (pri_{t-1})	-0.110 (0.086)	0.108 (0.189)	0.631** (0.279)	-0.568 (0.378)
Human Capital (hc_{t-1})	0.271*** (0.057)	2.416*** (0.422)	0.950** (0.369)	1.137 (0.685)
Labor Force Participation Rate (emp_{t-1})	-0.170 (0.176)	0.242 (0.437)	-0.423 (0.345)	0.283 (0.333)
Export (amount of export) (exp_{t-1})	-0.001 (0.012)	0.054** (0.021)	0.050** (0.024)	0.003 (0.021)
Growth Rate of Public Capital (Δpub_t)	0.954*** (0.340)	-0.296 (0.450)	-1.300* (0.769)	0.357 (1.012)
Growth Rate of Private Capital (Δpri_t)	0.493*** (0.128)	0.686*** (0.159)	1.045*** (0.211)	-0.213 (0.341)
Growth Rate of Human Capital (Δhc_t)	-0.508 (0.308)	0.638 (0.383)	0.658 (0.680)	0.101 (1.138)
Growth Rate of Labor Force Participation Rate (Δemp_t)	0.546** (0.220)	0.288 (0.475)	0.640** (0.269)	0.334 (0.351)
Growth Rate of Exports (Δexp_t)	0.036** (0.014)	0.073*** (0.019)	0.060** (0.027)	0.067*** (0.017)
Trend (t)	yes	yes	yes	yes
$D-W$ statistics	2.011	1.921	1.863	1.898
$Adj\ R^2$	0.771	0.883	0.817	0.771
N	176	56	60	60

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

estimated using lagged variables $\left(\Delta t = t_{-4} - t_{-8}\right)$ as instrumental variables for the growth rate variables $\left(\Delta k_{pub},\ \Delta k_{pri},\ \Delta hc\right)$. As a result, the coefficients and signs of the variables are similar to those in Table 9 and the coefficient of the level of public capital stock is statistically significant, at 0.479 (0.092, standard error). However, there remains a possibility that the endogeneity problem may occur in addition to the growth rate of the variables. Therefore, it is unreasonable to conclude that the problem is completely solved by this method. Therefore, additional work is needed in the form of a more detailed study in the future.

Next, I examine whether the effects of public capital on economic growth differ by period. To do this, the entire period is divided into the sub-periods of 1970 to 1984, 1985 to 1999, and 2000 to 2015. As in the previous analysis, the Prais-Winsten method is used to solve the autocorrelation problem, and the time lag of the growth rate is one year. These results are shown in Table 10.

Column (1) in Table 10 shows the results of the analysis of the entire period, identical to column (3) in Table 8. Column (2) is the result of the analysis from 1970 to 1984, column (3) is from 1985 to 1999, and column (4) is from 2000 to 2015. According to the analysis by period, the effect of public capital stock does

TABLE 11—THE EFFECT OF PUBLIC CAPITAL STOCK ON THE ECONOMIC GROWTH BY SECTOR AND PERIOD (ONE-YEAR LAG)

	(1)	(2)	(3)	(4)
Real GDP (gdp_{t-1})	-0.817*** (0.079)	-1.155*** (0.141)	-1.107*** (0.148)	-0.999*** (0.144)
Public Infrastructure (a_{-1})	0.734*** (0.107)	-1.363** (0.617)	-0.946* (0.527)	0.157 (0.319)
R&D/ICT ($tech_{-1}$)	0.056 (0.086)	-0.298 (0.234)	-0.030 (0.211)	0.123 (0.228)
Other Public Capital (ex_tech_{-1})	-0.150** (0.061)	-0.099 (0.102)	1.124* (0.568)	-1.079** (0.463)
Private Capital (pri_{t-1})	-0.086 (0.085)	0.487* (0.243)	0.291 (0.412)	0.252 (0.435)
Human Capital (hc_{t-1})	0.208*** (0.075)	2.457*** (0.485)	0.582 (0.658)	1.627*** (0.594)
Labor Force Participation Rate (emp_{t-1})	-0.253 (0.155)	0.368 (0.508)	0.310 (0.575)	0.325 (0.338)
Export (amount of export) (exp_{t-1})	0.007 (0.010)	0.015 (0.038)	0.013 (0.029)	0.039* (0.022)
Growth Rate of Public Infrastructure (Δa_{-1})	1.340*** (0.321)	-0.018 (0.567)	-1.048 (0.863)	-0.457 (0.992)
Growth Rate of R&D/ICT ($\Delta tech_{-1}$)	-0.316** (0.136)	-0.581* (0.287)	-0.173 (0.443)	0.578*** (0.197)
Growth Rate of Other Public Capital (Δex_tech_{-1})	0.001 (0.108)	-0.215** (0.090)	0.750 (0.534)	-0.713* (0.418)
Growth Rate of Private Capital (Δpri_t)	0.640*** (0.133)	0.880*** (0.198)	0.746** (0.344)	0.382 (0.345)
Growth Rate of Human Capital (Δhc_t)	-0.726** (0.326)	0.997** (0.487)	0.175 (1.038)	0.593 (0.957)
Growth Rate of Labor Force Participation Rate (Δemp_t)	0.588*** (0.218)	-0.005 (0.525)	1.063** (0.399)	0.113 (0.345)
Growth Rate of Exports (Δexp_t)	0.038*** (0.013)	0.057** (0.025)	0.039 (0.030)	0.070*** (0.017)
Trend (t)	yes	yes	yes	yes
$D-W$ statistics	1.850	1.932	1.923	1.837
$Adj\ R^2$	0.780	0.903	0.833	0.881
N	176	56	60	60

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

not appear to be positive. However, the level of human capital has been shown to have a positive impact on economic growth over the entire period.

Finally, I investigate the sectoral effect in more detail and determine its impact on economic growth by sector. A sectoral analysis is conducted in accordance with the criteria in the TFP analysis, again with the Prais-Winsten method used. These results are presented in Table 11. In Table 11, the levels of public infrastructure capital and its growth rate have positive effects on economic growth during the overall period. On the other hand, R&D and IT capital stock do not show statistically significant effects on economic growth. The coefficient of the human capital variable is shown to have a positive effect on economic growth. However, by analyzing this by period, while the level of public capital stock does not show a positive effect by period, the level of human capital is shown to have a positive

effect for each period. For R&D and IT assets, although the growth rate does not have a positive effect in the entire period, a positive effect was found in the 2000s. This is similar to the results of the productivity analysis.

In conclusion, the results of the assessment of the effect of public capital on economic growth suggest that public capital stock has a positive effect on economic growth in Korea, but the effect of the period is limited. As a result of the sectoral analysis, the levels of public infrastructure stock and R&D and IT assets since 2000 have had positive impacts on economic growth. For human capital, it appears to have had a positive impact on economic growth in general despite the differences by period. It can be interpreted that the role of public investment as an input factor of production is high in the Korean economic system. However, in comparison with the results of the productivity analysis, public investment has not played an important role in increasing production efficiency by reducing the inefficiency of production. It is believed that it is urgent to consider how to improve productivity through public investment.

Stochastic Frontier Function Approach

Through the two preceding analyses, I examined the effect of public capital on productivity and economic growth. As a result of these analyses, it was found that public capital stock has a positive effect on the economic growth but that it does not affect productivity improvements in the Korean economy. The question arises of how we can explain this phenomenon. Would it be possible to interpret this as a result of inefficiency in production?

To answer this question, I attempt to determine whether there is inefficiency in production processes associated with public investment through equation (11). Table 12 shows the results of a stochastic frontier function analysis conducted to determine the existence of inefficiency in the production processes. Columns (1) and (2) are the results of the assessment of whether there is inefficiency in the production processers when considering the total public capital stock. Column (1) assumes a one-year time lag between the variables, and column (2) assumes a two-year time lag. As a result, public capital stock and human capital stock have a positive effect on economic growth, similar to the results in Tables 8 and 10.

Next, the determination of whether there is inefficiency in production can be done from the value of λ in columns (1) and (2). As noted earlier, the errors in the stochastic frontier model consist of random error and inefficiency error, where $\lambda = \sigma_u / \sigma_v$ denotes the ratio of the standard error between them. In other words, when there is no technological inefficiency, it becomes 0. However, this explains only the existence of inefficiency and does not provide an answer as to whether it plays a role in reducing inefficiency. In other words, it is uncertain as to whether inefficiency in production is due to inefficiency in public investment or inefficient distributions of other factors of production. Nevertheless, it is meaningful to determine why public investment affects only economic growth and not productivity through this analysis. In both columns, the values of λ are statistically significant at 0.840 and 2.922, which indicate that technical inefficiency exists in the production process. That is, it can be interpreted that inefficiency in production processes has a negative effect on productivity in the Korean economy.

TABLE 12—THE ESTIMATES OF THE STOCHASTIC FRONTIER FUNCTION APPROACH

	(1)	(2)
Real GDP (gdp_{t-1})	-0.615*** (0.114)	-0.824*** (0.090)
Public Capital (pub_{t-1})	0.594*** (0.163)	0.719*** (0.107)
Human Capital (hc_{t-1})	0.093** (0.036)	0.115*** (0.041)
Labor Force Participation Rate (emp_{t-1})	-0.154 (0.148)	-0.017 (0.185)
Export (amount of export) (exp_{t-1})	0.016 (0.010)	0.037*** (0.012)
Growth Rate of Public Capital (Δpub_t)	0.382 (0.277)	-0.181 (0.261)
Growth Rate of Human capital (Δhc_t)	-0.178 (0.285)	0.525** (0.207)
Growth Rate of Labor Force Participation Rate (Δemp_t)	0.874*** (0.214)	0.472* (0.244)
Growth Rate of Exports (Δexp_t)	0.062*** (0.013)	0.054*** (0.014)
Trend (t)	yes	yes
λ	0.840***	2.922***
N	176	172

Note: Standard errors are in parenthesis and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

V. Concluding Remarks

The debate over whether public investment serves as a direct form of input to enhance production or as an indirect form to increase efficiency in the economy has long continued. Although clear conclusions have yet to be drawn, it is important to justify the role of public investment to determine its future direction. This study considers whether public investment contributes to productivity improvement or to economic growth, and whether production inefficiency exists. To this end, three different methodologies - the TFP approach, the production function approach, and the stochastic frontier function approach - are used. The findings of this study are as follows.

First, while public investment has a positive impact on economic growth, the contribution to productivity growth is not high. In the context of production inefficiency, it is stated that public investment has played a role as a direct input factor of production, and not as a productive factor. It can be interpreted that there is inefficiency of production which has a negative effect on productivity in the Korean economy.

Second, the effects of public investment on economic growth and productivity improvement differ according to the sector and period. For example, public infrastructure capital has a positive effect on economic growth, although the effect by period is not clear. R&D and IT assets since 2000 have enhanced productivity and economic growth. More interestingly, the impact of human capital also differs

by period, but it has generally a positive effect on productivity improvement and economic growth. These findings provide evidence that the role of public investment appears differently depending on the sector and period assessed.

In recent years, governmental revenue has decrease due to low economic growth and welfare expenditure increases. At this time, we need to focus on efforts to secure fiscal soundness by accomplishing a restructure of the government spending. To do this, the government must move toward reducing inefficiency in the economy for public investment. In other words, efforts need to be directed not only to increase the total output but also to raise productivity as an input of production.

In addition, the government has focused on building public infrastructure for economic growth during the past decade, and has mostly invested in sectors where direct effects could be rapidly realized. As in the results of this study, it is true that the performance of public investment clearly appeared in the past. However, we should be careful about undertaking public investment in a similar manner in the future. It has been reported that the level of transport SOC stock is not lower than those of advanced economies and that marginal productivity is steadily declining. In this context, efforts should be made to allocate sectoral resources effectively under the current budget constraints. It is necessary to consider the Korean economic situation and the global economic situation at the same time. As the interest in R&D and IT sector has increased worldwide since 2000, it is notable that the increase in this type of investment in Korea has a positive effect on productivity improvement. It is likely that this stems from the basis of efficiency. Thus, resource allocation by sector must respond flexibly to global economic conditions.

Finally, it is true that human capital has played an important role in Korean economic growth, which is also proved in this study. However, it is also true that the investment in human capital has focused on quantitative expansions thus far. However, in order to cope with rapidly changing economic situations in the future, qualitative growth must be realized. Rather than trying to form quantitative human capital by raising the entrance rate of tertiary education or the employment rate unconditionally, it is necessary to make efforts to improve the quality of education in order to keep pace with changes in the global economy and industrial structure. In order to do this, it is necessary to change the existing curriculum and establish a proper education policy to introduce an advanced education system.

Although there have been tangible contributions to the discussion on public investment introduced in this paper, there are also several limitations. First, there is some controversy about standard growth accounting, as the factors of production cannot be easily aggregated due to their quality and heterogeneity. For this reason, mixed results are shown in general. Second, it is difficult to consider all factors which explain economic growth in the analysis. For example, work by Hall and Jones (1999, QJE) found that a country's long-run economic performance depends on certain aspects of its social infrastructure, such as its institutions or government policies. Nevertheless, this study concentrates on the effect of public investment and reports that there is a limit when consider all influencing factors.

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Economic Effects of Regulatory Reform in Korea

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This paper adapts the World Bank Regulatory Quality Index (RQI), which is produced annually to provide a better understanding of the effects of regulatory reforms, instead of the Production Market Regulation (PMR) indicators, which are published every five years. We find that 9.9 to 36.0 billion USD worth of regulatory cost could be reduced if the regulatory quality in Korea improves to the level of the OECD average considering that the total burden of regulation in Korea is estimated to range from 2.2 to 357.4 billion USD. The estimated reduction in the regulatory cost accounts for roughly 0.76 to 2.47% of Korea's GDP in 2013, underscoring the importance of regulatory reforms for the Korean economy. This paper introduces a new method with which to examine the distribution of regulatory costs across different industries and firm sizes. This alternative method is largely consistent with the conclusions reached by other studies, specifically that small firms typically bear a disproportionate regulatory burden.

Key Word: Regulatory Quality Index, Regulatory Reform, Economic Impact Analysis
JEL Code: K20, L25, O43

I. Introduction

In Korea, regulatory reforms are among the top national priorities to achieve economic growth. Various measures have been undertaken in an effort to facilitate and enhance such reforms. The Korean government has launched an ambitious regulatory reform agenda as a part of its Three Year Economic Innovation Plan (March 2014 ~ February 2017). The agenda includes a focus on improving or eliminating regulations in order to promote employment and investment, with a view towards accelerating economic growth (i.e., the "what") –

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with a focus on health, education, tourism, finance, software, culture and logistics industry; and institutional improvements to facilitate regulatory reform (i.e., the "how"), with a focus on the introduction of a cost-in-cost-out system, the establishment of regulatory reform principles, and the disclosure of regulatory information.

Many countries, including Korea, tend to set their policy focus on regulatory reform during periods of economic stagnation. Since the early 1980, Korean administrations have attempted to reform regulations, though whether the reforms went far enough remains debatable (Lee *et al*., 2008). To maximize the effects of regulatory reform efforts, it is necessary to detect more burdensome regulations and to determine which industries are affected by those regulations. Through the process of introducing and repealing regulations, we must undertake an economic impact analysis of the social costs and benefits of the regulations. In this study, we focus on measuring the costs and benefits of regulations in monetary terms instead of the number of regulations.

Regulatory costs occur relatively implicitly, unlike most fiscal actions taken by governments. Crain and Crain (2010) provide an example involving the activities, products and services consumed by an ordinary household on one day. The costs of government regulations exist within an indistinct mixture of countless economic forces that determine the prices, costs, designs, locations, profits, losses, wages, dividends, and other factors. Isolating the contribution of regulations requires more than simply looking at sales receipts. A comprehensive list of regulatory influences is indeed extensive and overwhelming to track or summarize. Nonetheless, Crain and Crain (2010) assert that knowledge of the cumulative consequences of regulatory actions provides important information with which to assess and evaluate the performance of a political-economic social system.

The current paper initially aims to measure regulatory costs in Korea. Note that we measure regulatory costs via comparisons with other advanced countries instead of with 'zero' regulatory environments. Previous research undertaken to estimate these types of costs is available and country-level estimates are not rare. For instance, Crain (2005) and Crain and Crain (2010) estimate regulatory costs in the U.S., and Lee *et al*. (2008) estimate such costs in Korea. Inaccuracies in regulatory cost estimates become an issue when establishing or repealing regulations. This occurs firstly because most of ex ante studies cannot capture uncertainty and instability as these factors relate to policies and secondly because optimism bias can arise. Nevertheless, we consider economic analysis results as important given that they are among the criteria used to select the best regulation with a view toward simplifying policy decisions.

On the other hand, we need to take into account regulatory fairness with regard to diverse groups, as regulations can affect firms differently depending on their size. In the U.S., the Regulatory Flexibility Act was revised to ensure fairness for small to mid-size firms in 1980. This act also required reviews of all regulations for any unfairness. The Small Business Regulatory Enforcement Fairness Act, established in 1996, reduces punishments for small to mid-size firms when they violate regulations (Lee, 2012). Former British Prime Minister Tony Blair emphasized the significance of the voices of those who operated small to mid-size firms and the effects of regulations on them considering their different scale. The

program 'Think Small First' in the EU supports small to mid-size firms by paying attention to their perspectives and reflecting evaluations of their costs and benefits due to regulations to enhance the quality of regulations. Therefore, this paper also aims to introduce a proper methodology to measure regulatory costs borne by small and medium-sized firms while reviewing and comparing findings about how regulatory costs differ depending on the firm size.

The paper proceeds as follows. Chapter II reviews previous research in an attempt to estimate the costs of regulations and offers some constructive criticism that may improve the reliability of cost estimates. Chapter III provides the empirical results of how the quality and level of regulations affect GDP per capita. Chapter IV evaluates regulatory cost trends across industries and firm sizes by introducing a novel methodology. Chapter V concludes the paper.

II. Literature and Method

Much of the literature utilizes Product Market Regulation (PMR) indicators as a proxy for regulatory status in countries. Crain (2005) uses PMR indicators in OECD member countries and estimates that a unit increase in the PMR indicator reduces US GDP by 1,343 USD per capita. Lee *et al*. (2008) estimate the cost of regulations in Korea to be 951 USD per capita. When applied to the Korean economy as a whole, the aggregate cost from regulation is estimated to be roughly 65 billion USD, accounting for 7.7% of GDP (in 2006 prices), as shown in Table 1.

The current paper attempts to improve the assessment by utilizing improved data, although the available regulation indices are correlated. PMR indicators are published only once every five years; hence, the problem of a small sample may arise, thus affecting the robustness of the results. In addition, the PMR index is only available for OECD members and partner countries, which restricts data availability further. As the PMR mainly deals with regulations in the domestic goods market, important regulations pertaining to labor or international trade may not be fully captured. Hence, the current paper uses the Regulatory Quality Index of the World Governance Index by the World Bank in order to refine the analysis. The Regulatory Quality Index captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.[1] As this index is published annually for countries and

TABLE 1—OPPORTUNITY COST OF MARKET REGULATION

(1)	(2)	(3)	(4)	(5)
PMR of Korea	Cost per unit of regulation (per capita)	(1)*(2)	(3)/GDP per capita	(4)*GDP
1.5	$951	$1,427	7.7%	65 trillion won

Note: GDP per capita from (2), (3) and (4) is constant 2000. Nominal GDP in 2006 is 847 trillion won.

Source: Lee *et al*. (2008).

[1]Kaufmann, Kraay, and Mastruzzi (2010), p.3.

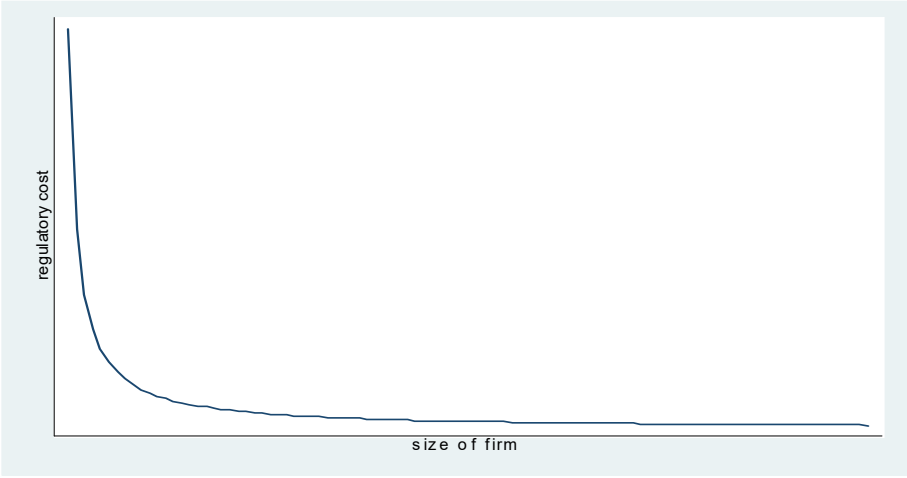

FIGURE 1. REGULATORY COST PER UNIT DEPENDING ON FIRM SIZE

not limited to product market regulation, utilizing this instead of the PMR is expected to improve quality of analysis.

This research also estimates the regulatory costs borne by South Korea and offers methods to examine the how the burden of regulations varies depending on firm size and across industries. Figure 1 depicts the negative relationship found between firm size and the average cost, which is derived from the concept of economies of scale. Fixed costs which arise when complying with environmental regulations and any additional inspections or accounting costs are burdens borne by all firms regardless of their size, indicating that small and mid-size firms bear a greater burden per unit due to fixed costs in comparison with larger firms.

Crain (2005) and Crain and Crain (2010) argue that regulatory costs per worker decrease as the firm size increases; meanwhile, the costs of economic regulations for each firm increase (see Table 2). Crain (2005) and Crain and Crain (2010) rely on a regulatory accounting approach that uses the number of employees as a common denominator, that is, the regulatory cost per worker. In this case, productivity will increase as the firm size increases, thus leaving smaller firms with a heavier regulatory burden, as shown in Figure 1. Note that the total regulatory cost per employee decreases as the firm size increases because the costs associated with environmental regulations, taxes, or occupational stability were included, meaning that small to mid-size firms will incur higher regulatory costs. However, the costs stemming from economic regulation increase as the firm size increases, as shown in Table 2.

On the other hand, Lee *et al*. (2008) counter by asserting that the economic regulatory cost burden increases as the firm size increases (see Table 3). Lee *et al*. (2008) propose that regulatory costs stemming from market regulations be taken into consideration in the estimation procedure. Based on their suggestion, they conclude that small firms bear a disproportionate burden of regulatory costs.

TABLE 2—REGULATORY COSTS PER WORKER IN THE US

Industry	Type of Regulation	All Firms	Firm Size by Number of Workers		
			<20	20 ~ 499	500+
Manufacture	Total	14,070	28,316	13,504	12,586
	Economic	6,004	4,454	5,481	6,952
	Environmental	7,211	22,594	7,131	4,865
	Tax	233	444	205	219
	OSHHS	622	824	687	550
Logistics	Total	5,289	5,453	6,242	4,753
	Economic	4,079	3,673	4,866	3,823
	Environmental	-	-	-	-
	Tax	616	1,013	737	418
	OSHHS	594	767	639	511
Service	Total	7,235	7,106	6,274	7,815
	Economic	5,595	4,181	4,668	6,648
	Environmental	10	25	8	5
	Tax	1,014	2,113	944	637
	OSHHS	616	786	655	524
Health Care	Total	4,221	5,375	3,707	4,204
	Economic	3,148	3,318	2,725	3,366
	Environmental	75	203	64	44
	Tax	418	1,103	292	293
	OSHHS	633	772	643	514
Etc	Total	14,992	21,906	12,878	11,964
	Economic	6,728	5,273	6,700	7,721
	Environmental	6,348	13,760	4,343	2,963
	Tax	1,283	2,101	1,192	765
	OSHHS	633	772	643	514
Total	Total	8,086	10,585	7,454	7,755
	Economic	5,153	4,120	4,750	5,835
	Environmental	1,523	4,101	1,294	883
	Tax	800	1,584	760	517
	OSHHS	610	781	650	520

Note: OSHHS is an acronym for Occupational Safety and Health, and Homeland Security Regulations.

TABLE 3—COSTS OF ECONOMIC REGULATIONS OF PER WORKER IN KOREA

	Firm size			Total
	5~29 People	30~499	Over 500	
Cost (100 million won)	288,031	350,827	141,813	780,670
Cost per Worker (10 thousand won)	1,045	1,170	1,428	1,157

Source: Lee *et al.* (2008).

Previous studies find relationships between regulatory indices and GDP. Lee *et al*. (2008) base their research on Crain (2005) by analyzing how the Product Market Regulation Index (PMR) affects GDP per capita. Crain (2005) stated that a one unit increase in the PMR index in 1998 decreased GDP per capita by $1,343, whereas Lee *et al*. (2008) conducted the same analysis with a different result, showing a $951 decrease from a one unit PMR increase. According to these estimates, Korea's cost (constant 2006) stemming from federal regulations is 65 trillion won, nearly 7.7% of GDP.

Crain (2005) and Lee *et al*. (2008) are criticized for the robustness of their analysis due to the small sample size. The dataset is small for many reasons. The PMR index is released every five years for OECD countries and cooperating partners. Moreover, data from countries before they joined the OECD are not provided. Not only does the PMR index reflect the domestic goods market while excluding labor and foreign regulations, but also the industries for which the PMR is provided are limited. This requires separate estimations of the regulatory costs for industries not specified (Crain and Crain, 2010). Crain and Crain (2010) resolve the small sample issue by including international and factor market regulations and the regulatory costs of more specific industries. The World Bank's Regulation Quality Index (RQI) is utilized in their subsequent analyses.

III. Regulatory Costs

A. *Relationship between GDP per capita and RQI*

Figure 2 shows the relationship between GDP per capita and the RQI for individual countries. The fitted line is upward sloping, meaning that better regulatory environments are aligned with higher levels of GDP. Countries that are above the fitted line have higher GDP per capita rates for their regulatory level because other factors affecting their income level (other than the quality of the regulatory environment) have stronger effects. The other factors have positive effects with regard to GDP per capita the countries above the fitted line and negative effects for those below. Thus, countries such as Korea, Brazil, Germany, Canada, and Australia, near the line, more strongly support the argument that the quality of regulations influences GDP per capita. India, on the other hand, falls outside of the 95% confidence level. Additionally, countries with stronger regulations, such as Russia, Indonesia, China, South Africa, and Saudi Arabia, have a tendency to be closer to the fitted line than less strictly regulated countries. Thus, RQI has more explanatory power with respect to GDP per capita for countries that are more regulated compared to the case for relatively less regulated countries.

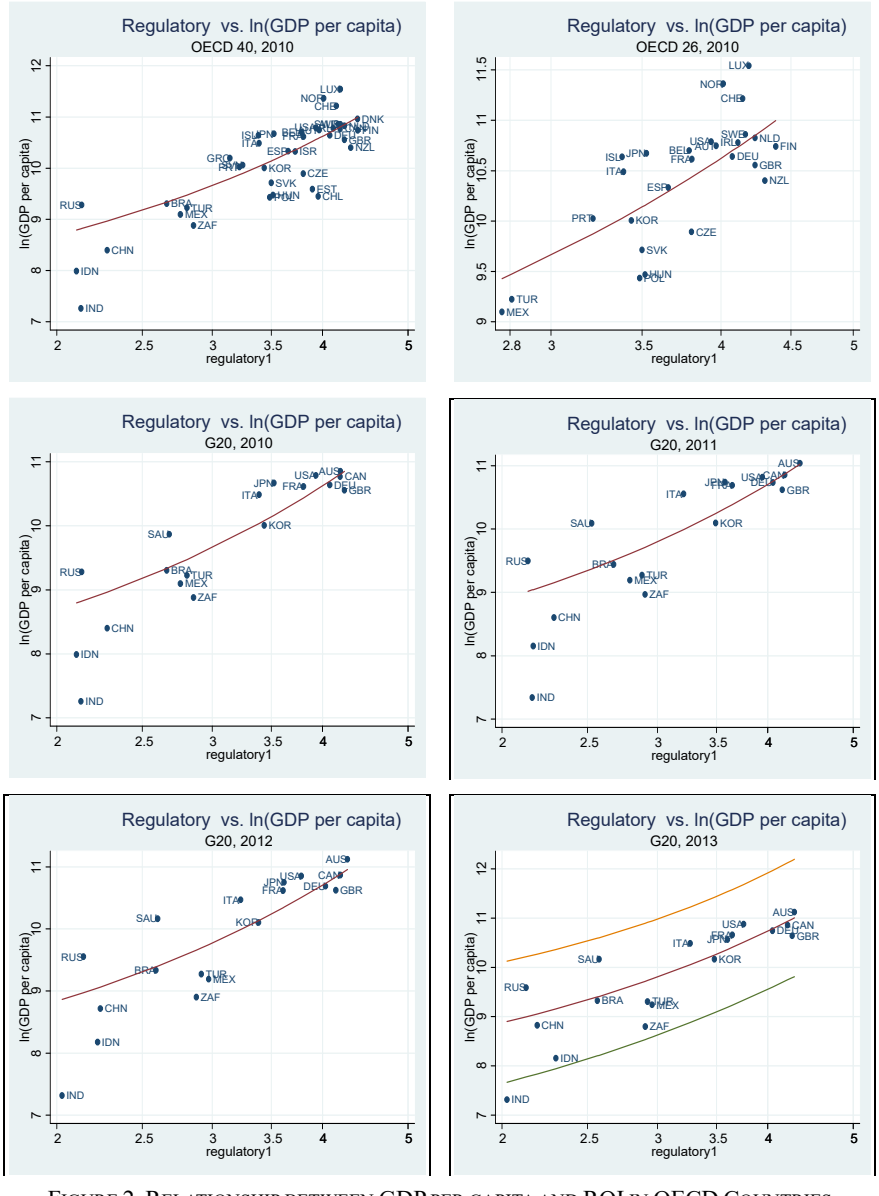

FIGURE 2. RELATIONSHIP BETWEEN GDP PER CAPITA AND RQI IN OECD COUNTRIES

Note: regulatory1 = regulatory quality index (RQI) + 2.5

Source: World Bank (2013).

B. *Estimation Model and Data*

This research explores the effects of regulations on GDP per capita while accounting for other significant variables. Equation (1) is from Crain and Crain (2010) and Lee *et al*. (2008), which are also based on the economic growth model of Barro (1997). The variable measuring the regulations is from the Worldwide

Governance Indicators (WGI) provided by World Bank for 215 countries. However, the WGI subcategory indicators are highly correlated with each other, as shown in Table 4, which could raise multicollinearity issues. Thus, only the Regulatory Quality Index (*rq*) is included in the analysis here.

In addition, regulations as measured by the RQI may affect GDP differently in developing versus developed countries. Developing countries tend to be more sensitive to explanatory variables than developed countries. In consequence, the relationship between income and regulations as estimated for the entire 215 country dataset may overestimate the effects of regulations on GDP in developed countries. Thus, the sample is refined by categorizing countries into different groups according to economic performance and analyzing them separately.

Table 5 presents the summary statistics. Figure 2 shows that the relationship between RQI and GDP per capita differs for each performance group, indicating that these estimates differ from those in previous studies. Table 6 presents the results using different subsamples.

Lastly, a conservative approach is needed when estimating different levels of groups. Because the standard deviation affects the regulatory burden per capita (see Table 7), depending on the sample, a single value cannot be provided by this study. Note that Table 7 depicts different estimation results depending on the period, with

$$\ln\left(GDP\ per\ capita\right)_{i,t} = \beta * Regulatory\ Level_{i,t} + \phi \ln\left(X\right)_{i,t} + \alpha_i + \gamma_t + \varepsilon_{i,t} \quad (1)$$

Regulatory Level	World Bank Regulatory Quality Index (RQI)
X	Control Variable - trade: dependency upon foreign trade, ratio of trade per GDP - bb: internet diffusion level - priedu: enrollment rate of primary school - pop: population - life: life expectancy
α_i	fixed country effect
γ_t	fixed time effect

TABLE 4—CORRELATION OF WORLDWIDE GOVERNANCE INDEX

		rq	voice	ge	politics	law	corrupt
Regulatory Quality	(rq)	1.000					
Voice of Accountability	(voice)	0.789	1.000				
Gov't Effectiveness	(ge)	0.937	0.776	1.000			
Political Stability and Absence of Violence	(politics)	0.630	0.674	0.674	1.000		
Rule of Law	(law)	0.895	0.820	0.932	0.779	1.000	
Control of Corruption	(corrupt)	0.871	0.774	0.932	0.729	0.939	1.000

Note: Correlation within 215 countries.

Source: World Bank (2013).

the periods being 2002~2008 and 2002~2012. Thus, the possibility of over-estimation was taken in consideration when calculating the regulatory burden (Simpson, 2014).

TABLE 5—SUMMARY STATISTICS

Variable	Definition	Mean	Min	Max
	All 52 Countries			
Gdp	Real GDP per capita	26,156.950	410.818	113,738.700
Rq	Regulatory Quality Index (-2.5~2.5)	1.000	-0.781	2.247
Trade	Trade per GDP	93.557	14.933	439.657
Bb	Internet Diffusion per 100	11.868	0.000	43.009
priedu	Primary Education	102.775	82.518	147.514
Pop	Population (million)	81.700	0.269	1,360.000
Life	Life Expectancy	76.314	51.557	83.096
	OECD 40 Countries (Members & Partners)			
Gdp	Real GDP per capita	26,209.280	410.818	113,738.700
Rq	Regulatory Quality Index (-2.5~2.5)	1.064	-0.781	2.077
Trade	Trade per GDP	81.120	14.933	371.440
Bb	Internet Diffusion per 100	13.118	0.000	43.009
priedu	Primary Education	102.998	92.168	147.514
Pop	Population (million)	105.000	0.269	1,360.000
Life	Life Expectancy	76.334	51.557	83.096
	OECD I (30 Countries)			
Gdp	Real GDP per capita	32,178.410	3,052.959	113,738.700
Rq	Regulatory Quality Index (-2.5~2.5)	1.281	0.031	2.077
Trade	Trade per GDP	85.825	18.756	371.440
Bb	Internet Diffusion per 100	15.204	0.000	43.009
priedu	Primary Education	102.339	92.168	122.389
Pop	Population (million)	38.900	0.269	316.000
Life	Life Expectancy	78.263	67.586	83.096
	G20			
Gdp	Real GDP per capita	19,535.620	410.818	67,524.760
Rq	Regulatory Quality Index (-2.5~2.5)	0.650	-0.781	2.023
Trade	Trade per GDP	51.845	14.933	110.000
Bb	Internet Diffusion per 100	10.290	0.000	38.792
priedu	Primary Education	104.236	91.017	147.514
Pop	Population (million)	222.000	18.300	1,360.000
Life	Life Expectancy	74.132	51.557	83.096

Note: 1) All 52 countries (G52) encompass 34 OECD members, six OECD partner countries, along with UAE, Bahrain, Bahamas, Cyprus, Oman, Kuwait, Malta, Puerto Rico, Qatar, Macao (China), Saudi Arabia, and Singapore, all of which with GDP per capita exceeding 20,000 dollars.

2) OECD I includes 30 countries out of 40 OECD members without six OECD partners and the four countries of Estonia, Israel, Chile, and Slovenia, which joined OECD after 2010.

3) OECD II indicates 25 countries covered in Crain (2010) excluding Australia, Canada, Greece, and Denmark. The statistics appear to be similar, as shown in Crain (2010). Crain (2010) does not suggest 25 countries specifically, but that study appears to have covered 26 countries with a balanced panel without missing values in the control variables.

TABLE 6—PANEL REGRESSION FOR DETERMINANTS OF GDP PER CAPITA (FIXED EFFECTS)

	ln(real_gdp)						
	I	II	III	IV	V	VI	VII
	G52	OECD	OECD I	OECD II	G20	Non-G20	Non-G8
Rq	0.217***	0.199***	0.216***	0.170***	0.163**	0.283***	0.298***
	(5.56)	(4.55)	(5.32)	(4.07)	(2.08)	(6.78)	(7.23)
ln(trade)	-0.724***	-0.808***	-0.646***	-0.642***	-0.916***	-0.340***	-0.561***
	(-11.91)	(-11.88)	(-8.60)	(-7.84)	(-9.82)	(-4.04)	(-8.28)
ln(priedu)	0.399**	0.720***	-0.219	-0.453	1.215***	0.109	0.919***
	(2.20)	(3.17)	(-0.74)	(-1.53)	(3.82)	(0.52)	(4.75)
ln(bb)	0.0702***	0.0721***	0.0490***	0.0559***	0.0855***	0.0549***	0.0613***
	(9.31)	(8.93)	(6.29)	(6.72)	(6.56)	(6.08)	(7.63)
ln(pop)	-0.372***	-1.211***	-0.868***	-1.448***	-0.167	-0.417***	-0.519***
	(-3.78)	(-4.45)	(-3.07)	(-4.98)	(-0.34)	(-4.71)	(-5.39)
ln(life)	5.253***	5.268***	4.518***	5.746***	6.233***	3.820***	3.175***
	(5.78)	(5.67)	(3.61)	(4.54)	(4.89)	(2.90)	(3.18)
time F.E	YES						
N	550	472	380	339	201	349	447

Note: 1) T-statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01. 2) Sample from 1996 to 2013.

TABLE 7—PANEL REGRESSION FOR DETERMINANTS OF GDP PER CAPITA (FIXED EFFECTS)

	ln(real_gdp)					
	I		IV		V	
	①	②	①	②	①	②
regulatory	0.173***	0.243***	0.0920*	0.230***	0.174*	0.295***
	(3.82)	(5.71)	(1.97)	(5.45)	(1.96)	(3.40)
ln(trade)	-0.612***	-0.712***	-0.583***	-0.439***	-0.732***	-0.810***
	(-8.06)	(-10.11)	(-6.55)	(-5.32)	(-6.45)	(-7.48)
ln(priedu)	-0.0940	0.265	-0.370	-0.330	0.832**	0.964***
	(-0.48)	(1.44)	(-1.18)	(-1.12)	(2.62)	(3.04)
ln(bb)	0.0845***	0.0929***	0.0912***	0.0870***	0.140***	0.142***
	(9.31)	(10.03)	(8.29)	(7.94)	(8.38)	(8.22)
ln(life)	3.130***	3.448***	4.397**	1.855	5.242***	3.479***
	(2.71)	(3.60)	(2.57)	(1.29)	(3.35)	(2.64)
time F.E	YES					
N	396	473	233	281	138	168
ln(pop)	-0.493***	-0.372***	-2.227***	-1.403***	-1.445**	-1.030*
	(-4.49)	(-3.93)	(-6.45)	(-4.89)	(-2.18)	(-1.91)

Note: 1) T-statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01. 2) ①Denotes the sample in years 2002~2008; ②Denotes 2002~2012.

C. *Reviewing and Comparing Various Models and Trends*

The variable α_i cannot be observed in equation (1), but it represents individual effects that encompass characteristics that affect each country's economic growth. For this reason, included is a fixed effect variable.

The data used for the results in Table 6 ranges from 1996 to 2013. RQI was only

provided biannually before 2002; hence, the moving average method was used from 1996 to 2002. The results suggest that a one unit rise in the regulatory level increases GDP per capita by 16.3~29.8%. In other words, a one unit improvement in the regulatory quality level has profound effects.

This result is much higher than the rate of 9.4% estimated by Crain and Crain (2010). Even estimates using the same model (17% from Model IV – OECD II, Table 6) differ significantly from the outcome in Crain and Crain (2010). This may stem from the different grouping methods and time periods. In Table 7, ① considers the time period from 2002 to 2008, whereas ② analyzes that from 2002 to 2012. However, the estimate from Model IV-① from Table 7 shows a result (9.2%) similar to that by Crain. Crain dropped the range in cases of missing values and only used 2002 to 2008. Table 7 also is provides a comparison to Table 6, showing that coefficient estimates are sensitive to the time period selected. It is important to note that regardless of the time period selected, RQI is consistently significant and positively correlated with GDP per capita for each specification. That is, the results suggest that regulatory quality affects GDP per capita but that the magnitude of the estimated effect may change depending on the time period.

As noted above, developing countries are more sensitive to regulations than developed countries. Model I in Table 6 considers OECD countries plus 12 countries for which the GDP per capita exceeds $20,000. Most countries in that group besides Macao and Singapore had a RQI of less than 1, resulting in relatively high cost estimators of the regulations. The effect of regulations on income level is lower when less developed countries are excluded (OECD II and G20 groupings) as compared to when they are included. Models VI and VII suggest that GDP per capita is highly sensitive to RQI. These groups only consist of developing countries. The effect of regulation on GDP per capita ranges from 28.3 to 29.8% for those two models.

The control variables are likewise sensitive to the time period included. In Table 7, only Models I, IV, and V were estimated with different time periods. Comparing the values in Table 7 with those in Table 3, the negative effect of trade is found to be lower. The trade estimator value from Model ① for all three models in Table 7 is closer to the values in Table 3 than it is from those in Model ② except for the OECD 26 countries (Model IV). Regarding the primary education rate (priedu), setting a different time period made a significant difference in the estimators, as inferred by comparing Table 6 and Table 7. Some estimators were significant in Table 6 but not in Table 7. Even the signs for the estimators changed depending on the time period. Broadband had a more important role in determining the income level in Table 7 than in Table 6, especially for Models IV and V. The results in both tables indicate that population has a negative correlation with GDP per capita. Lastly, life expectancy is positively correlated with income level, and Table 6 shows this relation more sensitively than Table 7.

Thus far, this analysis focuses on the level of regulatory quality. However, it is imperative to consider the optimal level of regulation for South Korea as well. As Table 6 depicts, 0.478 was the value of the regulatory quality for South Korea in 1996. It fell drastically during the Financial Crisis of 1997 and 1998 but started to recover in 1999. Between 1999 and 2013, the index approximately doubled.

Compared with the regulatory index of the 1990s, it has increased by nearly 250%. There was a sudden surge in the mid-2000s in the regulatory quality from 0.775 (the average index value in the early 2000s) to 1.27. Since then, there has been no precipitous increase in the index.

The RQI value for South Korea was 0.982 in 2013, the latest year for which data are available. That value places Korea in 28th place out of 52 countries. This value is 0.018 lower than the average of 52 countries, 0.083 lower than the OECD 40 countries' average, 0.300 lower than OECD 30, 0.275 lower than OECD 26, and 0.139 lower than the value for the G8. South Korea's value shows a difference of 0.918 from the three most regulated countries, and it is higher than the average of the G20.

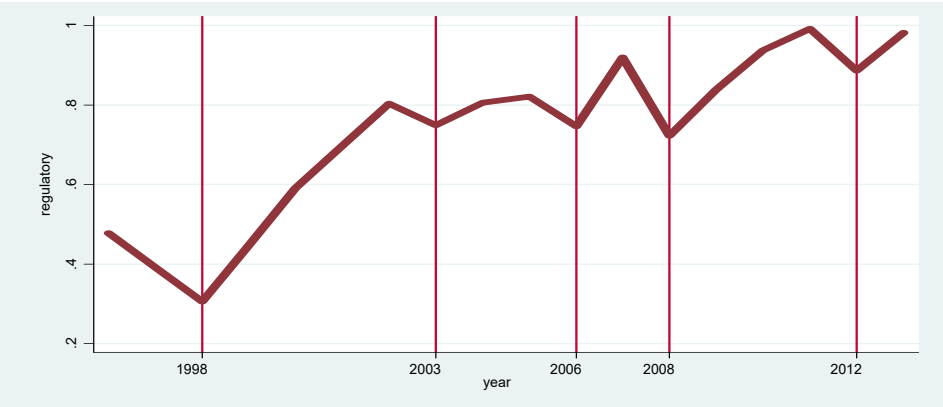

FIGURE 3. LEVEL OF REGULATIONS IN KOREA (USING RQI)

TABLE 8—REGULATORY COST ESTIMATION OF KOREA (IN US DOLLARS, 2013)

(Unit: million dollars)

		All 52	OECD 40	OECD 30	OECD 26	G8	Top 3
Regulatory Level Reform		0.018	0.083	0.300	0.275	0.139	0.918
I		5,229	23,397	84,879	77,890	39,352	260,070
I	-①	4,156	18,595	67,460	61,906	31,276	206,699
I	-②	5,846	26,160	94,905	87,091	44,000	290,789
II		4,801	21,483	77,935	71,519	36,133	238,795
III		5,212	23,319	84,598	77,632	39,222	259,208
IV		4,090	18,300	66,390	60,924	30,780	203,419
IV	-①	2,215	9,912	35,959	32,998	16,672	110,179
IV	-②	5,542	24,797	89,959	82,553	41,707	275,636
V		3,925	17,563	63,714	58,469	29,540	195,222
V	-①	4,182	18,712	67,883	62,294	31,472	207,994
V	-②	7,100	31,771	115,260	105,770	53,438	353,158
VI		6,812	30,481	110,579	101,475	51,267	338,816
VII		7,187	32,157	116,660	107,055	54,086	357,447

Note: The top three countries are the three most under-regulated countries according to the average for each year.

Table 8 provides an estimation of the effect of regulatory reforms. The 'level of regulatory reform' row indicates the difference between the regulatory quality of the targeted group and that of South Korea. For example, the value for the OECD 30 is 0.300 higher in terms of regulatory quality than that of South Korea, implying that the regulatory reform aims to reach this average by increasing the regulatory quality index by 0.300 in South Korea. The economic effect of this regulatory reform effort can be estimated by multiplying the suggested regulatory quality difference by the coefficients in Tables 6 and 7.

The burden of regulations in South Korea is estimated to be between 2.2 and 357.4 billion USD, as shown in Table 8. This amount is 0.17 ~ 27.41% of the total GDP (1,304.3 million dollars). If the regulatory quality improves to the OECD average, the estimated reduction in the regulatory cost would be 9.9 ~ 36.0 billion USD, which is 0.76 ~ 2.47% of the GDP for 2013. Note that according to the OECD's "Going for Growth" (2015), the goal of Product Market Regulations, a 20% improvement in the regulatory burden, would induce a 2.4% GDP gain for advanced economies and a 3.4% level gain for emerging economies. Our estimation utilizes a different dataset, the Regulatory Quality Index, but the expected effect from regulatory reform is comparable.

IV. Distribution of Regulatory Costs across Industries and Firm Sizes

In this study, we also introduce a method by which to measure and compare how regulatory costs are distributed across different industries and among firms of different sizes. As Hwang (2012) assumes, a standard production function, i.e., that labor input is a factor of production, is suggested below. Let l represent the total labor cost and f stand for fixed cost. We add the cost of regulatory compliance, fA, which a company should bear additionally, for example, to comply with environmental regulations. The marginal cost is denoted by a, and firm output is denoted by x. The relevant relationships follow equations (2) and (3).

(2) $$l = f + fA + ax$$

(3) $$\frac{l}{x} = a + \frac{f + f_A}{x}$$

As shown in equation (3), the variable $\frac{l}{x}$ embeds the concept of economies of scale. As output grows (x increases), the average cost of the labor input decreases, which implies economies of scale for production. Therefore, we can infer that the ratio of the total labor cost to sales (as a proxy for the firm's total production and costs) can be a representative estimate of how regulatory costs vary across industries, with regard to firm size. Specifically, if the ratio of labor costs to sales increases, the implication is that the regulatory burden becomes relatively less

important. Using the equations above, we are able to proxy how regulatory costs vary across industries and by firm size.

We compare the regulatory costs incurred by firms of different sizes in various industries using equations (2) and (3). Table 9 illustrates this variation in the ratio of labor costs to sales. To reiterate, as this ratio increases, the relative regulatory burden declines. Min and Max in Table 9 indicate the minimum regulatory cost (2.4257 trillion won calculated in Table 8) multiplied by the ratio and maximum regulatory cost (386.7222 trillion won) multiplied by the ratio.

We utilize company data from Mining and Manufacturing Industries as found in the 2010 Census Report, which is issued every five years. On the other hand, we follow the criteria to divide large, medium, and small firms as established by the Korea Standard Industrial Classification. The former report is a more detailed classification standard, while the latter has three criteria based on the number of employees. Thus, construction companies, for example, with four employees categorized in the first group (1~4 employees) in the Census Report are distributed into the small-sized company category (1~49 employees) following the Standard Industrial Classification.

First, medium-sized firms in agriculture, forestry, and fishery, construction, wholesale and retail, and the transportation industries incurred relatively high regulatory costs. Second, except for the construction industry, medium-sized firms incurred the highest regulatory cost while, surprisingly, the cost burdens were similar for small and large firms. Third, the mining, electricity, gas, steam and water supply, and sewage and waste industries experienced higher regulatory costs as the firm size increased, as predicted. Notably, large firms in the mining industry had the highest regulatory burden. Finally, we find that in the manufacturing industry, the ratio decreases as the firm size increases. As shown by equation (3), an increase in output allows a reduction in the average fixed cost, resulting in a decrease in the average total cost.

In addition, we can allocate the regulatory cost depending on the firm size using the ratio $\frac{l}{x}$. We derived the indexes $S\neg L$, SM, and SS using the equations (4) and (5). Relating the sum of each ratio, the labor cost per output, depending on the firm size to the total regulatory cost calculated in Table 8, $S\neg L$, SM, and SS respectively represent the regulatory costs of large, medium, and small firms.

(4) $$\frac{l_S}{x_S}+\frac{l_M}{x_M}+\frac{l_L}{x_L}=S$$

(5) $$\frac{\frac{l_i}{x_i}}{S}=S_i\ (i=S,M,L)$$

TABLE 9—SALES AND LABOR COSTS DEPENDING ON THE FIRM SIZE

Industry		Small Size	Medium Size	Large Size
Agriculture, forestry and fishing (0.21)	Sales (A)	1,542,775	6,925,071	740,137
	Labor Cost (B)	129,421	671,001	55,961
	Ratio (B/A)	8.39	9.69	7.56
	Regulatory Cost (S_i)	32.72	37.79	29.49
	Min (52)	17	19	15
	Max (8,220)	2,689	3,106	2,424
Mining and quarrying (0.08)	Sales (A)	2,600,751	615,516	433,740
	Labor Cost (B)	311,968	95,198	204,143
	Ratio (B/A)	12.00	15.47	47.07
	Regulatory Cost (S_i)	16.10	20.75	63.15
	Min (20)	3	4	13
	Max (3,258)	524	676	2,058
Manufacturing (33.80)	Sales (A)	369,225,236	369,966,989	725,144,320
	Labor Cost (B)	41,360,093	34,270,469	45,648,679
	Ratio (B/A)	11.20	9.26	6.30
	Regulatory Cost (S_i)	41.86	34.62	23.52
	Min (8,199)	3,432	2,838	1,929
	Max (1,307,140)	547,173	452,472	307,495
Electricity, gas, steam and water supply (2.78)	Sales (A)	5,404,799	66,802,856	48,349,089
	Labor Cost (B)	148,712	2,399,853	2,165,851
	Ratio (B/A)	2.75	3.59	4.48
	Regulatory Cost (S_i)	25.42	33.19	41.39
	Min (675)	172	224	279
	Max (107,615)	3,244,020	9,535,773	1,341,134
Sewage, waste management, materials recovery and remediation activities (0.33)	Sales (A)	3,244,020	9,535,773	1,341,134
	Labor Cost (B)	327,110	1,634,373	245,094
	Ratio (B/A)	10.08	17.14	18.28
	Regulatory Cost (S_i)	22.16	37.67	40.17
	Min (81)	18	31	33
	Max (12,920)	2,863	4,867	5,190
Construction (6.26)	Sales (A)	105,548,638	55,405,753	110,109,538
	Labor Cost (B)	13,978,171	8,461,539	9,311,984
	Ratio (B/A)	13.24	15.27	8.46
	Regulatory Cost (S_i)	35.82	41.31	22.87
	Min (1,518)	544	627	347
	Max (241,965)	86,671	99,947	55,347
Wholesale and retail trade (18.92)	Sales (A)	395,680,375	342,895,482	81,252,322
	Labor Cost (B)	16,543,598	19,554,823	4,398,731
	Ratio (B/A)	4.18	5.70	5.41
	Regulatory Cost (S_i)	27.33	37.28	35.39
	Min (4,590)	1,255	1,711	1,624
	Max (731,820)	200,017	272,818	258,984
Transportation (3.41)	Sales (A)	61,174,758	37,038,606	49,358,059
	Labor Cost (B)	6,485,688	7,916,742	5,535,120
	Ratio (B/A)	10.60	21.37	11.21
	Regulatory Cost (S_i)	24.55	49.49	25.96
	Min (826)	203	409	215
	Max (131,730)	32,336	65,191	34,203

Note: 1) Sales and labor costs in million won and regulatory costs in 100 million won. 2) Numbers in parentheses are the minimum and maximum of the total regulatory cost estimates for each industry.

V. Concluding Remarks

This study argues that improving the quality of regulations will have a positive effect on economic growth. This finding is consistent with those of earlier studies such as Crain & Crain (2010), who find a positive relationship between the quality of regulation and GDP per capita. Additionally, through an empirical analysis, enhancing the regulation quality levels incurs economic costs that vary depending on the firm size and on the industry.

The results indicate that GDP per capita would increase by 16.3~29.8% when the RQI for a country increases by one unit, meaning a better regulatory environment. The magnitude of the results differs depending on the sample and the time period selected. However, the general result holds.

In 2013, the Regulatory Quality Index of Korea was 0.982. To help with the establishment of realistic policy goals, this study suggests recognizing the regulatory costs relative to the average amounts in other countries. Here, the regulatory cost for Korea is estimated using regression results. The burden of regulation in South Korea is between 2.2 and 354.7 billion USD, which represents approximately 0.17~27.41% of total GDP (1,304.3 million dollars). If the regulatory quality improves to the OECD average, a reduction in the regulatory costs in the range of 9.9~32.2 billion USD can be expected. This corresponds to approximately 0.76 to 2.47% of the GDP of Korea in 2013, which underscores the importance of regulatory reforms for the Korean economy.

The results here must be carefully interpreted, as an increase in the index does not necessarily mean deregulation. Deregulation may bring about a more positive business environment, but it may also have negative effects over the short term, and vice versa. For example, more investment opportunities may arise when there is capital inflow in the market due to deregulation. On the other hand, in the long run, such a situation can lead to a financial crisis.[2] The index here evaluates the overall business environment, and short- and long-run effects of introducing or abolishing regulations must be considered.

This paper presents the regulatory costs incurred by firms of different sizes such that improved regulations that ensure fairness among all firms can be established. We introduce a new method to examine the distribution of regulatory costs across different industries and firm sizes. The findings when using this alternative method are largely consistent with the conclusions reached by other studies, specifically that small firms typically bear a disproportionate regulatory burden.

However, there are limitations to this new approach. Fixed costs vary significantly among industries, making a distinction between regulatory fixed costs and fixed costs as they pertain to factors of production difficult. Using the new method may not be suitable when comparing industries to other industries. Policymakers must be cautious when implementing this variable to all industries.

[2]The authors thank the referee for the valuable comments about this.

APPENDIX

The following presents additional regression results with reference to the determinants of GDP per capita considering capital and the labor force. To check the original analysis results, the net capital stock volume (2010=100) and unemployment rates of OECD countries are included here.

TABLE A1—PANEL REGRESSION FOR THE DETERMINANTS OF GDP PER CAPITA (FIXED EFFECT, CAPITAL AND LABOR VARIABLES INCLUDED)

	ln(real_gdp)						
	I	II	III	IV	V	VI	VII
	G52	OECD	OECD I	OECD II	G20	Non-G20	Non-G8
Rq		0.122**	0.117**	0.072	0.146**	0.236***	0.253***
		(2.38)	(2.23)	(1.53)	(2.06)	(4.73)	(4.22)
ln(trade)		-0.687***	-0.573***	-0.549***	-0.503***	-0.368***	-0.541***
		(-8.34)	(-6.60)	(-5.53)	(-5.28)	(-3.23)	(-5.51)
ln(priedu)		-0.471	-0.504	-0.627**	-0.683	0.094	0.308
		(-1.60)	(-1.62)	(-2.07)	(-1.07)	(0.35)	(1.01)
ln(bb)		0.061***	0.072***	0.082***	0.027*	0.043***	0.061***
		(6.02)	(7.18)	(7.38)	(1.85)	(4.04)	(5.60)
ln(pop)		-1.013**	0.251	-1.053**	2.171***	-2.378***	-1.605***
		(-3.02)	(0.62)	(-2.29)	(4.32)	(-7.21)	(-4.38)
ln(life)		6.605***	5.336***	6.714***	4.616***	6.175***	4.772***
		(6.20)	(4.13)	(5.30)	(3.32)	(5.17)	(3.56)
ln(capital)		0.034***	0.034***	0.043***	0.041***	-0.003	0.008
		(4.11)	(4.02)	(5.05)	(4.73)	(-0.26)	(-0.58)
ln(unemployment rate)		-0.161***	-0.158***	-0.113***	-0.240***	-0.176***	-0.154***
		(-5.56)	(-5.00)	(-3.52)	(-4.22)	(-6.86)	(-5.09)
time F.E				YES			
N		284	253	212	115	169	195

Note: 1) T-statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01. 2) Sample from 1996 to 2013. 3) Net capital stock and unemployment rates are from OECD Stat.

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The Effects of Institutions on the Labour Market Outcomes: Cross-country Analysis

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This paper re-examines the impacts an institutional arrangement may have on labour market outcomes such as the employment and unemployment rates. Based on the results from a generalized econometric model, the generosity of unemployment insurance benefits, organized labour and active labour market policy have effects on a labour market in line with previous findings. However, taxes on labour and the degree of employment protection are found to affect neither the employment rate nor the unemployment rate. Thus, some findings in this paper validate earlier findings, whereas others do not.

Key Word: Employment Rate, Unemployment Rate,
Labor Market Institutions, Cross-country Analysis
JEL Code: C01, J08, J21, P51

I. Introduction

Since the 1980s, OECD countries have witnessed that common economic shocks yield different labour market outcomes for each country. Some fared well, while many others fared poorly. These cross-country differences appear to be persistent rather than temporary, having profound implications.[1] When considering these observations, researchers have begun to pay more attention to the role institutions play in labour market outcomes.

The importance of institutions in a labour market has been well recognized. Labour market institutions such as employment protection legislation, unionization, taxes on labour earnings and work-related benefits differ from country to country, and by exploiting these variations, many studies have investigated the impacts the institutional factors may have on labour market performances. Researchers generally conclude that institutional obstacles (known as "labour market

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[1]Daveri and Tabellini (2000) reported a sharp contrast in the long-term trend of the unemployment rates

rigidities") could lower flexibility and mobility in a labour market and hence result in poor performances and low growth.[2]

It is fair to say, however, that the relationship between the institutional variables and labour market outcomes is not as clear as one may think. The results of previous findings are mixed: some studies confirmed an effect of an institutional variable on labour market outcomes, while others failed to find convincing evidence of such a linkage. Broadly speaking, there are two primary reasons for this. First, needless to say, the limited data availability and related comparability issues in cross-country analyses are at least partially responsible for the mixed results. Different definitions of variables and unbalanced time periods to cover, and many other data-related problems are obstacles which arise when researchers attempt to come up with correct inferences. Over years, the OECD has made strenuous efforts to improve data quality levels for cross-country analyses. Ambiguous results may partly arise from an insufficient understanding of the mechanisms through which institutional variables work. In other words, the question "How are labour market institutions related to economic performance?" must be handled with an appropriate representation of an econometric model and methodologies, as the results crucially depend on these factors. This paper indicates the problems that conventional approaches may have and proposes more flexible and practical empirical strategies.

The adequacy of the econometric model and methodology in this analysis produces results in contrast to those found in earlier studies. In spite of the advantages of the standard panel estimation approach adopted in previous studies, that method can fail to capture complicated data-generating processes commonly found in analyses of macro-variables in panel structures. This paper generalizes econometric specifications as a close approximation of reality without adding excessive computational burdens.

The questions asked here are to what extent labour market institutions matter and in which directions a variable may affect labour market outcomes such as the employment and unemployment rates. Using a generalized econometric model, some of the estimation results validate what previous studies have found, whereas others do not.

The paper is organized as follows. The next section introduces the background of labour market performances for the selected OECD countries. Section 3 reviews the findings in previous studies about the implications of labour market institutions. The econometric model used and the methodology adopted here are introduced in Section 4. Section 5 explains the data and presents the results. Section 6 concludes this paper.

II. Labour Markets of the Selected OECD Countries

Labour market performances of OECD countries appear to undergo sizable changes over time and show substantial variations across countries. Figure 1

between European countries and the US.

[2]See Nickell and Layard (1999) for a nice summary.

illustrates the selected OECD countries' employment rates and unemployment rates between 1985~1993 and 2000~2008. As shown, employment rates have improved substantially over time in Spain and the Netherlands, while countries such as Germany, Denmark, France, Norway, the UK and the US show only slight improvements. Exceptions are Finland and Sweden, where employment rates have deteriorated over time. The levels of employment differ significantly among the countries. In the period of 2000 to 2008, the employment rates range from approximately 56% (Italy) to 76% (Norway), showing a 20%p gap.

The unemployment rate also shows sizable cross-country variations ranging from 3.7% (Norway) to 10.6% (Spain) for 2000-2008. These figures show that the unemployment rates for 2000-2008 are lower than those for 1985-1993. The unemployment rates declined sharply in Spain and the Netherlands, as these countries marked significant improvements in their employment rates.

Various factors have been posited with regard to the cross-country variations and secular trends in the labour market outcomes. Cyclical shocks, not only country-specific but also common to countries, can yield different employment rates and unemployment rates, as they affect the countries' economies in distinct ways. In addition, institutional factors such as the environment, practices and legal framework can cause a country's labour market performance to different from those of others. Many studies have investigated the effects of labour market institutions while focusing on several institution-related variables, such as taxes on labour (tax wedge), the level of unemployment insurance benefits (replacement rate), organized labour (union density), the degree of employment protection, and measures which become labour market policies. There are extensive works on how

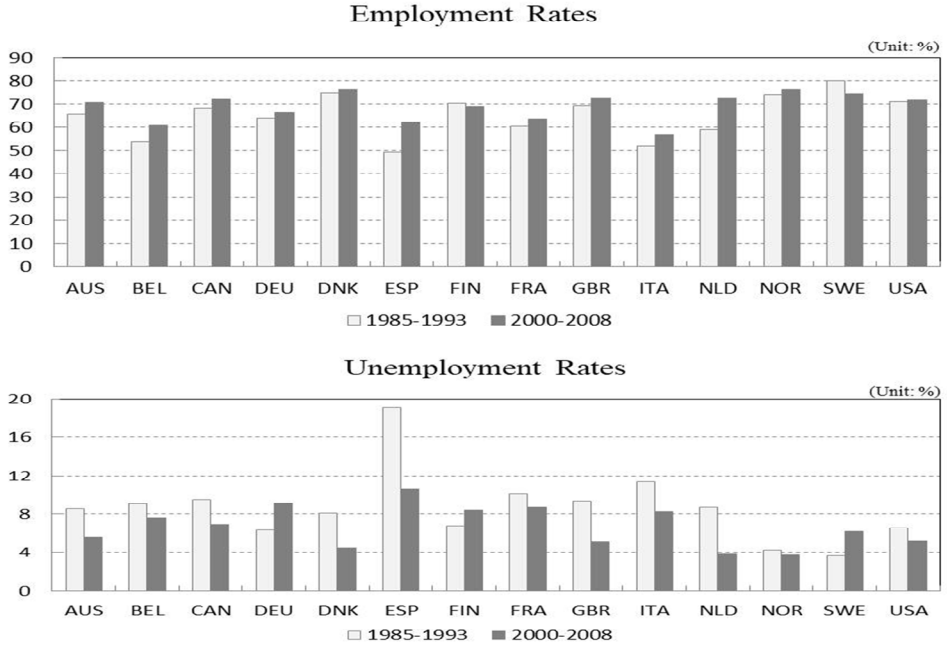

FIGURE 1. COMPARISON OF LABOUR MARKET PERFORMANCES

Source: OECD Labour Force Statistics.

and why these variables matter in labour market outcomes, which will be discussed in the next section.

III. Literature Review

Voluminous studies have focused on the roles of labour market institutions in determining labour market performance. Some of them directly analyzed this relationship empirically and others investigated related issues indirectly. Most papers focused on the impact taxes on labour, unemployment benefits, employment protection, and organized labour (unions) may have on the employment and unemployment rates. Some studies also include policy variables such as active labour market policies (ALMP). What is known thus far is that in general, policy variables and the institutional mechanisms do matter with regard to labour market performances. From extensive works on this issue, the relationship between a certain institutional variable and labour market performance has been found to be clear and unambiguous, whereas others links remain inconclusive.

The following sections summarize the effects of various institutions on labour market outcomes as found in earlier empirical studies.

• Taxes on labour (or the tax wedge)

Theoretically, it can be shown that the tax wedge (determined by taxes on payroll, consumption and income) affect labour supply and demand levels and hence likely affect the labour market. Whether its main impacts are on employment or on wages depends on the nature of the labour market.[3] Empirical results are mixed. Some studies confirm a significant and sizable effect on labour market performances (Pichelmann and Wagner, 1986; Nickell, 1997; Nickell and Layard, 1999; Elmeskov *et al*., 1998; Belot and Van Ours, 2000) while others report ambiguous results (Scarpetta, 1996; Daveri and Tabellini, 2000; Nicoletti and Scarpetta, 2001)

• Unemployment insurance (or the benefit replacement rate)

From a labour supply perspective, a high replacement rate can lower an individual's search intensity, raising unemployment. On the other hand, generous unemployment insurance may make the labour market more attractive, increasing the participation rate. These two opposite effects of the benefit replacement rate can make the impact on the labour market ambiguous. Many empirical studies support the contention that generous benefits are associated with a high unemployment rate. Meanwhile, studies focusing on the employment rate have not found negative effects with statistically significant levels.

• Union

The relationship between labour unions and overall labour market outcomes is not well understood. A union as a rent seeker may have negative influence on labour market outcomes by restricting employment. On the other hand, a union as

[3]One may expect that tax effects would be mostly on wages rather than on employment if the labour market is flexible enough to adjust fully for them. Blanchard and Wolfers (2000) hold that "their [tax-wedge] incidence may be on the wage, not on employment." (P. C13)

an insurance provider could minimize unemployment by enhancing employment possibilities. Thus, what a union does to labour market outcomes requires an empirical question. Thus far, empirical results do not appear to provide a clear answer. Some studies find a negative effect on the labour market, but it is believed that the relationship is much more complicated (Scarpetta, 1996; Nickell and Layard, 1999; Nicoletti and Scarpetta, 2001). As posited in previous studies, the factors that matter are the degree of employer-employee coordination and the coverage of collective bargaining (Clamfors and Driffill, 1988; Summers *et al.*, 1993; Scarpetta, 1996; Elmeskov *et al.*, 1998). Unfortunately, the measures for these variables are questionable in terms of their quality and reliability (Daveri and Tabellini, 2000).

• Employment protection

Employment protection is perceived to be a key element causing labour market rigidity (Lazear, 1990). Employment-protection-induced rigidity may proceed in two directions (Bertola, 1990; Hopenhayn and Rogerson, 1993; Nickell, 1997): it can reduce inflows into employment in expansionary phases on the hand, whereas it can reduce outflows from employment during economic contractions on the other. Some are skeptical of its effect because the primary effect may not be on the level of labour market outcomes (such as the employment or unemployment rates) but rather on the compositions (such as longer unemployment durations particularly for groups at the margins in a labour market for those who are self-employed) (Blanchard and Wolfers, 2000)[4] The findings of most empirical studies indicate a negative effect, implying that the stricter the regulations are, the worse the labour market outcomes become (Lazear, 1990; Scarpetta, 1996; Elmeskov *et al.*, 1998; OECD, 1999), though a few studies report negligible impacts (Bertola, 1990; Grubb and Wells, 1993; Garibaldi *et al.*, 1998; Nickell, 1997). Researchers seem to agree that employment protection affects groups (women, youth, elderly and etc.) differently in the labour force and that this complicated mechanism is one of the reasons why the overall effect of employment protection remains unclear.

• Active labour market policy (ALMP)

Given all of the concern over the deadweight/substitution/displacement effect, ALMP is believed to produce better labour market outcomes by facilitating job-matching processes and accumulating human capital, for instance. Several empirical results confirm its effects on the unemployment rate (Elmeskov *et al.*, 1998; Nickell and Layard, 1999), though others do not (Scarpetta, 1996; Belot and Van Ours, 2000). The effects of ALMP on the employment rate are not verified (Nickell, 1997; Nickell and Layard, 1999). Overall, the effects of ALMP on labour market outcomes are mixed and only marginally significant if at all.[5]

Table 1 reports the empirical results from the selected studies.

[4]Bertola (1990) shows theoretically and empirically that employment protection (the provision of job security) and labour market performances do not have a strong relationship. He argued that a high level of employment protection induces alternative types of jobs (such as self-employment), to which it cannot apply.

[5]Two reasons can be mentioned when explaining the mixed results. First, ALMP consists of various policy measures which vary widely across countries, and an aggregated measure of ALMP fails to capture this variation. Second, more technically, an ALMP measure is endogenously determined with labour market outcomes such as unemployment. This may cause statistical inferences to be difficult and imprecise.

TABLE 1—LABOUR MARKET INSTITUTIONS AND OUTCOMES

Regressors	Employment rate				Unemployment rate				
	Nickell (1997)†	OECD (1999)†	Nickell & Layard (1999)*	Nicoletti & Scarpetta (2001)*	Scarpetta (1996)*	Elmeskov *et al.* (1998)†	Nickell & Layard (1999)*	Daveri & Tabellini (2000)†	Belot & van Ours (2000)†
Data period	1983~88 & 1989~94	1985~90 & 1992~97	1983~88 & 1989~94	1982~98	1983~93	1983~95	1983~88 & 1989~94	1965~95	1960~96
Estimation	Random effect	Random effect	Random effect	Random effect	Feasible GLS	Random effect	Random effect	Fixed effect	Fixed effect
Depended variable	e	e	e	e	u	u	$\ln u$	Δu	*Standardized* u
Tax on labour	-0.24 (0.12)	-	-0.24 (-2.0)	0.00 (0.00)	0.01 (0.12)	0.14 (0.04)	0.027 (4.0)	0.27 (0.221)	0.27 (0.02)
Employment protection	-0.94 (0.30)	-1.59 (1.1)	-0.79 (-2.7)	-0.70 (-0.69)	0.37 (2.64)	0.37 (0.19)	-	-1.22 (0.734)	-0.04 (0.02)
UB replacement rate	-0.026 (0.072)	-	-0.067 (-1.0)	-0.04 (-1.38)	0.13 (6.78)	0.10 (0.02)	0.013 (3.4)	0.04 (0.070)	0.06 (0.02)
Union density	-0.082 (0.086)	-	-0.012 (-0.1)	-0.21 (-10.86)	0.11 (4.65)	-0.01 (0.02)	0.010 (2.3)	-	0.00 (0.02)
Coordination	5.03 (1.23)	-	4.75 (4.0)	-	-3.07 (-5.95)	-	-0.43 (-6.1)	-	0.00 (0.00)
Coverage	-0.96 (2.54)	-	-2.40 (-1.0)	-	-	-	0.38 (2.7)	-	-0.07 (0.03)
Active labour market	0.16 (0.11)	-	0.10 (1.0)	-	-0.05 (-1.72)	-0.53 (0.21)	-0.023 (-3.3)	-	-0.11 (0.06)

Note: 1) e and u are the employment rate and unemployment rate, respectively. 2) Numbers in parentheses are: † for standard errors and * for the t-ratio.

Source: 1) Employment rate: Nickell (1997) column (1) of Table 7 on p.65; OECD (1999) column (1) of Table 2.10 on p.80; Nickell and Layard (1999) column (1) of Table 16 on p.3054; Nicoletti & Scarpetta (2001) column (4) of Table 4 on p.29. 2) Unemployment rate: Scarpetta (1996) column (3) of Table 1 on p.58; Elmeskov *et al.* (1998) column (5) of Table 2 on p.216; Nickell and Layard (1999) column (1) Table 15 on p.3053; Daveri and Tabellini (2000) column (7) of Table 9 on p.75; Belot and van Ours (2000), column (1) of Table 6 on p.30.

IV. Econometric Model

This section starts with a standard panel econometric specification used in previous studies and then defines several problems associated with the model. To address these issues, an extended econometric model is proposed. The generalized model, however, poses some challenges with regard to conventional estimation techniques. A few existing studies of econometric techniques provide solutions for an estimation strategy partially, but not completely. Limitations on datasets such as a short time dimension and incomplete and unbalanced features further restrict the degree of choice of a feasible method.

Facing these difficulties, this paper suggests a flexible and practical estimation strategy for a dynamic panel model with time-varying individual effect and serially correlated error terms. This method is particularly attractive because it can be applied to an incomplete panel dataset. Bayesian estimation techniques adopted in this study are well developed in panel data models and have been applied to a wide variety of models, such as continuous, binary, censored, count, and multinomial response models.[6]

If there is a method by which to determine the likelihood of a model, the distributions of parameters, otherwise analytically intractable, can be characterized by numerical procedures such as MCMC methods. In general, the likelihood function of a model that includes latent variables with Gaussian errors can be obtained via a Kalman filter once we have a linear state space representation. In the following section pertaining to the estimation strategy, we show a linear state space transformation of our model and furthermore how a Kalman filter is modified to evaluate the likelihood of the model with an incomplete panel dataset. Consequently, with the specification of prior distributions which are introduced only to prevent autoregressive parameters from implying non-stationary processes, the Metropolis Hasting MCMC algorithm enables us directly to characterize the posterior distributions of the parameters of interest.

The estimation strategy proposed in this paper has several advantages which should be noted from an inference point of view. First, this methodology produces not only point-wise values of estimated coefficients but also their posterior distributions. This rich information enables a researcher to infer more accurate relationships between labour market institutions and employment/unemployment rates. Second, Bayesian estimation naturally allows us to perform model comparisons with Bayes factor or ratios of marginal likelihood. If there is an alternative model which can be used in a comparison with a benchmark model, the Bayes factor can tell which model is a better fit in light of available data.

A. Models

In order to assess the effects of institutional factors on labour market performances (e.g., the employment rate), many studies posit a standard panel econometric model, such as that shown below.

[6]For a more comprehensive survey, see Chib (2008).

(1) $$y_{it} = x_{it}'\beta_x + \varepsilon_{it},\ \varepsilon_{it} = \xi_i + \upsilon_{it} \text{ and } i = 1, \cdots N,\ t = 1 \cdots T$$

Here, y_{it} is the employment rate for country i at time t, x_{it} is a vector of k regressors (including a constant and time-dummies if necessary), β_x is a parameter vector to be estimated, ξ_i is denote the time-invariant country-specific heterogeneity, and υ_{it} is a time-varying error term (white noise). When estimating (1), ξ_i is taken into account by applying generalized least square (random effect) or differencing methods (fixed effect) on first-differenced, mean-differenced, or long-differenced data.

Despite a couple of advantages, such as simplicity and tractability, fitting (1) may not be appropriate for the underlying data-generation process and may be misleading for the following reasons. First, as in most time-series data analyses, an aggregated macro-dependent variable (employment rate) appears to depend substantially on its past value. That is, y_{it} is not likely to be independent of y_{it-1} (assuming that causality runs from the past to the present and not vice versa).

Second, (1) fails to capture the complicated effects of a contemporaneous shock. A possible means of controlling for a contemporaneous shock is to include a time-dummy variable (D_t) in (1) such as $y_{it} = x_{it}'\beta_x + \gamma D_t + \varepsilon_{it}$. This specification, however, assumes an unnecessarily strong neutrality of a contemporaneous shock in a sense that all countries are affected by the shock in the same direction to the same degree. Obviously, an economic shock commonly affecting many countries yields sizable cross-country differences in the responses of the countries.

Third, the assumption of the error term (υ_{it}) in (1) is unnecessarily strict. A time-dependent error term, particularly in a macro-dependent variable, is likely to be serially correlated due to inertia in a dependent variable due to variables (other than ξ_i) being excluded from the right-hand side of (1).

To address these problems, this study considers an extended version of (1) with a dynamic error-component, as follows:

(2) $$y_{it} = \beta_y y_{it-1} + x_{it}'\beta_x + \beta_c + \varepsilon_{it},\ i = 1, \cdots N,\ t = 1 \cdots T$$

$$\varepsilon_{it} = \Psi_{t_{it}}\xi_i + \upsilon_{it}$$
$$\Psi_{t_{it}} - 1 = \psi\left(\Psi_{t-1} - 1\right) + \sigma_\eta \eta_t,\ \forall t\ \ \eta_t \text{ is iid.}$$
$$\upsilon_{it} = \rho\upsilon_{it-1} + \nu_{it},\ \left|\rho\right| < 1,\ \nu_{i1}, \cdots \nu_{iT} \text{ are iid.}$$

Unlike (1), (2) includes a lagged dependent variable as a regressor in order to capture persistence in the employment rate. The error component, ε_{it}, in (1) is modified in two ways. First, a country-specific effect, ξ_i, is multiplied by a time-varying common factor (i.e., $\Psi_t\xi_i$) in order to capture how a common shock may

have different responses across countries. Second, the white noise error term υ_{it} in (1) is allowed to have a serial correlation in order to account for the possibility of employment rate inertia arising from variables not included in (2).

An auto-regressor (y_{it-1}), time-varying common factor ($\Psi_t \xi_i$), and serially correlated error term (υ_{it}) when arising together poses serious challenges when attempting to estimate the parameters in (2). Conventional panel estimation techniques are undesirable because they cannot remove the endogeneity between $\Delta y_{it-1}\left(= y_{it-1} - y_{it-2}\right)$ and $\Delta \upsilon_{it}\left(= \upsilon_{it} - \upsilon_{it-1}\right)$. An attempt to use a high-order lagged response variable as an instrument (Arellano and Bond, 1991) also fails because the serially correlated υ_{it} is related to all past response variables. Furthermore, a simple differencing of (2) cannot control for country-specific heterogeneity because ξ_i multiplied by Ψ_t is no longer time-invariant.

Several methods which filter the unobserved individual heterogeneity component in linear models are readily available in the literature.[7] However, these methods are only valid when the time-varying idiosyncratic error terms are not serially correlated. Although a differencing method with some extension can eliminate the time-varying individual effects and serial correlations of the error terms, using such a method leads to an equation in which the coefficients of the observable regressors are nonlinear functions of the original parameters. A standard linear regression will not be applicable in this situation, and the inference on the original parameters cannot be directly characterized. Moreover, the differenced equation includes high orders of lagged variables; thus, instrumental variables of higher orders of the lagged variable, reducing the size of the time observations of the dataset, are necessary to handle the endogeneity problem. This is undesirable, especially when the data is scant in the time dimension, a situation prevalent with panel datasets.

B. Estimation Methodology

We adopt a Bayesian approach to maximize the posterior distribution of parameters in the model. For the estimation, the Random Walk Metropolis Hastings MCMC method is used for the numerical procedure to characterize the posterior distribution. Because the posterior distribution is composed of the prior specified by the researcher's belief about the parameters and of the likelihood - which needs to be numerically evaluated – the method used to evaluate the likelihood of the model is crucial. As the model includes complicated dynamics due to the autoregressive processes of latent variables, such as common factors and error terms, the model is transformed into a state space representation which becomes applicable for evaluating the likelihood using a Kalman filter. In addition, there is a need to modify the standard Kalman filter to accommodate an incomplete panel dataset. From a time-series perspective, an incomplete panel dataset can be

[7]For example, Ahn *et al.* (2001) suggest quasi-differencing when the unobserved heterogeneity can vary across time periods, and Nauges and Thomas (2003) further extend the filtering method by double-differencing when the individual effects are both time-varying and time-invariant effects.

considered as a dataset with partially missing observations for each period. The Kalman gain, which efficiently estimates the state of the following period using current observations, can be appropriately adjusted when certain observations of the current period are not available. The following subsections will illustrate the state space representation, the augmented Kalman filter to accommodate the incomplete panel dataset, and the Metropolis Hastings algorithm.

1. Kalman Filter with an Incomplete Panel Dataset

In order to apply the Kalman filter, (2) must be expressed by a linear state space representation. This representation is straightforward, as (2) is linear with Gaussian errors. In general, the linear state space form is expressed as follows:

$$\begin{aligned} Y_t &= Hz_t \\ z_{t+1} &= Fz_t + \Lambda_{t+1} \quad \text{with } \Lambda_t SIMN(0,Q) \end{aligned} \tag{3}$$

H denotes the coefficient matrix in the observation equation, as

$$H \equiv \left[\Xi \;\; I_N\right]$$

where $\Xi = \left[\xi_1, \cdots, \xi_N\right]'$ and I_N is the identity matrix with a dimension of N. The state variable, z_t, is a vector of unobserved latent variables such that $z_t \equiv \begin{bmatrix} \Psi_t - 1 \\ \upsilon_{1t} \\ \vdots \\ \upsilon_{Nt} \end{bmatrix}$.

It is important to note that the long-run mean of the state vector is conveniently zero. It follows immediately that the autoregressive coefficient matrix, F, is $F \equiv \begin{bmatrix} \psi & 0 & \cdots & 0 \\ 0 & \rho & 0 & \vdots \\ \vdots & 0 & \ddots & 0 \\ 0 & \cdots & 0 & \rho \end{bmatrix}$ and the error term ε_t in the state equation is $\Lambda_{t+1} \equiv \begin{bmatrix} \sigma_\eta \eta_{t+1} \\ \nu_{1t+1} \\ \vdots \\ \nu_{Nt+1} \end{bmatrix}$.

Consequently, we can also demean the left-hand side of the observation equation to match the zero mean with the right-hand side by defining

$$Y_t \equiv y_t - y_{t-1}\beta_y - x_t\beta_x - 1_N\beta_c - \Xi,$$

where $y_t \equiv [y_{1t}, \cdots, y_{Nt}]'$, $x_t \equiv [x_{1t}, \cdots, x_{Nt}]'$ and 1_N is a column vector of ones.

When Y_t is fully observed, the standard Kalman Filter allows to estimate z_t by minimizing the predicted error variance-covariance matrix of z_t given the history of the observation until t. We define the covariance matrix of z_t as Σ_t; then, the standard Kalman filter procedures are as follows:

1. Given $z_{t|t-1}$ and $\Sigma_{t|t-1}$, observe Y_t
2. $Y_{t|t-1} = Hz_{t|t-1}$
3. $K_t = \Sigma_{t|t-1}H'\left(H\Sigma_{t|t-1}H'\right)^{-1}$
4. $\Sigma_{t|t} = \Sigma_{t|t-1} - K_tH\Sigma_{t|t-1}$
5. $z_{t|t} = z_{t|t-1} + K_t\left(Y_t - Hz_{t|t-1}\right)$
6. $\Sigma_{t+1|t} = F\Sigma_{t|t}F' + Q$
7. $z_{t+1|t} = Fz_{t|t}$.

For an incomplete panel dataset, step 5 in the procedure above is not implementable because Y_t is not fully observed in some periods. As Harvey (1991) has proposed, we can update the Kalman gain using only available information. Without a loss of generality, we can for instance observe

$y_{-k,t} \equiv \begin{bmatrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{k-1t} \\ y_{k+1t} \\ \vdots \\ y_{Nt} \end{bmatrix}$ but not observe y_{kt}. We can use the corresponding partitions of H and K_t accordingly with the available observations of

$$K_{-k,t} = [K_{1t}, K_{2t} \cdots K_{k-1t}, K_{k+1t}, \cdots K_{Nt}]$$

$$H_{-k} \equiv \begin{bmatrix} H_1 \\ H_2 \\ \vdots \\ H_{k-1} \\ H_{k+1} \\ \vdots \\ H_N \end{bmatrix}.$$

Step 5 will then be updated, as

$$z_{t|t} = z_{t|t-1} + K_{-k,t}\left(Y_{-k,t} - H_{-k} z_{t|t-1}\right).$$

In general, if y_t randomly has missing observations other than the kth element, we need to eliminate the corresponding rows of K_t and H.

2. Metropolis Hasting MCMC Algorithm

The Bayesian approach to estimate the model is to randomly draw a set of parameters in which the posterior-density-maximizing parameters are drawn with higher probabilities. We define the set of parameters and the dataset as follows:

$$\theta \equiv \left(\beta_c, \beta_y, \beta_x, \psi, \Xi, \rho, \sigma_\eta\right)$$
$$Y^T \equiv \left\{y_1, \cdots, y_T\right\}$$

The posterior density function is defined as shown below.

$$p\left(\theta \mid Y^T\right) \equiv \pi\left(\theta\right) l\left(\theta \mid Y^T\right)$$

Given numerically drawn values of θ, the above posterior distribution can be evaluated using the modified Kalman filter. Subsequently, the Random Walk Metropolis Hastings algorithm can be implemented as follows:

1. Initialize $\theta^{(0)}$ and evaluate $\mathrm{p}\left(\theta^{(0)} \mid Y^T\right)$
2. Draw $\theta^* \sim N\left(\theta^{(k)}, V^{\tilde{\theta}}\right)$
3. Evaluate $\mathrm{p}^*\left(\theta^* \mid Y^T\right)$

4. Accept or reject based on posterior odds $\frac{p^*\left(\theta^* \mid Y^T\right)}{p^{(k)}\left(\theta^{(k)} \mid Y^T\right)} \sim Unif\left(0,1\right)$

5. If accept, record $\theta^{(k+1)} = \theta^*$ else $\theta^{(k+1)} = \theta^k$

6. Go back to step 2

Step 2 is to draw θ^* based on a normal distribution around the previously accepted draw $\theta^{(k)}$ with variance $V^{\tilde{\theta}}$. In this random-walk sampling scheme, the practical convention for the choice of $V^{\tilde{\theta}}$ is the inverse of the Hessian of the likelihood function evaluated in the posterior mode; i.e., $l\left(\tilde{\theta} \mid Y^T\right)$ where $\tilde{\theta}$ is the posterior mode. However, the posterior mode, $\tilde{\theta}$, clearly cannot be found directly and thus can be continuously updated with many trials and errors involving different values of $\tilde{\theta}$. An alternative is to use a simulated annealing method to search the posterior mode and initiate the MCMC procedure given this posterior mode.[8] Whether the choice of $\tilde{\theta}$ is valid or not can often be confirmed by the mixing properties, the convergence statistics of the sequence of parameter draws and the acceptance rate.

V. Data and Estimation Results

A. Data and Variables

The variables and dataset used in this study come from various sources. The employment rate, the ratio of those in employment to the working age population for those aged 15~64 years old, is obtained from OECD (2011). Data on the net replacement rate of unemployment insurance and on labour taxes are available from Vliet and Caminada (2012).[9]

The replacement rate (%) is defined as the ratio of net benefits to net earnings. Taxes on labour denote the effective tax rate (%) based on the actual tax wedge.[10] Both variables are calculated at the average wage level for an average production worker. OECD (2010c) reports the union density as the ratio of the number of trade union members to all paid employees. This variable differs from the gross union density, which includes those who are unemployed, self-employed and unpaid family workers as a denominator.

Based on several indicators, OECD (2010a) reports a cross-country comparable

[8]See Andreasen (2010).

[9]For data sources, see http://www.law.leidenuniv.nl/org/fisceco/economie/hervormingsz/datasetreplacementrates.html

[10]The tax wedge denotes the labour costs that an employer should bear per worker minus the amount that the employee could take home. Thus, social insurance contributions and other cash benefits are included in the calculation of the tax wedge.

measure for employment protection, which is the unweighted average of sub-indicators for regular and temporary employment. A government's commitment to the labour market is proxied by its expenditures on active measures per unemployed person relative to output per capita (Scarpetta, 1996). Total expenditures on active labour market programs (category 10-70) are obtained from OECD (2010b). Finally, an output gap is included to control for cyclicality. It is calculated by A/T-1, where A is the actual GDP and T is the Hodrick-Prescott filtered GDP. Information on the real GDP comes from the Penn World Table (PWT version 7.1).

The dataset is an unbalanced panel of OECD countries from 1985 to 2009. The total number of observations is 492 from 28 countries. Most countries have approximately 20 observations on average, sizable and sufficient to facilitate a panel data analysis. Table 2 summarizes the dataset used in this study.

It is important to explore possible relationships between each institutional variable and the employment and unemployment rates graphically. Figure 2 and Figure 3 plot the employment rate and unemployment rate (on the vertical axis) against various institutional variables (on the horizontal axis).[11] The partial correlations shown in the figures are, in general, consistent with the findings of previous studies: a tax on labour is negatively (positively) related to the employment (unemployment) rate, suggesting the possibility that a higher tax may be associated with a lower (higher) employment (unemployment) rate. Similarly, the replacement rate of unemployment insurance benefits and the union density appear to have a negative (positive) correlation with the employment (unemployment) rate, hinting that countries with generous unemployment benefits or more union members tend to have lower (higher) employment (unemployment) rates. Employment protection, on the other hand, is found to be weakly related to the employment (unemployment) rate. The direction of measures for active labour market policies is not apparent because a positive correlation appears to disappear once outliers (Netherlands and Sweden) are excluded.

Although the above figures suggest that a certain institutional variable are candidates to explain cross-country variations in labour market outcomes, the points

TABLE 2—SUMMARY STATISTICS

	Variables	Mean	Std. dev.	Minimum	Maximum
Dependent variable	Employment rate (%)	66.51	7.67	46.19	83.12
	Unemployment rate (%)	7.94	4.11	1.62	24.04
Independent variable	GDP gap	0.81	3.91	-12.18	35.13
	UI Replacement rate (%)	55.83	17.43	17.21	89.77
	Tax on labour (%)	27.29	7.88	13.42	46.96
	Union density (%)	35.76	20.60	7.05	83.89
	Employment protection[12]	1.93	0.98	0.21	4.19
	Active labour market policy[13]	24.43	23.51	2.44	178.00

Note: There are 492 observations.

Sources: OECD (2010a), OECD (2010b), OECD (2010c), OECD (2011), PWT 7.1, and Vliet and Caminada (2012).

[11]The graphs are based on deviations from means.
[12]Index ranges from 0 to 6. Higher index reflects stricter regulations of employment protections.
[13]See Scarpetta (1996) for the proxies.

in most figures are heavily scattered around the variables' means, making it difficult to consolidate the relationships between labour market outcomes and institutional variables visually. Hence, precise inferences on the effect of institutional variables on labour market outcomes require an econometric analysis, as discussed in section 4.

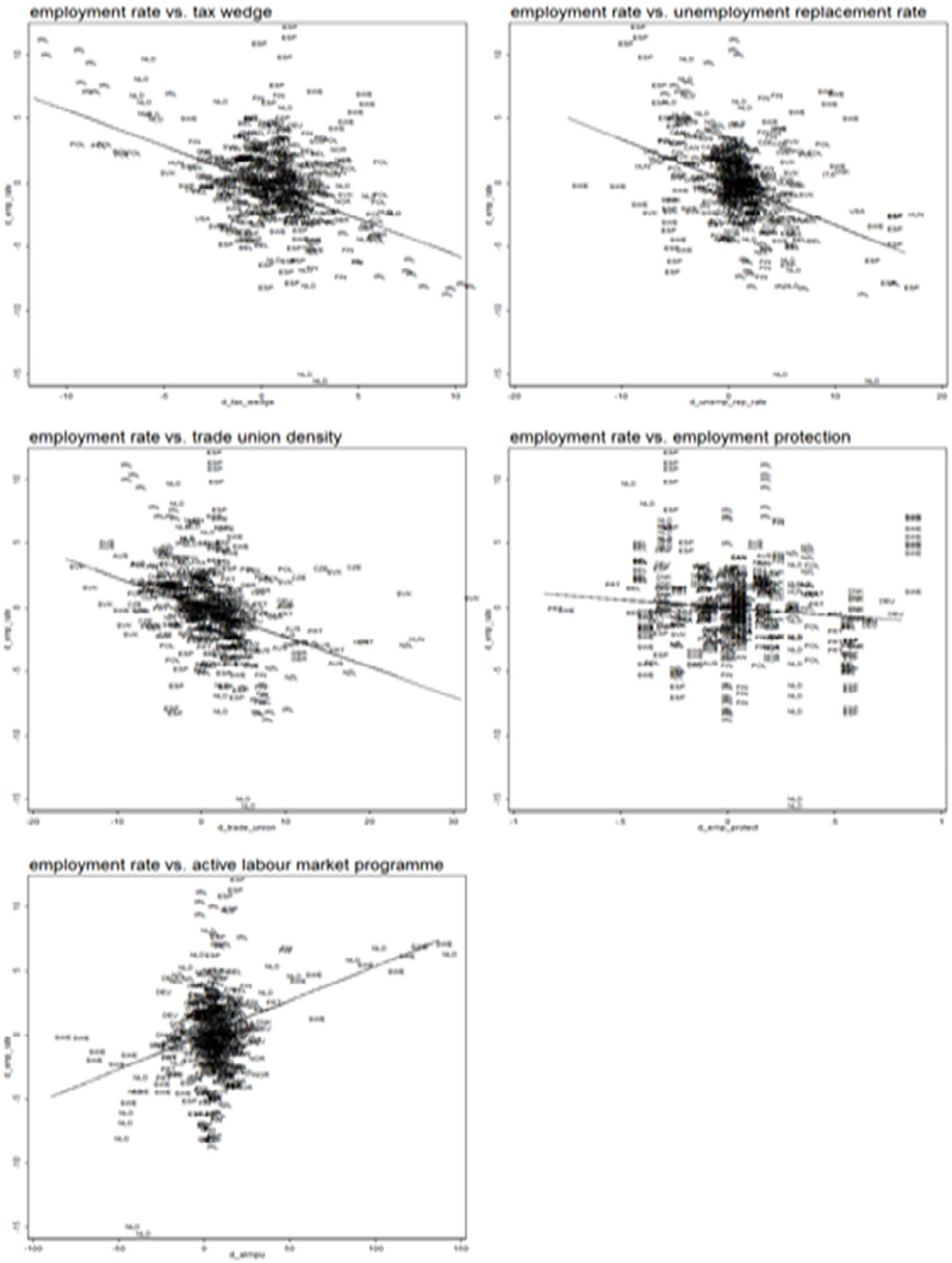

FIGURE 2. EMPLOYMENT RATE AND LABOUR MARKET INSTITUTIONS

Source: See Appendix.

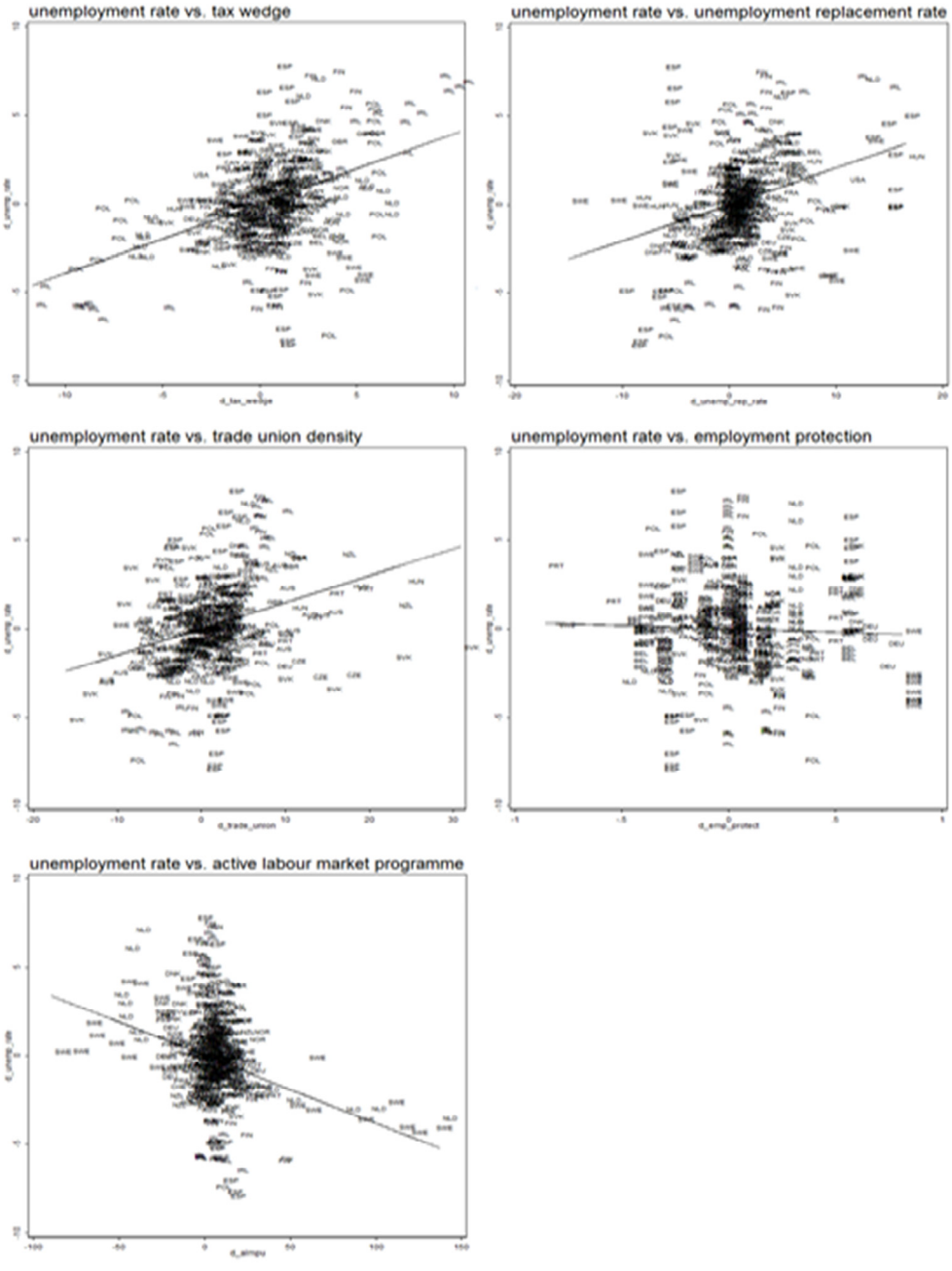

FIGURE 3. UNEMPLOYMENT RATE AND LABOUR MARKET INSTITUTIONS

Source: See Appendix.

B. Results

The estimation results with the choice of prior densities are presented in Table 3 (employment rate) and Table 4 (unemployment rate) and their corresponding

posterior distributions are given in Figures 4 and 5.[14] The prior distributions for the persistent parameters of ψ, ρ, and β_y are set to prevent the system from being non-stationary. While the prior distributions for ρ, and β_y are neutral, that for ψ is set to imply high persistence. Although the model allows for a time-varying common factor, we wanted to have common factor bounded within a small range.

Before discussing the institutional variables of our interest, the data confirms the GDP gap to be an important determinant of labour market outcomes, having a sizable positive effect on the employment rate and a negative effect on the unemployment rate. Therefore, it is fair to say that labour market outcomes are to large extent affected by the cyclicality of the economy.

When compared to earlier findings, special attention should be given when interpreting the results. First, the econometric model adopted in this paper is more generalized and elaborate compared to those in previous studies. Second and more importantly, the estimated coefficients reported in this paper are more concerned with long-term effects rather than those based on the short-term year-to-year variations in previous studies.[15]

Bearing this in mind, some of the results in this paper are in line with the findings of previous studies, whereas others are not. The results consistent with the previous studies are as follows:

• The effect of the replacement rate (β_{x2}) on the unemployment rate

In the unemployment rate equation, the estimated coefficient is positive (with its mode equal to 0.024). The positive support its posterior distribution locates hints that the replacement rate is directly related to the unemployment rate (Scarpetta, 1996; Elmeskov *et al*., 1998; Nickell & Layard, 1999; Belot & van Ours, 2000).

• The effect of the union (β_{x4}) on the employment rate and unemployment rate

The estimated coefficient of a union as measured by its density has a negative mode (-0.022) in the employment rate equation. With 90% of the posterior distribution having a negative value of β_{x4}, and it is fair to say that a high union density may lower the employment rate (Nicoletti & Scarpetta, 2001).

• Although the estimated coefficient has a mode with a slightly positive value (0.005) in the unemployment rate equation, the effect of a union on the unemployment rate is inconclusive, as shown by its posterior distribution. The support ranges from a negative to a positive value, implying that the estimated coefficient could be either case with considerable probabilities. In fact, the estimated coefficient of union density was found to be positive (Scarpetta, 1996;

[14]The estimation results without a serial correlation (i.e., $\rho = 0$ in (2)) are in the Appendix. In addition, the estimated results from a random-effect model based on (1) are presented in the Appendix.

[15]Note that (2) can be rewritten as $\left(1-\beta_y L\right) y_t = \beta_x x_t + \varepsilon_t$ where L is a lag operator. Then $E\left(y_t\right) = \frac{\beta_x}{1-\beta_y} E\left(x_t\right)$ long-run effect.

Nickell & Layard, 1998), negative (Elmeskov *et al.*, 1998) or even insignificant (Belot & van Ours, 2000).

• The effect of employment protection (β_{x5}) on the unemployment rate

For the unemployment rate, the estimated result shows that employment protection may have either positive or negative effects, as shown by its less informative posterior distribution. To some extent, this finding is consistent with mixed results found in previous studies.

• The effect of ALMP (β_{x6}) on the unemployment rate

In the unemployment equation, the mode of the ALMP coefficient appears to be -0.019, and its posterior distribution indicates that β_{x5} is very likely to have a negative value. From this result, it is safe to say that ALMP may lower the unemployment rate (Elmeskov *et al.*, 1998; Nickell & Layard, 1998).

On the other hand, the following results are different from what the previous studies reported.

• The effect of the replacement rate (β_{x2}) on the employment rate

Unlike previous empirical studies, the estimated coefficient of the replacement rate in the employment rate equation has a mode of -0.024 with 90% of its posterior distribution lying well below zero. Hence, the data suggest that a higher replacement rate is associated with a lower employment rate.

• The effect of labour taxes (β_{x3}) on the employment and unemployment rates

The estimation result could not convincingly support the negative (positive) effects of taxes on the employment (unemployment) rate found in previous research. Because a posterior distribution is less informative with regard to the value of this parameter, it is difficult to judge whether the estimated coefficient of taxes has a positive or negative value.

• The effect of employment protection (β_{x5}) on the employment rate

Unlike the negative effect reported in previous studies, the impact EPL may have on the employment rate is found to be inconclusive due to the less informative posterior distributions. Although the estimated coefficient has a mode of -0.331, its confidence cannot be maintained by its posterior distribution.

• The effect of ALMP (β_{x6}) on the employment rate

In contrast to the previous result showing no direct relationship between ALMP and the employment rate, the measure for ALMP in the employment equation in this study has an estimated coefficient of a positive mode (0.022) with the support of its posterior distribution entirely being in a positive range. This result implies that ALMP is very likely to raise the employment rate.

TABLE 3—MODEL WITH SERIAL CORRELATION (EMPLOYMENT RATE)

	Prior distribution			Posterior distribution						
	Distr.	Mean	St. Dev.	Mode	Mean	St. Dev.	5%	10%	90%	95%
ψ	Beta	0.875	0.052	0.973	0.961	0.02	0.922	0.934	0.983	0.986
ρ	Beta	0.500	0.151	0.87	0.855	0.043	0.773	0.794	0.905	0.915
β_c	n.a.	n.a.	n.a.	37.199	35.197	2.903	30.565	30.812	38.619	39.838
β_y	Beta	0.500	0.151	0.511	0.535	0.035	0.480	0.490	0.581	0.588
β_{x1}	n.a.	n.a.	n.a.	0.217	0.222	0.028	0.176	0.186	0.257	0.268
β_{x2}	n.a.	n.a.	n.a.	-0.024	-0.026	0.018	-0.056	-0.049	-0.004	0.002
β_{x3}	n.a.	n.a.	n.a.	-0.006	0.006	0.023	-0.042	-0.034	0.023	0.033
β_{x4}	n.a.	n.a.	n.a.	-0.022	-0.025	0.017	-0.053	-0.046	-0.004	0.002
β_{x5}	n.a.	n.a.	n.a.	-0.331	-0.313	0.306	-0.817	-0.706	0.074	0.178
β_{x6}	n.a.	n.a.	n.a.	0.022	0.021	0.005	0.014	0.015	0.027	0.029
$\sigma\eta$	InvGamma	0.100	2.000	0.049	0.053	0.011	0.036	0.039	0.068	0.073

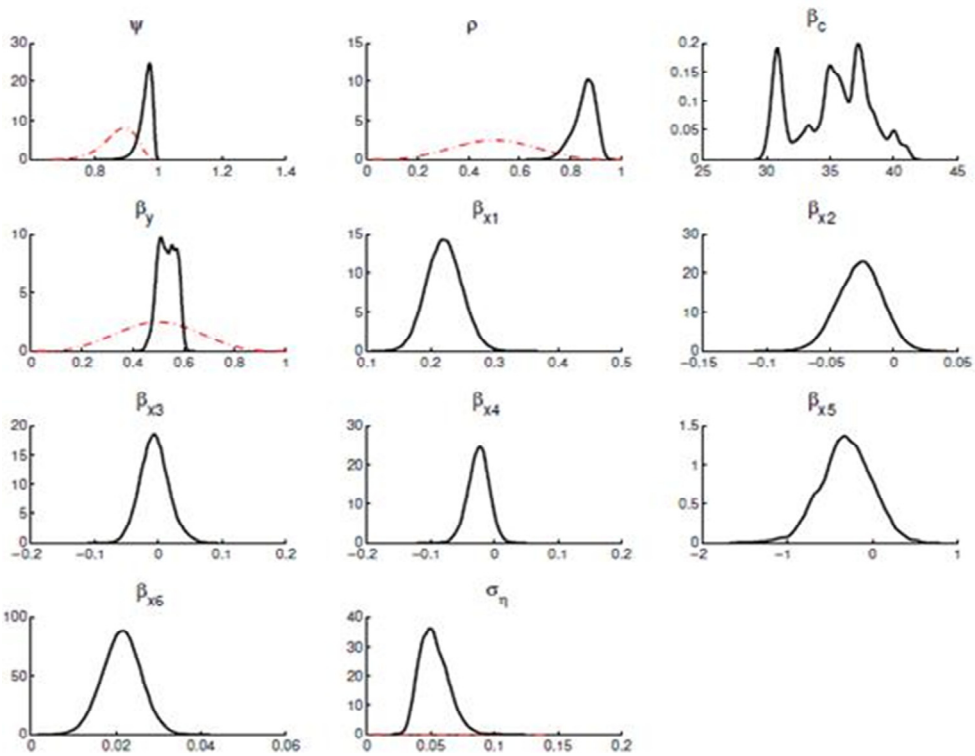

FIGURE 4. PRIOR AND POSTERIOR DISTRIBUTIONS OF THE EMPLOYMENT MODEL WITH SERIAL CORRELATION

TABLE 4—MODEL WITH SERIAL CORRELATION (UNEMPLOYMENT RATE)

	Prior distribution			Posterior distribution						
	Distr.	Mean	St. Dev.	Mode	Mean	St. Dev.	5%	10%	90%	95%
ψ	Beta	0.875	0.052	0.962	0.949	0.024	0.904	0.918	0.976	0.980
ρ	Beta	0.500	0.151	0.87	0.859	0.037	0.793	0.810	0.903	0.913
β_c	n.a.	n.a.	n.a.	2.783	2.499	0.530	1.602	1.764	3.173	3.288
β_y	Beta	0.500	0.151	0.499	0.503	0.058	0.408	0.429	0.578	0.599
β_{x1}	n.a.	n.a.	n.a.	-0.211	-0.216	0.028	-0.262	-0.252	-0.180	-0.170
β_{x2}	n.a.	n.a.	n.a.	0.024	0.027	0.014	0.005	0.010	0.045	0.050
β_{x3}	n.a.	n.a.	n.a.	0.005	0.003	0.019	-0.029	-0.022	0.027	0.034
β_{x4}	n.a.	n.a.	n.a.	0.005	0.007	0.015	-0.015	-0.011	0.027	0.033
β_{x5}	n.a.	n.a.	n.a.	-0.325	-0.354	0.286	-0.844	-0.732	0.011	0.112
β_{x6}	n.a.	n.a.	n.a.	-0.019	-0.019	0.005	-0.027	-0.025	-0.013	-0.011
$\sigma\eta$	InvGamma	0.100	2.000	0.082	0.087	0.018	0.060	0.065	0.110	0.119

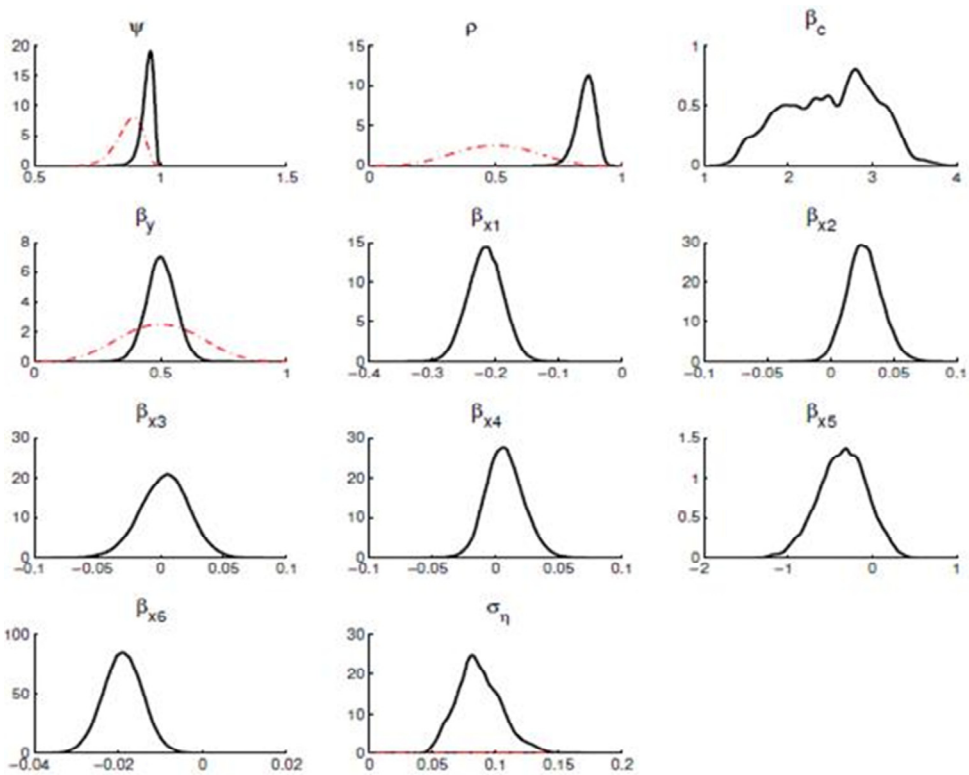

FIGURE 5. PRIOR AND POSTERIOR DISTRIBUTIONS OF THE UNEMPLOYMENT MODEL WITH SERIAL CORRELATION

In summary, there are several points to note. First, the effects of employment protection on labour market outcomes are not confirmed. This does not mean that employment protection is relevant to labour market performances. In fact, as indicated in many studies, employment protection has a profound impact on inflows/outflows in the labour market as well as on the composition of labour market participants (Blanchard and Wolfers, 2000). This result can be interpreted by considering that the primary effect of EPL in the long run may rest not on the level of labour market outcomes but on other aspects of the labour market.

Second, surprisingly, the commonly recognized effect of taxes on labour does not appear either in the employment rate or unemployment rate. A possible explanation is that the primary effect of taxes on labour may be on the level of wages and not on the level of employment or unemployment. This is particularly true in the long run, when a labour market fully adjusts tax incidences.

Finally, an active labour market policy appears to reduce the level of unemployment, while other many institutional variables such as taxes on labour, the union density, and the degree of employment protection do not. Card et al. (2010) assessed the effectiveness of various active labour market programs in a meta-analysis of 199 programs of the OECD countries and concluded that job search assistance and training programs are effective in the long and medium terms. Hence, this result may reflect the large share of employment services and training spending in OECD active labour market policies.[16]

VI. Conclusion

This comparative study re-examines the role institutional arrangements play in labour market outcomes using panel data from selected OECD member countries. While many studies recognize countries' institutional differences as an important factor explaining variations in employment and unemployment, the empirical results are far less satisfactory. This is partly due to data limitations and the econometric methods applied in the analysis.

The contribution of this paper is twofold. First, owing to the effort of the OECD in collecting data, this study can utilize highly qualified information consistently defined over a long period. This enables us to exploit the advantages and benefits panel data can provide. Secondly and more importantly, the econometric model adopted in this paper is modified in order to reflect the dynamic features of labour market reality while fully incorporating the heterogeneity of each country. Moreover, this complicated model can be estimated through the relatively simple strategies proposed in the paper.

Some of results in the paper are generally consistent with what previous studies have found while others are somewhat different. For instance, the level of UI replacement appears negatively to affect labour market outcomes such that generosity in this regard raises the unemployment rate. The organized labour and active labour market measures have effects in line with those in previous findings.

[16]In 2010, the share of employment services and training were 26% and 28.5% of all ALMP expenditures in OECD countries.

Other variables known to be important in determining labour market outcomes are found to have weak long-run relationships with the levels of overall employment and unemployment. Notably, taxes on labour have neither an effect on the employment rate nor on the unemployment rate. In addition, the estimation result hints that the primary effect of employment protection may not be on the level of overall employment or unemployment and may rather be on other labour market aspects, such as in-and-out flows and/or the composition of labour market participants.

Although this study investigates the relationship between institutional environments and labour market performance outcomes, it nonetheless leaves many unanswered questions. Above all, institutional variables, by nature, are very difficult to measure or summarized using a single index or number. The proxies for institutional variables in most empirical studies are typically error-ridden, and the results from troubled variables are prone to be biased. More seriously, the institutional arrangements are not purely exogenous but are endogenous. Again, the endogeneity make it difficult for a researcher to reach a correct inference from the results. These issues must be explored further in the future.

APPENDIX

TABLE A1—MODEL WITHOUT SERIAL CORRELATION (EMPLOYMENT RATE)

	Prior distribution			Posterior distribution						
	Distr.	Mean	St. Dev.	Mode	Mean	St. Dev.	5%	10%	90%	95%
ψ	Beta	0.875	0.052	0.944	0.934	0.027	0.895	0.898	0.965	0.971
β_c	n.a.	n.a.	n.a.	3.296	2.832	0.400	2.220	2.337	3.397	3.550
β_y	Beta	0.500	0.151	0.956	0.965	0.006	0.955	0.957	0.973	0.975
β_{x1}	n.a.	n.a.	n.a.	0.019	0.010	0.013	-0.013	-0.008	0.027	0.032
β_{x2}	n.a.	n.a.	n.a.	0.002	-0.003	0.004	-0.009	-0.007	0.002	0.003
β_{x3}	n.a.	n.a.	n.a.	0.005	-0.003	0.004	-0.009	-0.008	0.002	0.004
β_{x4}	n.a.	n.a.	n.a.	-0.009	-0.005	0.003	-0.011	-0.010	-0.001	0.000
β_{x5}	n.a.	n.a.	n.a.	-0.162	-0.082	0.066	-0.193	-0.167	-0.001	0.021
β_{x6}	n.a.	n.a.	n.a.	0.005	0.005	0.001	0.003	0.004	0.007	0.007
$\sigma\eta$	InvGamma	0.100	2.000	0.274	0.233	0.051	0.155	0.169	0.301	0.323

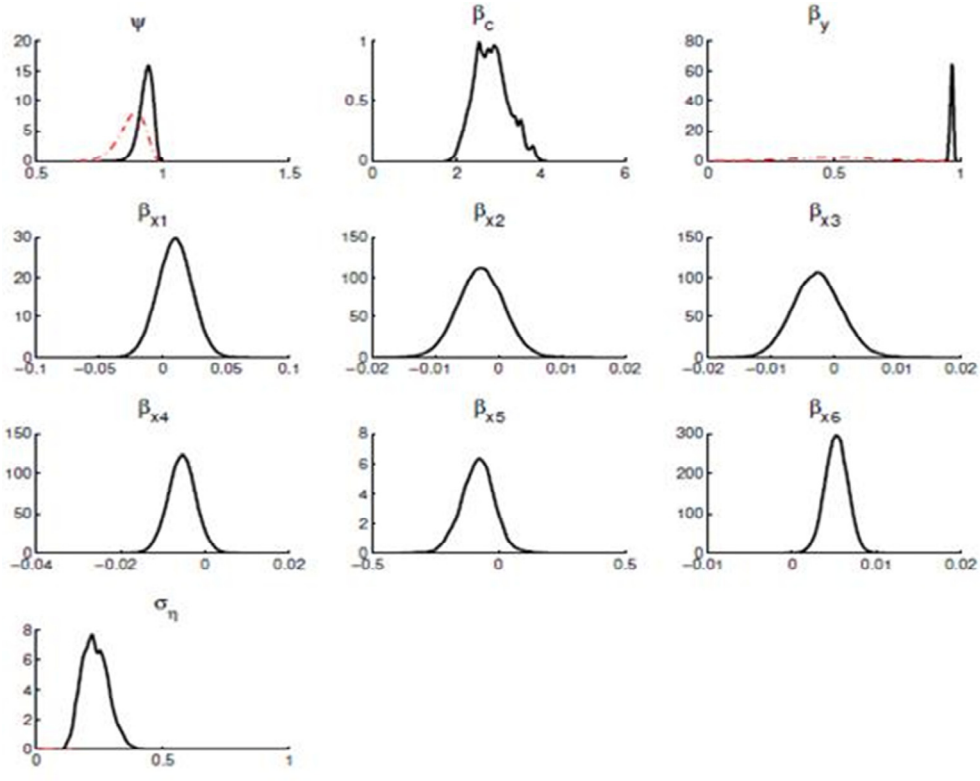

FIGURE A1. PRIOR AND POSTERIOR DISTRIBUTIONS OF THE EMPLOYMENT MODEL WITHOUT SERIAL CORRELATION

TABLE A2—MODEL WITHOUT SERIAL CORRELATION (UNEMPLOYMENT RATE)

	Prior distribution			Posterior distribution						
	Distr.	Mean	St. Dev.	Mode	Mean	St. Dev.	5%	10%	90%	95%
ψ	Beta	0.875	0.052	0.973	0.965	0.017	0.934	0.943	0.983	0.986
β_c	n.a.	n.a.	n.a.	0.410	0.306	0.222	-0.091	0.018	0.572	0.637
β_y	Beta	0.500	0.151	0.918	0.918	0.013	0.897	0.902	0.935	0.940
β_{x1}	n.a.	n.a.	n.a.	-0.012	-0.011	0.013	-0.033	-0.029	0.006	0.011
β_{x2}	n.a.	n.a.	n.a.	0.002	0.002	0.004	-0.004	-0.002	0.007	0.008
β_{x3}	n.a.	n.a.	n.a.	0.003	0.003	0.004	-0.003	-0.002	0.008	0.009
β_{x4}	n.a.	n.a.	n.a.	0.001	0.001	0.003	-0.004	-0.003	0.005	0.006
β_{x5}	n.a.	n.a.	n.a.	0.066	0.060	0.059	-0.038	-0.016	0.135	0.156
β_{x6}	n.a.	n.a.	n.a.	-0.004	-0.004	0.001	-0.006	-0.005	-0.002	-0.001
$\sigma\eta$	InvGamma	0.100	2.000	0.112	0.130	0.034	0.086	0.093	0.175	0.194

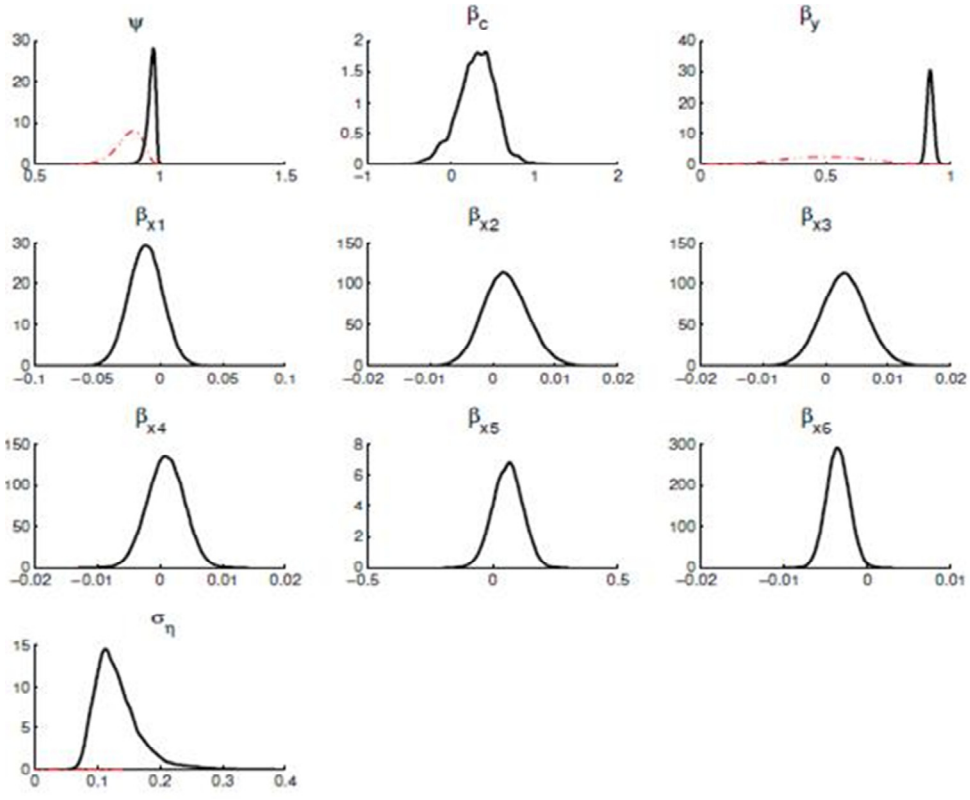

FIGURE A2. PRIOR AND POSTERIOR DISTRIBUTIONS OF THE UNEMPLOYMENT MODEL WITHOUT SERIAL CORRELATION

TABLE A3—ESTIMATION RESULTS WITH A RANDOM EFFECT MODEL

	Employment		Unemployment	
	Est. Coeff.	t-statistics	Est. Coeff.	t-statistics
β_c	91.894***	59.602	-7.155***	-6.067
β_{x1}	0.339***	11.108	-0.307***	-13.162
β_{x2}	-0.337***	-11.468	0.253***	11.266
β_{x3}	-0.186***	-4.519	0.094***	2.988
β_{x4}	-0.161***	-8.105	0.104***	6.879
β_{x5}	0.054	0.134	-1.426***	-4.664
β_{x6}	0.061***	12.365	-0.037***	-9.815
N	489		489	

Note: *** p<0.01, ** p<0.05, * p<0.1.

Source: Table 3-3 and Table 3-4 from Kim (2013).

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