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# Inference and Forecasting Based on the Phillips Curve†

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*In this paper, we conduct uniform inference of two widely used versions of the Phillips curve, specifically the random-walk Phillips curve and the New-Keynesian Phillips curve (NKPC). For both specifications, we propose a potentially time-varying natural unemployment (NAIRU) to address the uncertainty surrounding the inflation-unemployment trade-off. The inference is conducted through the construction of what is known as the uniform confidence band (UCB). The proposed methodology is then applied to point-ahead inflation forecasting for the Korean economy. This paper finds that the forecasts can benefit from conducting UCB-based inference and that the inference results have important policy implications.*

Key Word: Time-varying NAIRU, Random-walk Phillips curve, New-Keynesian Phillips curve, Uniform confidence band, Model validation, Inflation forecasting
JEL Code: C12, C13, C14

## I. Introduction

Since Milton Friedman introduced the idea of the non-accelerating inflation rate of unemployment (*NAIRU*) in his presidential address to the American Economic Association in 1968, the *NAIRU* has served as a general guideline for those establishing macroeconomic policies. The idea has also been very useful as an empirical basis for predicting changes in the inflation rate. Among the various hypotheses regarding this important structural parameter, there has been a general recognition among many economists that if a *NAIRU* does exist, it must change over time (Stiglitz 1997; Ball and Mankiw 2002).

Perhaps the most widely accepted belief with regard to time-variation in the U.S. *NAIRU* is that the parameter has been falling since the early 1980s (Stiglitz 1997;

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Shimer 1998). Although this consensus on a decreasing *NAIRU* appears reasonable and is supported by empirical research in this area, there remains no formal justification of this hypothesis in the literature. Furthermore, there is a lack of evidence of any time-varying *NAIRU* for economies other than that of the U.S. Given this limitation, the paper conducts inference of the *NAIRU* parameter for the Korean economy and shows how the developed methodology can be applied to forecasting Korean monthly inflation.

To meet these goals, the paper considers two versions of the Phillips curve: the random-walk Phillips curve[1] (Staiger, Stock, and Watson 1996, 1997) and the New-Keynesian Phillips curve (*NKPC*) (Gal´ı and Gertler 1999). Given the uncertainty surrounding the *NAIRU*, we extend the Phillips curves such that the new model framework can deal with uncertainty. That is, the *NAIRU* in the suggested framework does not assume any specific parametric form. Only data determine the unknown form, of which the estimate will be used to fore-cast inflation.

The unique feature of the approach in this work is that the proposed model validation procedures can be used directly for the forecasting exercise. Thus far, most studies of the Phillips curve in macroeconomics have focused on either model validation or on the forecasting performance, but not both. In this work, we generalize the two widely used versions of Phillips curve such that the modified models can incorporate the uncertainty surrounding the *NAIRU* parameter more efficiently. Uniform inference procedures for the model are proposed and used to suggest a new forecasting methodology that is applied to Phillips-curve-based inflation forecasting. Given that it attempts to combine these two rather distinct areas of research, the current work stands out among the numerous papers related to the forecasting ability of the Phillips curve.

Until recently, the empirical literature on the Phillips curve rarely provided inference based on estimates of the *NAIRU* parameter. A handful of pioneering works in this direction include those by Gordon (1997, 1998) and Staiger, Stock and Watson (1996, 1997, 2001), where the authors estimate a time-varying *NAIRU* in the traditional expectations-augmented Phillips curve (Friedman, 1968; Phelps, 1970) with adaptive expectations and construct its confidence intervals. Unfortunately, these works on the inference of the time-varying *NAIRU* involve only the construction of point-wise confidence intervals of the parameter. In the treatment of dynamic models, such as the *NKPC* with a time-varying *NAIRU*, it is more appropriate and more useful to construct uniform confidence bands (*UCB*) than their point-wise counterparts, as *UCB*s allow us to perform statistical inference for the parameter. That is, the *UCB* allows us to test whether the parameter assumes any specific structure (i.e., constant, linear) on it. In principle, point-wise confidence intervals/bands are not appropriate for testing these hypotheses on the parameter because any inference results based on point-wise outcomes pertain to one specific point only.

In order to construct the asymptotic *UCB* of the time-varying *NAIRU* $U_N(t)$ with the level $100(1-\alpha)\%$, $\alpha \in (0,1)$ form, it is necessary to find the following

[1]The model originates from the expectations-augmented Phillips curve (Friedman 1968; Phelps 1970).

two functions $f_n(\cdot)$ and $g_n(\cdot)$ based on the data:

$$\lim_{n\to\infty} \mathbb{P}\{f_n(t) \le U_N(t) \le g_n(t) \ \ for \ \ all \ \ t \in T\} = 1-\alpha \tag{1}$$

where $T=[0,1]$. The purpose of constructing the *UCB* above is to test whether the *NAIRU* $U_N(\cdot)$ takes a certain parametric form. That is, using the *UCB* of $U_N(\cdot)$, we are able to test the null hypothesis $H_0 : U_N(\cdot) = U_\theta(\cdot)$, where $\theta \in \Theta$ and where $\Theta$ is a parameter space. For example, in order to test $H_0 : U_\theta(t) = \theta_0 + \theta_1 t,$ it is possibly simply to check whether $f_n(t) \le \hat{\theta}_0 + \hat{\theta}_1 t \le g_n(t)$ holds for all $t \in T$. Here $\hat{\theta}_0$ and $\hat{\theta}_1$ are the least squares estimates of $\theta_0$ and $\theta_1$, respectively. If it does hold for all $t \in T,$ then we fail to reject the null hypothesis at level $\alpha$.

In general, the *UCB* is a more conservative confidence band than the traditional point-wise confidence band in the sense that the *UCB* is usually wider than its point-wise counterpart. Thus, test results based on the *UCB* would be more robust than those under the point-wise outcomes. For these reasons, the *UCB* has recently attracted more attention in the econometrics and statistics literature. For example, Baillie and Kim (2015) revisit the forward premium regression approach (Fama 1984) in an effort to understand the potential source of model instability. They undertake the *UCB*-based inference of the model parameters to identify the driving force behind the dynamics and to capture potential incidences of co-movement among the parameters for different currencies. Kim (2016) constructs a *UCB* of the non-parametric trend in a semi-parametric regression model, where the independent variables are non-stationary processes. The *UCB* is then used to test for a parametric specification of the unknown trend in the model. Given these interesting results, we shall construct the *UCB* of a time-varying *NAIRU* and carry out inference about the parameter.

The developed inference procedures can be applied to forecasting inflation variables. Given the *UCB* of *NAIRU*, one can test whether or not a certain parametric form is accepted. If it is accepted, then the estimated structure is used to forecast inflation, involving mainly the extrapolation of the data. If it is rejected, the non-parametric fits of the *NAIRU* can then be used to forecast the variable. Given that non-parametric fits vary over time, we need to combine these time-specific estimates for forecasting. We combine them by averaging the estimates. To compare the performances of the proposed method and of the traditional Phillips curve, the paper conducts a pseudo out-of-sample forecasting experiment. Both the entire sample and sub-samples are utilized to in an assessment of their performances in this experiment. The results and the implications are discussed in detail.

The organization of the paper is as follows: Section II discusses the methodology. The first part is for testing for any potential structural break in the data. We employ a non-parametric break test to rule out any potential bias from specifying a parametric form. The subsequent parts concern the inference that is carried out based on two popular versions of the Phillips curve - the random-walk

Phillips curve (Staiger, Stock, and Watson 1996) and the new Keynesian Phillips curve (Gal´ı and Gertler 1999). The steps used to perform the inference are explained in detail. The section also discusses how forecasting is conducted based on the inference procedures. Essentially, the uniform confidence band is used to select an appropriate model that is eventually used for extrapolation. Section III explains the data used and summarizes and interprets the estimation and forecasting outcomes. This section also discusses the policy implications of the empirical results. Section IV concludes the paper and discusses potential future research. The proof of the theoretic result and the figures and tables are given in the appendix of the paper.

## II. Methodology

Inference of the Phillips curve is carried out by the construction of a *uniform* confidence band (*UCB*) (Kim 2015, 2016; Baillie and Kim 2015). The *UCB* is a powerful tool for undertaking the inference of an unknown function in an economic causal model. Unlike the traditional point-wise confidence intervals, the *UCB* can be used for model validation by determining the correct function form. Because this is mostly done by a simple visual check of the result, the entire procedure is also very tractable. As discussed in the introduction, the stability of the *NAIRU* parameter in the Phillips curve is a major source of debate. The *UCB*-based inference method introduced here can be readily used for the validation of the Phillips curve and can potentially contribute to improving the accuracy of inflation forecasts based on the model.

### A. *Stability of the NAIRU Parameter*

One of the issues to consider when applying the Phillips curve to the Korean economy in recent years is the potential parameter instability during the 1997 Asian financial crisis. The possible existence of what is known as a structural break due to this shock can basically invalidate the outcomes of any traditional analysis. Hence, it is desirable to determine this possibility before conducting the *UCB*-based inference of the Phillips curve for the Korean economy. Among the many available tests of change points, we employ a non-parametric subsample-based test (Carlstein 1986) using monthly Korean unemployment data during July of 1982 to May of 2015.[2] Here, we let $U_t$ denote the monthly unemployment rate at time $t = 1, 2, \cdots, n$. We start by partitioning the sample to obtain the following $\{A_i\}$,

$$A_i = \frac{1}{k_n}\sum_{j=1}^{kn} U_{j+ik_n}, \qquad i = 0, 1\cdots$$

where $k_n = [n^{2/3}]$. Here $[\cdot]$ is the integer part of a real number. The test statistic

[2]For the Korean economy, the monthly inflation series starts in July of 1982.

that we utilize is the maximal difference between two adjacent block-wise means:

$$D_n = \max_{1 \le i \le m-1} | A_i - A_{i-1} |$$

Here, $m = [n / k_n]$. Under some suitable conditions, one can show that

$$\mathbb{P}\left( \sqrt{log(m)} \left( k_n^{1/2} \sigma^{-1} D_n - \gamma_m \right) \le u \right) \Rightarrow exp\left( -\pi^{-1/2} exp(-u) \right)$$

where $\gamma_m = [4log(m) - 2log(log(m))]^{1/2}$ and $\alpha$ is the standard deviation of the de-meaned inflation variable. Hence, we reject, at level $\alpha$, the stability of the *NAIRU* parameter if

$$D_n > D_m := k_n^{-1/2} \sigma \left( \gamma_m + c_\alpha log\left( m \right)^{-1/2} \right)$$

where $c_\alpha = -log[-log(1-\alpha)] - 0.5\ log(\pi)$. Here, the standard deviation $\sigma$ can be estimated with any of the following:

$$\sigma_1 = \frac{\sqrt{\pi k_n}}{2(m-1)} \sum_{i=1}^{m-1} | A_i - A_{i-1} |$$

$$\sigma_2 = \frac{\sqrt{k_n}}{\sqrt{1.348}} \text{median}\left( | A_i - A_{i-1} | \right), \quad 1 \le i \le m-1$$

$$\sigma_3 = \frac{\sqrt{k_n}}{\sqrt{2(m-1)}} \left( \sum_{i=1}^{m-1} | A_i - A_{i-1} |^2 \right)^{1/2}$$

The test results are reported by Table 1. As shown in the table, the results are mixed depending on which estimate is used to estimate $\sigma$. While a break is detected under $\sigma = \sigma_2$, there seems to be not enough evidence of a structural break in the Korean monthly unemployment rate when the other two estimates of σ are used instead, as suitably illustrated by Table 1. Unlike other popular structural break tests that utilize some parametric framework, the test considered here is purely non-parametric in that no model structure is required to carry it out. This may have led to the lack of a consensus among the test results.

TABLE 1—TEST FOR STRUCTURAL BREAK

| | $D_n$ | $D_m$ | Result |
|---|---|---|---|
| $\sigma = \sigma_1$ | 1.9566 | 2.8475 | No break |
| $\sigma = \sigma_2$ | 1.9566 | 1.8791 | Break |
| $\sigma = \sigma_3$ | 1.9566 | 3.0244 | No break |

## B. *Inference of the Random-Walk Phillips Curve*

Given the change-point test results, we undertake the inference of two versions of the Phillips curve: the random-walk Phillips curve and its New Keynesian counterpart. In particular, the random-walk Phillips curve in (2) has been used extensively on the empirical frontier (Staiger, Stock, and Watson 1996, 1997, 2001; Gordon 1997, 1998; Fair 2000; Ball and Mankiw 2002),

$$\pi_i = \pi_{i-1} + \alpha(U_i - U_N) + \epsilon_i, \tag{2}$$

where $\pi_i$ and $U_i$ represent the inflation and unemployment rates at time $i = 1, \cdots, n,$ respectively. Here, $\epsilon_i$ is a zero-mean random error at time *i*, often dubbed the supply shock, and $U_N$ and $\alpha$ are unknown parameters. The *NAIRU* parameter $U_N$ embeds all shifts in the inflation-unemployment trade-off. The version in (2) employs only one lagged unemployment value, while multiple lag terms can be introduced without changing the methodology. For simplicity, we use one lag term.

In principle, $U_N$ can exhibit substantial variation over time (Gordon 1997, 1998; Staiger, Stock, and Watson 1996, 1997; Ball and Mankiw 2002). To address this possibility, we build on the traditional random-walk-type model (2) and propose the following Phillips curve with the potentially time-varying *NAIRU* $U_N(\cdot)$,

$$\pi i = \pi_{i-1} + \alpha\left[U_i - U_N\left(\frac{i}{n}\right)\right] + \epsilon_i \tag{3}$$

where $U_N(\cdot)$ varies over time in its domain [0, 1]. The time-varying *NAIRU* $U_N(t)$ can be estimated by the semi-parametric two-step estimator proposed by Kim (2016),

$$\tilde{U}_N(t) = \sum_{i=1}^{n} w_n(t,i)\left(U_i - \frac{\Delta\pi_i}{\hat{\alpha}_D}\right) \tag{4}$$

where $\Delta\pi i = \pi i - \pi i - 1$, and $\hat{\alpha}_D$ is the differencing estimate of the *fixed* parameter $\alpha$ in (3). Here, $w_n(t,i) = K\left(\frac{t - i/n}{b_n}\right)\frac{S_2(t) - (t - i/n)S_1(t)}{S_2(t)S_0(t) - S_1^2(t)}$ with $S_j(t) = \sum_{i=1}^{n}(t - i/n)^j K\left(\frac{t - i/n}{b_n}\right)$, $j = 0,1,2.$ For the kernel function $K(\cdot)$, we employ the Epanechnikov kernel $K(x) = 3max(1 - x^2, 0)/4.$ The bandwidth $b_n$ is established by the generalized cross-validation (*GCV*) method (Craven and

Wahba 1979). The main idea in (4) is that we first estimate α by a first-differencing approach (Yatchew 1997) and then employ a local-smoothing technique based on the first-differencing estimate to estimate the unknown trend. We refer to Kim (2016) for details. According to both (4) and Theorem 2 in Kim (2016), the *UCB* of $U_N(\cdot)$ in (3) is constructed as follows:

(i) Select the bandwidth $b_n$ by means of generalized cross-validation (*GCV*) (Craven and Wahba 1979) and obtain the two-stage semi-parametric estimate (Kim 2016) under the Epanechnikov kernel. To deal with the under-smoothing issue, one can consider a *bias-corrected* estimator instead.

(ii) Compute $\sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,\, i)Z_i\right|$, where the $\{Z_i\}$ values are generated *IID* standard normal random variables.

(iii) Repeat (ii), for instance 1,000 times. We obtain the 95th quantile of the sampling distribution of $\sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,\, i)Z_i\right|$, and denote it as $\hat{q}_{0.95}$.

(iv) Estimate $\sigma_\epsilon$ using the following variant of the subseries variance estimator proposed by Carlstein (1986):

$$\hat{\sigma}_\epsilon^2 = \frac{1}{2(m-1)k_n}\sum_{i=1}^{m-1}\left[\sum_{j=1}^{k_n}\left(U_{j+ik_n} - U_{j+(i-1)k_n} - \left(\Delta\pi_{j+ik_n} - \Delta\pi_{j+(i-1)k_n}\right)/\hat{\alpha}_D\right)\right]^2 \tag{5}$$

where $k_n$ is the length of the subseries and $m = \lfloor n/k_n \rfloor$ is the largest integer not exceeding $n/k_n$. Carlstein (1986) shows that the optimal length of the subseries is $k_n \asymp n^{1/3}$. Hence, we let $k_n \asymp n^{1/3}$ here. For a finite sample, we choose $k_n = [n^{1/3}]$. The asymptotic consistency of $\hat{\sigma}_\epsilon^2$ with regard to the long-run variance $\hat{\sigma}_\epsilon^2$ is given by Lemma 5 in Kim (2016).

(v) According to Theorem 2 in Kim (2016), the 95% *UCB* of $U_N(t)$ is $[\tilde{U}_N(t) \pm \hat{\sigma}_\epsilon \hat{q}_{0.95}]$.

Note here that the above *UCB* is more effective in a finite sample than the usual *UCB* based on the asymptotic results, as that suggested here avoids the problem of slow convergence. For more on this issue, we refer to Theorem 2 and the following discussion in Kim (2016).

### C. *Inference of the New Keynesian Phillips Curve (NKPC)*

For the *NKPC* side, we consider the hybrid *NKPC* (Gal´ı and Gertler 1999) based on the unemployment gap. Although it is a theoretically coherent framework,

the original *NKPC* is known to have several empirical limitations, including that related to its ability to forecast inflation. This led to the development of the following hybrid *NKPC* framework,

$$\pi_i = \delta(U_i - U_N) + (1-\varphi)\mathbb{E}(\pi_{i+1} \mid \mathcal{I}_i) + \varphi\pi_{i-1}$$

where $\pi_i$ and $U_i$ are inflation and unemployment rate at time $i = 1, \cdots, n$, and $U_N$ is the *NAIRU* parameter. Here $0 < \varphi < 1$ controls the inflation persistance and $\delta$ is related to the parameter that governs the degree of price stickiness. The *NKPC* proposed in this work is the unemployment-gap-based hybrid *NKPC* with a time-varying *NAIRU* $U_N(\cdot)$:

$$\pi_i = \delta(U_i - U_N(i/n)) + (1-\varphi)\mathbb{E}(\pi_{i+1} \mid \mathcal{I}_i) + \varphi\pi_{i-1} \tag{6}$$

For the inflation series πi in (6), we assume that

$$\pi_i = \mu_\pi(i/n) + \pi^i, \tag{7}$$

where the unknown mean μπ (·) of inflation is Lipschitz-continuous over [0, 1], and the demeaned inflation πi is a mean-zero stationary random process such that

$$\pi_i^d = \mathcal{F}(\mathcal{I}_i), \tag{8}$$

where $\mathcal{F}(\cdot)$ is a measurable function and $\mathcal{I}_i = (\cdots, \epsilon_{i-2}, \epsilon_{i-1}, \epsilon_i)$ is the information set available up to time $i$. The framework in (8) is general such that both linear and non-linear time series processes such as the ARCH process (Engle 1982) can be represented in this way. Moreover, the de-meaned inflation $\{\pi_i^d\}$ is assumed to have a finite fourth moment. Under (7) and (8), the hybrid *NKPC* in (6) can be written as follows,

$$\delta(U_i - U_N(i/n)) = \mu_\pi^*(i/n) + \pi_i^* \tag{9}$$

where $\mu_\pi^*(i/n)$ and $\pi_i^*$ are defined respectively by

$$\mu_\pi^*\left(\frac{i}{n}\right) := \mu_\pi\left(\frac{i}{n}\right) - (1-\varphi)\mu_\pi\left(\frac{i+1}{n}\right) - \varphi\mu_\pi\left(\frac{i-1}{n}\right) \tag{10}$$

and

$$\pi_*^i := \pi_d^i - \varphi\pi_{i-1}^d - (1-\varphi)\mathbb{E}(\pi_{i+1}^d \mid \mathcal{I}_i), \tag{11}$$

According to (7) and (8), $\pi_*^i$ is a mean-zero stationary random process. Moreover, because $\mu_\pi(\cdot)$ is Lipschitz-continuous over [0, 1], one can show that

$$(12) \qquad \left|\mu_\pi^*\left(\frac{i}{n}\right)\right| \le \left|\mu_\pi\left(\frac{i+1}{n}\right)-\mu_\pi\left(\frac{i}{n}\right)\right| + \varphi\left|\mu_\pi\left(\frac{i+1}{n}\right)-\mu_\pi\left(\frac{i-1}{n}\right)\right| = O\left(\frac{1}{n}\right)$$

Thus, by applying (12) to (9), we can rewrite the hybrid *NKPC* with a time-varying *NAIRU* in (6) as in the following equation:

$$(13) \qquad U_i = U_N\left(\frac{i}{n}\right) + O\left(\frac{i}{n}\right) + e_i$$

Here, $e_i = \pi_i^* / \delta$ is mean-zero stationary due to the mean-zero stationarity of $\pi_i^*$. In addition, the inflation variables in (6) are included as $O(1/n)$ and $e_i$. Equation (13), derived from the model (6), will serve as the main workhorse in estimating and constructing the *UCB* of the *NAIRU* parameter in the hybrid *NKPC* here. Given equation (13), we propose a local-linear regression (Cleveland 1979) estimate of the time-varying *NAIRU* $U_N(\cdot)$ because this method minimizes the well-known boundary problem in the kernel-based regression process. The estimation of $U_N(\cdot)$ can be done by the following local-linear regression,

$$(14) \qquad \hat{U}_N(t) = \sum_{i=1}^{n} w_n(t, i) U_i$$

Where $w_n(t, i) = K\left(\frac{t - i/n}{b_n}\right)\frac{S_2(t) - (t - i/n)S_1(t)}{S_2(t)S_0(t) - S_1^2(t)}$ with $S_j(t) = \sum_{i=1}^{n}(t - i/n)^j K\left(\frac{t - i/n}{bn}\right)$. As in (4), the Epanechnikov kernel is used and the bandwidth is chosen by GCV. The time domain of $t$ is fixed over $t \in [0, 1]$ and $w_n(t, i)$ is the weight given to each observation. The asymptotic consistency of the local-linear estimate $\hat{U}_N(t)$ is provided by Kim (2016).

To carry out inference of the *NAIRU* in (6), one can employ the idea of uniform inference as in the previous section. Given its estimate in (14), the uniform confidence band (*UCB*) of $U_N(\cdot)$ in (6) can be constructed. The theoretic justification of the methodology is provided by the following:

**Theorem 1. (Invariance Principle)** *Let* $\hat{U}_N(t)$ *be the estimator from (14). According to* $nb_n^3 + 1/(nb_n^2) = o(1)$ *and given the trend-stationarity in (7) and (8),*

$$(15) \qquad \sqrt{\frac{nb_n}{\log(n)}} \sup_{0\le t\le 1}\left|\frac{\hat{U}_N(t)-U_N(t)}{\sigma_e}-\sum_{i=1}^{n} w_n(t,\,i)Z_i\right| = o_{\mathbb{P}}(1)$$

*where* $\sigma_e^2 = \sum_{k\in\mathbb{Z}} \mathbb{E}(e_0 e_k)$ *is the long-run variance of* $e_i = \pi_i^* / \delta$ *in (13). Here,* $Z_i$ *is an IID standard normal random variable.*

The main idea in the proof of (15) is provided in the Appendix. The invariance principle in Theorem 1 states that we can approximate the quantiles of $sup_{0\le t\le 1}\left|\frac{\hat{U}_N(t)-U_N(t)}{\sigma_e}\right|$ using the quantiles of the sampling distribution of $sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,\,i)Z_i\right|$, because we have $sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,\,i)Z_i\right| = O_{\mathbb{P}}\left(\sqrt{\frac{\log(n)}{nb_n}}\right)$ from Kim (2016). This is an important and useful result because it means that we can easily approximate the quantiles of the proposed test statistic using IID standard normal random variables instead. Without this result, we have to use the asymptotic distribution of $sup_{0\le t\le 1}\left|\frac{\hat{U}_N(t)-U_N(t)}{\sigma_e}\right|$ in order to construct the uniform confidence bands of $U_N(t)$. However, this approach should be used with great caution because the asymptotic distribution $sup_{0\le t\le 1}\left|\frac{\hat{U}_N(t)-U_N(t)}{\sigma_e}\right|$ is an extreme-value (or Gumbel) distribution (Kim 2015). It is well known that convergence to this distribution is extremely slow and that the confidence bands based directly on this distribution could be very inaccurate if the sample size is not large enough. Given Theorem 1, we propose the following steps to carry out the uniform inference of *NAIRU*:

(i) Select the optimal bandwidth bn for our local-linear regression (14) based on the generalized cross-validation (*GCV*) method (Craven and Wahba 1979).
(ii) Obtain the local-linear estimate ÛN (t) proposed in (14). Here, we use an Epanechnikov kernel.
(iii) Compute $sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,\,i)Z_i\right|$, where $w_n(t,\,i)$ is the weight for local-linear regression in (14), and the $\{Z_i\}$ values are generated IID standard normals.
(iv) Repeat (iii), for instance 1,000 times. We obtain the 95th quantile of this sampling $sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,\,i)Z_i\right|$, and denote it as $\hat{q}_{0.95}$.

(v) Estimate $\sigma_e$ using the following *subseries variance estimator* proposed by Carlstein (1986) and extended by Kim (2016),

$$\hat{\sigma}_e^2 := \frac{1}{2(m-1)k_n}\sum_{i=1}^{m-1}\left[\sum_{j=1}^{k_n}\left(U_{j+ik_n} - U_{j+(i-1)k_n}\right)\right]^2 \tag{16}$$

where $k_n$ is the length of the subseries and $m = \lfloor n/k_n \rfloor$ is the largest integer not exceeding $n/k_n$. Carlstein (1986) shows that the optimal length of the subseries is $kn \asymp n^{1/3}$. In practice, we choose $k_n \in \left(n^{1/3}, n^{1/2}\right)$. The asymptotic consistency of $\hat{\sigma}_e^2$ to $\sigma_e^2$ is given by Carlstein (1986) and Kim (2016).

(vi) The 95% *UCB* of $U_N(t)$ is $\left[\hat{U}_N(t) \pm \hat{\sigma}_e \hat{q}_{0.95}\right]$.

As in the case of the random-walk Phillips curve, the above *UCB* is more effective for inference with a finite sample than the usual *UCB* based on asymptotic results because the proposed method allows us to avoid the problem of slow convergence. The constructed *UCB* will be used to test various hypotheses regarding the *NAIRU*, such as the hypothesis that it has been falling since the early 1980s. A detailed description of the data and the empirical results will be provided in the following section.

## D. *Inflation Forecasting*

One of the main purposes of using the Phillips curve in practice is to forecast inflation series. Given the uniform inference procedures developed here, one carry out the forecasting through model validation. If a parametric model is justified through uniform inference, then the model is then used to generate forecasts. If not, alternative semi-parametric fits can be used to forecast the variable. That is, the *UCB* can provide the model selection criterion for forecasting. Specifically, we propose the following steps to forecast monthly inflation for the Korean economy:

(i) Test for a structural break.
(ii) If there is a break, then reduce the sample to the post-break period. Otherwise, use the entire sample.
(iii) Construct the uniform confidence band (*UCB*) of the *NAIRU* parameter.
(iv) Test the null hypothesis of a constant *NAIRU* based on the constructed *UCB*.
(v) If the null hypothesis is accepted, inflation is forecast based on the estimate of the constant *NAIRU*.
(vi) If not, use the average of the non-parametric estimates for the *NAIRU* to forecast inflation.

In this experiment, we generate point-ahead forecasts of inflation and obtain the forecast errors. A subset of the sample is used to estimate the Phillips curve. Given the estimate, the underlying model is updated to the next time point. Using the first-stage estimate and the updated covariate, the inflation variable is forecast. In principle, the above procedures are applied to the sample after the potential break date only. However, we also apply them to the entire sample for reference such that the forecasting results based on the two samples can be compared.

## III. Empirical Results

The data are obtained from the homepage at the Bank of Korea (http://www.bok.or.kr). They include the monthly consumer price index (CPI) and monthly unemployment rate from July of 1982 to May of 2015. The CPI is converted to the monthly inflation rate before it is used with the two Phillips curves. Given the potential break at the end of 1997, the sample is divided into the pre-break period (until the end of 1997) and the post-break period (the remaining sample). In the forecast of inflation, we employ both the entire sample and the sample of the post-break period only. Regarding the inference on the *NAIRU* parameter, both the random-walk Phillips curve and the new Keynesian Phillips curve (*NKPC*) are used. First, the inference results for the random-walk Phillips curve and for the *NKPC* are summarized in Figures 1 and 2, respectively.

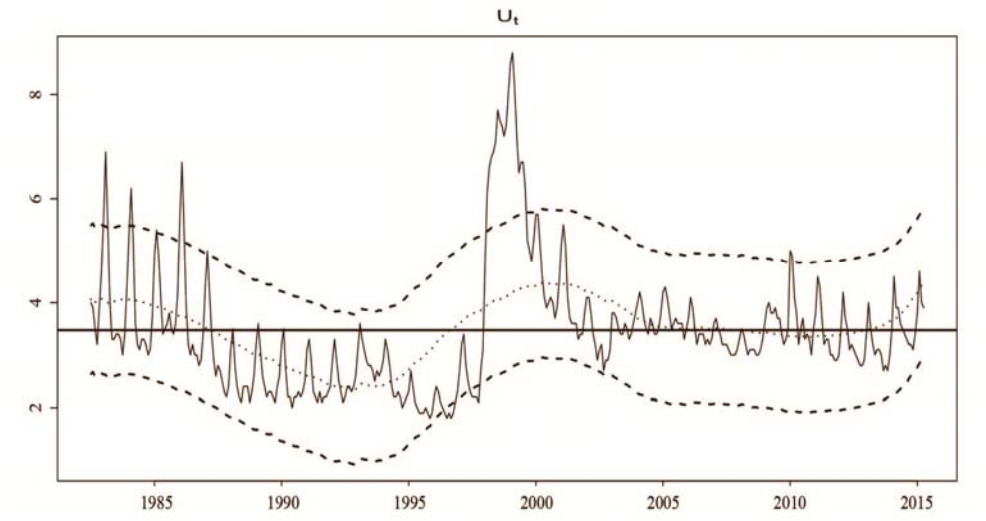


FIGURE 1. TIME-VARYING *NAIRU* FOR THE KOREAN ECONOMY (JULY 1982 – MAY 2015)

*Note*: The curve (dotted) in the middle of the band is a local-linear estimate of *NAIRU* in the **Random-Walk Phillips Curve**. For the local-linear regression, we use an Epanechnikov kernel. The GCV chooses bn = 0.15. The band (dashed) is 95% uniform confidence band (*UCB*) of *NAIRU*. The estimate of *NAIRU* and the *UCB* are placed over the monthly unemployment rates (light solid). The fitted horizontal line for a constant *NAIRU* (dark solid) is U = 3.47.

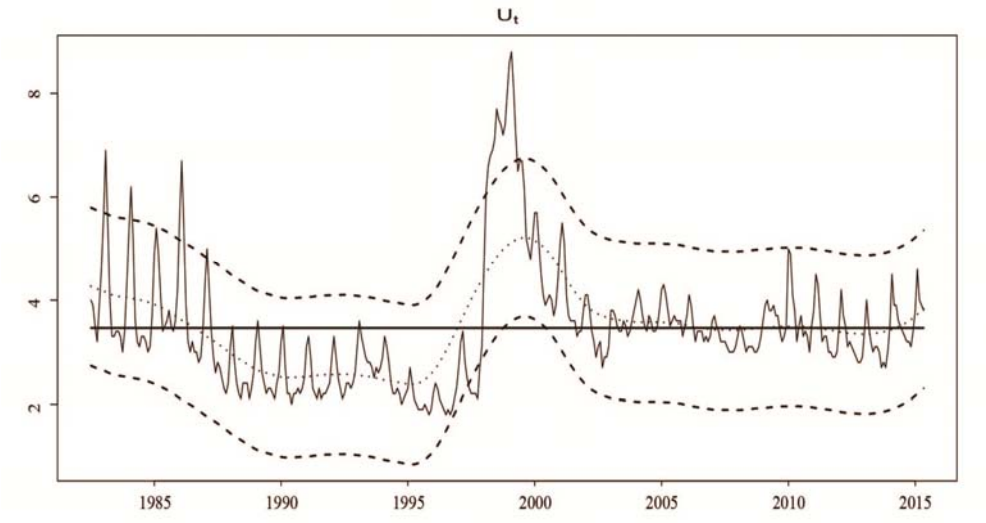


FIGURE 2. TIME-VARYING *NAIRU* FOR THE KOREAN ECONOMY (JULY 1982 - MAY 2015)

*Note*: The curve (dotted) in the middle of the band is a local-linear estimate of the *NAIRU* in the **New Keynesian Phillips Curve**. For local-linear regression, we use an Epanechnikov kernel. The GCV chooses bn = 0.09. The band (dashed) is the 95% uniform confidence band (*UCB*) of the *NAIRU*. The estimates of the *NAIRU* and the *UCB* are shown over the monthly unemployment rates (light solid). The fitted horizontal line for a constant *NAIRU* (dark solid) is U = 3.46.

## A. *Inference of the NAIRU*

Figure 1 reports the monthly unemployment data (light solid) and the estimate of the fixed *NAIRU* (dark solid) in the random-walk Phillips curve. The estimate of the traditional fixed *NAIRU* for July of 1982 to May of 2015 is 3.47(%). The light-dotted curve is the semi-parametric fit in (4), and the surrounding band (dark-dotted) is the 95% uniform confidence band (*UCB*) of the *NAIRU* parameter. As shown in the figure, the semi-parametric fits clearly show the time variation of the *NAIRU* during this period. The *NAIRU* decreases during the economic expansion of the late 1980s and the early 1990s. The estimate rises in the late 1990s and reaches its peak just after the 1997 financial crisis. Then, it starts declining again and remains around the fixed estimate from that point. The variation in the cyclical unemployment matches the Korean business cycles during the period, which indicates that the model-based semi-parametric *NAIRU* estimates are reasonable.

One of the advantages of using the results in Figure 1 is that they enable the uniform inference of the *NAIRU*. In order to accept a certain null hypothesis for the *NAIRU* parameter, the null value must be contained by the *UCB* over the entire period. Otherwise, the null hypothesis is rejected. For example, if the 95% *UCB* contains the estimate of the fixed *NAIRU* during the period of July of 1982 to May of 2015, the hypothesis of a constant *NAIRU* during the period is accepted. If not, the null is rejected at the 5% level. The important point is that the null value must be contained by the *UCB* during the entire period to be accepted. Figure 1 indicates that the hypothesis of a constant *NAIRU* is accepted at the 5% level because the fixed estimate is entirely contained within the 95% *UCB*.

In contrast, Figure 2 illustrates the estimation and inference results under the

*NKPC* during the same period. The estimate of a fixed *NAIRU* under *NKPC* is shown by the horizontal line at 3.46%. That is, there is little difference in the fixed *NAIRU* estimate between the random-walk Phillips curve and the *NKPC*. As before, the non-parametric estimate of the time-varying *NAIRU* and its 95% *UCB* for the *NKPC* are shown by the light-dotted and dark-dotted curves, respectively. Although they agree in general, the finer results under the *NKPC* and those based on the random-walk Phillips curve differ. For example, the maximum value of the time-varying *NAIRU* under the *NKPC* is higher than that in the random-walk case. However, the increase in the *NAIRU* at the end of the sample period is higher under the random-walk Phillips curve than in the *NKPC* case. Otherwise, the results under the different models are in general agreement.

The most noticeable difference between Figure 1 and Figure 2 is that the hypothesis of a constant *NAIRU* is rejected at the 5% level for the *NKPC*. The 95% *UCB* presented in Figure 2 fails to contain the horizontal estimate of a fixed *NAIRU* at the turn of the century. The dramatic increase in the *NAIRU* from the late 1990s raises the confidence level as well, and this increase eventually leads to the rejection of the null hypothesis at the 5% level. As noted above, the relatively high increase in the *NAIRU* estimate under the *NKPC* during the late 1990s explains why there is a change in the test result. Indeed, Figures 1 and 2 provide useful information regarding the potential variation in the *NAIRU*. However, they also raise the issue of robustness given the range of possible models to consider in the inference process.

## B. *Inflation Forecasting*

For forecasting inflation based on the Phillips curves, we employ both the full sample (July of 1982 to May of 2015) and the post-break sample (January of 1998 to May of 2015). For each sample, a pseudo-out-of-sample forecasting experiment is conducted based on the random-walk Phillips curve using the first half of the observations.

In each case, both a rolling window of a fixed length and an expanding window with an increasing length are utilized to assess the robustness of the results. To measure the accuracy of point-ahead inflation forecasts, the standard mean-absolute-error (MAE) and the root-mean-squared-error (RMSE) are used. The forecasting results are summarized in Tables 2 and 3. In both tables, "fixed *NAIRU*" refers to the forecast results under the constant *NAIRU*, while "time-varying *NAIRU*" means that the forecasting is carried out through validation of the *UCB*-based model.

Table 2 shows the forecast results based on the full sample. Each error is divided by the lowest corresponding error. For example, the RMSE under the fixed *NAIRU* when the expanding window is used is divided by the RMSE under the time-varying *NAIRU* because the latter is smaller than the former, and so forth. In each case, the error measure under the time-varying *NAIRU* is lower than that under the fixed *NAIRU*, indicating that the inflation forecasts obtained through the inference procedure are more accurate than those based on the fixed *NAIRU* estimate. As shown in Table 3, the same pattern carries over to the case when only the post-break data are used to forecast the monthly inflation. Although the forecast gain is

TABLE 2—FORECAST ERRORS: FULL SAMPLE
(EACH ERROR IS DIVIDED BY THE LOWER CORRESPONDING ERROR)

| | expanding window | | rolling window | |
|---|---|---|---|---|
| | Fixed *NAIRU* | Time-varying *NAIRU* | Fixed *NAIRU* | Time-varying *NAIRU* |
| RMSE | 1.1104 | 1.0000 | 1.1441 | 1.0000 |
| MAE | 1.0807 | 1.0000 | 1.1024 | 1.0000 |

TABLE 3— FORECAST ERRORS: POST-BREAK SAMPLE
(EACH ERROR IS DIVIDED BY THE LOWER CORRESPONDING ERROR)

| | expanding window | | rolling window | |
|---|---|---|---|---|
| | Fixed *NAIRU* | Time-varying *NAIRU* | Fixed *NAIRU* | Time-varying *NAIRU* |
| RMSE | 1.0918 | 1.0000 | 1.0779 | 1.0000 |
| MAE | 1.0814 | 1.0000 | 1.0889 | 1.0000 |

not great in both cases, the results in Tables 2 and 3 confirm that one can clearly benefit from generating inflation forecasts through the *UCB*-based inference approach suggested in this study.

## C. *Policy Implications*

In macroeconomics, the *NAIRU* parameter plays an important role because this structural parameter allows us to determine the current status of the economy in the business cycle. If the current unemployment rate is below the *NAIRU*, the economy is believed to be undergoing an economic expansion. Otherwise, it is in recession. Given an alternative means of estimating and conducting inference on this important parameter, we discuss the policy implications of the empirical results here.

Figures 1 and 2 demonstrate that there are multiple time points during which the unemployment rate is located between the fixed *NAIRU* estimate and the smoothly varying semi-parametric estimate. From Figure 1, the Korean unemployment rate is above the semi-parametric estimate and below the fixed estimate during much of the first half of the 1990s. According to the fixed *NAIRU*, the Korean economy expanded during this time. However, the semi-parametric estimate says the opposite: the economy went through a recession. This finding has significant policy implications due to they need to introduce completely different policy changes depending on which estimate to believe. If using the fixed estimate of 3.47%, it becomes necessary to stabilize the economy with certain contractionary policies. If policymakers use the semi-parametric measure instead, they need to stimulate the economy by introducing expansionary policies.

Given these two completely different options on the table, policymakers may want to resort to using the *UCB*-based inference of the Phillips curve. That is, if the constructed *UCB* accepts the hypothesis of a constant *NAIRU* by completely covering it, it may be wise to determine that the economy is undergoing an expansion and to change policies accordingly. In contrast, if the *UCB* rejects the hypothesis, it would be reasonable to believe that the economy is in a recession and

to stimulate it by introducing the proper policies. Given the gravity of the consequence of adopting incorrect policies, it is crucial to decide wisely when determining the status of the business cycle. Clearly, the *UCB*-based inference methodology in this work can be used to achieve this goal.

Regarding this issue, one also must consider the robustness of the inference. The inference results based on the two models here are quite contradictory: the *UCB* based on the random-walk Phillips curve accepts the fixed *NAIRU* hypothesis, whereas that based on the *NKPC* rejects it. That is, one cannot use the fixed *NAIRU* estimate for policy analysis if the *NKPC* is believed to be the underlying model. Given that we understand how different the policy suggestion could be depending on which *NAIRU* estimate to trust, it is important to be able to determine which model is the true underlying framework. Unfortunately, the methodology developed in this work applies only to the selection of the correct form for the *NAIRU* parameter. Further research is needed to develop a methodology to determine the proper model framework.

## D. *Comparison to Business Cycle Measures*

Given the potential difference between business cycle decisions based on the traditional fixed *NAIRU* and the time-varying case, we can compare the results under these two different specifications and the official business cycle decisions announced by the South Korean Government on a routine basis. Among the most standard measures of the business cycle are those by the Korean Statistical Information Service (KOSIS), which are announced every month. The data contain binary values: either zero (i.e., a recession) or one (i.e., an expansion). The sample is trimmed for a comparison between the official decisions by KOSIS and the decisions under our methodology during the period of July of 1982 to July of 2011. The frequency of the data is monthly, which gives us a total of 349 decisions.

We first compare the KOSIS decisions on the Korean business cycle and those made with the time-varying *NAIRU* estimates in order to observe the percentage of these decisions that matches. Because the original monthly Korean unemployment data are very irregular, we perform some preliminary smoothing before comparing them to the time-varying *NAIRU* estimates. The data shows that approximately 71 percent of the business cycle decisions during the period of July of 1982 to July of 2011 match, with the number slightly increasing to approximately 73 percent between the fixed-*NAIRU*-based decisions and the KOSIS announcements.

Two features are noteworthy in this outcome. First, the majority of these decisions based on the different approaches appear to agree in general, although there is also quite a considerable amount of discrepancy among the decisions. In a sense, some degree of difference among the results is predictable because the three methodologies are fundamentally different. Second, the decisions based on the fixed *NAIRU* hypothesis appear to be marginally closer to the KOSIS decisions than those based on the time-varying *NAIRU*. One potential reason for this outcome stems from the methodology used for the KOSIS decisions, which is likely to be based on the traditional hypothesis of a "fixed" *NAIRU*, although we are not entirely sure of the particular methodology employed for the decision. Because we innovate with the traditional fixed-*NAIRU* assumption in this paper,

the results derived under the proposed methodology are likely differ from the decisions based on the traditional assumption regarding the parameter, which is what we observe in this experiment. The reported difference among the business cycle decisions makes it very important to have some reliable inference procedures for the potentially time-varying *NAIRU* parameter. The methodology proposed in this work can be used to such an end.

## IV. Conclusion

In this study, we consider two widely used version of the Phillips curve: the random-walk Phillips curve (Staiger, Stock and Watson 1996, 1997) and the New-Keynesian Phillips curve (*NKPC*) (Gal´ı, J. and Gertler 1999). We undertake uniform inference of each model and check whether the empirical data support the representative parametric framework. The inference is conducted through the construction of a uniform confidence band (*UCB*) for the *NAIRU*. It was found that the widely believed constancy of the *NAIRU* is rejected under the *NKPC* for the Korean economy, whereas parameter constancy is accepted under its random-walk counterpart.

We apply the developed methodology to inflation forecasting. If the parametric fit is entirely covered by the constructed *UCB*, the in-sample fit is extended out-of-sample to forecast the inflation variable. If the fit is not covered by the *UCB*, we resort to the averaged semi-parametric fits of the time-varying *NAIRU*. In a pseudo-out-of-sample forecasting experiment conducted here, the forecasts under this method and those under the traditional random-walk Phillips curve are compared to assess their relative advantages. For both the entire sample and the post-break sample, the *UCB*-based forecasts are found to be superior to those based on the traditional approach. The superiority of the *UCB*-based forecasts persists under both the rolling-window and expanding-window schemes.

The current project leaves a number of interesting topics for potential future research. First, the paper uses the uniform inference methodology to choose between the fixed *NAIRU* estimate and the smoothly time-varying cases for inflation forecasting. In fact, the presence of structural breaks is highly likely in the Korean economy. At the same time, both the number of potential breaks and their dates are uncertain. To address this uncertainty, one can perform forecast averaging based on the *UCB*. Assuming that any date in the sample could be a potential break date, we forecast based on parametric models with breaks that are justified by the *UCB* only. The forecasts accepted by the *UCB* are then combined through averaging. Because this approach handles model uncertainty via an averaging method, the accuracy of the forecasts could be higher than that of the forecasts here.

Another interesting extension would be to develop a methodology for selecting the correct Phillips curve in the beginning. The current work assumes that the correct Phillips curve to use is either the random-walk curve or the *NKPC*. Inference is then conducted on the model parameter. In this sense, the approach here is semi-parametric. However, no justification of the assumption is provided in the current work. As shown in Figures 1 and 2, the inference outcome could be

rather model-sensitive, and it lacks in robustness. By providing some reliable guideline on the issue, we can make the current result more robust and reliable from the perspective of policy analysis. Further insight can be gained by extending the work in these and in other directions.

## APPENDIX

The proof of Theorem 1 is based on the trend-stationarity of the inflation variable and the invariance principle in Kim (2015). We provide here only a sketch of the proof. For details of the proof, we refer the reader to Kim (2015).

**Proof of Theorem 1**

Recall that we have the hybrid *NKPC* in equation (9) due to (7) and (8). By performing a Taylor's expansion on $U_N(\cdot)$ in (9), we can show the following,

$$
\begin{aligned}
&\sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,i)\left[U_i - U_N(t)\right] - \sigma_e \sum_{i=1}^{n} w_n(t,i) Z_i\right| \\
&= \sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,i)\left[U_N(i/n) + O(1/n) + e_i - U_N(t)\right] - \sigma_e \sum_{i=1}^{n} w_n(t,i) Z_i\right| \\
&= \sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,i)\left[U_N(i/n) - U_N(t)\right] + O(1/n) + \sum_{i=1}^{n} w_n(t,i)\left(e_i - \sigma_e Z_i\right)\right| \\
&= \sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t-i/n)\, w_n(t,i) U_N'(t)\right| + C \sup_{0\le t\le 1}\left|\sum_{i=1}^{n} (t-i/n)^2\, w_n(t,i) U_N''(t)\right| \\
&\quad + O(1/n) + \sup_{0\le t\le 1}\left|\sum_{i=1}^{n} w_n(t,i)\left(e_i - \sigma_e Z_i\right)\right| \\
&= O(b_n) + O(b_n^2) + O(1/n) + o_{\mathbb{AS}}\left(\frac{\log(n)}{n^{3/4} b_n}\right)
\end{aligned}
\tag{17}
$$

where $C$ is some constant. The last equality is due to the smoothness of the *NAIRU*, the Lipschitz-continuity of the kernel, and Lemma 2 in Kim (2015). Then, according to $\sum_{i=1}^{n} w_n(t,i) = 1$, we have

$$
\sqrt{nb_n}\sup_{0\le t\le 1}\left|\hat{u}^*(t) - u^*(t) - \sigma_e \sum_{i=1}^{n} w_n(t,i) Z_i\right| = O\left(n^{1/2} b_n^{3/2}\right) + O\left(\sqrt{\frac{bn}{n}}\right) + o_{\mathbb{AS}}\left(\frac{\log(n)}{n^{1/4} b_n^{1/2}}\right)
$$

Then, with $nb_n^3 + 1/(nb_n^2) = o(1)$,

$$\sqrt{nb_n}\sup_{0\le t\le 1}\left|\frac{\hat{U}_N(t)-U_N(t)}{\sigma_e}-\sum_{i=1}^{n}w_n(t,i)Z_i\right| = o_{\mathbb{P}}(1)$$

which leads to

$$\sqrt{\frac{nb_n}{\log(n)}}\sup_{0\le t\le 1}\left|\frac{\hat{U}_N(t)-U_N(t)}{\sigma_e}-\sum_{i=1}^{n}w_n(t,i)Z_i\right| = o_{\mathbb{P}}(1)$$

□

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# Private Equity as an Alternative Corporate Restructuring Scheme: Does Private Equity Increase the Operating Performance of PE-Backed Firms?

*By* JAHYUN KOO*

*There has been a surge of interest in private equity as an alternative corporate restructuring scheme to complement the current institutional forms such as workouts and court receivership. By empirically examining whether private equity in Korea can improve investee companies, we find that while private equity in Korea did not sacrifice the long-term growth potential of investee firms, it did not improve their profitability (e.g. ROA, ROE, and ROS) or growth (e.g. sales growth) either. Both the negative correlation between business performance and firm age and our empirical results showing that young firms were favored by private equity for investment imply that Korean private equity may perform as growth capital, similar to venture capital rather than as buyouts for corporate restructuring.*

Key Word: private equity, corporate restructuring, business performance, buyouts, growth capital
JEL Code: G34, G32, H25

## I. Introduction

The Korean economy has continued to show sluggish growth since 2010, and company profitability levels have deteriorated among Korean firms. In addition, the number of marginal firms, termed “zombie companies,” has increased. Accordingly, preemptive corporate restructuring must take place before a large number of corporate insolvencies can be realized (Bank of Korea 2015; Jeong 2014; Jeong and Nam 2015). The country's current leading corporate restructuring schemes include corporate structure improvements, “workouts,” and corporate rehabilitation proceedings, also known as “court receiverships.” However, these corporate restructuring procedures led by institutions have had limited effects on business regeneration as they are basically different forms of ex post corporate

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restructurings, as the processes are conducted after corporate distress has progressed significantly, thereby resulting in considerable costs being incurred, such as a large number of employment adjustments and conflict of interests among stakeholders. Financially advanced countries, including the U.S., actively undertake ex ante corporate restructuring in an effort to eliminate inefficiencies in companies prior to corporate failures, also enacting post-restructuring processes for insolvent companies by utilizing the capital market and, in particular, private equity. Though the opinion that private equity should be actively engaged in corporate restructuring as a complementary corporate restructuring scheme for government-led initiatives is gaining popularity in Korea (Kim and Bin 2012), few studies have attempted to test whether Korean private equity can perform such roles empirically and to determine the policy options for revitalizing private equity as an alternative corporate restructuring procedure or invigorating private equity industry itself. This study attempts to fill this gap.

Whether private equity can assume the functions of alternative corporate restructuring schemes is eventually determined by whether private equity can increase the value of the companies in which it invests. While research continues on how business performance has changed since private equity investing has been actively carried out overseas (e.g., Kaplan 1989; Smith 1990; Cohn and Towery 2014), few studies have been done in Korea given its short history of private equity. This paper empirically investigates how the operating performance of PE-backed firms oriented toward profitability and growth has changed since firms accepted private equity investment. In particular, we carried out an event study which statistically tests changes in operating performance levels between business performances levels before and after a firm accepts private equity investment for the period from 2006 to 2012. We analyzed firm performance while deleting outliers and adjusting industry average levels to enhance robustness. We also ran a regression model to estimate whether the characteristics of private equity have had an impact on the profitability of PE-backed firms. In addition, we made use of propensity score matching for 2012, a year with relatively many PE-backed firms, to complement the results of the event study. Finally, we draw implications from the perspective of policy and the private equity industry.

The results of the event study and those of the statistical test demonstrate that private equity in Korea has been unable to improve profitability (e.g., ROA, ROE, and ROS) and growth (e.g., sales growth), although it does not seem to affect the long-term growth potential of the investee companies in terms of their investment activities, financial stability, and employment levels. Furthermore, the negative relationship between business performance and the age of firms, and the fact that younger firms have been favored by private equity with regard to investment choices, both suggest that private equity in Korea may not be in the form of buyouts (which serve as a corporate restructuring vehicle) but rather as growth capital (acting as venture capital). One of the reasons private equity could not demonstrate the ability to create value in its portfolio is that private equity firms have not had enough opportunities to build up such a capability owing to their short history. Different corporate restructuring market conditions existed compared to those immediately after the foreign exchange crisis, along with governmental regulation and excessive intervention. Therefore, the government should deregulate

to foster dynamism and innovativeness among Korean private equity. The private equity industry itself should also strengthen its capacity through various efforts (e.g., obtaining professional management teams). Finally, private equity funds must grow before they can carry out market-friendly corporate restructuring given the likely increase in the level of demand for corporate restructuring in the future, especially for large companies.

The remainder of this paper is organized as follows. Section II discusses the impact of private equity investments on business performances levels by reviewing the literature in this area. Section III describes our data, and Section IV explores whether private equity firms in Korea have improved the operating performance levels of their investee companies. We analyze and discuss the empirical results in Section V, and Section VI concludes the paper.

## II. The Impact of Private Equity Investment on Business Performance

Whether private equity can take on the role of alternative corporate restructuring schemes eventually depends on whether private equity can increase the value of a company in which it invests. Both theoretical and empirical studies have actively been carried out in an effort to examine whether private equity increases the value of the firms in the portfolio. Theoretically, it is argued that private equity can improve the operations of supported firms by reducing agency costs (Jensen 1986, 1989). Private equity adjusts manger incentives to meet the interests of executives such that improvements in the operating performance of a firm are a benefit for them. They also closely monitor the firms in which they have invested by actively joining the board of directors and taking part in proceedings. From a practical perspective, private equity has the ability to improve the operations of firms through what are known as the 4Cs: capabilities, clarity, culture, and capital (Private Equity Council 2015).[1]

Empirical research on whether private-equity-backed firms show improved operations has been vigorous internationally. Kaplan (1989) examined changes in the business performances levels of 76 instances of large management buyouts of public companies between 1980 and 1986, finding evidence which showed that within three years after the transaction, operating income, cash flow and market value all show improvements. He argued that enhanced performance arose not due to cost reductions by cutting jobs but as a result of an increase in efficiency through enhanced incentive measures. Smith (1990) and Smart and Waldfogel (1994) also showed substantial improvements in operating performance levels after U.S. management buyouts in the 1980s. By investigating the changes in operating performance between the time periods prior to and after private equity investments, Muscarella and Vetsuypens (1990) found substantial increases in the profitability of the reverse leveraged buyouts, referring to firms that have completed an initial public offering under a leveraged buyout.

[1]In the same context, Kaplan and Strömberg (2009) argued that private equity enhances the value of the investees through three actions—financial engineering, governance engineering, and operational engineering—which are not necessarily mutually exclusive.

More recent papers also confirm that private equity plays a positive role in improving firms in which investments have been made. Guo, Hotchkiss, and Song (2011) delved into whether leveraged buyouts of 192 firms between 1990 and 2006 created value, finding empirical evidence corroborating the claim that public-to-private companies show improvements with regard to EBITDA/sales by 11% in comparison to a matched sample of firms that had not been taken private. Cohn and Towery (2014), making use of U.S. corporate tax return data on private firm buyouts between 1995 and 2009, provided evidence that private firms acquired in private equity buyouts go through substantial operational increases in the post-buyout period, both in terms of operating performance and growth. They argued that private equity creates value in the portfolio firms either by leading to operational turnarounds of struggling firms or by relaxing financing constraints that limit the growth of healthier firms.

Meanwhile, in contrast to claims that private equity opportunistically attempts to increase the operating value of acquired firms either by stripping the firm, reducing investments, or slashing large numbers of jobs rather than making efforts ultimately to create value, a number of empirical papers have shown the opposite. Smith (1990) found significant evidence that 58 buyout firms showed increases in operating returns when comparing the years before and after the buyouts. These positive changes in operating performance levels were not the result of layoffs or reductions in expenditures for R&D or equipment. Davis *et al.* (2014) argued that private equity raises the total factor productivity of the target firms by divesting the less productive business sectors and acquiring more productive ones. With respect to employment, Boucly *et al.* (2009) demonstrated increases in employment by 13 percent when comparing the three years before and four years after buyouts for French buyout firms. In addition, Davis *et al*. (2011) found that the net relative job losses at target firms were less than 1 percent of initial employment, owing to the rapid reallocation of jobs across establishments within the target firms. Finally, Amess and Wright (2007) found that buyouts in the UK brought about modest declines in employment.

In comparison to western countries, which have a long history of private equity, allowing for active research to access whether private equity can enhance the business performance of target firms, few studies have investigated the effect of private equity on the target value of firms in Asia. Kim and Cho (2009), utilizing 29 samples from 2004 to 2006, estimated that private equity investment has a positive effect on current ratios, risk, and on the ratio of net income to net sales for firms. Park *et al.* (2006) analyzed value changes in firms which maintained business relationships with First Bank after First Bank was acquired by overseas private equity. They found evidence that the acquisition of what was a domestic bank by overseas private equity had negative effects on the value of firms with which First Bank had a business relationship. Recently, Song (2015) conducted event studies of 43 companies which had received private equity investments and which were listed on KOSPI and KOSDAQ from 2006 to 2011. Song explored through t-tests whether private equity investment had helped to improve the business performance of the target firms and argued that private equity had a positive effect on the firms' investment activities, productivity levels, and PBR. He also argued that private equity investment had a negative effect on profitability,

dividends, and employment, although the empirical results were not statistically significant.

## III. Data

This study uses data reported to the Financial Supervisory Service of Korea by private equity firms.[2] We analyzed companies listed on KOSPI and KOSDAQ targeted by private equity firms from 2006 to 2012. We utilized 70 sample observations in our analysis of companies that had received investments from private equity companies more than twice out of 77. To study general trends in operating performance levels, we adopted an event study approach by lining up years across companies and assessed the changes in business performances levels prior to and after private equity investments. We designated the year during which the private equity firm made the investment as year t. We also analyzed profitability by measuring the variables of return on assets (ROA), return on equity (ROE), and return on sales, while growth was captured by sales growth. We also explored the performance metrics of investment activities, leverage, and employment, which are represented by the fixed asset ratio, debt-to-asset ratio, and the number of employees, respectively. We retrieved accounting data from Kis-Database for our analysis. Figure 1 shows the trends of private equity investment activities in the capital market. Private equity firms increased their investments throughout the years from 2006, reaching a total of 77 companies in 2012.

Looking at the total and yearly trends of private equity investee companies by stock market, private equity in Korea invested in KOSDAQ companies grew more than twice as much as in that in companies listed on KOSPI, as shown in Figure 2 and Figure 3. Electric companies and electronic firms were most commonly favored by private equity firms, with machinery companies taking second place, shown in Figure 4.

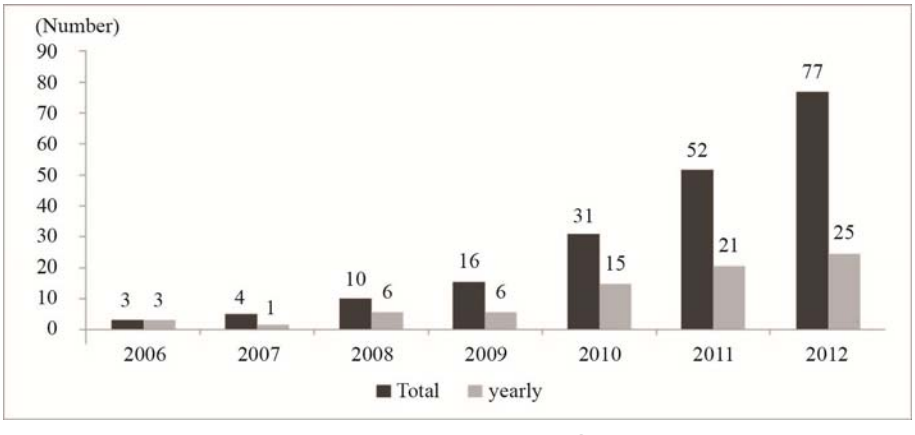


FIGURE 1. NUMBER OF PRIVATE-EQUITY-BACKED COMPANIES BY YEAR

[2]We are grateful to the Financial Supervisory Services (FSS) for providing the data.

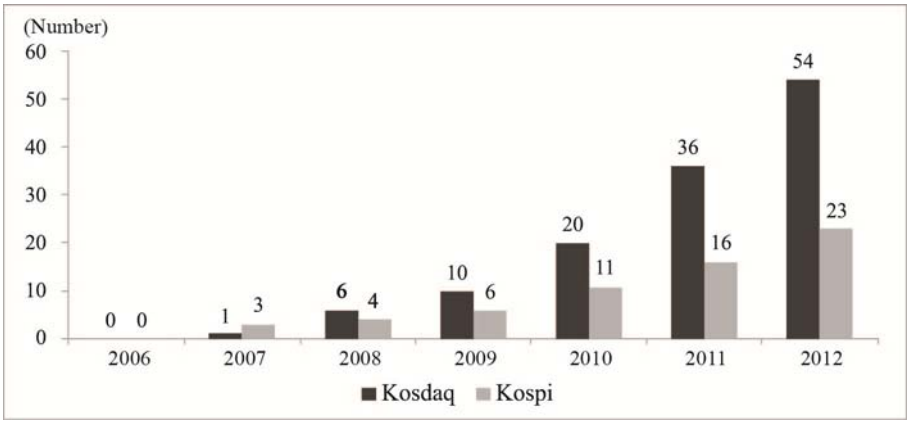


FIGURE 2. TOTAL NUMBER OF PRIVATE-EQUITY-BACKED COMPANIES BY STOCK MARKET

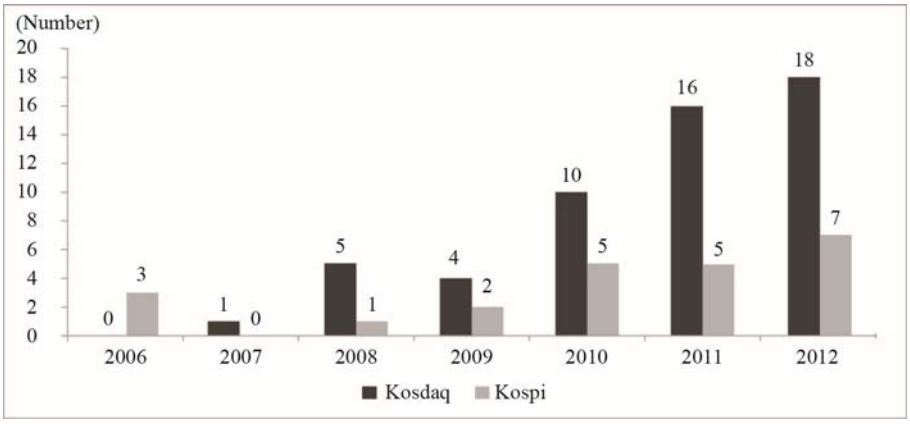


FIGURE 3. YEARLY NUMBER OF PRIVATE-EQUITY-BACKED COMPANIES BY STOCK MARKET

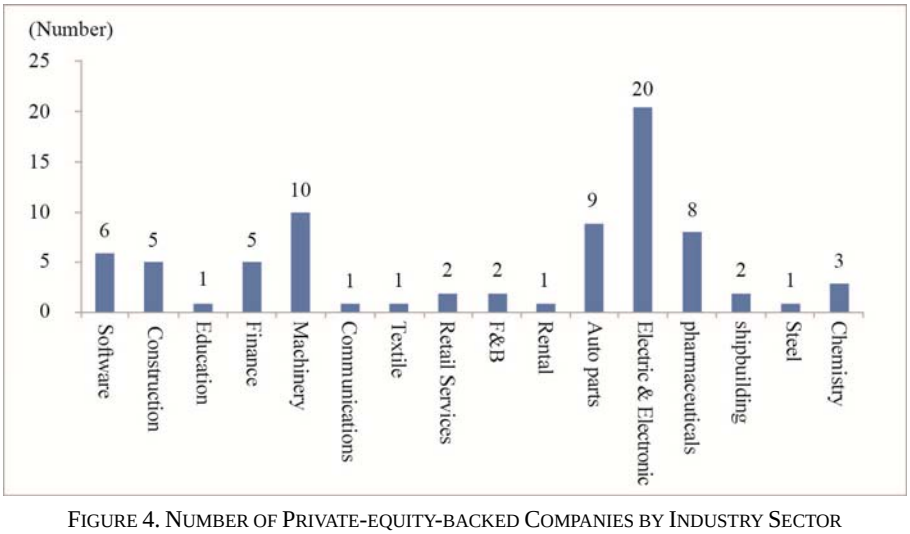


FIGURE 4. NUMBER OF PRIVATE-EQUITY-BACKED COMPANIES BY INDUSTRY SECTOR

## IV. Empirical Results

We mainly focused on how the operating performance metrics, in this case the profitability and growth of the companies targeted by private equity, changed, with an additional assessment of changes with regard to investment activity, leverage, and employment. First, we carried out an event study of ROA, ROE, return on sales and sales growth using all of the samples and then did this with samples winsorized at 5% to limit the influence of potential outliers. We also conducted an event study of these variables after adjusting for industry trends to control for business cycles and idiosyncratic factors within the industry. In addition, we examined whether the individual characteristics of private equity (e.g., investment size) may affect the profitability of PE-backed companies through panel estimations. Regarding the impact on investment activity, leverage, and employment caused by private equity investments, we executed an event study focusing on the fixed asset ratio, debt-to-asset ratio, and number of employees. Finally, we made use of propensity score matching for 2012, when the number of PE-backed companies was highest, to complement the results of the event study and to determine the determination rationale of the private equity investments.

### A. *Operating Performance Results*

#### 1. Operating Performance Trends

We examined operating performance trends for the firms in our sample from two years before (t-2) to two years after (t+2) private equity investments and carried out a t-test to check this statistically and to provide visual evidence. Figures 5 to 8 show the trends of the mean, 25th quartile, and 75th quartile with regard to ROA, ROE, ROS, and sales growth, as well as all of the operating performance metrics expressed in terms of the means, showing that they reached a peak t value and then decreased afterwards. This implies that private equity firms select companies that have a good business before the investment but cannot increase the operating performance levels further of these backed firms. Table 1 contains the results of the t-tests of changes in operating performance levels between t-1 and t+1, between t-1 and t+2, between t-2 and t+1, and between t-2 and t+2. We note that the differences in operating performance levels compared to the levels one year before the investment are all negative and statistically significant, excluding ROE, confirming the implications of the visual evidence. The results of a comparison two years before the investment (t-2) activity show similar outcomes.

To determine if our results are robust, we conducted a t-test to assess changes in operating performance levels from two years before (t-2) to four years after (t+4) private equity investments. As shown in Table 2, the results are qualitatively similar to those of the t-test of the outcomes two years after (t+2) the private equity investments.

TABLE 1—RESULTS OF THE T-TESTS

| | t-1 to t+1 | t-1 to t+2 | t-2 to t+1 | t-2 to t+2 |
|---|---|---|---|---|
| ROA | -1.109 | -3.535* | -0.599 | -3.037 |
| | (1.893) | (1.863) | (1.926) | (1.848) |
| ROE | -0.921 | -23.173 | -0.389 | -23.280 |
| | (6.092) | (17.662) | (6.680) | (18.476) |
| ROS | -3.110 | -4.686*** | 1.839 | 0.303 |
| | (2.360) | (1.550) | (3.978) | (3.348) |
| Sales Growth | -35.853** | -39.104** | -24.745* | -25.103* |
| | (17.947) | (18.769) | (13.017) | (13.350) |

*Note*: Standard errors are in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

TABLE 2—RESULTS OF THE T-TESTS FOR T+4

| | t-1 to t+1 | t-1 to t+2 | t-1 to t+3 | t-1 to t+4 | t-2 to t+1 | t-2 to t+2 | t-2 to t+3 | t-2 to t+4 |
|---|---|---|---|---|---|---|---|---|
| ROA | 0.430 | -4.264 | -6.018** | -3.794 | 1.503 | -3.192 | -4.946 | -2.722 |
| | (3.277) | (3.504) | (2.863) | (3.230) | (4.081) | (3.938) | (4.231) | (4.299) |
| ROE | -4.442 | -53.992 | -21.091 | -4.619 | 115.174 | 65.624 | 98.525 | 114.997 |
| | (6.335) | (38.653) | (15.733) | (5.434) | (112.163) | (119.961) | (113.740) | (11.752) |
| ROS | 0.727 | -5.580* | -8.977 | -10.548 | 5.839 | -0.468 | -3.866 | -5.437 |
| | (3.470) | (3.185) | (5.605) | (6.757) | (6.418) | (5.354) | (8.022) | (9.092) |
| Sales Growth | -57.233 | -63.312 | -67.303 | -71.454* | -161.531 | -160.636 | -160.614 | -166.420 |
| | (38.665) | (40.989) | (42.036) | (40.157) | (128.944) | (129.218) | (129.266) | (128.603) |

*Note*: Standard errors are in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

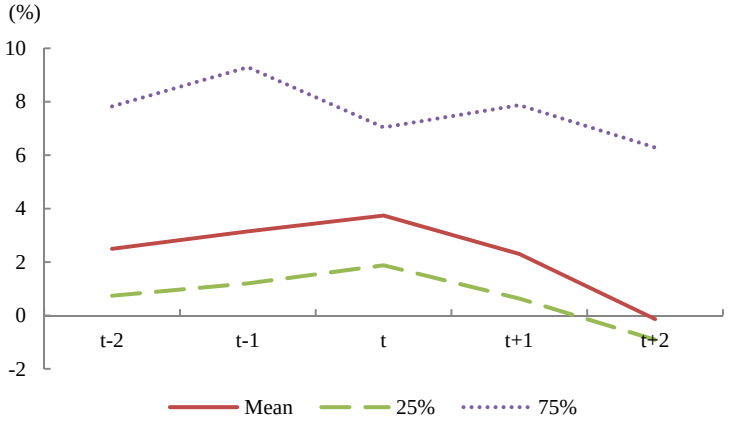


FIGURE 5. TRENDS IN RETURN ON ASSETS

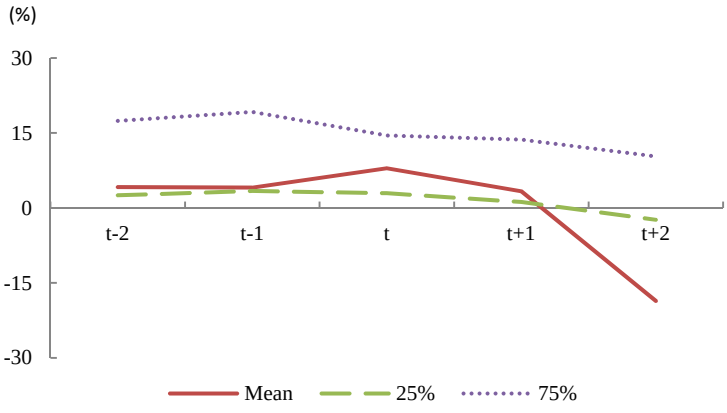


FIGURE 6. TRENDS IN RETURN ON EQUITY

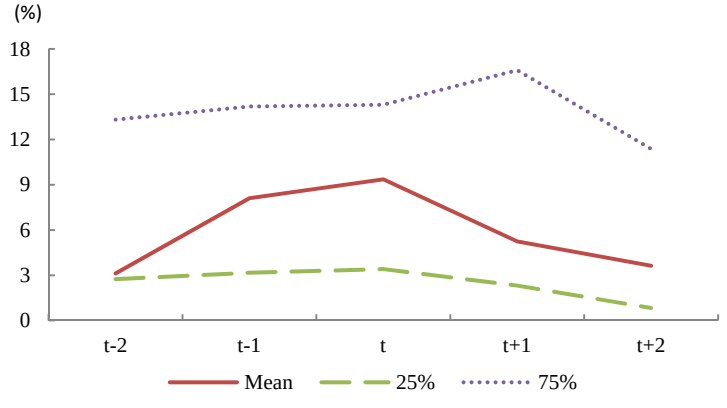


FIGURE 7. TRENDS IN RETURN ON SALES

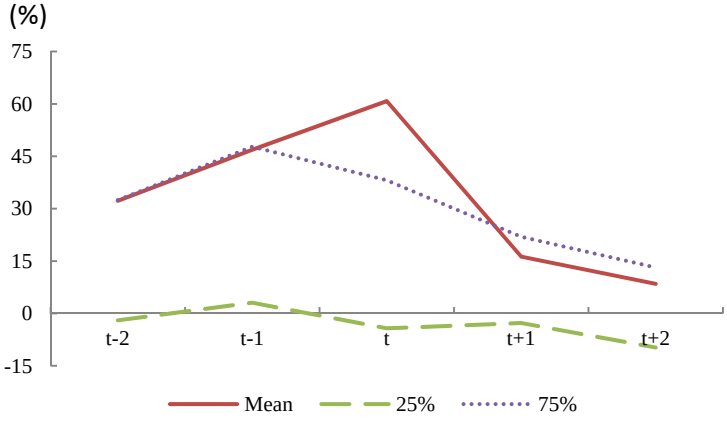


FIGURE 8. TRENDS IN SALES GROWTH

## 2. Trends in Operating Performance Metrics when Controlling for Outliers

Some of the operating performance levels (e.g., ROE and sales growth) show different movements among the means and quartiles from earlier figures. We conducted an event study of the operating performance levels by making use of samples winsorized at 5% to limit the influence of potential outliers. Nearly all of the operating performance metrics excluding ROS peaked at period t-1 and showed a downward trend afterwards, as shown in Figure 9 through Figure 12, indicating that the implication that private equity in Korea had not created value in portfolio companies remains accurate. Furthermore, the results of t-tests using the winsorized samples in Table 2 more strongly support the outcomes with all of the samples.

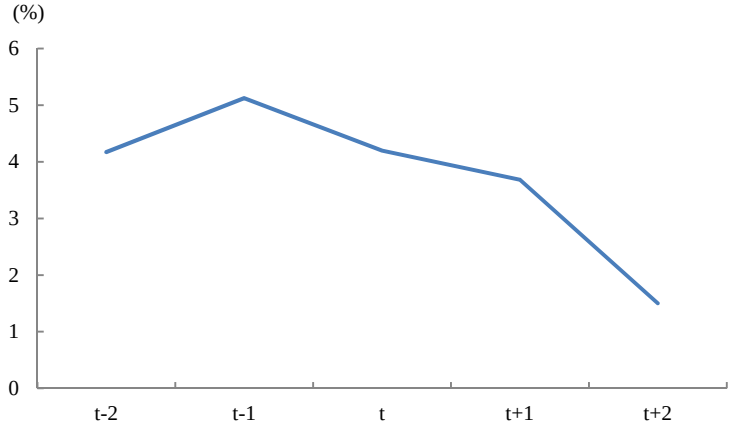


FIGURE 9. TRENDS IN RETURN ON ASSETS

*Note*: ROA is compiled after winsorizing at 5%.

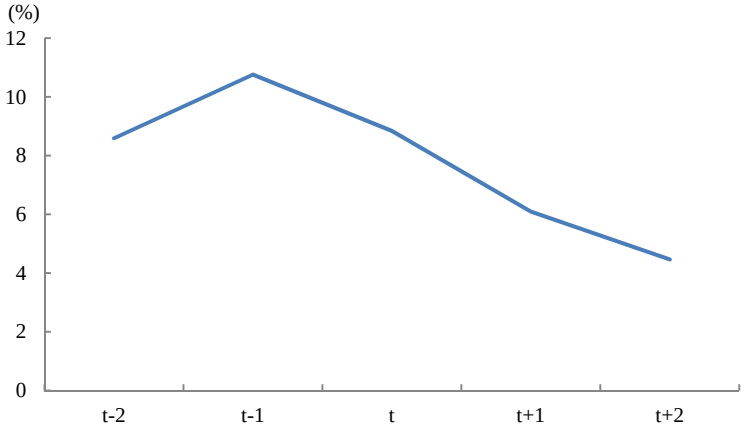


FIGURE 10. TRENDS IN RETURN ON EQUITY

*Note*: ROA is compiled after winsorizing at 5%.

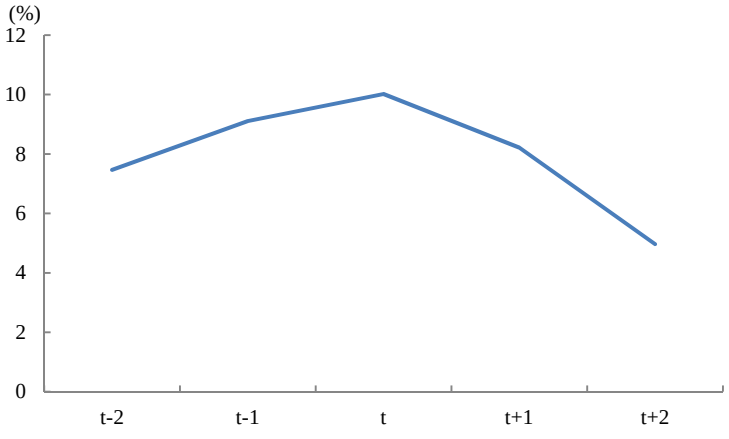


FIGURE 11. TRENDS IN RETURN ON SALES

*Note*: ROA is compiled after winsorizing at 5%.

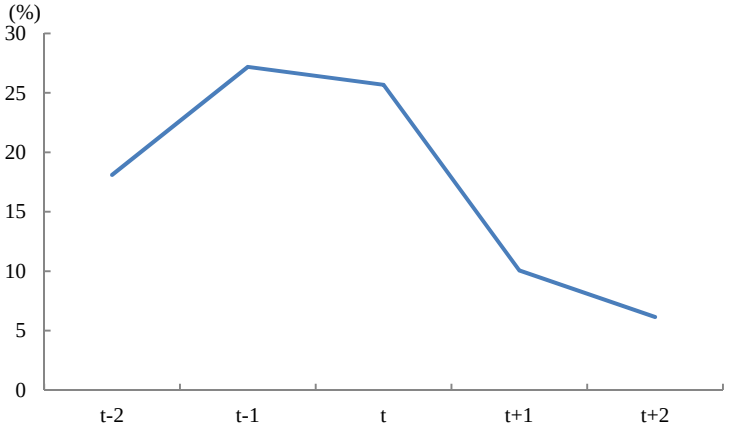


FIGURE 12. TRENDS IN SALES GROWTH

*Note*: ROA is compiled after winsorizing at 5%.

In Table 3, although the gaps in operating performance levels between the outcomes one year before and one year after private equity investment and two years after private equity investments are negative, the magnitude of the performance differences and the statistical strength both show increases over time. The statistical test results for two years before investment (t-2) and one year after (t+1), and for two years after (t+2) have identical implications with regard to the comparison with the outcomes one year before investment (t-1).

For robustness of our result, running a t-test of changes in operating performance levels from two years before (t-2) to four years after (t+4) private equity investment, with the results presented in Table 4, confirmed that the results are qualitatively similar to those of the t-test of the outcomes two years after (t+2) private equity investments.

TABLE 3—RESULTS OF T-TESTS USING WINSORIZED SAMPLES

| | t-1 to t+1 | t-1 to t+2 | t-2 to t+1 | t-2 to t+2 |
|---|---|---|---|---|
| ROA | -1.198 | -3.205*** | -1.000 | -2.765*** |
| | (0.769) | (0.854) | (0.876) | (0.883) |
| ROE | -4.586*** | -6.394*** | -2.885 | -5.528*** |
| | (1.591) | (1.823) | (1.745) | (1.323) |
| ROS | -0.884 | -4.201*** | 0.543 | -2.078 |
| | (1.087) | (1.110) | (1.768) | (1.523) |
| Sales Growth | -13.610** | -15.260*** | -10.638** | -12.527*** |
| | (5.870) | (5.471) | (4.795) | (4.204) |

*Note*: Standard errors are in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

TABLE 4—RESULTS OF T-TESTS USING WINSORIZED SAMPLES FOR T+4

| | t-1 to t+1 | t-1 to t+2 | t-1 to t+3 | t-1 to t+4 | t-2 to t+1 | t-2 to t+2 | t-2 to t+3 | t-2 to t+4 |
|---|---|---|---|---|---|---|---|---|
| ROA | 0.974 | -2.653* | -3.992** | -2.895 | 1.461 | -3.526** | -5.336*** | -4.124** |
| | (1.226) | (1.464) | (1.712) | (1.818) | (1.866) | (1.534) | (1.799) | (1.567) |
| ROE | -2.730 | -3.883 | -12.417*** | -6.978** | -2.835 | -4.691* | -10.849*** | -8.785*** |
| | (2.790) | (3.299) | (3.690) | (3.318) | (4.326) | (2.348) | (3.330) | (3.074) |
| ROS | 2.389 | -3.934 | -3.332 | -3.090 | 3.766 | -3.098 | -2.608 | -3.897 |
| | (1.740) | (2.565) | (2.121) | (2.389) | (3.323) | (3.312) | (3.391) | (3.473) |
| Sales Growth | -8.108 | -6.502 | -13.909 | -11.113 | -10.965 | -13.32 | -16.102 | -16.307* |
| | (8.721) | (7.323) | (8.964) | (9.275) | (8.688) | (9.129) | (9.422) | (8.480) |

*Note*: Standard errors are in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

## 3. Trends in Operating Performance Levels after Industry Adjustments

The operating performance levels of firms were discovered to be influenced by either business cycles or idiosyncratic shocks in each industry for which PE-backed companies are associated with private equity (Cohn *et al.* 2014). For example, although the operating performance levels of the target companies deteriorated after private equity firms invested in them, private equity had positive effects on the target firms when the deterioration of such performance metrics was less than the industry average. We conducted an additional event study with industry-adjusted samples when subtracting the annual averages of the operating performance levels for each industry from the operating performance levels of individual firms. We calculated the averages of the operating performance levels in each industry using Kis-Data up to two digits referring to industrial classification codes. ROA, ROE, and sales growth showed the poorest performance levels for t+2, although ROS reached a trough at t+1 and rebounded slightly during t+2, as shown in Figures 13 to 16. Changes in operating performance levels between t-1 and t+1 and between t-1 and t+2 are also mostly negative but not statistically significant, as shown in Table 5.

TABLE 5—RESULTS OF T-TESTS USING INDUSTRY-ADJUSTED SAMPLES

| | t-1 to t+1 | t-1 to t+2 | t-2 to t+1 | t-2 to t+2 |
|---|---|---|---|---|
| ROA | -10.555 | -12.158 | -0.734 | -2.325 |
| | (9.406) | (9.349) | (2.056) | (1.949) |
| ROE | 1.986 | -19.795 | 2.305 | -20.139 |
| | (6.475) | (18.846) | (7.010) | (19.581) |
| ROS | -3.689 | -3.002 | 1.032 | 1.824 |
| | (2.911) | (2.389) | (3.754) | (2.995) |
| Sales Growth | -16.460 | -21.189 | -6.721 | 1.609 |
| | (20.814) | (20.216) | (15.115) | (13.851) |

*Note*: Standard errors are in parentheses.

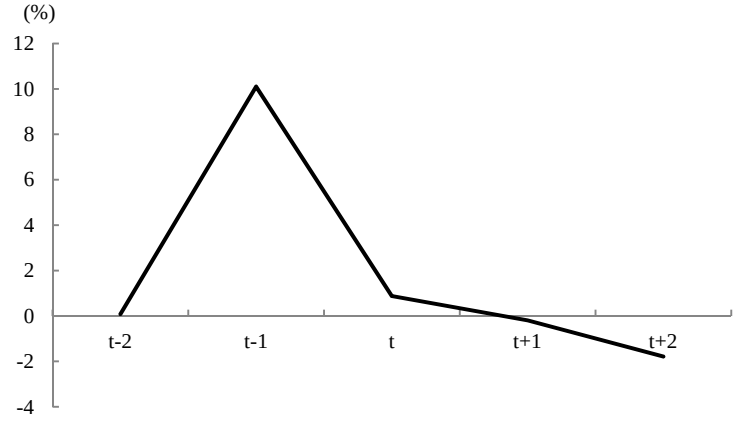


FIGURE 13. TRENDS IN RETURN ON ASSETS

*Note*: ROA is compiled after adjusting for industry.

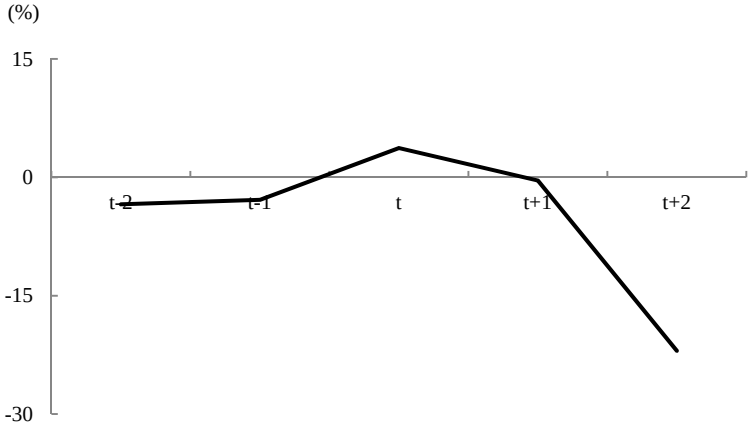


FIGURE 14. TRENDS IN RETURN ON EQUITY

*Note*: ROA is compiled after adjusting for industry.

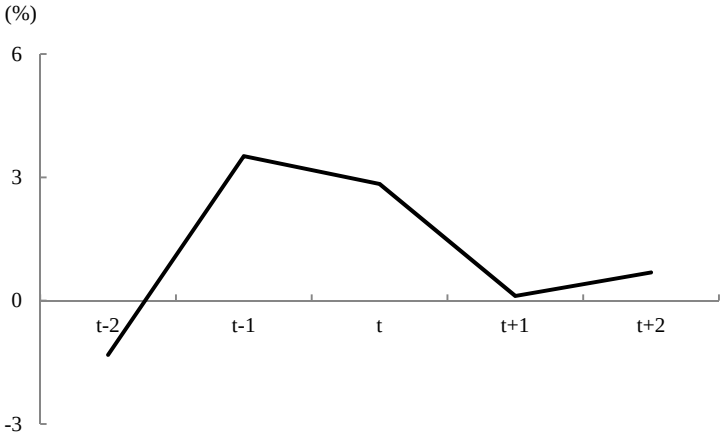


FIGURE 15. TRENDS IN RETURN ON SALES

*Note*: ROA is compiled after adjusting for industry.

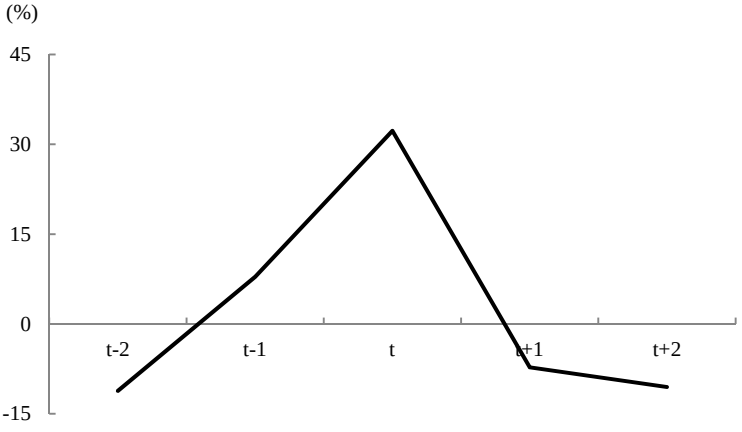


FIGURE 16. TRENDS IN SALES GROWTH

*Note*: ROA is compiled after adjusting for industry.

## B. *Investment Activity, Financial Stability, and Employment Results*

The critics against private equity argue that private equity opportunistically attempt to obtain profits in the short-term at the expense of long-term growth potentials of the firms they acquire by either stripping assets or reducing investments, cutting large numbers of jobs, and raising leverages for tax benefits (Capizzi *et al.* 2014). We examined the effects of private equity on investment activity, leverage, and employments for the firms they invest in Korea. Accordingly, we conducted an event study with regards to the fixed asset ratio, debt ratio, the number of employees, and t-statistical test.

Figures 17 through 19 demonstrate the trends of the means, the 25th quartiles, and the 75th quartiles for the fixed asset ratio, debt ratio, and employment. The fixed asset ratio increased after private equity investments, as shown in Figure 17. The debt ratio decreased after private equity investments were made, although there was a slight increase from t+1 to t+2. Finally, the condition of employment at the targeted firms showed improvements. Visual evidence of this is shown by the statistical test results compiled in Table 6. The changes in the fixed asset ratio and employment levels between the outcomes one year before and one year after private equity investments are positive, while the difference in the debt ratio is negative. The statistical test results are pronounced when we test gaps between outcomes one year before and two years after the private equity investments. The visual and statistical evidence implies that private equity in Korea may not pursue benefits for their targeted companies because they sacrifice the long-term growth potential of these firms.

TABLE 6—RESULTS OF T-TESTS OF INVESTMENT, LEVERAGE, AND EMPLOYMENT

| | t-1 to t+1 | t-1 to t+2 | t-2 to t+1 | t-2 to t+2 |
|---|---|---|---|---|
| Fixed asset ratio | 0.725 | 2.659* | 0.928 | 2.920 |
| | (1.093) | (1.414) | (1.541) | (1.813) |
| Debt ratio | -5.988*** | -4.851** | -2.450 | -1.433 |
| | (2.081) | (2.462) | (2.237) | (2.633) |
| Employees | 72.039*** | 91.809*** | 45.824 | 57.660 |
| | (21.681) | (28.252) | (63.140) | (70.923) |

*Note*: Standard errors are in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

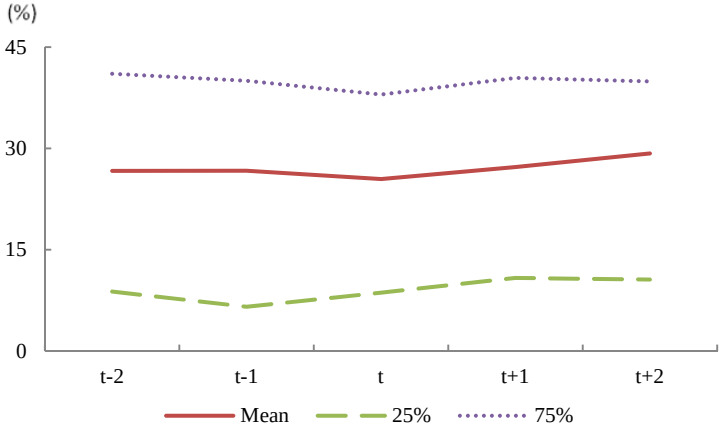


FIGURE 17. TRENDS IN FIXED ASSET RATIO

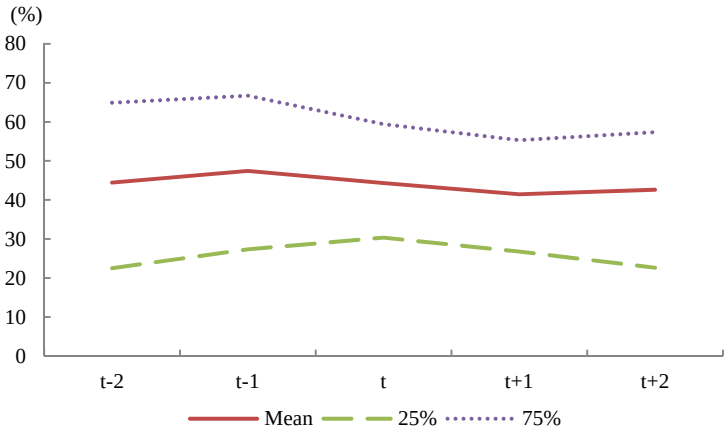


FIGURE 18. TRENDS IN DEBT RATIO

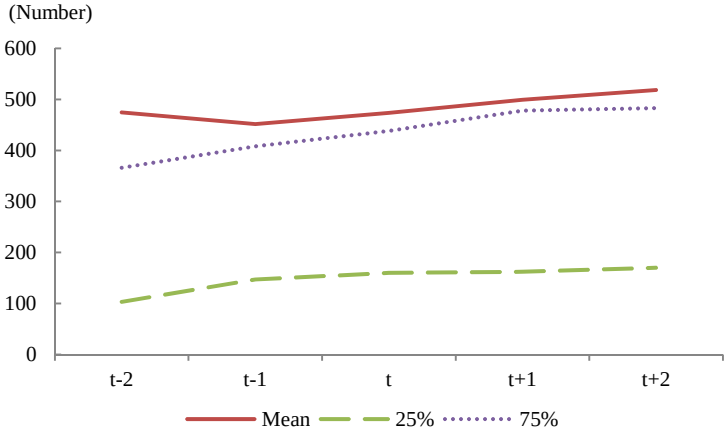


FIGURE 19. TRENDS IN EMPLOYMENT

## C. *Characteristics of Private Equity with regard to Operating Performance Results*

In section B, we failed to find evidence demonstrating that private equity improves the operating performance levels of targeted firms in terms of visual metrics and statistical t-tests from the event study. We attempt to uncover hints that could explain what may have brought about such poor outcomes in this section. Past studies have argued that the effects of private equity on the operating performance levels of targeted firms hinge on the characteristics of the private equity firms themselves, among other factors (Badunenko *et al.* 2010; Gompers *et al.* 2015; Harris *et al.* 2014). For example, private equity with a buyout objective is inclined to invest sizable amounts to buy a large portion of the equity for management rights, such as 50% of the total equity, compared to firms with a

growth capital goal of supporting the financial activities of a growing young company, similar to venture capital firms and private equity firms, for which the GP has long been assumed to be linked to a high likelihood of success in creating value in targeted firms based on the experience and know-how accumulated over many years by the investing firm.

In this study, we estimated the effect of the amount invested by private equity on the ROE, which is represented by the operating performance, to determine whether private equity in Korea focuses on buyouts or growth capital. The estimation equation is as follows:

$$ROE_{it} = a + b_1\, fund\ size_{it} + b_2 current\ ratio_{it} + b_3 age_{it} + b_4 asset_{it} + b_5 current\ asset\ ratio_{it} + b_6 debt\ ratio_{it} + e_{it} \quad (1)$$

We employed ROE as a dependent variable and the current ratio (current asset to current liabilities), the age of the firm, assets, the current asset ratio (current asset to total asset), and the debt ratio (debt to total asset) as control variables. We performed a regression to improve the pooling of the OLS, FGLS, and random effects, as this method was found to be a more suitable panel estimation model through a Hausman test.

Table 7 shows the estimation results. We observed that the relationship between the amount invested by private equity and the ROE is significantly negative in all of our estimation models. That is, the smaller the size of the investment by private equity, the better the operating performance is. Furthermore, the younger the firm is, the more likely it is for the firm to show higher profitability. This result, along with the result showing the negative relationship between the amount invested and the operating performance level, imply that Korean private equity firms have not been acting as buyout firms, which in general target more mature, underperforming firms that need to be restructured. This nonetheless provides growth capital as financial resources for young firms to grow.

TABLE 7—RESULTS OF THE ESTIMATION OF THE PE EFFECTS ON THE OPERATING PERFORMANCE

| | Pooled OLS | FGLS | Random Effect |
|---|---|---|---|
| Investment size | -5.223** | -2.905*** | -4.826* |
| Current ratio | -0.007 | -0.006*** | -0.007 |
| Age | -0.519** | -0.266*** | -0.493** |
| Asset | 11.178*** | 5.891*** | 10.516*** |
| Current asset ratio | 0.438*** | 0.130*** | 0.403*** |
| Debt ratio | -0.202*** | -0.122*** | -0.203*** |
| Constant | -148.634*** | -67.809*** | -139.936** |
| Adjusted R square | 0.684 | 0.680 | 0.708 |

*Note*: *** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

## D. *Results from the Propensity Score Matching Estimation*

In the previous section, we failed to find critical evidence that substantiates the claim that private equity improves the operating performance levels of targeted firms, yet there is some visual and statistical evidence that such private equity funds do not pursue profits from these firms at the expense of their long-term growth potential in terms of investment, financial stability, and employment. However, the event study conducted here has limitations in that there was no control group. Therefore, we utilize the propensity score matching estimation (PSM) model, which has been actively used in policy evaluation studies that share this limitation (Heinrich *et al.* 2010). Propensity score matching selects control groups that are most similar to the firms targeted by private equity companies by making use of the observable characteristics of these firms. Considering that PSM is a cross-sectional estimation method, we use PSM for 2012, the year in which the number of investment firms was largest, as an estimation method complementary to the event study. By making use of Epanechnikov kernel matching for PSM, we explore whether private equity improves the operating performance levels of the targeted firms by comparing these companies with the control group. In particular, we examine the operating performance levels of the firms for the near future (t+1) and the comparatively longer future (t+2) after the investment by private equity.

$$I_i^{PE\ investment} = \alpha + \beta_1 age_i + \beta_2 current\ ratio_i + \beta_3 asset_i + \beta_4 current\ asset\ ratio_{it} + \beta_5 debt\ ratio_{it} + \varepsilon_{it} \quad (2)$$

In the first stage, we estimate the probability of receiving investments from private equity funds by running a probit regression. We consider the age of the firm, the current ratio, assets, the current asset ratio, and the debt ratio as the determinants of investment by private equity funds. Following the selection of the investment targets, we calculate the differences in operating performance levels, investment activity, financial stability, and employment one year after private equity investments have been made.

$$ATE\left(average\ treatment\ effect\right) = E\left(\delta\right) = E\left(Y_1 - Y_0\right) \quad (3)$$

Here, $\delta_i = Y_{1i} - Y_{0i}$ is defined as the difference between the potential outcome in the case of investment by private equity and the outcomes in the absence of investment, and $E(.)$ represents the average.

The results of the balancing test, by which matching based on the propensity score works, are shown in Table 8. The reduction of sample selection bias is successful, as no statistically significant variables remain after matching in term of the p-values. Table 9 presents the results of the private equity investment determination. We found that the probability of receiving investments from private equity is higher for larger firms and for younger firms. The outcome showing that younger firms are more likely to obtain investments from private equity companies implies that private equity favors younger firms with greater growth potential than

TABLE 8—RESULTS OF THE BALANCING TEST

| Variable | Unmatched | Mean | | Bias(%) | Reduction of | t-test | |
|---|---|---|---|---|---|---|---|
| | Matched | Treated | Control | | bias (%) | t | p>\|t\| |
| Age | U | 19.72 | 27.24 | -44.6 | 52.6 | -2.12 | 0.034 |
| | M | 17.26 | 20.83 | -21.1 | | -0.78 | 0.440 |
| Current ratio | U | 207.69 | 3,473.50 | -3.7 | 98.4 | -0.12 | 0.902 |
| | M | 224.80 | 227.82 | -0.1 | | -0.23 | 0.816 |
| Asset | U | 26.49 | 25.87 | 36.3 | 91.8 | 1.90 | 0.057 |
| | M | 26.29 | 26.24 | 3.0 | | 0.09 | 0.928 |
| Current asset ratio | U | 25.95 | 26.78 | -3.9 | 45.5 | -0.21 | 0.833 |
| | M | 25.73 | 25.27 | 2.1 | | 0.07 | 0.946 |
| Debt ratio | U | 45.43 | 41.37 | 18.5 | 48.0 | 0.86 | 0.389 |
| | M | 42.91 | 40.80 | 9.6 | | 0.31 | 0.758 |

TABLE 9—RESULTS OF PRIVATE EQUITY INVESTMENT DETERMINATION

| Variable | Coefficient | Standard error | P-Value |
|---|---|---|---|
| Age | -0.020** | 0.008 | 0.013 |
| Current ratio | -0.000 | 0.000 | 0.418 |
| Asset | 0.117** | 0.052 | 0.024 |
| Current asset ratio | -0.004 | 0.005 | 0.441 |
| Debt ratio | 0.004 | 0.004 | 0.325 |
| Constant | -4.819 | 1.314 | 0.000 |
| Observation | | Treatment =22<br>Control =1,665 | |

*Note*: ** Significant at the 5 percent level.

TABLE 10—RESULTS OF THE AVERAGE TREATMENT EFFECT (T+1)

| | ATE | Standard error | t-Value |
|---|---|---|---|
| ROE | 5.940 | 4.734 | 1.255 |
| ROA | 1.326 | 2.388 | 0.555 |
| ROS | -2.212 | 5.720 | -0.387 |
| Sales Growth | -18.650** | 8.283 | -2.251 |
| Fixed asset ratio | 0.961 | 5.111 | 0.188 |
| Debt ratio | 1.895 | 5.139 | 0.369 |
| Employees | 123.704 | 266.685 | 0.464 |

*Note*: ** Significant at the 5 percent level.

their mature counterparts, which typically require a turnaround through restructuring. Looking at the results of the average treatment effect in Table 10, sales growth deteriorates with statistically significant negative differences compared to the control group, whereas the effect on profitability is not conclusive, with mixed signs of negative ROE and ROA and positive but not statistically significant ROS outcomes. This implies that we cannot support the claim that private equity has the ability to improve the operating performance levels of its targeted companies. With respect to the effects on investment, financial stability, and employment, private equity may not sacrifice the long-term growth potential of

TABLE 11—RESULTS OF THE AVERAGE TREATMENT EFFECT (T+2)

| | ATE | Standard error | t-Value |
|---|---|---|---|
| ROE | -5.180 | 16.135 | -0.321 |
| ROA | 0.356 | 1.755 | 0.203 |
| ROS | 0.304 | 1.804 | 0.169 |
| Sales Growth | -6.176* | 3.234 | -1.910 |
| Fixed asset ratio | 1.125 | 4.883 | 0.230 |
| Debt ratio | 2.208 | 4.824 | 0.458 |
| Employees | -12.637 | 174.680 | -0.072 |

*Note*: ** Significant at the 5 percent level.

targeted companies for short-term gains considering that changes in the fixed asset ratio and number of employees are positive with a slight increase in debt ratio. However, we cannot assign any critical meaning to this estimation outcome because the results are not statistically significant. The estimation results for the longer horizon in Table 11 present qualitatively similar implications.

## V. Implications of the Empirical Results

In Korea, private equity was introduced in an effort to foster a native corporate restructuring mechanism which could compete with overseas private equity, as overseas private equity funds began to rake in money in the domestic corporate restructuring market immediately after the currency crisis. Therefore, private equity has been considered as pursuing buyouts, taking control of management and reforming their targeted companies. However, in reality, private equity funds appear to be more akin to growth capital, which provides financial support to funds which show growth potential. Based on the results of the empirical analysis, as the age of the firm becomes younger, profitability improves among companies targeted by private equity firms, as shown in Table 5. Furthermore, private equity appears to favor younger companies when it comes to determining their investment portfolios, as shown in Table 7. That is, private equity funds, up until recently, took on the role of growth capital by supporting the growth of young companies by providing financial resources rather than playing a buyout role and turning around mature companies that are underperforming. The financial supervisory authority has also announced that most private equity funds in Korea are not similar to buyouts funds but are more similar to growth capital funds (Financial Supervisory Service 2015).

## VI. Conclusion

Recently, corporate restructuring has become a critical issue, especially considering the deterioration of the profitability of certain businesses followed by years of low growth with increases in the number of marginal firms. The main corporate restructuring schemes consist of corporate structure improvements, “workouts” by voluntary agreement between creditors, and corporate rehabilitation

proceedings or "court receivership" by the courts. This institutional, court-led, *ex-post* corporate restructuring process basically targets firms with insolvency issues, causing these firms to pay painstakingly high costs, such as significant job losses, 'fire sales', and conflicts of interests among stakeholders. Therefore, as an alternative measure, corporate restructuring by the capital market, particularly through private equity funds, has gained popularity as an *ex-ante*, preemptive complementary corporate restructuring scheme which takes place before insolvency. It is therefore considered to be more effective in that it can reduce agency costs by taking control of management and increasing the overall monitoring capabilities. Corporate restructuring schemes headed by domestic private equity funds are also important in that they can provide some competition with overseas private equity funds to prevent the types of cases which arose during the currency crises in the late 1990s and early 2000s.

This study investigates the revitalization of private equity in Korea as an alternative corporate restructuring mechanism by empirically analyzing whether Korean private equity funds have increased the operating performance levels of their targeted firms and by drawing policy implications based on empirical results. Whilst the visual and statistical evidence indicates that private equity in Korea may not have sacrificed the long-term growth potential of the firms, we also could not find evidence that they can improve the profitability (e.g., ROA, ROE, and ROS) and growth (e.g., sales growth) of the targeted firms. The results of propensity score matching confirm that private equity likely did not increase the operating performance levels of targeted companies, as deduced from the results of an event study conducted here. Furthermore, we find substantial evidence that the relationship between business performance and firm age is negatively correlated and that young firms are favored by private equity firms when determining their investments. This implies that private equity in Korea does not engage in buyouts, which were the original reason given for introducing private equity in Korea, taking control of management and executing turnarounds of underperforming companies, instead serving as growth capital, providing timely financial resources to companies which are relatively young, similar to venture capital firms.

In addition, we did not find evidence that Korean private equity could improve its investee portfolio, which implies that private equity in Korea is not yet ready for any corporate restructuring mechanism. We present explanations for this and discuss potential policy actions which can be taken to enhance the role of private equity firms as a corporate restructuring vehicle based on preceding research and on the results of our survey. One of the reasons private equity funds were unable to create value in their portfolios is the dearth of sufficient opportunities to build up such capabilities. In contrast to the period following the currency crisis, underperforming companies may not want to receive investments from private equity firms at the expense of its management rights, and with its possession of a number of underperforming companies, the government may also crowd out investment choices for private equity funds. Furthermore, the history of private equity may be too short for private equity firms to have amassed sufficient know-how and experience with regard to buyouts (Kim and Bin 2012). To invigorate private equity as an corporate restructuring scheme, government deregulation is needed to foster dynamism and innovativeness in the Korea private equity industry,

as regulations pertaining to private equity funds that guide firms towards executing buyouts may limit the activities of private equity. Moreover, the private equity industry itself should build up capacity by making efforts (e.g., hiring professional management teams), and the enlargement of the size of private equity funds is necessary to carry out market-friendly corporate restructuring given likely increase in the demand for corporate restructuring, in particular for large companies (Koo 2015).

Meanwhile this research has some limitations that we would like to leave for follow-up studies. First, we are not able to examine whether private equity takes part in corporate restricting for targeted firms comprehensively, as we could not look at whether private equity disposes of assets and reorganizes the business structures of these firms. Second, the present study draws upon data of listed firm due to the difficulty in accessing that of non-listed firms. Therefore, this study relies on investment data for listed firms through the Financial Supervisory Service. Unlike overseas, where detailed data on private equity investments (e.g. preqin) are commercially available, such data that include the non-listed firms are not available in South Korea.[3] Finally, due to data limitations, we could not take into account the effect of put-back options on the profitability (e.g., ROE) of targeted firms.[4]

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[3]Although we can collect non-listed firm data by reviewing newspaper articles, this can cause sample selection bias.

[4]A put-back option was often employed when private equity invested in firms up to 2012. However, the financial policy authority has regulated on put-back option since early 2013 by considering it as lending activity and not equity investment.

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# The Interaction between China, Japan, and Korea in the Export Market†

*By* KYU-CHUL JUNG*

*This paper analyzes changes in the export potential and competitiveness of China, Japan, and Korea. The analysis of Japan's export market share reveals that in sectors where Korea's potential was strong in the early 1990s, Japan's market share diminished. This suggests the possibility that Korea was catching up with Japan, eating into Japan's market share. The same analysis of Korea's export market share in the 2000s shows, for items in which China's export potential was high, Korea's market share has declined comparatively since 2010, with the tendency growing much larger. China's export potential continues to expand in markets for Korea's key export products, making it difficult to rule out the possibility that Korea's competitiveness in key export products will be hindered, driven by the catching up of China. To respond to these challenges, it is important for Korea continuously to foster and enhance creative and core capabilities that latecomers will not easily be able to emulate.*

Key Word: catch up, product space, export market competition, comparative advantage, export potential
JEL Code: F14, F47, O57

## I. Introduction

Korea has pursued export-driven growth since its initial development stage, and exports are still a major growth engine of Korea. It is inevitable that small economies such as Korea seek growth by relying on foreign demand. Thus, to determine whether Korea can sustain its economic dynamism, it is necessary to grasp whether the country can maintain its competitiveness in the export market in the future.

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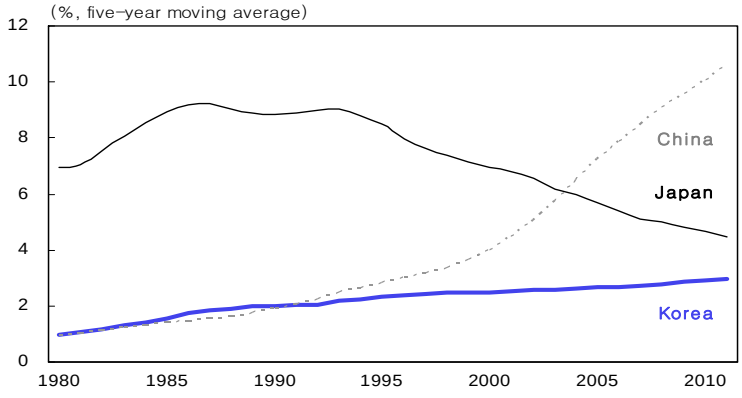


FIGURE 1. GLOBAL EXPORT MARKET SHARES OF CHINA, JAPAN, AND KOREA

*Source*: UNCTAD

This paper studies the impacts of export competitors on Japan's exports in the 1990s and on Korea's exports in the 2000s and compares them. As reported in Cho (2014), the Korean economy of today and the Japanese economy in the early 1990s are similar in many respects. For example, Korea's demographic structure follows Japan's, with a lag of approximately 20 years, and Korea's inflation rate is declining, as Japan's was in the early 1990s. Given that Japan's long recession started at that time, it is meaningful to analyze the possibility that in the near future the Korean economy will follow the way of Japan. This paper analyzes the Japanese and Korean economies, focusing on the export sector.

Here, we examine what happened with regard to Japan's exports. In the early 1980s, Japan achieved economic growth with a rapid expansion of its export market dominance, but later experienced an economic downturn in the 1990s, with exports also sluggish. Figure 1 shows the trend of Japan's export market share. Japan's export market share was extended in the early 1980s, maintaining a high level until the beginning of the 1990s. The market share, however, began consistently to decline after reaching its peak in 1993. Japan's market share was 9.6% in 1993, following the US at 12.3% and Germany at 10.1%. However, it has since continued to fall, reaching a level of 3.6% in 2014. It is comprehensible that Japan's domestic demand declined during the recession of the 1990s to some extent. This is, however, different from the recession experiences in other countries in that the Japanese economic downturn appeared even in the export sector, which mainly depends on foreign demand in the short term. In other words, in a recession exports are expected to expand more than domestic demand and thus to somewhat mitigate the economic downturn, but a further analysis reveals that this does not apply in Japan's case. Thus, it is difficult to attribute the sluggish Japanese economy in the 1990s to insufficient demand, as the Japanese economy went through a slump in both its domestic and foreign markets at that time. Instead, it may be a signal that Japanese firms became less competitive.

There were numerous factors that weakened the competitiveness of Japanese firms. Examples include changes in the demographic structure of the country, labor market rigidity, inefficient resource allocation, and mismanaged macroeconomic

policies. Because the analyses of these factors are covered in detail in other chapters of Cho (2014), this paper will focus mainly on the impact of export competitors.

The exchange rate of the yen may affect the competitiveness of Japanese goods. Due to the Plaza Accord in 1985 and following Japan's monetary policy, the yen/dollar exchange rate (annual average) dropped from 238.5 in 1985 to 94.0 in 1995. The appreciation of the yen deteriorated the price competitiveness of Japanese goods in the global market. As Obstfeld (2011) reported, this significant appreciation clearly also affected Japan's export market share. Although the exchange rate of the yen is an important issue, this paper does not address this issue in depth. Instead, the dynamic competition among China, Japan, and Korea is the main topic here.

In contrast to Japan, China's market share increased from 1.8% in 1990 to 12.4% in 2014. In particular, China's market share skyrocketed in 2000s. Despite the rapid rise of China, Korea's market share has grown at a comparatively steady pace. Korea's market share was close to 2% in the early 1990s; it continued to expand moderately, reaching 3% in 2010, and has maintained this level since then.

If Korea follows Japan and Korean firms become less competitive in the export market, the impact on Korea would be severer, as Korea relies more on exports for economic growth than Japan did. The ratio of exports to GDP of Japan in the early 1990s was only approximately 10%, while that of Korea today is greater than 50%. These figures themselves may mislead, as Korea is more involved in global value chains than Japan was and hence a percentage of Korea's exports consists of imported inputs, which do not contribute to Korea's GDP directly. (See Koopman, Wang, and Wei 2014; Timmer, Erumban, Los, Stehrer, and de Vries 2014; Johnson 2014 for double counting in gross exports.) After controlling for imported inputs in the export production figures, Korea still relies on exports much more than Japan did in the 1990s. Figure 2 shows the ratios of value-added exports to GDP. Japan's export ratios in the 1990s were slightly less than 10%, while Korea's export ratio in 2011 exceeded 30%.

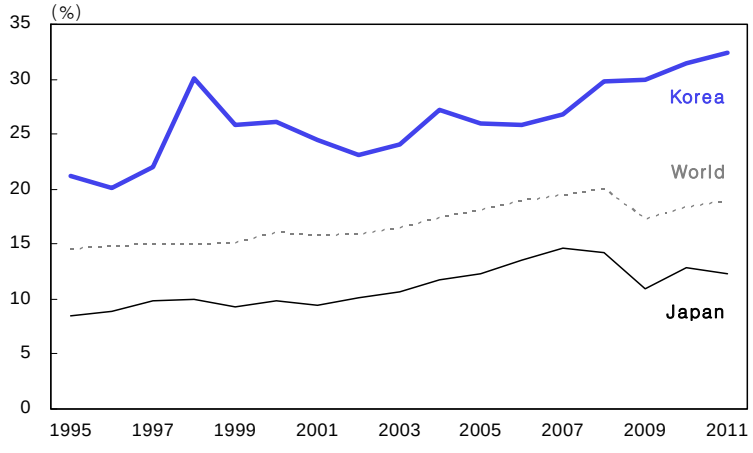


FIGURE 2. RATIOS OF VALUE-ADDED EXPORTS TO GDP

*Source*: Author's calculations using WIOD data.

As Korea's export figures have remained stagnant since the second half of 2014, concerns are growing in Korea that China may catch up in the export industry, much like Korea benchmarked Japan to do the same. A clear resolution to this issue is very difficult to find. This paper intends to uncover clues regarding this question so as to urge policymakers to prepare for this potential threat to the Korean economy.

The main analysis method of this paper is based on the concept of the product space in Hidalgo *et al.* (2007). The product space is a useful tool with which to measure the export potential of an individual product. I measure the export potential of export competitors and attempt to determine how it affects a certain county's export market share.

There is, obviously, a considerable body of literature on the export competitiveness of China, Japan, and Korea. In this paper, I focus on the interaction among China, Japan, and Korea considering the catch-up efforts of the countries.

Choi, Tcha, and Kim (2005) and Shin and Lee (2003) studied Korea's export competitiveness with a focus on competition with China and Japan by analyzing export market shares, export basket similarities, and comparative advantages by industry. In contrast, this paper analyzes dynamic catch-up patterns based on the export potential and compares the Korean economy of today to the Japanese economy of the past.

Lee (2008) and Jung (2014) also analyzed the impact of China on Korea's exports, similar to this paper. These papers, however, analyzed China as an export market of Korean products, whereas this paper does considers countries as competitors in the global export market.

Hidalgo *et al.* (2007) introduced the concept of the product space, upon which this paper is based. The product space is a useful tool for measuring a certain country's capability to produce and export a certain product. They reported that it is more probable to have a comparative advantage in terms of a certain product, as products similar to the product have a comparative advantage. Hausmann, Hwang, and Rodrik (2007) used the product space concept and empirically showed that what countries produce matters in terms of economic growth. Poncet and de Waldemar (2015) conducted a micro-data analysis of Chinese firms and reported that firms tend to export more products that are closely related to products having a comparative advantage. The key concept used in the main analyses of those papers is essentially a match to that used in this paper. I apply the concept of the product space to the dynamic competition among China, Japan, and Korea.

Youn (2013) and Choi (2014) also analyzed Korea's export products using the concept of the product space. Youn (2013) compared the degrees of export complexity among the United State, Japan, Korea, and China, while Choi (2014) studied the relationship between participation in global value chains and export complexity. I expect the present paper to add to the contributions to those papers in how it analyzes the interaction between the three countries in terms of export competitiveness in a dynamic setting.

There are papers about catching up in the export market that focus on particular industries, such as those of Lee and Lim (2001) and Mu and Lee (2005). The empirical analysis of export markets overall in this paper may complement those studies.

This paper is organized as follows. Section II presents the main framework of the empirical analysis. Section III examines Japan's dominance in the global export market in the 1990s, with emphasis on Korea's impact on Japan. Section IV, in the same vein, studies China's influence on Korea's dominance in the export market since 2000, and Section V concludes the paper.

## II. The Main Framework of the Empirical Analysis

This paper uses the concept of the product space as developed by Hidalgo *et al.* (2007). In this section, I introduce this concept briefly and explain how it is applied in this study.

First, it is necessary to measure the comparative advantage of a certain item of a certain country. Following Balassa (1965), I define the revealed comparative advantage (RCA) of a country's item as the ratio of the share of the item in the country's exports to that in the world's exports. That is, the RCA of item $i$ of country $k$ is

$$RCA_i^k = \frac{x_i^k / \sum_j x_j^k}{x_i^{world} / \sum_j x_j^{world}},$$

where $x_i^k$ is the export of item $i$ from country $k$. If a country's RCA for an item is high, it indicates that the country exports the item relatively more than other countries, reflecting the country's comparative advantage. RCA can be rewritten as

$$RCA_i^k = \frac{x_i^k / x_i^{world}}{\sum_j x_j^k / \sum_j x_j^{world}}.$$

That is, a country's RCA for an item is the ratio of the country's dominance in the item's market to that in the total export market. Given that the revealed comparative advantage of an item reflects the dominance of the item, RCA also represents the country's export competitiveness for the item.

At this point, I explain the concept of the product space developed by Hidalgo *et al.* (2007). With the product space, we seek to measure the capability a certain country has to produce a certain item. To do this, we investigate whether the country has a comparative advantage in items that require similar capabilities to produce the original item. If this country has the capability to produce the item effectively, it will have a comparative advantage in the near future even if it does not have this initially. That is, with the product space, we can measure the potential that a certain country will have competitiveness with regards to a certain item. For an intuitive explanation of the product space, one can refer to Hidalgo and Hausmann (2008). Several previous studies, including Hidalgo *et al.* (2007) and Hausmann, Hwang, and Rodrik (2007) found that the product space is useful for

predicting specialization patterns and economic growth in the near future.

To construct the product space, we need to define the concept of the distance or proximity between two goods. In the product space, because we measure the export potential, proximity must refer to more than simple superficial similarity. If two items are similar in terms of the production potential, then when a country has a comparative advantage in one item, the country should also tend to have a comparative advantage in the other item. Using this concept, Hidalgo *et al.* (2007) defined proximity as the conditional probability that a country has a comparative advantage in one item given that the country has a comparative advantage in another item. That is, the proximity of items $i$ and $j$ is expressed as

$$\phi_{ij} = \min\{\Pr(RCAx_i \mid RCAx_j),\ \Pr(RCAx_j \mid RCAx_i)\},$$

where $RCAx_i$ represents the event that a country has a comparative advantage in item $i$. In practice, we calculate the conditional probability using its property of

$$\Pr(RCAx_i \mid RCAx_j) = \frac{\Pr(RCAx_i \cap RCAx_j)}{\Pr(RCAx_j)}.$$

The probabilities on the right-hand side are measured by the maximum likelihood estimation with the data of all countries available in a corresponding year. The proximity is common to all countries in a year, but it may evolve over time.

Following Hidalgo *et al.* (2007), I define the export potential index (or density) of a certain item from a certain country as the weighted average of the transformed comparative advantage indices, setting the levels of similarity as the weights,

$$w_i^k = \frac{\sum_j \phi_{ij} f(RCA_j^k)}{\sum_j \phi_{ij}}, \tag{1}$$

where $f(\cdot)$ is a non-decreasing function. In this definition, the export potential index of an item is higher as items similar to the item tend to have higher comparative advantage indices. This is consistent with the definition of proximity, which increases in the probability that a country has comparative advantages in both items.

In Hidalgo *et al.* (2007), the numerator on the right-hand side of eq. (1) is set to the sum of proximity indices of items with a comparative advantage. That is, the export potential (density) in the paper is defined as

$$\tilde{w}_i^k = \frac{\sum_{\{j:RCA_j^k>1\}} \phi_{ij}}{\sum_j \phi_{ij}}.$$

In other words, Hidalgo *et al.* (2007) set $f(RCA_j^k) = 1(RCA_j^k > 1)$, where $1(\cdot)$ is an indicator function. Note that RCA may take any non-negative number. In this paper, I use a different function, $f(\cdot)$, to gain more information from RCA. For example, we expect that the degrees of the competitiveness of items with RCA values of 0.99 and 1.01 are not very different. Moreover, an item with an RCA value of 0.99 is far more competitive than an item with an RCA value of 0.01. If there are a large number of items and their RCA values are spread widely, this restriction of the indicator function may not affect the export potential index much. In this paper, I do not rely on this assumption. In contrast with Hidalgo *et al.* (2007), where a discrete function was used, I define the export potential index using a smoothly increasing function.

Because RCA is the ratio of an item's share in a country's export basket to that in the world's export basket, it takes a value between zero and one for an item with a comparative disadvantage, whereas it is assigned a value greater than one for an item with a comparative advantage. Thus, the RCA value of an item with a comparative disadvantage is restricted to a far smaller range compared to an item with a comparative advantage. Thus, if the untransformed RCA is used, the export potential is then sensitive to items with comparative advantages. I introduce a transformation of RCA to adjust this property. To do this, the transformation function should be increasing more rapidly in the domain (0,1) than in the domain $(1, \infty)$. In addition, a function is expected to reflect RCA better if it is a smooth function and its range is bounded. In sum, we need a function that is continuous, concave, and bounded. We consider the following function.

$$f(RCA_j^k) = 1 - \exp(-RCA_j^k).$$

This function is a continuously increasing concave function, and its range is between zero and one. There are, of course, numerous other functions that have identical properties. Nevertheless, in this paper, I adopt this function, which has the required characteristics.

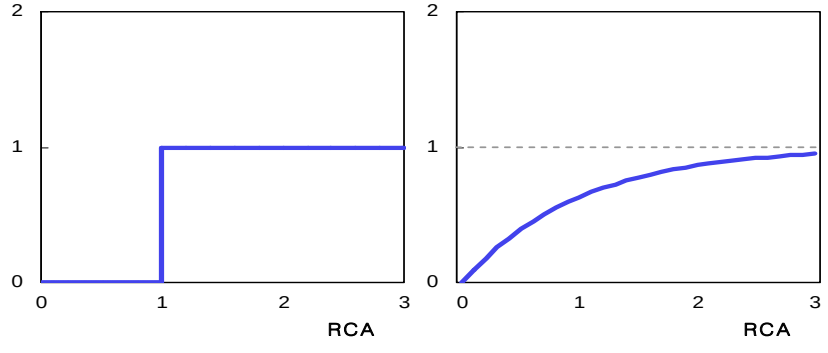


FIGURE 3. THE TRANSFORMATIONS OF RCA IN THE DEFINITION OF THE EXPORT POTENTIAL INDEX

*Note*: The figure on the left shows the transformation of RCA in Hidalgo *et al.* (2007), and the figure on the right shows this for the transformation in this paper

Figure 3 compares the two transformations in Hidalgo *et al.* (2007) and this paper. The figure on the left shows the transformation used in Hidalgo *et al.* (2007), which has a discontinuity when RCA = 1. In contrast, the figure on the right shows the transformation used in this paper, which is continuous and strictly increasing. Although there is not a notable difference in the export potential indices between the two measures, the measure in this paper predicts future comparative advantages marginally better than that in Hidalgo *et al.* (2007).

At this point, I explain how the product space is applied to the dynamic catch-up relationship in this paper. If country A chases country B, then one may expect that country B's market share will gradually drop relatively further in items where country A's export potential is high. That is, the current export potential of country A will be negatively correlated with changes in country B's export market share in the future. I will test this hypothesis to analyze the evolution of Japan's and Korea's export market shares.

## A. *Data Description*

In the empirical analysis, export data by country and item for each year are used. In this paper, items are classified according to the four-digit SITC (Standard International Trade Classification). Although HS (Harmonized System) is more commonly used than SITC, the latter reflects the processing stage better than the former. Hidalgo *et al.* (2007) also classified items according to the four-digit SITC. The data source is the UN Comtrade Database (retrieved on November 26, 2014). Data for Korea and Japan by item are available starting in 1988, while those of China are available starting in 1992. Thus, I used the data from 1992, as they cover the beginning of the period when Japan's exports declined. Note that to construct the product space, data from a sufficient number of countries are needed. When I collected the data for this paper, not enough countries reported detailed export data for 2013. If the data of 2013 are used, the product space for 2012 may be far different from that of 2013 because they would be constructed with very different sets of countries. Thus, the data from 1992 to 2012 are used. This paper studies not short-term cycles of exports but export trends; to clean certain idiosyncratic factors year by year, three-year average values are most commonly used in this paper. This implies that the empirical analysis in this paper ranges from 1993 (1992-1994 average) to 2011 (2010-2012 average).

## B. *Export Potential and Comparative Advantage*

To show the usefulness of the export potential (density) and to explore the evolution of the revealed comparative advantage, Hidalgo *et al.* (2007) divided products into three categories. *Transition products* are those for which $RCA_{i,1990} < 0.5$ and $RCA_{i,1995} > 1$, and *undeveloped products* are those for which $RCA_{i,1990} < 0.5$ and $RCA_{i,1995} < 0.5$. The third category was *others*. Hidalgo *et al.* (2007) found that transition products tended to have a higher density than undeveloped products. In words, among products that a country did not export

actively ( $RCA_{i,1990} < 0.5$ ), those with a higher density are more likely to be exported in five years with a comparative advantage ( $RCA_{i,1995} > 1$ ).

Table 1 shows the relationship between the export potential and the revealed comparative advantage of each country. The correlation coefficients of the export potential in 2000 and the future revealed comparative advantage indices are all positive. First, the export potential and revealed comparative advantage for the same year (t=2000) are not perfectly correlated. The correlation coefficients are 0.6, indicating that they measure a different property of the economy. Second, the correlation tends to decrease as the time gap between the export potential and the revealed comparative advantage becomes wider. This occurs because the export potential itself evolves, making it difficult to predict the export composition of the very distant future with only the export potential of today.

Nevertheless, the export potential still contains information about future export market shares. Table 2 displays the simple regression results, showing that for items where Korea's export potential index was higher by one standard deviation in 2000 than the average, the market shares in 2006 are approximately 3.5($=e^{1.24}$) times higher than the average. While the market shares in 2011 are only 2.9 times higher than average, these values are nonetheless statistically significant.

Note that the correlation coefficients of Japan do not decrease much over time. This may be due to the relative stability of Japan's export structure. This pattern stands in contrast with those of China and Korea, whose export structures have been evolving relatively quickly.

TABLE 1—RELATIONSHIP BETWEEN THE EXPORT POTENTIAL AND REVEALED COMPARATIVE ADVANTAGE

Correlation coefficients of the export potential in 2000 and the revealed comparative advantage for each year

| Correlation coefficients | China | Korea | Japan |
|---|---|---|---|
| Revealed comparative advantage in 2000 | 0.62*** | 0.66*** | 0.66*** |
| Revealed comparative advantage in 2006 | 0.50*** | 0.54*** | 0.66*** |
| Revealed comparative advantage in 2011 | 0.37*** | 0.45*** | 0.60*** |

*Note*: *** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

TABLE 2—RELATIONSHIP BETWEEN KOREA'S EXPORT POTENTIAL AND EXPORT MARKET SHARES

Regression model: $\ln marketshare_{it} = \beta_{0,t} + \beta_{1,t} exportpotential_{i,2000} + \epsilon_{it}$

| Year of dependent variables | Regression coefficients $\beta_{1,t}$ | t-statistics |
|---|---|---|
| t=2000 | 1.49*** | (27.9) |
| t=2006 | 1.24*** | (20.7) |
| t= 2011 | 1.05*** | (16.3) |

*Note*: *** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

## III. Japan's Experience in the 1990s

This section analyzes Japan's dominance in the global export market in the 1990s based on neighbor countries catching up with Japan. As shown in Figure 1, Japan's dominance in the global export market started to decline in 1993. First, this paper looks at the composition of Japan's export basket and how it changed in the 1990s.

In the 1990s, Japan's exports were concentrated in the sector of machinery and transport equipment (SITC #7). Japan's export dominance in that sector was rapidly dwindling, however, in the 1990s. Japan's market share in the sector was 18.0% in 1992-1994; shrinking to 12.3% by the end of the 1990s. In contrast, the market shares in this sector of Korea and China increased from 2.6% and 1.1% to 3.4% and 2.6%, respectively, during the same period. This suggests the possibility that the latecomers ate into Japan's share of its key export markets.

Next, I examine the systematic relationship between Japan's market share and its competitors' export potential. If Korea or China caught up with Japan, it is expected that Japan's market shares would decline relatively more in the sectors where Korea's or China's export potential levels were high. The regression model is expressed as

$$\ln(RCA^{JPN}_{i,1999}) - \ln(RCA^{JPN}_{i,1993}) = \beta_0 + \beta_1 w^{KOR}_{i,1993} + \beta_2 w^{CHN}_{i,1993} + \beta_3 w^{JPN}_{i,1993} + \epsilon_i .$$

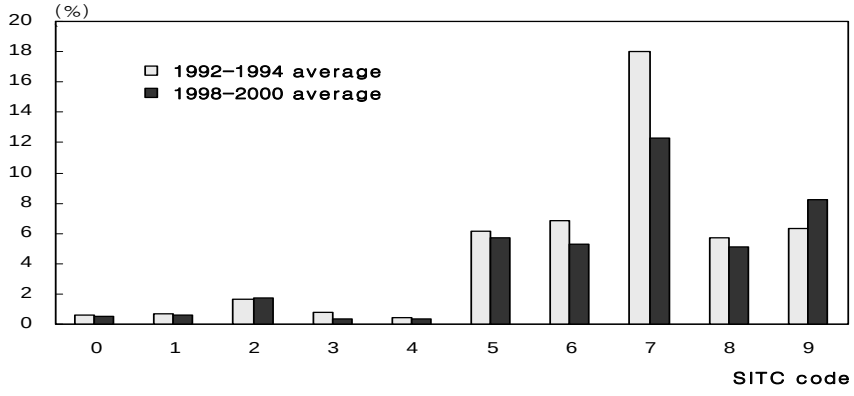


FIGURE 4. JAPAN'S EXPORT MARKET SHARE BY ITEM

*Note*: One-digit SITC descriptions are as follows.
0: Food and live animals,
1: Beverages and tobacco,
2: Crude materials, inedible, except fuels,
3: Mineral fuels, lubricants and related materials,
4: Animal and vegetable oils, fats and waxes,
5: Chemicals and related products, n.e.s.,
6: Manufactured goods classified chiefly by material,
7: Machinery and transport equipment,
8: Miscellaneous manufactured articles,
9: Commodities and transactions not classified elsewhere in the SITC.

*Source*: UN Comtrade Database

The dependent variable is the rates of change of Japan's comparative advantage index in the 1990s. The main independent variables are Korea's and China's export potential levels for the starting year of the measured period. Because Japan's own export potential may also affect the change in Japan's market share, I control for Japan's potential in the starting year of the measured period.

Note that the dependent variable is the log difference (growth rate) of the comparative advantage indices. Given that RCA is the ratio of a country's dominance in an item's market to that in the total export market, the dependent variable also indicates the growth rate of the item's export market share. We can see this from the following equations:

$$\ln(RCA_{i,1999}^{JPN}) - \ln(RCA_{i,1993}^{JPN}) = \ln\left(\frac{x_{i,1999}^{JPN} / x_{i,1999}^{WORLD}}{\sum_j x_{j,1999}^{JPN} / \sum_j x_{j,1999}^{WORLD}}\right) - \ln\left(\frac{x_{i,1993}^{JPN} / x_{i,1993}^{WORLD}}{\sum_j x_{j,1993}^{JPN} / \sum_j x_{j,1993}^{WORLD}}\right)$$

$$= \ln\left(\frac{x_{i,1999}^{JPN}}{x_{i,1999}^{WORLD}}\right) - \ln\left(\frac{x_{i,1993}^{JPN}}{x_{i,1993}^{WORLD}}\right) + \text{terms independent of } i.$$

I normalize the export potential such that the export potential of a certain country in a certain year has a mean of zero and variance of one. Note that such an affine transformation does not affect the t-statistics of the coefficient estimates. The interpretation of the regression coefficient is then straightforward. For an item of which Korea's export potential is higher by one standard deviation than the average export potential of Korea, the expected rates of change of Japan's export market share from 1993 to 1999 is higher by $\beta_1$ than the average rates of change of Japan's export market shares.

The empirical analysis shows that for items in which Korea showed high export potential levels, Japan's market share decreased. This finding indicates that a fall in Japan's market share of a certain item was contingent on the pace at which Korea caught up. In Table 3, a significantly negative regression coefficient for Korea's export potential indicates that Japan's market share has dropped comparatively

TABLE 3—IMPACT OF KOREA AND CHINA ON JAPAN'S EXPORT MARKET SHARE IN THE 1990S

Dependent variable: rates of change of Japan's export market shares between 1993 and 1999

| Independent variables | Regression coefficients | t-statistics |
|---|---|---|
| Korea's potential in 1993 | -0.14** | (-2.32) |
| China's potential in 1993 | 0.00 | (0.01) |
| Japan's potential in 1993 | -0.01 | (-0.33) |
| constant | -0.03 | (-1.27) |
| Number of observations | 1,031 | |
| R-squared | 0.03 | |

*Note*: *** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

TABLE 4—IMPACT OF KOREA AND CHINA ON JAPAN'S EXPORT MARKET SHARE IN THE 1990S WITH DIFFERENT TIME GAPS

Dependent variables:
(1) rates of change of Japan's export market shares between 1993 and 1999 (baseline)
(2) rates of change of Japan's export market shares between 1993 and 1998
(3) rates of change of Japan's export market shares between 1993 and 1997
(4) rates of change of Japan's export market shares between 1993 and 1996

| Independent variables | Measured periods | | | |
|---|---|---|---|---|
| | (1) t=1993 to 1999 | (2) t=1993 to 1998 | (3) t=1993 to 1997 | (4) t=1993 to 1996 |
| Korea's potential in 1993 | **-0.14**** | **-0.12*** | **-0.11*** | **-0.04** |
| | (-2.32) | (-1.96) | (-1.96) | (-1.02) |
| China's potential in 1993 | 0.00 | 0.00 | 0.03 | -0.02 |
| | (0.01) | (-0.01) | (0.40) | (-0.45) |
| Japan's potential in 1993 | -0.01 | -0.01 | 0.01 | -0.01 |
| | (-0.33) | (-0.18) | (0.27) | (-0.20) |
| Constant | -0.03 | -0.05* | -0.05** | -0.02 |
| | (-1.27) | (-1.85) | (-2.08) | (-1.20) |
| Number of observations | 1,031 | 1,031 | 1,031 | 1,031 |
| R-squared | 0.03 | 0.02 | 0.01 | 0.01 |

*Note*: t-statistics are in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

further in sectors where Korea's potential is high. In items where Korea's export potential index was higher by one standard deviation in 1993, the rates of change of Japan's market share dropped by nearly 14 percentage points more, meaning that Korea's impact on the changes in Japan's market share was significant. In contrast, when Korea's potential was controlled for, China's impact on Japan's export shares was statistically insignificant. This result does not necessarily imply that China's overall impact on Japan's export was negligible. Note that the analysis controls for countries' average export market shares across items. If a country's market shares for all items increased at the same rate, the analysis cannot capture this data. The regression results simply indicate that China did not have a significant impact on Japan's exports, particularly for items whose market shares dropped in the 1990s at a rate greater than the average. Because China's global export share increased from 2.4% to 3.4%, it is still possible that China caused the decline in Japan's overall export market share.

Of course, Korea's export potential alone may not explain most of the change in Japan's export market share for each item. The regression shows only the trend in the change pattern for Japan's export market composition in the 1990s. Because the regression includes only a few independent variables, it is also possible that omitted-variable bias exists. Note that the dependent variables are the relative changes in the market shares. Thus, it is less likely that the regression result depends on Japan's macroeconomic environment. However, it is still possible that countries other than Korea and China systematically affected Japan's export market shares. As presented previously, the US and Germany were the major exporters in the early 1990s. They may affect the export market competence levels of both Japan and Korea. To examine this, I also include the export potential of the US

and/or Germany as independent variables. The regression coefficients for these variables were statistically insignificant while regression coefficients of Korea's export potential were nearly identical to the baseline results.

In the empirical analysis in this section, I establish a six-year gap to cover the period from 1993 and 1999. I set the starting year as 1993, as Japan's export dominance started to decline in 1993 and China's data are available starting only in 1993. I set the ending year to 1999 to cover the 1990s. I found that a shorter time gap leads to a smaller regression coefficient for Korea's export potential, meaning that it takes time for latecomers to catch up. Table 4 shows the results with different time gaps. For the cases with the five-year and the four-year gaps, the coefficients of Korea's export potential are marginally insignificant at 5 percent with the p-values of 0.0507 and 0.0503, respectively, while with a three-year gap, the coefficient is insignificant at 10 percent.

## IV. Korea's Export Competitiveness and China's Catch-up Actions

In this section, I examine Korea's export competitiveness of today through the lens of Japan's experience of the 1990s.

First, similar portfolios of export products were noted for Japan in the past and Korea recently. Figure 5 shows the export basket for Japan and Korea for these two respective eras. Both countries have particularly high market shares in the machinery and transport equipment sector (SITC #7). They have also relatively high shares in the chemicals and related products sector (#5) and in manufactured goods classified chiefly by materials (#6). Note that the market share of Japan in the machinery and transport equipment sector dropped rapidly in the 1990s. On the one hand, concerns arise that Korea's market shares may decline in key export markets, such as electrical and electronic products, ships, and iron and steel, due to latecomers which eventually catch up with Korea, similar to Japan in the 1990s. On the other hand, the similarity of the export portfolios may result from Korea's benchmarking Japan for a long time.

If Korea caught up with Japan in these sectors, latecomers may then also easily be able to catch up with Korea in the same sectors. Of course, it is difficult to determine whether Korea will follow Japan or not by merely comparing their export portfolios. To uncover a clue about Korea's export competitiveness in the future, I undertake the same empirical analysis used in the previous section.

At this stage, I analyze the impact of China's and Japan's export potential levels at a certain point in time on Korea's export market share after that point in time. The empirical method used here is identical to that in the analysis of Japan's export competitiveness. The regression model is expressed as

$$\ln(RCA_{i,t+6}^{KOR}) - \ln(RCA_{i,t}^{KOR}) = \beta_{0,t} + \beta_{1,t} w_{i,t}^{CHN} + \beta_{2,t} w_{i,t}^{JPN} + \beta_{3,t} w_{i,t}^{KOR} + \epsilon_{i,t}.$$

The dependent variable is the rate of change of each export-market share (or revealed comparative advantage index) of Korea. The main independent variables are the export potential indices of China and Japan at the beginning of the year of

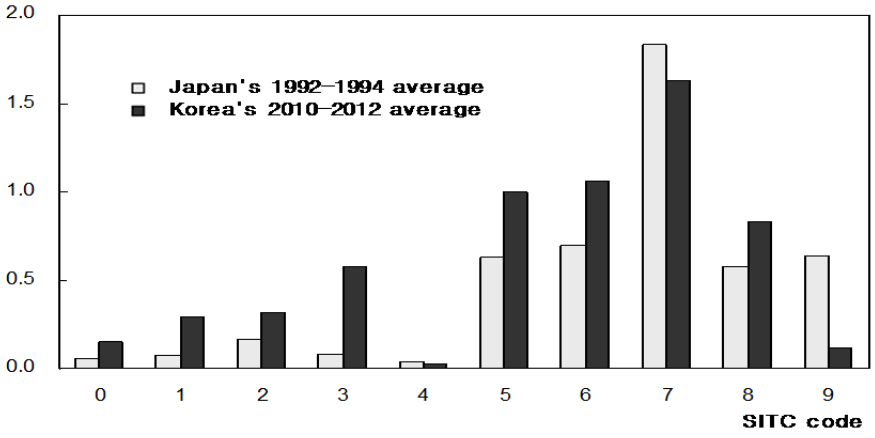


FIGURE 5. REVEALED COMPARATIVE ADVANTAGE OF JAPAN AND KOREA BY ITEM

*Note*: One-digit SITC descriptions are as follows.
0: Food and live animals,
1: Beverages and tobacco,
2: Crude materials, inedible, except fuels,
3: Mineral fuels, lubricants and related materials,
4: Animal and vegetable oils, fats and waxes,
5: Chemicals and related products, n.e.s.,
6: Manufactured goods classified chiefly by material,
7: Machinery and transport equipment,
8: Miscellaneous manufactured articles,
9: Commodities and transactions not classified elsewhere in the SITC.

*Source*: UN Comtrade Database

the measured period. As before, I control for Korea's export potential index and set the time gap to six years.

Table 5 shows the empirical results year by year. Until the early 2000s, the regression coefficient of China's potential remained insignificant, meaning that there were no noticeable inclinations at that time between the rates of change in Korea's market shares and China's export potential. However, as the coefficient decreased gradually to show a statistically significant negative correlation in the mid-2000s, Korea's market shares started to decrease comparatively in the sectors where China's export potential levels were high. For items where China's export potential index was higher by one standard deviation in 2005, the rate of change of Korea's market share dropped by nearly 21 percentage points more in 2011. Note that China's negative regression coefficient of its export potential is gradually rising. This implies that the impact of its catching up with Korea on Korea's market share is growing.

The coefficients of Korea's export potential, which is a control variable, are all negative and statistically significant. Recall that Korea's export potential was positively correlated with Korea's current and future market shares and that the correlation with current market shares is higher than that with future market shares. These findings imply that Korea's export potential is negatively correlated with the future rates of change of its market shares. I set the future rate of change of the market shares as the dependent variable instead of the future market shares because market shares are persistent. If future market shares were set as a dependent

TABLE 5—IMPACT OF CHINA AND JAPAN ON KOREA'S EXPORT MARKET SHARE IN THE 2000S

Dependent variable: rates of change of Korea's export market shares between t and t+6

| Independent variables | Measured periods | | | | | |
|---|---|---|---|---|---|---|
| | t=2000 to 2006 | t=2001 to 2007 | t=2002 to 2008 | t=2003 to 2009 | t=2004 to 2010 | t=2005 to 2011 |
| China's potential in t | **0.13*** | **0.01** | **-0.01** | **-0.11** | **-0.16**** | **-0.21***** |
| | (1.66) | (0.19) | (-0.10) | (-1.34) | (-2.21) | (-3.09) |
| Japan's potential in t | **0.46***** | **0.38***** | **0.38***** | **0.35***** | **0.33***** | **0.27***** |
| | (6.66) | (5.14) | (4.39) | (3.88) | (3.50) | (2.75) |
| Korea's potential in t | -0.49*** | -0.45*** | -0.47*** | -0.42*** | -0.40*** | -0.33*** |
| | (-6.40) | (-5.70) | (-5.41) | (-4.53) | (-4.01) | (-3.17) |
| constant | -0.18*** | -0.19*** | -0.22*** | -0.14*** | -0.09*** | -0.04 |
| | (-4.85) | (-5.31) | (-5.73) | (-3.79) | (-2.45) | (-1.04) |
| Number of observations | 1,031 | 1,031 | 1,031 | 1,031 | 1,031 | 1,031 |
| R-squared | 0.12 | 0.13 | 0.11 | 0.12 | 0.12 | 0.11 |

*Note*: t-statistics are in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

variable, the regression result may mislead us in that a low market share of an item may not be caused by the impacts of other countries but by Korea's poor performance with regard to the item in question in the past. That is, by constructing the regression model, it is likely that the coefficient of Korea's potential is negative. Hence, the interpretation of the coefficient of Korea's export potential should be cautious, and one should not give weight to it. In the regression analysis of Japan's market shares, the coefficient of Japan's potential is statistically insignificant. As shown in Section II, the correlation of Japan's export potential and future market shares does not decrease over time, which implies that Japan's export potential may not be significantly correlated with future changes in market shares. The main difference between Korea and Japan is likely that Japan's export structure is more stable than Korea's.

To address this issue, I set future market shares as a dependent variable and Korea's current market shares and export potential as control variables. The qualitative results are virtually identical to the baseline.

These results are consistent with those of Amiti and Freund (2010). Their paper analyzed the evolution of China's export structure, finding that machinery and transport equipment (SITC #7) grew most strongly and that within the category telecoms (SITC #76), electrical machinery (SITC #77), and office machines (SITC #75) experienced the fastest growth. These were Korea's key export sectors in the early 2000s. While Korea has maintained its market share in electrical machinery, Korea's market shares in telecoms and office machines have been dropping, while China's market shares in these areas have been increasing to high levels. China's comparative advantage indices for these sectors in 2012 are 3.1 (SITC #75), 2.5 (SITC #76), and 1.5 (SITC #77). Thus, the results in Amiti and Freund (2010) partly support the claim of this paper.

Determining with regard to China which sectors have been catching up with Korea is important. If China has affected Korea's market shares in sectors where Korea does not have a comparative advantage, Korea may not need to worry much.

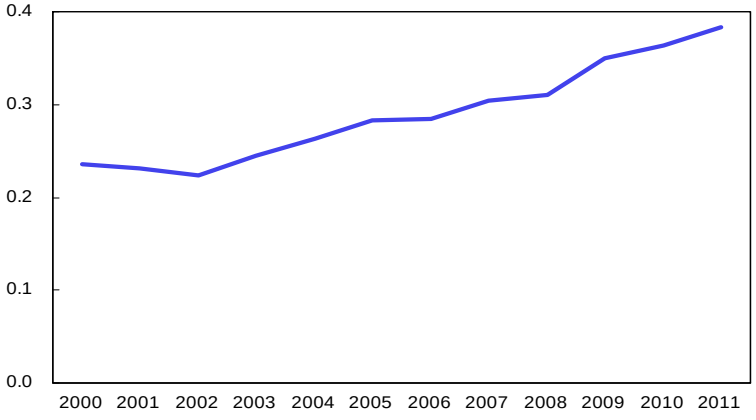


FIGURE 6. THE CORRELATION OF KOREA'S REVEALED COMPARATIVE ADVANTAGE AND CHINA'S EXPORT POTENTIAL INDICES

*Note*: For each year, we calculate the simple correlation coefficient of Korea's RCA and China's export potential indices across products.

In contrast, if China has been chasing Korea in Korea's key export markets, this would represent a critical problem that Korea should address.

China's potential continues to grow in items where Korea has a high export market share. This implies that there may be a considerable burden on Korea to sustain its export competitiveness in key export items in the future. Figure 6 shows that the correlation coefficient between Korea's comparative advantage index and China's export potential index has gradually widened since 2003, indicating China's intensifying catch-up efforts with Korea in items where Korea's market share is large. If this trend continues, it is highly likely that, much like Japan in the 1990s, Korea could experience a decrease in its market dominance in key export items due to the increasing competition from latecomers, including China.

## V. Concluding Remarks

This paper found that Korea faces a similar predicament to Japan in the early 1990s, when its long-term slump in exports began, in terms of the composition of export items and the catching up of latecomers. Korea's export product composition in recent times has been mainly composed of machinery and transport equipment, showing characteristics similar to those of Japan in the early 1990s. Moreover, Japan's falling export market shares of its key products in the 1990s, partially driven by the catch-up efforts of latecomers, have been echoed in Korea since 2010.

The empirical analysis shows that in items where China's export potential was high, Korea's market dominance has posted a relative decline since 2010, with the tendency growing much larger. China's export potential continues to expand in markets for Korea's key export products, making it difficult to rule out the possibility that Korea's competitiveness in key export products will be hindered.

To respond to these challenges, it is important for Korea continuously to foster and enhance creative and core capabilities that latecomers will not easily be able to emulate. Due to the catching up of latecomers, Japan's overall export market dominance has weakened, but its relative strength has been sustained in sectors that require sophisticated technology. Sectors where Japan's export market dominance has been maintained are those that require (relatively) highly advanced technology. Examples include specialized machinery for particular industries (SITC #72), metalworking machinery (SITC #73), road vehicles (SITC #78), photographic apparatuses, and equipment and supplies and optical goods, n.e.s.; watches and clocks (SITC #88). Rather than merely emulating this strategy and catching up, Korea now needs to take the lead in technological development and strengthen its own unique competitiveness, differentiated from that of latecomers.

Furthermore, based on the recognition that the rapidly changing environment has left Korea with no other alternative but to change its industrial structure, it should formulate an economic platform that can respond to this challenge in a flexible and efficient manner. If the Korean economy fails promptly to shift its limited production resources, such as labor and capital, from industries that have a comparative disadvantage to those that have a comparative advantage, it could lead to a decline in productivity overall and hence cause a reduction in Korea's competitiveness in export markets.

The results of this paper should be interpreted cautiously. There are, of course, numerous factors that affect the competitiveness of a country in the global export market. This paper focused only on neighbor countries catching up and did not rule out other important factors such as changes in the demographic structure, labor market rigidity, inefficient resource allocation, and mismanaged macroeconomic policies. To grasp precisely whether Korea can maintain its competitiveness in the export market in the future, more comprehensive studies are needed. In addition, this paper did not explain why a country caught up with a particular country at a specific time. The analysis with cross-country panel data may help us resolve this issue. Another issue that this paper did not address is overseas production. Indeed, it is said that Japan expanded overseas productions tremendously in the 1990s. The decline of Japan's export market share due to overseas production may not reflect the weakened competitiveness of Japanese firms. Thus, it may be a factor of the estimation bias that this paper did not consider the foreign direct investment and international fragmentation of production by multinational firms.

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# The Impact of Government Support of Graduate Schools on the Research Productivity of Professors and Students†

*By* JIN-YEONG KIM*

*This paper examines the effects of major funding projects for graduate education in Korea, specifically the BK21 and the WCU programs, on the research productivity of professors and young researchers. We apply the standard DID method, which compares the increase in research outputs as measured by papers per year between groups before and during the project period. The DID estimates show that the effects are quite different for different fields, but they mostly indicate that the BK21 project is more effective in terms of the research productivity of the participating professors, especially those who study science and engineering areas. With regard to the productivity of graduate students, the results show that there was an increase in the research productivity of locally educated Korean doctoral degree holders after the graduate funding programs, mainly in natural science and engineering fields.*

Key Word: Research fund, Research Productivity, BK21, WCU
JEL Code: I23, H52, J44

## I. Introduction

This paper examines the effect of government research grants to graduate schools on the research productivity of professors and graduate students using an individual-level dataset derived from the National Research Foundation of Korea. From the late 1990s, the Korean government attempted to establish world-class research universities by giving unprecedentedly large amounts of research funds to a few selected universities. The most notable funding programs are the Brain Korea 21 (henceforth, BK21) project, which started in 1999, and the World Class University (henceforth, WCU) project, which started in 2009. These two programs applied very different funding schemes. In the BK21 project, most

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† This paper was developed from a pre-feasibility study by KDI of the government's graduate funding projects.

research funds were given to graduate students in the form of grants. In the WCU project, much of the research funding was used to promote international academic cooperation, mainly by inviting renowned scholars from abroad, including some Nobel Prize laureates. Also in the WCU project, research teams are encouraged to open a new department or a program inside a department.

This contrasting feature of the funding schemes provides us a rare opportunity empirically to evaluate the effects of different research funding schemes on the productivity of major researchers in the receiving university, i.e., professors and graduate students. When we investigate the research productivity of professors, we compare the research outputs between two treatment groups, which consist here of participants of the BK 21 and the WCU projects, and a comparison group, which consists of top researchers among non-participants. We applied the standard DID method, which compares the increase in research outputs as measured by the number of papers per year among these groups, before and during the projects. From this investigation, we attempt to evaluate the efficiency of the two different research schemes for different academic disciplines.

With regard to the research productivity of students, we compare the research productivity of Korean doctoral holders who earned their doctorates in Korea and those who received theirs in the USA, which is widely believed to have the best graduate programs in the world in many academic disciplines. Again, we applied the standard DID method, which compares the annual production of papers of these two groups of doctoral degree holders before and after the BK 21 project.

If we recognize that the research productivity of professors and graduate students is a good proxy for the quality of graduate schools, we can expect to find evidence from this empirical investigation with which to determine whether the government funding for the graduate studies had any positive and/or significant effects on the quality of the graduate studies. In addition, we attempt to evaluate the relative efficiency of contrasting research funding schemes for different academic disciplines, thereby to draw policy implications which can inform the creators of better research funding schemes.

The remainder of this paper organized as follows. In section II, we briefly review the related literature. Section III explains the institutional backgrounds. Section IV introduces the dataset and the framework of the empirical investigation. Section V presents the empirical results and discusses their policy implications. Section VI concludes the paper.

## II. Literature Review

There are not a few empirical studies on the research productivity. Recently, Aksnes (2012) provided an extensive literature review of the scientists' research productivity levels,[1] documenting that demographic factors such as age and gender

[1]This review is not confined to the economics literature. It is only natural that researchers in any field have much interest in research productivity, and there is indeed a large body of literature with authors from various academic fields. However, it should also be noted that economists' analyses employ the most rigorous statistical methods.

are closely related to research output. With regard to age, although the results of previous studies have not always been entirely consistent, it is quite firmly established that there is a quadratic relationship between age and productivity. This pattern has been found across many fields and nations. For example, in the economics literature, Levin and Stephan (1991) find that life cycle effects are present in physics and earth sciences, Goodwin and Sauer (1995) find similar effects of age on research output in economics, and Oster and Hamermesh (1998) find that economists' productivity levels over their careers as measured by publications in leading journals declines very sharply with age. With reference to gender, many studies have shown large gender differences in scientific productivity levels.

The availability of resources, both in terms of financial support and human resources, affect research productivity as well. Kyvik (1991) reports that scientists who have more graduate students and technicians tend to be more productive that those who do not have as many supporting staff members.[2] As we will see later, one finding of this paper can be explained in line with this observation.

Institutional or organizational characteristics can also affect research productivity. For example, according to this review, many studies have shown that the productivity of publications at individual levels tends to increase within the hierarchy of academic positions. Some studies find that such factors as the department climate, age structure, and a higher level of freedom are correlated with publication productivity, though it is difficult to establish a causal relationship. One can argue that rather than favorable institutional characteristics affecting the productivity of an individual, a productive individual is more likely attracted by such institutions.

Meanwhile, there are not many empirical studies of the relationship between funding and research output, especially at the individual level. Some studies find weak positive relationships between research funding and outputs for different academic disciplines. Averch (1988) estimates the determinants of citations per dollar of NSF funding for a random sample of 93 projects in chemistry. He finds only a very modest relationship between citations per dollar and the characteristics of the principal investigators' affiliated institutions, although their characteristics do have some impact on citations per dollar. By contrast, for behavioral and neural sciences, Averch (1987) finds that even principal investigators' characteristics are unrelated to citations per dollar.

Aroma and Garmbrardelia (2005) find that NSF funding has only a modest effect on publication output, using dataset of 1473 applications for NSF in economics during 1985-1990. More recently, Jacobs and Lefgren (2011) estimate the impact of receiving a NIH grant on subsequent publications and citations. They find that receipt of a NIH research grant leads to only one additional publication over the next five years, representing only a 7% increase. Their interpretation of this small effect is that the loss of NIH grants simply causes a shift to another source of research funding in the presence of many alternatives. Methodologically, this study

[2]Aksnes (2012) explains that this is due to the fact that students and technicians will do much of the time-consuming data collection and data analysis work, and that supervisors may become coauthors of publications mainly written by graduate students and research associates.

uses a rich dataset that includes information about successful and unsuccessful applications while also attempting to handle the issue of selection bias.

With regard to empirical analyses of Korean graduate funding projects, we find very few. A monograph by the RAND Corporation (2008) points out that the net effect of BK21 on human resources and national R&D capacity building "compared to other projects" remains unverified. This monograph presents the conceptual framework by which the BK21 project is evaluated in detail, but empirical analyses and results are not presented.

Kim (2015) empirically examines the effect of the Brain Korea 21 project on the research productivity of participating professors, finding that for many in the science and engineering fields, the effects are positive and significant, whereas for most in the humanities and social sciences fields, the effects are insignificant or even negative. He interprets these results as evidence that grants to graduate students can be an effective means of increasing the research productivity of professors in some fields that require extensive experiments and help from research assistants.

This paper extends Kim's (2015) analysis in two directions. First, it includes another major graduate funding project. Second, it includes an analysis of new doctoral graduates' productivity levels in the evaluation of the effect of funding on educational quality levels.

## III. Institutional Background: BK21 vs WCU

The first phase of the BK21 project started in 1999, as a seven-year project. After the first phase, the second phase of the project started in 2006. Like Phase I, the main purpose of this phase was to foster world-class research graduate schools in various academic disciplines. To achieve this policy goal, the program was designed to provide most of the research funds to graduate students and young post-doctoral scholars. The fund beneficiary unit is the research group, which consists of professors, post-doctoral researchers, doctoral students, and master students. To gain BK21 funds, a research group should apply for funding by submitting the group's research proposal to the National Research Foundation of Korea (henceforth the KRF). The KRF reviews and evaluates the proposals and then selects research groups in each field.

There are several important restrictions when applying for BK21 funding. First, a research group should consist of more than 70 percent of faculty members in departments that have a doctorate program with enrolled doctoral candidates. Second, the number of faculty members participating in the research group must exceed seven for humanities and social sciences groups, ten for basic science groups, and ten to twenty five for applied science groups. In addition, all of the participating professors should produce more than the minimum average number of publications for the prior three years. The selection criteria are related to the issue of a comparison group, as discussed below. Third, all research groups must secure matching funds from their universities, which must be greater than five percent of the level of BK21 funding from the government. All of these preconditions are favorable to large research universities with relatively large research funds.

BK21 recipient research groups are selected at the beginning of each seven-year phase.[3] A very unique feature of the BK21 funding scheme is that, although the largest portion of it is used for scholarships and stipends, individual recipients are not selected on their own merit. The award selection criteria are based on the qualifications of the research group to which the individuals belong; the excellence of their department; and to their university's commitment to the department, institutional reform, and research infrastructure. However, the most important selection criterion is the research ability of the participating professors. There have been annual evaluations of research groups, and in a few cases, some groups were eliminated from the project. To fill the vacancy, a new research group comes in, again after the selection process.

The amount of BK21 research fund is approximately 280 million US dollars annually. The seven-year total amounts to nearly two billion US dollars. Each research group has little discretion in managing the research funds in that there are important restrictions. Table 1 presents the major spending items and restrictions on spending. The major spending item is grants to young researchers, including graduate students and post-doctoral researchers. Other than grants, there is a category termed "international cooperation, with funds usually spent on hosting or participating in international academic conferences. The operational cost includes incentives for professors (less than 300 US dollars per year), salaries for assisting staff members, and other minor expenses such as conference registration fees and the publication fees. The lack of a pecuniary incentive for professors is another important aspect of the BK21 project.

It should be noted that while international cooperation was encouraged, such collaborations did not widely occur. Participating in an international conference has been the major form of the international cooperation, and inviting world-class scholars was rare and there have been few, if any, continuing relationships. This is one of the reasons why the Korean government decided to launch another project, the WCU.

TABLE 1—BUDGET ITEMS OF BK 21 PROJECT

| Category | Major Spending Items | Prohibited Items |
|---|---|---|
| Grants to Students | ◦ Master (more than $500 per month)<br>◦ Doctoral (more than $900 per month per student) | ◦ More than the maximum amount set by the government<br>◦ More than 30 days of overseas training |
| Grants to New PhDs | ◦ Post-doc: more than $2000 per month<br>◦ Part-time professor; More than $2500 per month | ◦ More than the maximum amount set by the government |
| International Academic Cooperation | ◦ Participating in International Conferences<br>◦ Inviting World-class Scholars | ◦ Fees for professors (when the sole participant)<br>◦ Passport, Visa fees, etc. |
| Operational Costs | ◦ Incentives for professors (less than 300 dollars per year)<br>◦ Salaries for assisting staff members<br>◦ Conference registration fees, publication fees, etc. | ◦ Land, buildings, etc.<br>◦ Equipment facilities<br>◦ Consulting fee for participants<br>◦ Patent-related fees for individuals, etc. |

[3]As of 2012, the second phase had ended. In the third phase, the program will continue. The second phase ended in 2012. The third phase, another 7 year project, started from the next year with the project title "BK21 Plus".

Before comparing the two projects, let us briefly review some important financial restrictions applied to these projects. In the case of the BK21 project, grants to students should be more than 60% of the total funds in the natural science and engineering fields endowed to graduate students. The maximum portion is 72%. Grants to young post-doctoral scholars account for another 20% of the total budget. From the perspective of professors, nearly 80% of research funds go to supporting staff. The remaining 20% go for international academic cooperation and operational costs. Participating in international conferences is very much encouraged, but funding is given only when professors are accompanied by students and young post-doctoral researchers.

As of 2010, there were approximately 400 research groups in the natural sciences and engineering areas. On average, 500 thousand US dollars are given to each research group. The financial restriction is observed well by the participating research groups. On average 63% of funds were given to graduate students in 2010. Nearly 20% were given to post-doctoral scholars. In addition, approximately 12% of funds are allotted for international academic cooperation on average, and operational costs take another 8%.

In the humanities and social sciences, the research groups are generally smaller in terms of funding. The total funding for each research group is about 250 thousand US dollars, which is about half of what the science and engineering field receives. Similar to the science and engineering field, more than 80% of the funds were given to graduate students and post-doctoral scholars.

In terms of financial restrictions, the WCU project is quite similar to the BK21 project. Most of all, the recipient unit is identical; specifically, a research team is composed of professors and graduate students and post-doctoral researchers, but it has a different funding scheme from the BK21 program. There are three types of research teams in the WCU program. In type 1, funds are given to research teams that create a new department or a distinct program inside the department. Type 2 funds are given to research teams which invite a foreign scholar and work with him/her. For type 3, very much similar to the second type, funds are given to research teams that invite renowned foreign scholars, usually Nobel Prize winners or strong candidates, and work with him/her. There is a common factor between the BK21 and WCU programs in that the funds are given to research teams composed of professors, students, and new doctoral researchers. However, in the WCU program, international cooperation was greatly emphasized, and it is possible to have smaller teams.

The funds for WCU projects are divided into three categories. For each research team, grands to students or foreign scholars account for the largest share, at more than 40% of the all funds. The research infrastructure, including laboratories and equipment, is allocated another 40% as well. The remaining 20% pays overhead costs. As a result of the WCU project, 34 new department or fields were established and 288 foreign scholars were invited. As the project emphasizes international cooperation, many English courses are offered: 242 out of 302 new courses. Table 2 summarizes the key features of the BK21 and the WCU projects.

TABLE 2—COMPARISON OF THE BK21 AND THE WCU PROJECT

| | BK21 | WCU |
|---|---|---|
| Purpose | Providing research funding to a group of researchers to enhance the quality of post-graduate education, thereby fostering world-class graduate programs | Enhancing research productivity in some key academic fields, and fostering the next generation of researchers. Providing a new research environment through cooperation with foreign scholars. |
| Unit of Recipients | Research group or team | New department or new major within the department (type 1)<br>Research team with individual foreign scholar(s) (type 2)<br>Inviting world-class scholars (existing department, type 3) |
| Duration | Seven years, 2006-2012 | Five years, 2008-2012 |
| Number of Recipient Units | 58 research teams in the humanities and social sciences (41 teams from the national competition and 17 from local-based competition)<br>150 research teams in the natural sciences and technology (94 teams from the national competition and 56 from local-based competition) | 34 departments or fields (type1),<br>43 research teams (type 2),<br>46 research teams (type 3),<br>A total of 123 new departments or research teams |
| Funding Levels | Total: $200 million (2011),<br>$30 million for social sciences and humanities<br>$170 million for natural sciences and engineering<br><br>$400,000 for each unit on average, and $900,000 for each unit on average for natural sciences and engineering | Total: $140 million (2011)<br>$2.9 million for type 1<br>$800,000 for type 2<br>$180,000 for type 3 |

## IV. The Data and the Empirical Framework

### A. *The Data*

The basic dataset comes from the BK21 and WCU databases. Each research team reports basic information, such as the number of research members and their publications, to the National Research Foundation of Korea (Henceforth, the KRF). The KRF gathers the information and manages the database. Accordingly, the BK21 and the WCU datasets have detailed information on the research output of the professors participating in the program.

Yet without information about a proper comparison group, specifically a group of researchers who do not participate in the project but with comparable research abilities, a strict evaluation is not possible. To compose a control group, we also used a dataset drawn from the KRF's researcher database. This dataset has information about the research output of individual researchers who agreed to allow their information to be made public. Approximately 15% of the researchers agreed to reveal their information about their research output. The dataset is based upon this 15% sample.

In Korea, every new doctoral recipient is supposed to register with the KRF online. Once registered, the information is updated whenever researchers report their research outputs to the KRF online. For a published paper, they report the

title, the year of the publication, the name of the journal, and the number and names of any co-authors. They also report if the paper was published in science citation index (henceforth SCI) or in social science citation index (henceforth SSCI) journals. In this paper, we only count papers in SCI or SSCI journals as those published in an international journal. Likewise, we only count papers published in the Korean citation index (henceforth, the KCI) journals as cases of a national journal.[4] There is some verification process on the part of the KRF to check if the researcher's report is correct. This takes some time; accordingly, there is a possibility of some measurement error in the number of published papers, especially in recent years.

Before discussing the control group, we consider the differences in research outputs among different fields. Comparing the research productivity levels of different academic disciplines has practically no meaning, especially when we measure productivity in terms of the quantity of the output, as in this paper. Let us look at examples.

Table 3 shows the average number of annual publications per researcher for certain science fields from 1995 to 2010. When calculating the number of publications, we assign a value of 1 for a single-author paper. When there are two or more authors, we assign a value of 0.5 when the researcher is the first or the corresponding author. Otherwise, when the number of authors is n, we simply assign this case a value of 1/n. In this manner, we can calculate the number of papers produced by each researcher in a specific year.

We present the number of papers per researcher in SCI and KCI journals. From the table, two aspects are immediately noticed. The first is that the research productivity of Korean scholars has increased in every science field from 1995 to 2010. For example, the average number of papers in SCI journals in physics was

TABLE 3—ANNUAL AVERAGE PUBLICATIONS PER PERSON IN SCI JOURNALS (NATURAL SCIENCES)

| | Annual publication per person | | | | Ratio (Math=1) | | |
|---|---|---|---|---|---|---|---|
| Year | Math | Physics | Chemistry | Biology | Physics | Chemistry | Biology |
| 1995 | 0.069 | 0.277 | 0.222 | 0.116 | 3.99 | 3.21 | 1.67 |
| 1996 | 0.104 | 0.308 | 0.242 | 0.148 | 2.96 | 2.33 | 1.42 |
| 1997 | 0.134 | 0.396 | 0.337 | 0.138 | 2.96 | 2.52 | 1.03 |
| 1998 | 0.160 | 0.454 | 0.297 | 0.194 | 2.83 | 1.86 | 1.21 |
| 1999 | 0.151 | 0.512 | 0.339 | 0.184 | 3.39 | 2.25 | 1.22 |
| 2000 | 0.202 | 0.612 | 0.367 | 0.247 | 3.02 | 1.81 | 1.22 |
| 2001 | 0.260 | 0.666 | 0.450 | 0.268 | 2.57 | 1.73 | 1.03 |
| 2002 | 0.255 | 1.093 | 0.675 | 0.393 | 4.29 | 2.65 | 1.54 |
| 2003 | 0.458 | 1.440 | 1.077 | 0.637 | 3.14 | 2.35 | 1.39 |
| 2004 | 0.520 | 1.328 | 1.084 | 0.817 | 2.56 | 2.09 | 1.57 |
| 2005 | 0.643 | 1.545 | 1.239 | 0.761 | 2.40 | 1.93 | 1.18 |
| 2006 | 0.589 | 1.515 | 1.277 | 0.834 | 2.57 | 2.17 | 1.42 |
| 2007 | 0.775 | 1.547 | 1.498 | 0.982 | 2.00 | 1.93 | 1.27 |
| 2008 | 0.733 | 1.653 | 1.620 | 1.087 | 2.26 | 2.21 | 1.48 |
| 2009 | 0.862 | 1.608 | 1.740 | 1.155 | 1.87 | 2.02 | 1.34 |
| 2010 | 0.883 | 1.995 | 1.872 | 1.378 | 2.26 | 2.12 | 1.56 |

[4]KRF evaluates the quality of each journal every two years and determines the KCI index journals. Because many universities count only papers published in KCI journals in their faculty evaluations, professors try to publish their works in these journals.

TABLE 4—ANNUAL AVERAGE PUBLICATIONS PER PERSON IN SSCI JOURNALS (SOCIAL SCIENCES)

| | Annual publication per person | | | | Ratio (Education=1) | | |
|---|---|---|---|---|---|---|---|
| Year | Education | Economics | Pub. Admin | Sociology | Economics | Pub. Admin | Sociology |
| 1995 | 0.017 | 0.035 | 0.023 | 0.047 | 1.98 | 1.30 | 2.67 |
| 1996 | 0.023 | 0.074 | 0.018 | 0.075 | 3.23 | 0.80 | 3.28 |
| 1997 | 0.034 | 0.032 | 0.009 | 0.011 | 0.96 | 0.28 | 0.33 |
| 1998 | 0.024 | 0.047 | 0.004 | 0.037 | 1.96 | 0.18 | 1.55 |
| 1999 | 0.025 | 0.081 | 0.034 | 0.033 | 3.27 | 1.38 | 1.34 |
| 2000 | 0.035 | 0.032 | 0.018 | 0.033 | 0.92 | 0.51 | 0.96 |
| 2001 | 0.033 | 0.087 | 0.015 | 0.016 | 2.67 | 0.46 | 0.49 |
| 2002 | 0.032 | 0.065 | 0.020 | 0.008 | 2.06 | 0.64 | 0.25 |
| 2003 | 0.022 | 0.127 | 0.019 | 0.021 | 5.79 | 0.87 | 0.98 |
| 2004 | 0.024 | 0.185 | 0.030 | 0.079 | 7.79 | 1.24 | 3.32 |
| 2005 | 0.036 | 0.185 | 0.046 | 0.060 | 5.08 | 1.27 | 1.65 |
| 2006 | 0.057 | 0.216 | 0.037 | 0.095 | 3.77 | 0.65 | 1.66 |
| 2007 | 0.045 | 0.201 | 0.054 | 0.120 | 4.46 | 1.19 | 2.66 |
| 2008 | 0.054 | 0.185 | 0.046 | 0.181 | 3.40 | 0.84 | 3.32 |
| 2009 | 0.048 | 0.232 | 0.061 | 0.138 | 4.79 | 1.26 | 2.84 |
| 2010 | 0.050 | 0.290 | 0.048 | 0.100 | 5.76 | 0.96 | 1.99 |

0.27 in 1995, 0.515 in 1999 (the first year of phase I of BK21), and 1.5 in 2006 (the first year of Phase II of BK21), and close to 2 in 2010, the final year for which we have data. This is major increase. We can find similar patterns in other areas as well. In chemistry, the number of annual publications per person increased from 0.22 in 1995 to 1.87 in 2010.

The second easily recognizable aspect is the difference in the number of publications among science researchers. We can see this more clearly when we derive the quantity publication index relative to mathematics. The annual average per-person number of publications for physics and chemistry are more than twice that of mathematics for 2010. For biology, this figure exceeds 1.5. Under the assumption that the research efforts of different fields are not systematically different, it may be reasonable to interpret these differences largely as stemming from the difficulty of publication. To anyone who attempts to estimate research productivity, the most obvious implication of this difference is that one should compare the research productivity levels of scholars field by field.

We can find a similar pattern in the social sciences. When we derive the same index, specifically annual publications per person for several social science fields, we note how difficult it is to publish SSCI journal papers in Korea. As of 2010, the per-person SSCI journal publication is less than 0.3 for economics. We also found major differences in the numbers of publications among different fields. For example, the number of per-person SCI journal publications in economics is nearly six times greater than that for education in 2010.[5] Nonetheless, it should also be noted that the average annual number of publications for economics researchers is only one-seventh of that of physics researchers. Again we can say that there is no meaning in comparing the number of publications, for instance of an individual economist with that of a physicist.

[5]We suspect the same research effort in the social sciences. The research effort and difficultly with publication among different academic fields would be an interesting future research topic.

TABLE 5—NATIONAL-INTERNATIONAL PUBLICATION RATIO (SELECTED FIELDS)

| | Natural Science | | | | Social Science | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Math | Physics | Chemistry | Biology | Education | Econ | Pub Admin | Sociology |
| 1995 | 1.73 | 0.24 | 0.23 | 0.63 | 6.47 | 4.25 | 11.33 | 4.57 |
| 1996 | 1.71 | 0.19 | 0.25 | 0.72 | 6.83 | 2.42 | 18.10 | 3.00 |
| 1997 | 0.74 | 0.19 | 0.26 | 1.14 | 5.15 | 8.77 | 36.40 | 24.39 |
| 1998 | 0.75 | 0.15 | 0.32 | 0.65 | 9.98 | 5.35 | 81.83 | 7.94 |
| 1999 | 0.69 | 0.21 | 0.23 | 0.64 | 12.70 | 3.87 | 13.77 | 7.90 |
| 2000 | 0.56 | 0.14 | 0.26 | 0.49 | 9.78 | 9.92 | 21.63 | 6.74 |
| 2001 | 0.45 | 0.14 | 0.32 | 0.52 | 11.13 | 4.18 | 34.31 | 29.37 |
| 2002 | 0.95 | 0.11 | 0.30 | 0.50 | 13.81 | 5.78 | 26.78 | 59.77 |
| 2003 | 0.41 | 0.08 | 0.15 | 0.34 | 22.60 | 3.91 | 26.25 | 23.26 |
| 2004 | 0.54 | 0.11 | 0.15 | 0.29 | 22.72 | 2.11 | 17.05 | 5.99 |
| 2005 | 0.44 | 0.07 | 0.14 | 0.33 | 14.06 | 2.10 | 10.92 | 8.29 |
| 2006 | 0.33 | 0.09 | 0.14 | 0.27 | 10.38 | 2.29 | 14.29 | 6.74 |
| 2007 | 0.36 | 0.10 | 0.09 | 0.22 | 13.62 | 2.87 | 9.99 | 4.65 |
| 2008 | 0.37 | 0.10 | 0.10 | 0.22 | 13.20 | 2.94 | 11.34 | 2.42 |
| 2009 | 0.39 | 0.11 | 0.12 | 0.24 | 17.20 | 3.17 | 11.75 | 5.26 |
| 2010 | 0.34 | 0.11 | 0.12 | 0.24 | 21.09 | 2.82 | 16.93 | 8.37 |

We can also note differences in the ratios between national and international publications in different fields. In Table 5, we present the ratio between the national and international publications for different fields. In all of the natural science fields, this ratio decreases over time, meaning that researchers in Korea endeavor continually to publish their works in the international journals. For example, for physics and chemistry, this ratio is around 0.2 to 0.25 in 1995, meaning that Korean researchers in these fields published four to five times more papers in international journals than in national journals. In 2010, this ratio dropped to around 0.1. This is common in many of the natural sciences.

However, in the social sciences, the pattern is quite different. We note in Table 5 that most of the social science research output is published in Korea. The publishing ratios of national journals to international journals are 21.9 in education, 2.8 in economics, 16.9 in public administration, and 8.4 in sociology in 2010. In addition to economics, this ratio has increased since 1995, precisely the opposite of the natural sciences. Though not presented in the form of a table, it should be noted that very few papers in the humanities were published in international journals.

This is another piece of evidence that the comparison of individual researchers' productivity levels should be done within the same fields. Reflecting these differences in the publishing pattern, we will concentrate on papers published in international journals, when we examine the natural sciences and the engineering fields. In social sciences and humanities, we will examine both international and national journals.

## B. *Framework for the Empirical Analysis*

We attempt to estimate the effects of different research funding schemes on the research productivity of professors using information about both project participants and non-participants.[6] To do this, we need to compare productivity

[6]It should be emphasized again that the aim of this section is not an evaluation of the BK21 or the WCU projects themselves. Rather, we want to compare the effect of these two projects on the productivity levels of the

changes before and after the research funding projects between the treatment groups and the comparison group. The obvious treatment groups are those professors who are participating in the project. Given that the participating professors are the best researchers in the leading graduate programs, it is only natural that they produce large amounts of research output before and after the project. However, the question should be, "Did their research output increase due to the government funding programs? What if these researchers did not have research funds such as BK21 or WCU?" Considering the research environment of Korean universities, the lack of such research funds mostly means a lack of good research assistants for many academic disciplines in the case of the BK21 program, and a lack of research assistants plus international cooperation in the case of the WCU program.

In an ideal situation, where we have information on the rank or scores of all the research teams at the selection stage, including those eliminated, we can apply a regression discontinuity approach to evaluate the causal relationships associated with these funds. Unfortunately, we do not have proper information about the selection process. What we do know about the selection process is that the most important selection criteria are the quantity and quality of the research produced by the faculty members. Thus, the first qualification of the control group is that it should be composed of professors that have shown the highest research performance levels among non-participants.

One can raise questions about whether this can be a proper control group, but this appears to be the only possible means of finding a control group of researchers that have shown similar research abilities, with the given dataset. Given the lack of information about individual researchers' characteristics as closely related to research output levels, the output level itself would be the best criterion for selecting researchers who are close to the top researchers selected as actual funding recipients.

Another important fact about this control group is that the professors in this group may experience a loss of graduate students due to these research projects. Before the introduction of the first phase of the BK21 project in 1999, it was the convention in Korean academia, unlike that in the USA, that an undergraduate student of any university usually chose the same university for their graduate study if it had graduate program. However, with unprecedented increase in grants given to a few departments in each field, many prospective graduate students have chosen departments with BK21 funds. This caused a major decrease in the number of incoming students, especially those with better qualifications, into many graduate programs that were not selected.

Some professors argue that the entire structure of the BK21 and the WCU projects is counterproductive for their research owing to the slight pecuniary incentive and the high costs of the administrative burden. For example, they should write extensive research proposals to be selected, and once selected, they should write annual reports, both of which are quite time-consuming. Despite all of these

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participating professors. It must be noted that the main purpose of the BK21 project is to foster scholars from the younger generation through high-quality institutions. However, the research productivity of professors is a very important selection criterion; at the same time, it is the major performance indicator in annual reviews.

complaints, nearly all professors in top research schools create research teams and submit proposals. Along with pressure from the university, concern over losing research assistants was the major reason for this "revealed preference" for the large government funding project. It is very likely that researchers in the control group can receive many types of research funds. However, among many research funds in Korea, there are none other than the BK21 or the WCU that permit so large a portion of funds to go to graduate students.

This unique feature of the funding scheme — high compensation for graduate students or foreign scholars and little compensation for professors — can provide a useful policy experiment during which we can evaluate the importance of the research assistance and co-authors during the research process in different fields. By devising a control group of researchers with comparable abilities yet lacking a stable source of funding for research assistants, we can create a setting that compares the "BK21 project or the WCU project vs. all other research funding projects."

In the case of the WCU program, international cooperation or cooperation with foreign scholars is an additional treatment related to research assistance. Research teams receiving WCU funds must invite foreign scholars and should pay for them. Regardless of the contents of the cooperation, it is the most important feature that distinguishes WCU projects from BK21 projects.

To compare the relative efficiency of the two different projects, we ran two separate Regressions: one including BK21 project participants and non-participants in the sample and the other including WCU project participants and non-participants. More specifically, we obtain DID estimates from the following two equations.

$$PubIndx_{it} = \alpha_0 + \alpha_1 YBK + \alpha_2 DBK + \alpha_3 YBK * DBK + \Gamma_1 RCH_{it} + \delta Time + a_i + \varepsilon_{it}$$

$$PubIndx_{it} = \beta_0 + \beta_1 YWCU + \beta_2 DWCU_{it} + \beta_3 YWCU * DWCU + \Gamma RCH_{it} + \delta Time + a_i + \varepsilon_{it}$$

In the above equation $PubIndx_{it}$ denotes the index of the research output of individual $i$ in year $t$. It is measured by the total number of annual publications adjusted by the number of co-authors, as explained in the previous section.[7]

$YBK$ is a dummy variable, taking a value of 1 for the years of the BK21 project, specifically after 2006. $DBK$ is a dummy variable taking a value of 1 for an individual participating in the BK21 project. The coefficient of this variable is the difference in the number of annual publications between participants and non-participants before phase II of the BK21 project. The coefficient of the interaction term $DYB*DBK$, $\alpha_3$ is a DID estimator measuring the net effect of participating

[7]It must be noted that this index does not properly reflect the quality of the published works. We try to reflect the quality by limiting papers published in SCI, SSCI, AHCI, or KCI journals, but there are wide variety in the quality of those journals. It would be better if we can used the information on the impact factors. While not impossible, it is not easy to gather all information on the impact factors of different journals at different times. So we only use this quantitative index in this paper and leave the analysis of quality-adjusted measures of publication as a future research topic.

in the BK21 project.

In the same manner, *YWCU* is a dummy variable taking a value of 1 for the years of the WCU project, specifically the years 2009 and 2010. *DWCU* is a dummy variable taking a value of 1 for an individual participating in the WCU project. The coefficient of the interaction term *YWCU*DWCU*, $\beta_3$, is a DID estimator measuring the net effect of participating in the WCU project. By comparing two DID variables, we can determine which program works better with regard to the productivity of participating faculty members.

We add a time trend variable to control for the general increasing trend of publications. There are several reasons for the increasing trend in the number of publications in all academic fields. At the university level, an increasing number of universities have adopted a stricter faculty promotion system since the late 1990s. This induces more effort from the professors, leading to the increasing trend in research output. In the humanities and social sciences fields, the number of KCI journals increased in the 2000s, contributing to the trend of the increasing number of publications.

There should be certain control variables related to researchers' characteristics (RCH). Unfortunately, we do not have many variables in the dataset. The only variable we can use is the age of the researcher. To control for life-cycle aspects with reference to research activity, we add the age and squared age to the regression.

In the estimation, selecting proper control groups is the key issue. The control groups are composed of professors who earned their doctoral degree before 2006 and who produced highest annual average number of papers among the non-participants. The numbers of professors in the control groups are identical to the numbers of participating professors, specifically the sum of the number of professors participating in the BK21 or the WCU project. We use the same control group for both projects. The research performances in terms of the average annual publications from 1999~2010 are presented in Table 6.

It is clear that the annual average number of publications is higher in the treatment group in many fields. However, in some fields, such as mathematics and economics, the control group's number is higher. Between the two treatment groups, participants in the WCU program show higher productivity. It must be noted that there are fewer participants in the WCU program, and it is possible for the selection process to be more restrictive to the most productive researchers. It is also interesting to note that there are some very productive researchers who were not selected for participation in the WCU project. When we select the same small number of most productive researchers among non-participants of the WCU program, their average numbers of annual publications are much higher than those of the WCU participants in many fields. Typically, this number is more than double the former. This large gap implies that the productivity of professors is not the only selection criterion linked to the WCU program. For example, it is possible that some of the productive scholars work at less renowned institutions.

At this point, we consider the effect of research funding on the quality of graduate education programs. If we can distinguish the recipients of graduate funding from non-recipients, it would be relatively easy to infer the effect of the

TABLE 6—THE AVERAGE NUMBER OF ANNUAL PUBLICATIONS IN INTERNATIONAL JOURNALS (1999-2010)

| | BK21 parti. | WCU parti. | non BK21[1)] | non WCU[2)] | non parti.[3)] |
|---|---|---|---|---|---|
| Physics | 2.25 (132) | 2.13 (31) | 1.17 (132) | 4.83 (31) | 0.95 (147) |
| Biology | 1.03 (153) | 1.32 (20) | 1.41 (153) | 3.65 (20) | 1.3 (162) |
| Chemistry | 1.82 (158) | 3.31 (32) | 1.16 (158) | 3.46 (32) | 0.94 (169) |
| Mathematics | 0.69 (61) | 0.85 (7) | 0.95 (61) | 3.16 (7) | 0.93 (62) |
| Electronic Engin. | 1.41 (235) | 3.32 (18) | 0.63 (235) | 4.51 (18) | 0.57 (243) |
| Computer Science | 0.76 (144) | 1.91 (8) | 0.41 (144) | 2.9 (8) | 0.41 (144) |
| Mechanical Engin. | 1.15 (148) | 1.2 (12) | 0.57 (148) | 4.6 (12) | 0.56 (150) |
| Economics | 0.39 (50) | 0.18 (2) | 0.45 (50) | 2.38 (2) | 0.44 (51) |
| Education | 0.11 (40) | 0.46 (3) | 0.33 (40) | 0.94 (3) | 0.32 (42) |
| History | 0.01 (25) | 0.01 (3) | 0.26 (25) | 0.65 (3) | 0.24 (28) |

*Note*: 1) Non-BK21 refers to the groups of the most productive professors who do not participate in the BK21 program. Each group includes the same number professors as BK21 participants. It possibly includes those who participate in the WCU program. 2) Non-WCU refers to the groups of the most productive professors who do not participate in the WCU program. Each group includes the same number professors as WCU participants. It possibly includes those who participate in the BK21 program 3) Non Parti. represents the group of the most productive professors who participate neither in the BK21 nor the WCU program. Each group includes the sum of the BK and the WCU participants. Due to some professors who receive both funds, this number is not the same as the sum of the BK21 the WCU participants. 4) Numbers in parenthesis are the number of project participants.

projects by comparing the performances of the two groups. However, we do not have such information. It may be possible to identify institutions from which Korean PhD recipients earned their degrees, but there is no guarantee that they are actually fund recipients, as there are not a few individual non-recipients in the fund-receiving institution.

Given this difficulty in identifying true recipients, we use an indirect means of gaining information about the quality of education before and after the funding project. We look at the performances of PhD recipients who earned their doctoral degree from a Korean institution. That is, rather than asking whether the research funding projects enhance the productivity of recipients, we ask whether graduate funding programs lifted the general quality of graduate education in Korea. This is justifiable because this is the ultimate purpose of a funding project.

To answer this question, we compare the performances of doctoral recipients from Korean institutions with those from US institutions, which are widely believed to have highest graduate education quality in the world. More specifically, we compare the performance of doctoral degree holders from Korean institutions to those from US institutions before and after the establishment of the major graduate funding programs. We estimate the following simple equation for different cohort of doctoral degree holders.

$$PubIndx_{it} = \beta_0 + \beta_1 DKOR + \Gamma RCH + \delta Time + a_i + \varepsilon_{it}$$

The sample is composed of Korean doctoral degree holders who earned their doctorates in Korea or in the USA. In the above equation, *DKOR* is a dummy variable indicating doctoral degree holders who earned their doctorates in Korea. We estimate the equation for three different cohorts of doctoral degree holders: those who earned their doctorate (1) from 1995 to 2000, (2) from 2001 to 2005,

and (3) after 2006. The coefficients of the dummy variable *DKOR* can be interpreted as the performance gap between doctoral degree holders from Korean institutions and those from US institutions. By examining the changes in the performance gap for these different cohorts, we can determine if the performance gap decreased after the funding projects for graduate programs began. The differences in the two estimates derived from different cohort samples can be considered as the DID estimator, indicating the change in the performance gap. If the research funding projects had positive effects, we will find a decreasing performance gap.

Let us first investigate the simple average numbers of annual publications. It is clear that Korean doctoral degree holders are more productive in recent years than in the past. In Table 7, we compare the same cohorts of Korean doctoral degree holders who earned their degree in Korea and in the US. There is not a clear pattern that can be applied to all the fields, but we note that in some fields, the performance gap has decreased. Physics is a very distinctive case in that recent graduates from Korean institutions are more productive than those from US institutions in terms of the number of papers. For the cohort of doctoral degree holders in physics who earned their degree between 1995 and 2000, the performance gap between US doctoral degree holders and their Korean counterparts is approximately 0.6 papers per year. The gap was narrowed to 0.4 papers for the 2001~2005 cohort. For the 2006~2010 cohort, doctoral degree holders from Korean institutes produce 0.5 more papers than those from US institutions, but in the humanities and social sciences, the performance gap has not been narrowed. As in the effect on the professors' productivity levels, the effects on graduate students are small for those in the humanities and social science fields. One possible reason is that in those academic disciplines, researchers tend to

TABLE 7—COMPARISON OF PRODUCTIVITY OF KOREAN DOCTORATE FROM US AND KOREAN INSTITUTION BY FIELDS - ANNUAL AVERAGE PRODUCTION OF PAPERS (INTERNATIONAL JOURNALS)

| | 1995~2000 | | 2001~2005 | | 2006~2010 | |
|---|---|---|---|---|---|---|
| | US | Korea | US | Korea | US | Korea |
| Physics | 1.23(34) | 0.61(47) | 1.13(13) | 0.71(66) | 0.30(11) | 0.83(79) |
| Biology | 0.55(59) | 0.53(110) | 0.73(29) | 0.58(154) | 0.88(14) | 0.35(181) |
| Chemistry | 0.71(31) | 0.73(54) | 1.08(39) | 0.61(60) | 0.62(29) | 0.50(83) |
| Computer | 0.35(49) | 0.11(163) | 0.40(33) | 0.20(181) | 0.40(18) | 0.20(151) |
| Electronic | 0.84(54) | 0.19(227) | 0.80(54) | 0.33(194) | 0.72(38) | 0.40(165) |
| Mathematics | 0.26(24) | 0.21(30) | 0.45(17) | 0.51(44) | 0.27(9) | 0.26(29) |
| Mechanical | 0.60(35) | 0.16(102) | 0.83(24) | 0.38(76) | 0.78(24) | 0.34(104) |
| Architectural | 0.26(18) | 0.02(72) | 0.46(14) | 0.07(70) | 0.06(10) | 0.06(57) |
| Nuclear | 0.61(4) | 0.49(4) | 0.67(1) | 0.12(5) | 0.00(1) | 0.35(10) |
| Environmental | 0.64(18) | 0.20(39) | 0.90(20) | 0.21(40) | 0.63(11) | 0.36(31) |
| Food | 0.86(13) | 0.28(33) | 0.85(16) | 0.77(26) | 1.05(14) | 0.58(25) |
| Economics | 0.20(42) | 0.08(40) | 0.16(41) | 0.04(19) | 0.13(15) | 0.02(29) |
| Education | 0.10(51) | 0.01(131) | 0.08(58) | 0.01(180) | 0.12(50) | 0.01(162) |
| History | 0.04(16) | 0.01(105) | 0.05(8) | 0.01(73) | 0.07(4) | 0.00(60) |
| Sociology | 0.04(22) | 0.01(17) | 0.18(9) | 0.09(13) | 0.23(12) | 0.00(22) |
| Public Admin | 0.06(9) | 0.00(35) | 0.05(16) | 0.00(44) | 0.19(11) | 0.00(44) |
| English Lit | 0.03(40) | 0.00(55) | 0.01(36) | 0.00(28) | 0.01(17) | 0.02(22) |

*Note*: Numbers in parenthesis are the number of doctoral degree holders in each category.

publish their works in national journals. We will assess this possibility in the next section, presenting the result of the regression analysis.

## V. Empirical Results

### A. *Comparing the Two Different Funding Schemes in terms of Research Productivity*

This section presents the major results from the estimations of many academic disciplines. We will present OLS, fixed effects and random effects estimation results. Before examining the results, it should be noted that previous researchers pointed out problems when using the DID method for evaluating research fund programs. For example, Jaffe (2002) warns that in some cases, the DID method can produce more biased results than a simple regression.[8] It would be better to interpret our result as the maximum estimates of the net effect.

Let us look at the result for physics, shown in Table 8. The dependent variable is the number of publications in SCI journals for each year. For physics, the number of BK participants is 132, and that for WCU is 31. Because there are some professors who participate in both projects, and the sum of the professors participating either one of the projects is 147; accordingly, the control group numbers 147. In Table 8, we can see very similar results for BK21 and WCU. The coefficient of the participating dummy has a positive sign, meaning that the participants had higher performance levels before the project. However, the year dummy had a negative sign, meaning that the increasing trend in publications was weakened. The coefficient of the key variables, specifically the interaction term of the participating dummy and the year dummy variable, take a positive sign but are statistically insignificant. Both participants in the project and non-participants produced more research papers in international journals after the project, and we cannot say that the participants are more productive due to the project.

Table 9 presents the DID estimates for several selected fields for which we have A relatively large number of fund recipients in the sample. Like physics, the DID estimators for the WCU project are insignificant in nearly all academic disciplines. The only exception is mechanical engineering. In this field, the DID estimators are positive and significant for both the BK21 and the WCU projects, but the absolute value is higher for the WCU program.

[8]The following quote from Jaffe (2002) explains this point clearly. "The limitation of this (DID) approach is that it only controls for time-invariant unobservables. To the extent that the agency can and does evaluate the proposed project distinctly from the proposing entity, the resulting selection bias is not eliminated by differencing. In addition, one could imagine other sources of unobserved performance differences that vary across individuals and time. For example, applicants may decide to enter the grant competition when they have been enjoying unusually good (or bad?) recent performance. Any unobserved variation of this kind makes the differences estimator biased; differencing eliminates the time-invariant but introduces a new error related to the deviation in the previous period from the applicant's 'normal' performance. Indeed, depending on the relative magnitude of time-invariant and time-varying individual effects, differencing could produce estimates that are more biased than simple regression estimates"

TABLE 8—THE EFFECT OF PARTICIPATING IN THE BK21 OR WCU PROGRAM - PHYSICS

| | BK21 | | | WCU | | |
|---|---|---|---|---|---|---|
| | OLS | RE | FE | OLS | RE | FE |
| D_Parti | 1.170*** | 1.068*** | | 1.058*** | 0.970*** | |
| | (0.138) | (0.224) | | (0.169) | (0.321) | |
| P_Year | -0.450*** | -0.502*** | -0.533*** | -0.509*** | -0.539*** | -0.547*** |
| | (0.163) | (0.154) | (0.154) | (0.151) | (0.153) | (0.155) |
| Year*Parti | 0.203 | 0.297 | 0.361 | 0.451 | 0.572 | 0.635 |
| | (0.194) | (0.243) | (0.242) | (0.520) | (0.559) | (0.559) |
| Age | 0.133*** | 0.247*** | 0.532*** | 0.126*** | 0.197** | 0.430*** |
| | (0.0388) | (0.0824) | (0.139) | (0.0377) | (0.0837) | (0.132) |
| Agesq | -0.00108** | -0.00235*** | -0.00371** | -0.00111*** | -0.00189** | -0.00271* |
| | (0.000439) | (0.000890) | (0.00157) | (0.000412) | (0.000911) | (0.00152) |
| Trend | 0.166*** | 0.166*** | | 0.160*** | 0.160*** | |
| | (0.0248) | (0.0247) | | (0.0168) | (0.0279) | |
| No. Obs | 3,051 | 3,051 | 3,051 | 1,888 | 1,888 | 1,888 |
| $R^2$ | 0.094 | | 0.061 | 0.117 | | 0.110 |
| No. Scholars | | 279 | 279 | | 178 | 178 |

*Note*: 1) The Variable "Parti" is the dummy variable take value if professors take part in the BK21 or WCU project 2) Numbers in the parenthesis are robust standard errors.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE 9—DID ESTIMATORS FOR SELECTED ACADEMIC DISCIPLINES (INTERNATIONAL JOURNALS)

| | BK21 | | | WCU | | |
|---|---|---|---|---|---|---|
| | OLS | FE | RE | OLS | FE | RE |
| Physics | 0.203 | 0.297 | 0.361 | 0.451 | 0.572 | 0.635 |
| | (0.194) | (0.243) | (0.242) | (0.520) | (0.559) | (0.559) |
| Biology | -0.175 | -0.225 | -0.240 | -0.182 | -0.224 | -0.263 |
| | (0.110) | (0.162) | (0.167) | (0.395) | (0.387) | (0.392) |
| Chemistry | 0.478*** | 0.527*** | 0.546*** | 0.163 | 0.275 | 0.346 |
| | (0.131) | (0.166) | (0.168) | (0.464) | (0.584) | (0.577) |
| Computer | 0.160* | 0.151* | 0.147* | -0.298 | -0.238 | -0.193 |
| | (0.0905) | (0.0829) | (0.0837) | (0.805) | (0.672) | (0.678) |
| Electronic | 0.452*** | 0.491*** | 0.506*** | 1.122 | 1.123 | 1.104 |
| | (0.109) | (0.147) | (0.150) | (0.794) | (0.767) | (0.774) |
| Mathematics | -0.399*** | -0.510** | -0.541** | -0.0419 | -0.105 | -0.123 |
| | (0.149) | (0.239) | (0.250) | (0.383) | (0.403) | (0.413) |
| Mechanical | 0.346*** | 0.426*** | 0.450*** | 0.912** | 0.955** | 0.975** |
| | (0.107) | (0.115) | (0.117) | (0.455) | (0.483) | (0.485) |
| Economics | -0.277*** | -0.303*** | -0.312*** | -0.219 | -0.234** | -0.238* |
| | (0.102) | (0.0928) | (0.0969) | (0.330) | (0.119) | (0.128) |
| Education | -0.0880 | -0.136* | -0.169** | -0.00717 | 0.00777 | 0.0616 |
| | (0.0645) | (0.0806) | (0.0827) | (0.224) | (0.0773) | (0.0629) |
| History | -0.198*** | -0.198* | -0.241* | -0.180 | -0.180 | -0.200 |
| | (0.0684) | (0.108) | (0.129) | (0.123) | (0.133) | (0.137) |

*Note*: All coefficients are DID estimators. Numbers in parenthesis are robust standard errors.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

It is also notable that there are some cases, such as mathematics and economics, for which the DID estimators take negative values which are statistically significant. It is quite notable that the BK21 project appears to have an adverse effect on mathematics, unlike other science and engineering fields. One intuitive reason for this result is that research assistants in mathematics may not contribute

much to their professors' research productivity levels. The same reasoning can be applied to the humanities and social sciences fields. In many humanities and social sciences fields, research assistants' roles are limited. However, in such science and engineering fields as chemistry and electronic engineering, where laboratory experiments are an indispensable part of the research, graduate students who serve as research assistants can greatly enhance the productivity of their professors.

We can summarize the results as follows. In terms of the research productivity levels of professors, BK21 had a more positive effect than WCU in certain science and engineering fields. Thus, we can say that BK21 was more favorable with regard to professors' research productivity levels than WCU. However, in the humanities and social sciences fields, neither project had a positive effect, and BK21 usually had a negative effect on the productivity levels of professors in these fields. The negative effects are relatively small in the WCU case. In a sense, WCU is less harmful than BK21 to professors' research productivity levels in the humanities and social science fields.

It is quite clear that grants to graduate students have the potential to increase the productivity of professors in some fields in which research assistants make large contributions to the research process. Nonetheless, it is difficult find an intuitive explanation for the weak effect of the WCU project on the research productivity of participating professors in the science and engineering fields.

Moreover, it must be noted that the main purpose of these funding programs is not to increase the productivity of professors. Rather, the main purpose is to increase the quality of graduate studies. Next, we will examine the changes in the productivity of Korean doctoral degree holders from Korean institutions.

### B. *The Effect of Government Research Funds on the Productivity of Graduate Students*

At this stage, we examine the performance gap between doctoral degree holders educated in Korea and those educated in the USA. Table 10 presents the estimates of the performance gap in certain academic fields from a random effects model. For the 1995~2000 cohort, doctoral degree holders from US institutions produced more papers than those from Korean institutions in all academic disciplines. The situation does not change much for the 2000~2005 cohort, but for the 2006~2010 cohort, the performance gaps are either narrowed or, as in the case of physics and nuclear engineering, doctoral degree holders from Korean institutions produced more papers.

This clear sign of a narrowing gap in these cases can be considered as indirect evidence that major funding projects have somehow succeeded in lifting up the educational quality in Korean graduate schools in some science and engineering fields.

However, there are good reasons to suspect that the sample selection process could be a decisive factor that made the performance gap between the US doctoral degree holders and Korean doctoral degree holders smaller in recent years. Consider the case of doctoral degree holders from the US institutions who work in Korea. Doctoral degree holders who earned their degrees ten years earlier and stayed in the US for some years showed good performances and thus enjoyed

TABLE 10—COMPARISON OF THE PRODUCTIVITY OF KOREAN DOCTORAL DEGREE HOLDERS FROM US AND KOREAN INSTITUTIONS BY FIELD - REGRESSION RESULTS

| | International Journals (SCI or SSCI) | | | National Journals (KCI) | | |
|---|---|---|---|---|---|---|
| | 1995~2000 | 2001~2005 | 2006~2010 | 1995~2000 | 2001~2005 | 2006~2010 |
| Physics | -0.635*** | -0.418 | 0.532** | -0.00564 | -0.0465 | 0.0309** |
| | (0.246) | (0.311) | (0.259) | (0.0252) | (0.0861) | (0.0122) |
| Biology | -0.0858 | -0.0989 | -0.612 | 0.0532* | 0.0638** | -0.183 |
| | (0.0958) | (0.156) | (0.515) | (0.0323) | (0.0305) | (0.210) |
| Chemistry | -0.154 | -0.439** | -0.124 | 0.0328 | 0.0438* | 0.0244 |
| | (0.186) | (0.191) | (0.160) | (0.0437) | (0.0229) | (0.0284) |
| Computer | -0.238** | -0.195** | -0.164* | -0.0740** | -0.0430 | 0.0998 |
| | (0.0962) | (0.0806) | (0.0896) | (0.0334) | (0.0657) | (0.0642) |
| Electronic | -0.604*** | -0.411*** | -0.379*** | -0.124** | 0.00322 | 0.128** |
| | (0.172) | (0.142) | (0.139) | (0.0518) | (0.0562) | (0.0569) |
| Math | -0.122 | 0.0254 | -0.0278 | 0.110** | 0.0557 | 0.0464 |
| | (0.0776) | (0.152) | (0.101) | (0.0528) | (0.0340) | (0.0285) |
| Mechanical | -0.415*** | -0.302* | -0.518*** | -0.0715 | 0.145** | 0.0318 |
| | (0.110) | (0.171) | (0.161) | (0.0468) | (0.0741) | (0.0699) |
| Archit. | -0.235*** | -0.364** | 0.00738 | -0.378*** | -0.467* | 0.0411 |
| | (0.0832) | (0.166) | (0.0399) | (0.146) | (0.244) | (0.102) |
| Nuclear | -0.0481 | -0.622*** | 0.543*** | 0.218*** | 0.0611 | 0.0609 |
| | (0.269) | (0.0532) | (0.185) | (0.0771) | (0.0581) | (0.0558) |
| Environ. | -0.394** | -0.575*** | -0.220 | -0.121 | -0.143 | 0.275* |
| | (0.174) | (0.184) | (0.266) | (0.112) | (0.154) | (0.154) |
| Food | -0.496** | 0.159 | -0.390* | -0.0735 | -0.0830 | 0.212** |
| | (0.243) | (0.331) | (0.208) | (0.112) | (0.116) | (0.103) |
| Economics | -0.0619 | -0.109*** | -0.109* | 0.142 | 0.0376 | 0.0763 |
| | (0.121) | (0.0380) | (0.0599) | (0.213) | (0.0789) | (0.132) |
| Education | -0.0837*** | -0.0701*** | -0.111*** | -0.0988 | 0.0872 | 0.0591 |
| | (0.0278) | (0.0218) | (0.0338) | (0.0935) | (0.0718) | (0.123) |
| History | -0.0291 | -0.0379 | -0.0734 | 0.0540 | -0.247 | -0.0322 |
| | (0.0212) | (0.0400) | (0.0665) | (0.0987) | (0.182) | (0.150) |
| Sociology | -0.0337 | -0.114 | -0.221** | -0.0790 | -0.226 | 0.209 |
| | (0.0206) | (0.149) | (0.0987) | (0.109) | (0.164) | (0.193) |
| Pub. Admin | -0.0688* | -0.0508** | -0.190* | 0.0991 | -0.377*** | -0.0821 |
| | (0.0408) | (0.0231) | (0.101) | (0.165) | (0.120) | (0.214) |
| English Lit | -0.0295** | -0.00711 | 0.0198 | -0.394*** | -0.318*** | 0.0382 |
| | (0.0123) | (0.00528) | (0.0176) | (0.0823) | (0.101) | (0.149) |

*Note*: Numbers in the parenthesis are robust standard errors.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

good chances to return to Korea and be hired at prestigious institutions. Their performances would be better than doctoral degree holders who earned their degrees ten years earlier, when there was little government funding for graduate students.

Now, let us consider the younger cohort. The best young researchers among those who just earned their degree in the USA had a greater chance to stay in the US than less able researchers. Thus, it is possible that we are comparing the average doctoral degree holders from Korean institutions with less able doctoral degree holders from US institutions. In the meantime, the large increase in research funding for graduate studies could cause many students stay in Korea rather than to choose to study abroad. Thus, the decrease in the performance gap may largely reflect a decrease in the ability gap among graduate students rather than a decrease in the educational quality gap in graduate schools.

Considering these selection effects, a more proper comparison group should be a group of Korean doctoral degree holders who studied and then stayed in the USA, which is simply not possible with the current dataset. We need to gather information on Korean scholars staying in the USA. While it is very likely that selection bias prevails, it is not likely that all of the decrease in the performance gap can be attributed to selection effects, especially in certain cases, such as physics.

Meanwhile, in the humanities and social sciences fields, the performance gap measured by the number of publications in international journals does not change much after the major graduate funding projects. The results are similar for national journals. The positive effect on the research productivity of graduate students after graduation is not clearly seen yet in many academic disciplines.

## C. *Summary and Policy Implications*

Here, we summarize the empirical results and derive some policy implications from them. Table 11 summarizes the empirical results presented in the previous section. The BK21 project had a positive effect in some natural science and engineering fields. The effect of the WCU projects is usually very weak. The only exception is mechanical engineering, where both the BK21 and the WCU had positive effects, with WCU having a stronger effect. In some academic disciplines that WCU project works better than BK21 because WCU project is less harmful, rather having overall positive effects. There are several possible reasons for this weak effect. Most of all, the emphasis on international cooperation does not appear to be a wise way to spend research funds efficiently.

All things considered, the BK21 funding scheme appears to be a good program in that it can raise the research productivity of professors while training future researchers in many natural science and engineering fields. It also appears to be a better funding scheme than the WCU scheme. In some academic fields in which research assistants provide important input to the research process, it appears only natural that a direct subsidy to research assistants will have noticeable effects.

However, we must worry about the negative effects of funding projects in certain fields. It is difficult to believe that a funding project can have negative effects, but we can conceive of several possible reasons for this. For example, we suspect that

TABLE 11—SUMMARY OF RESULTS

| | BK21 Eff | WCU Eff | Relative Effectiveness | Educ Quality |
|---|---|---|---|---|
| Physics | – | – | Similar | ○ |
| Biology | – | – | Similar | – |
| Chemistry | ○ | – | BK21 over WCU | ○ |
| Mathematics | × | – | WCU over BK21 | – |
| Electronic Engin. | ○ | – | BK21 over WCU | ○ |
| Computer Science | ○ | – | BK21 over WCU | ○ |
| Mechanical Engin. | ○ | ○ | WCU over BK21 | – |
| Economics | × | × | Similar | – |
| Education | × | – | WCU over BK21 | – |
| History | × | – | WCU over BK21 | – |

*Note*: ○ Positive effect, — No Effect, × Negative Effect

the selection of the recipients was not based on the individual professors' productivity levels in some fields. For example, the restriction that more than 70% of faculty members should join the research team can induce some free-riding unproductive recipients to participate in the project. It is also possible that some of the recipients made their maximum effort before the program started, only to be selected, while they have little incentive to work as diligently after the selection.

The small pecuniary incentive for faculty members can also be a reason for the small effect. Regardless of the reason, there should be wiser ways to spend research funds more efficiently. Specifically, for certain fields in which these funds do not have positive effects on either professors' or graduate students' research productivity levels, we need to think about other schemes.

For example, we can consider economics. How can we interpret the negative effects of the BK21 and the WCU projects shown in economics? Do we need a large research group in economics? Is it the best way to educate researchers of the next generation to give grants only to students in two or three graduate schools? Why should we distribute grants to graduate students based on their professors' or departments' merit, instead of their own merits?[9] These questions lead us to think that there could be better ways to enhance the productivity of current professors while providing a higher quality education for the next generation of researchers in diverse academic disciplines.

In terms of the educational quality, it is challenging to derive policy suggestions. We find that the performance gaps between doctoral degree holders from Korean institutions and those from US institutions have narrowed in certain natural science and engineering fields. However, there are many academic disciplines for which these performance gaps are maintained with all government subsidies. Hence, it is difficult to reach the conclusion that the major funding projects enhanced the overall quality of graduate education, especially for many social science and humanity fields. Even in fields that succeeded in decreasing the gaps, there are reasons to suspect that it was the selection process rather than the educational quality which served as the main cause of the dragging down of the performance gap.

Nonetheless, it is not likely that selection bias explains the overall decrease in the gap. It should also be noted that the decreasing performance gap is more evident in such fields as chemistry, electronics engineering, and computer science, where the BK21 project showed a positive effect on professors' productivity levels as well. This can be interpreted as a sign that research grants to graduate students ultimately enhanced their research productivity, perhaps through the cooperation with their professors. This in turn implies that the performance levels of the current generation and the next generation are highly correlated. If this is indeed the case, the best means of enhancing the research productivity of the next generation of researchers would be to induce higher productivity in the current generation regardless of the field of study.

[9]In a different context, Conley *et al.* (2013) recently raised a similar concern with US data. They find that the research rankings of top economics departments are a surprisingly poor predictor of the subsequent research rankings of their PhD graduates.

## VI. Concluding Remarks

In this paper, we have examined the effects of research funds to graduate schools on the research productivity of professors by comparing the quantity of publications between projects participants and non-participants. The most notable result is that the effects of the BK21 and WCU projects on professors' research productivity levels differ for different fields. For BK21, we find a positive effect in many natural science and engineering fields. In these fields, the effects of the WCU are generally weaker than those of the BK21 project. The restriction on fund use may be the main cause of this weak effect. There is no reason to believe that international cooperation is the key element in enhancing research productivity for the current generation or future generation of researchers. Rather, it appears that one of the key factors behind the increase in research productivity is help from research assistants in academic fields for which experiments are indispensable during the research process.

While the empirical results are quite clear and have strong policy implications, there are obvious limitations. Most of all, the lack of information about a proper control group is the main problem in the empirical analysis. Specifically, it appears to be challenging to correct any possible selection bias with the current dataset. Moreover, our measure of research productivity has a clear limitation in that it places too much weight on quantity. We need to incorporate information on the quality aspects of research productivity in the analysis.[10] In the case of the research productivity of graduate students, we need better datasets that can identify recipients of funding projects among Korean doctoral degree holders. All of these limitations are naturally suggesting future research directions.

Despite these instances of a lack of empirical rigor due to data limitations, the differences in the effects among academic disciplines should be taken seriously. For some fields for which the BK21 or WCU projects had weak or negative effects, we should think about revising the funding schemes to reflect the characteristics of the research process of the corresponding academic disciplines.

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[10]There are many people in Korean academia who offer the criticism that the government and universities place too much weight on the quantity of the research products, and that as a result there are not as many challenging and influential studies as desired.

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# A Signaling Theory of Education under the Presence of Career Concerns

By SUNJOO HWANG*

*A person's life consists of two important stages: the first stage as a student and the second stage as a worker. In an integrated model of education and career concerns, I analyze the welfare effects of education. In Spence's job market signaling model, education as a sorting device improves efficiency by mitigating the lemon market problem. In contrast, in the integrated model, education as a sorting device can be detrimental to social welfare, as it eliminates work incentives generated by career concerns.*

Key Word: education, signaling, career concerns
JEL Code: D86, G38

## I. Introduction

Life consists of two important stages. In the first stage, as students, people decide how much education to obtain. In the second stage, as workers, they choose jobs and exert effort in the workplace (and then they retire). Therefore, education and careers are two important choices people make in life. However, people do not choose education and careers independently. They choose education while anticipating its impact on their future careers. However, the existing literature rarely considers possible interactions between education and careers. The standard model of (stand-alone) education is the job market signaling model of Spence (1973), in which education is used to signal workers' hidden productivity to the labor market. The standard model of (stand-alone) careers is the career concerns model of Holmstrom (1999), in which workers exert efforts to achieve good performance, which signals to the labor market that they are talented workers. Although the education and career concerns literatures starting from the two aforementioned seminal papers are both vast, little work has been done on the interactions between education and career concerns.

This paper examines an integrated model of education and career concerns. By

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explicitly considering the interactions between education and career concerns, I find new welfare implications of education: if society uses education to sort agents according to productivity, then education could reduce the total surplus. This is inconsistent with Spence's standard job market signaling model, which implies that education as a sorting device enhances welfare (even if it has no human capital value). Suppose that there are high type and low type agents. The labor market treats them equally, as they are indistinguishable. In such a case, high type agents leave and only low type agents prevail in the labor market (with an appropriate assumption on reservation payoffs). This loss of top talent (i.e., the lemon market problem) can be resolved if education reveals hidden types.

This story of the lemon market problem, however, may be overturned if not merely hidden productivity (type) but also hidden effort can contribute to output. Suppose that there exists a post-education work stage, in which an agent exerts effort to produce output. If the labor market does not fully know the agent's hidden productivity, she works diligently to demonstrate her talent. However, if education reveals the hidden talent, she is demotivated, exerts little effort, and hence output decreases. Therefore, education as a sorting device could be detrimental to welfare.

This paper is organized as follows. Section II presents an integrated model of education and career concerns. Section III analyzes the welfare implications of education. Section IV discusses an important technical issue in the integrated model. Spence's standard model has a unique separating equilibrium and no pooling equilibrium if one uses the Intuitive Criterion suggested by Cho and Kreps (1987), a standard equilibrium refinement. If the integrated model also has no pooling equilibrium, this paper's main welfare implication has of little value. In Section IV, I argue that pooling equilibria could survive the Intuitive Criterion in the integrated model. Section 5 presents the conclusion.

## II. The Model

An agent's hidden productivity $\theta$ is either $h$ (high) or $l$ (low) where $0 = l < h < 1$. There are many agents whose total measure is normalized to one. One half is of high type and the other half is of low type.

The timeline is as follows. There are three periods $t = 0, 1, 2$. At $t = 0$, each agent as a student chooses a publicly-observable education level $e \in [0, \infty)$ at the cost of education $C(\theta, e)$ such that $C(\theta, 0) = 0$, $C_e > 0$, $C_\theta < 0$, and $C_{e\theta} < 0$, where the lower subscript denotes the (cross-) partial derivatives. At $t = 1, 2$, the competitive labor market pays wage $w_t$; Given $w_t$, each agent as a worker chooses privately-observable effort level $a_t \in [0, \overline{a}]$ at the cost of effort $c(a_t)$ such that $c(0) = c'(0) = 0$, $c' > 0$, and $c'' > 0$; Given $a_t$, a publicly-observable output $y_t \in \{0, 1\}$ is realized.

Effort and productivity contribute to output in the following manner: let $f(\theta, a_t)$ be the conditional probability of success

$$f(\theta, a_t) \equiv \mathbb{P}(y_t = 1 \mid \theta, a_t) = \theta + ka_t, \; k > 0 \tag{1}$$

Note that the probability of success increases with effort and productivity. (The following analysis holds even if $f(\theta, a_t)$ has a general functional form such that $f_a > 0$ and $f_\theta > 0$). To ensure that $f(\theta, a_t) \leq 1$ for any $a_t \in [0, \bar{a}]$, it is necessary to assume that $\bar{a} \leq 1 - h$. Given that $y_t \in \{0, 1\}$, one can interpret $f(\theta, a_t)$ as the expected output conditional on $(\theta, a_t)$.

I assume that the labor market is competitive, and hence wage $w_t$ equals the market's expectation of output. I assume that output $y_t$ is not contractible.

Given a wage structure, a type $\theta$ agent's preference is represented by

$$-C(\theta, e) + \mathbb{E}^\theta[w_1 \mid \cdot] - c(a_1) + \delta\{\mathbb{E}^\theta[w_2 \mid \cdot] - c(a_2)\} \tag{2}$$

where $\delta \in (0, 1)$ is the discount factor and $\mathbb{E}^\theta[\cdot \mid \cdot]$ denotes the type $\theta$ agent's expectation with respect to the relevant information structure.

Below, I consider two cases. First, high type agents choose a higher level of education than low type agents—separating equilibrium. Second, both types choose the same level of education—pooling equilibrium.

## A. *Separating Equilibrium*

Note that education has no human capital value. It can only signal hidden productivity. Thus, the most reasonable case is one in which low type agents choose zero education while high type agents choose the minimum level of education, which the low type agents cannot mimic because of higher cost of education. This separating equilibrium is known as the Riley equilibrium. I confine my attention to the Riley equilibrium, which is later shown to be the only separating equilibrium that satisfies the Intuitive Criterion suggested by Cho and Kreps (1987).

In the Riley equilibrium, types are revealed, as is the expected output. Suppose the market expects that $a_t^e(\theta)$ will be chosen in equilibrium. A type $\theta$ agent's wage is then, for $t = 1, 2$,

$$w_t = f(\theta, a_t^e(\theta)) = \theta + ka_t^e(\theta)$$

That is, the wage is fixed and independent of effort $a_t$ (though it depends on $a_t^e(\cdot)$). Let $a_t^*(\theta)$ denote the equilibrium effort type $\theta$ agent actually chooses. Because effort is costly and has no effect on wages, it follows that $a_t^*(\theta) = a_t^e(\theta) = 0$ in rational expectations equilibria.

Let $e(\theta)$ be the equilibrium level of education, which the type $\theta$ agent

chooses. Thus, $e(l)=0$ *and* $e(h)>0$. Note that $e(h)$ represents the minimum education level low type agents cannot profitably mimic. That is, $e(h)$ is characterized by

$$h(1+\delta)-C(l,\ e(h))=l(1+\delta)-C(l,\ e(l))=0 \tag{3}$$

Let $u^{\theta}$ denote the type $\theta$ agent's reservation payoff, which she can obtain by leaving the labor market. This is perhaps the payoff of self-production or of participating in an alternative labor market. I assume that $u^{l}=0$ for simplicity and that

**Assumption 1** $\frac{1}{2}h<u^{h}<h$

Assumption 1 implies that the lemon market problem exists: high type agents will not participate unless the types are revealed, despite the fact that their participation is socially efficient. I also assume that education is not prohibitively costly for the high type (though it is highly costly for the low type):

**Assumption 2** $(1+\delta)\left[h-u^{h}\right]>C(h,\ e(h))$

(3) implies that Assumption 2 holds if the education cost decreases sufficiently with productivity. Assumption 2 implies that the high type willingly participates in the labor market by undertaking costly education, as the hidden type is reveled, and therefore, a higher wage is promised.

The total surplus in this Riley separating equilibrium is given by

$$\frac{1}{2}\left\{(1+\delta)h-C(h,\ e(h))\right\} \tag{4}$$

as the low type agent's utility equals zero regardless of whether or not they participate.

As for a benchmark case, suppose that education cannot be used as a sorting device. Due to the lemon market problem, the total surplus is then given by

$$\frac{1}{2}\left\{(1+\delta)u^{h}\right\} \tag{5}$$

Assumption 2 and equations (4) and (5) imply that education as a sorting device mitigates the lemon market problem by inducing high type agents' participation in the labor market. Furthermore, education as a sorting device improves efficiency in the Paretian sense, as low type agents' payoffs are unchanged while high type agents' payoffs increase.

## B. *Pooling Equilibrium*

In a pooling equilibrium, education has no sorting effect, and hence, the labor market cannot distinguish types. Given that education has no role but is only costly, I confine my attention to the most efficient pooling equilibrium, in which both type agents choose zero education. In Spence's standard job market signaling model, where interactions between education and career concerns are ignored, this pooling equilibrium fails to satisfy the Intuitive Criterion. Later, I shall discuss that this is not the case if one considers the interactions between education and career concerns.

Suppose that the market expects that $a_t^e(\theta)$ is chosen in equilibrium. Let $\boldsymbol{a}_t^e$ denote $\left(a_t^e(h),\, a_t^e(l)\right)$ and $\mathbb{E}^m$ denote the market's expectation conditional on $\boldsymbol{a}_t^e$. Then, wages are given by

$$w_1 = \mathbb{E}^m\left[y_1\right] \tag{6}$$

$$w_2(y_1) = \mathbb{E}^m\left[y_2 \mid y_1\right] \tag{7}$$

Importantly, the date-2 wage (i.e., the expected date-2 output) depends on the date-1 output $y_1$. This is because market observes the date-1 performance $y_1$, which is informative of an agent's hidden productivity $\theta$, which determines the date-2 performance $y_2$. (In a separating equilibrium, in contrast, the date-1 performance has no value of information, as the hidden productivity is already unraveled). This observation is crucial in this paper. Even if there are no explicit incentive contracts, agents face date-1 incentives because the date-1 effort (stochastically) determines the date-1 output, which determines the date-2 wage. However, the date-1 wage is fixed and independent of output, as no output is realized in the beginning of date-1.

To observe this formally, note that at date-2, a type θ agent maximizes $w_2(y_1) - c(a_2)$. Since $w_2(y_1)$ is independent of $a_2$ (while it depends on $a_2^e(\theta)$), the agent chooses $a_2^*(\theta) = 0$ for $\theta = h, l$. Then, in rational expectations equilibria, it follows that $a_2^e(\theta) = a_2^*(\theta) = 0$. At date-1, the agent chooses $a_1 = a_1^*(\theta)$, which maximizes

$$w_1 - c(a_1) + \delta\left\{\mathbb{E}^\theta\left[w_2(y_1) \mid a_1\right] - c(a_2)\right\} \tag{8}$$

where $\mathbb{E}^\theta$ is the type $\theta$ agent's expectation conditional on $\theta$ and $\boldsymbol{a}_t^e$. Since $a_1$ affects the probability of $y_1$, $a_1 = a_1^*(\theta)$, is characterized by the following first-order condition

$$
\begin{aligned}
c'(a_1) &= \delta \frac{\partial}{\partial a_1} \mathbb{E}^{\theta}\left[ w_2\left(y_1\right) | a_1 \right] \\
&= \delta \frac{\partial}{\partial a_1}\left[ f\left(\theta, a_1\right) w_2(1) + \left\{1 - f\left(\theta, a_1\right)\right\} w_2\left(0\right)\right] \\
&= \delta f_a\left(\theta, a_1\right)\left[ w_2\left(1\right) - w_2\left(0\right)\right] : \text{ the marginal incentive}
\end{aligned} \tag{9}
$$

In general, $a_1^*(\theta)$ depends on $\theta$, as $f_a(\theta, a_1)$ depends on $\theta$. Given the simplification that $f\left(\theta, a_t\right) = \theta + ka_t$, however, $a_1^*(\theta)$ is independent of $\theta$, though the main result of this paper is robust to the functional form of $f\left(\theta, a_t\right)$ under certain regularity conditions.[1] Thus, I let $a_1^*(\theta) = a_1^*$ and $a_1^e(\theta) = a_1^e$. One may expect that the wage wedge $\left[w_2(1) - w_2(0)\right]$ is positive. This is true because better date-1 performance implies that hidden productivity is greater, indicating that the expected date-2 performance would be greater. The following lemma provides a formal account.

**Lemma 1** *The marginal incentive in (9) is positive, independent of* $\theta$*, and equal to*

$$
\delta k \frac{VAR^m\left(\theta\right)}{VAR^m\left(y_1\right)} \tag{10}
$$

*where* $VAR^m$ *is the market's assessed variance conditional on* $\mathbf{a}_t^e$.

*Proof*: First of all, the marginal incentive is positive since the variances are always nonnegative and $\theta$ is a nondegenerate random variable from the market's perspective. Independence with respect to $\theta$ is obvious. Next, I shall prove that $\left[w_2\left(1\right) - w_2\left(0\right)\right]$ equals the ratio of variances. Initially, the wage is given by

$$
\begin{aligned}
w_2\left(y_1\right) &= \mathbb{E}^m\left[y_2 \mid y_1\right] = \mathbb{E}^m\left[\mathbb{E}^m\left[y_2 \mid \theta, y_1\right] \mid y_1\right] \quad \text{(the iterated expectation)} \\
&= \mathbb{E}^m\left[1 \cdot f\left(\theta, a_2^e\right) + 0 \cdot \left\{1 - f\left(\theta, a_2^e\right)\right\} \mid y_1\right] \\
&= \underbrace{f\left(h, a_2^e\right)}_{=h} \mathbb{P}^m(h \mid y_1) + \underbrace{f\left(l, a_2^e\right)}_{=0} \{1 - \mathbb{P}^m(h \mid y_1)\}
\end{aligned} \tag{11}
$$

[1] Assume a set of regularity conditions: $f_a > 0$, $f_\theta > 0$, and $f_{a\theta} \geq 0$ for any $(\theta, a)$, where the subscripts denote (cross) partial derivatives. In this case, it can be shown that $a_1^*(h) \geq a_1^*(l) > 0$ Although the equilibrium effort depends on type, it is unobservable by the market. Thus, under the absence of education as a sorting device, the market cannot identify the high type from the low type, and hence, the agent has work incentives. I thank an anonymous referee for having pointed out to me the necessity of certain regularity conditions.

where $\mathbb{P}^m(h \mid y_1)$ is the market's posterior of $\theta = h$ given $y_1$ and $\boldsymbol{a}_1^e$. This posterior is given by

$$\mathbb{P}^m(h \mid y_1 = 1) = \frac{\frac{1}{2} f\left(h, a_1^e\right)}{\frac{1}{2} f\left(h, a_1^e\right) + \frac{1}{2} f\left(l, a_1^e\right)}$$

$$\mathbb{P}^m(h \mid y_1 = 0) = \frac{\frac{1}{2}\left[1 - f\left(h, a_1^e\right)\right]}{\frac{1}{2}\left[1 - f\left(h, a_1^e\right)\right] + \frac{1}{2}\left[1 - f\left(l, a_1^e\right)\right]}$$

Then, it follows

$$w_2(1) - w_2(0) = \frac{\frac{1}{4} f\left(h, a_2^e\right)\left[f\left(h, a_1^e\right) - f\left(l, a_1^e\right)\right]}{\frac{1}{2}\left[f\left(h, a_1^e\right) + f\left(l, a_1^e\right)\right]\left[1 - \frac{1}{2}\left\{f\left(h, a_1^e\right) + f\left(l, a_1^e\right)\right\}\right]} \tag{12}$$

Note that the numerator equals $\frac{1}{4}h^2$, which equals $VAR^m(\theta)$ since

$$VAR^m(\theta) = \mathbb{E}^m\left[\theta^2\right] - \mathbb{E}^m\left[\theta\right]^2 = \frac{1}{2}h^2 - \frac{1}{4}h^2 = \frac{1}{4}h^2$$

The denominator equals $VAR^m(y_1)$ since

$$\begin{aligned} VAR^m(y_1) &= \mathbb{E}^m\left[y_1^2\right] - \mathbb{E}^m\left[y_1\right]^2 \\ &= \mathbb{E}^m\left[y_1\right](1 - \mathbb{E}^m\left[y_1\right]) \text{ since } y_1 \in \{0, 1\} \text{ implies } \mathbb{E}^m\left[y_1^2\right] = \mathbb{E}^m\left[y_1\right] \end{aligned}$$

where $\mathbb{E}^m\left[y_1\right] = \mathbb{E}^m\left[\mathbb{E}^m\left[y_1 \mid \theta\right]\right] = \mathbb{E}^m\left[f(\theta, a_1^e)\right] = \frac{1}{2}\left\{f\left(h, a_1^e\right) + f\left(l, a_1^e\right)\right\}$. ■

Lemma 1 implies that the date-1 marginal incentive is determined by the signal-to-noise ratio—the extent to which the data $y_1$ conveys information about a hidden variable $\theta$. Holmstrom (1999) finds the same result under a simpler model in which neither the market nor the agent knows the hidden type. Thus, making $\theta$ private information does not affect the size of the career concerns motive of work incentives under the current specification, in which the expected output is linear in

$\theta$ and $a_t$ (i.e. $f(\theta, a_t) = \theta + ka_t$). In a more general specification, work incentives depend on $\theta$.

A key observation from (10) is as follows. If an agent's hidden ability is not revealed to the labor market, the agent faces date-1 work incentives in order to convince the market that she is of high ability.

The next lemma demonstrates the existence of a rational expectations equilibrium $\left(a_t^* = a_t^e\right)$. Note that $w_2(y_1)$ depends on $a_1^e$. To highlight this dependence, I write $w_2(y_1) = w_2(y_1)\left(a_1^e\right)$.

**Lemma 2** *Suppose* $c'\left(\frac{1-h}{k}\right) > h\delta k$. *Then, there exists a rational expectations equilibrium* $a_1^* \in \left(0, \frac{1-h}{k}\right)$ *such that*

$$\delta k\left[w_2(1)(\hat{a}_1) - w_2(0)(\hat{a}_1)\right] = c'(\hat{a}_1) \quad at \quad \hat{a}_1 = a_1^*$$

*Proof*: Let $v\left(a_1^e\right) \equiv w_2(1)\left(a_1^e\right) - w_2(0)\left(a_1^e\right) > 0.$ In addition, let $g(\cdot) \equiv \frac{c'(\cdot)}{\delta k}$. Then, (*) there exists a unique $a_1 \in \left(0, \frac{1-h}{k}\right)$ for each given $a_1^e$ such that $g(a_1) = v\left(a_1^e\right)$ since $c'(0) = 0$, $c'\left(\frac{1-h}{k}\right) > h\delta k$, and $h > v\left(a_1^e\right)$. Then, $a_1 = g^{-1}\left(v\left(a_1^e\right)\right)$. Let $\Psi\left(a_1^e\right) \equiv g^{-1}\left(v\left(a_1^e\right)\right)$. $\Psi\left(a_1^e\right)$ is a continuous function on the closed interval $\left[0, \frac{1-h}{k}\right]$ to the same interval. Then, the Brouwer fixed point theorem and (*) imply that there exists an $a_1^* \in \left(0, \frac{1-h}{k}\right)$ such that $a_1^* = \Psi(a_1^*)$. That is, there exists a rational expectations equilibrium $a_1^*$. ■

Given the equilibrium effort $a_1^*$, the date-1 wage equals

$$w_1 = \mathbb{E}^m[y_1] = \mathbb{E}^m\left[\mathbb{E}^m[y_1 \mid \theta]\right] = \mathbb{E}^m\left[f\left(\theta, a_1^*\right)\right] = \frac{1}{2}h + ka_1^*$$

Additionally, according to (11), a type $\theta$ agent's expectation of the date-2 wage equals

$$\mathbb{E}^\theta\left[w_2(y_1)\right] = h\mathbb{E}^\theta\left[\mathbb{P}^m(h \mid y_1)\right]$$

Subsequently, a type $\theta$ agent's payoff equals

$$U_P(\theta) \equiv \frac{1}{2}h + ka_1^* - c(a_1^*) + \delta h \mathbb{E}^{\theta}\left[\mathbb{P}^m(h \mid y_1)\right] \tag{13}$$

Note that this payoff increases with the level of equilibrium effort $a_1^*$ since (9) implies that $a_1^*$ is lower than the first-best effort, which maximizes $ka - c(a)$. Thus, if there are two equilibrium efforts, $a'$ and $a''$ such that $a' < a''$, then every agent is strictly better off with $a''$ than $a'$. Therefore, the remaining part of this paper focuses on the maximum (or the supremum) of equilibrium efforts based on the notion of the Pareto optimality.

Note that low type agents will always participate in the labor market, as their reservation payoff $u^l$ is zero. However, high type agents will participate if and only if

**Assumption 3** $\frac{1}{2}h + ka_1^* - c(a_1^*) + \delta h \mathbb{E}^{h}\left[\mathbb{P}^m(h \mid y_1)\right] \geq (1+\delta)u^h$

To observe when high type agents profitably participate, suppose for the moment $k = 0$, and hence, $a_1^* = 0$ by (10). Note that $\mathbb{E}^{\theta}\left[\mathbb{P}^m(h \mid y_1)\right] \in (0, 1)$ is the type $\theta$ agent's expectation of the market's posterior given $y_1$. High type agents are more optimistic about the future than low type agents, as they know their superior ability: $\mathbb{E}^{l}\left[\mathbb{P}^m(h \mid y_1)\right] < \frac{1}{2} < \mathbb{E}^{h}\left[\mathbb{P}^m(h \mid y_1)\right]$. This is related to the market's learning effect. The labor market updates its expectation of date-2 output by observing the date-1 output. High type agents then expect more income, as the date-1 output is (stochastically) higher. If the learning effect is slight (i.e., $\left|\mathbb{E}^{h}\left[\mathbb{P}^m(h \mid y_1)\right] - \frac{1}{2}\right|$ has a small value), Assumption 1 implies that Assumption 3 is violated. If instead the learning effect is large enough, Assumption 3 is satisfied.

Even if the learning effect is slight, if $k > 0$ and the surplus $ka_1^* - c(a_1^*)$ generated by career concerns is large enough, then Assumption 3 is satisfied.

As long as high type agents find it optimal to participate (i.e. Assumption 3 holds), the total surplus in this pooling equilibrium is $\frac{1}{2}\left[U_P(h) + U_P(l)\right]$, which equals

$$\frac{1}{2}(1+\delta)h + ka_1^* - c(a_1^*) \tag{14}$$

according to the martingale property, that is, the expectation of the posterior equals its prior.

## III. Welfare Implications

By comparing (14) to (4), it is apparent that the total surplus in the pooling equilibrium is greater than that in the Riley separating equilibrium. That is, the use of education as a sorting device reduces the total surplus. There are two reasons. First, education as a signaling device reveals hidden productivity. Thus, agents need not persuade their ability to potential employers in the labor market, which means that their post-education work incentives (motivated by career concerns) are eliminated. In consequence, the work stage surplus $ka_1^* - c\left(a_1^*\right)$ is not realized. Second, education is wasteful and incurs cost $C\left(h, e\left(h\right)\right)$.

The detrimental effect of education as a sorting device hinges on Assumption 3. If this assumption is not satisfied, only low type agents participate in the labor market. Expecting this fact rationally, the market then pays zero to the participants. Thus, the total surplus in the pooling equilibrium equals

$$\frac{1}{2}\left(1+\delta\right)u^h$$

Thus, we return to the standard result, where the use of education as a signaling device improves the total surplus. One might wonder when Assumption 3 is more likely to be satisfied. This depends on $h$ and $u^h$. The degree of the lemon market problem can be measured by $|h-u^h|$ since adverse selection discourages the participation of high type agents in the labor market. Note that Assumption 3 holds if $h$ is large or $u^h$ is small, as in this case high type agents will participate even if the work stage surplus is relatively low. Thus, Assumption 3 is satisfied if the degree of the lemon market problem is severe, which is of high interest, whereas it is violated if the lemon market problem is not very important, which is of little interest. In the standard Spence model in which the post-education work stage is ignored, education as a sorting device is more beneficial if the lemon market problem is more severe. However, in this very case, education as a sorting device is more detrimental if the post-education work stage is explicitly considered.

Summarizing the analysis brings the following main result:

**Proposition 1** *Suppose that the lemon market problem exists (i.e., Assumption 1) and that education is not prohibitively costly (i.e., Assumption 2). Then,*
*(i) If there is no post-education work stage, the use of education as a sorting device increases the total surplus.*

*Suppose for the following that there is a post-education work stage.*

*(ii) If high type agents profitably participate in the labor market in the most efficient pooling equilibrium (i.e. Assumption 3), which is the case when the lemon market problem is severe, then education as a sorting device decreases the total surplus.*
*(iii) If high type agents cannot profitably participate in the most efficient pooling equilibrium (i.e. Assumption 3 is violated), which is the case when the lemon*

*market problem is unimportant, then education as a sorting device increases the total surplus.*

In the following, I consider three extensions. In the first extension, I consider multiple types. Productivity is determined by various hidden factors. For instance, intelligence and fitness-to-work are two important factors that contribute to overall productivity. Let $\theta_1$ denote intelligence, which agents observe but the market does not. The marginal cost of education $C_e(\theta_1, e)$ decreases in $\theta_1$. Let $\theta_2$ denote fitness-to-work, which is unobservable to agents and the market. Let $\theta \equiv g(\theta_1, \theta_2)$ be productivity, where $g$ increases in each argument. In this case, education can reveal only $\theta_1$. Lemma 1 then implies that an agent's post-education marginal incentive under separating equilibria equals

$$\delta k \frac{VAR^m(\theta \mid \theta_1)}{VAR^m(y_1)}$$

while the marginal incentive under pooling equilibria equals

$$\delta k \frac{VAR^m(\theta)}{VAR^m(y_1)}$$

That is, the marginal incentive is greater under pooling equilibria. This result holds irrespective of whether or not $\theta_1$ and $\theta_2$ are independent. That is, the more information education reveals, the more likely it will be detrimental to welfare.

In the second extension, I assume that education has both a human capital-enhancing effect and a sorting effect. This situation can be modeled in the following way: the overall productivity $\theta'$ equals $\theta + \alpha e$, where $\alpha > 0$. In this case, the welfare implication of education is ambiguous. On the one hand, it improves efficiency by raising productivity. On the other hand, it reduces efficiency by discouraging post-education work incentives.

In the third extension, explicit incentive contracts are considered. Thus far, I have assumed that workers face only the implicit incentive generated by career concerns but not an explicit incentive provided by a performance-based contract. Suppose instead that output $y_t$ is contractible at no cost. Then, the linear contract $w_t(y_t) = y_t - K$, where $K$ is a constant, induces the first-best effort since the agent becomes a residual claimant. However, such a 'perfect' contractibility is not satisfied in many real-life principal-agent relationships. Performance measures of workers in administration offices are often nonverifiable. Subjective and hence non-contractible performance measures (such as quality) often contain more information than objective performance measures (such as quantity). For these reasons, suppose that $y_t$ is non-contractible. Let $p_t$ be a contractible but imperfect performance measure. Workers then face an imperfect explicit incentive

generated by a contract $w_t(p_t)$. The implicit incentive generated by career concerns could then complement the imperfect explicit incentive. Therefore, education as a sorting device could reduce the welfare to an extent, which increases in the imperfectness of $p_t$.

Proposition 1 implies that uncertainty in types is beneficial for social welfare. This seems at odd at a first glance, as one might expect that the uncertainty, as a source of market failure, reduces social welfare. However, this is consistent with the general theory of second-best suggested by Lipsey and Lancaster (1956): if there is an existing source of market failure (so that the economy is in a second-best outcome), an additional source of market failure could either increase or decrease social welfare (see Milgrom and Roberts (1982) and Kim (2004) for other examples of the general theory.) However, Proposition 1 is not a simple corollary of the general theory. In fact, the general theory is too general to explain why an additional source of market failure is socially beneficial; the general theory only raises the possibility that an additional market failure is beneficial.

Proposition 1 is also related to the information disclosure literature. In a dynamic tournament setting, Ederer (2010) shows that disclosing interim performance can reduce incentives due to the trade-off between evaluation and motivation effects. In the presence of career concerns and relational contracting, Mukherjee (2008) shows that if the current employer discloses workers' performance levels to the labor market, the career concerns motive of incentives increases, whereas the effectiveness of relational contracting is reduced. Proposition 1 is, however, different from these papers in that (1) it examines the effect of disclosing types rather than performance on incentives and (2) these papers consider only post-education workplace behaviors, while the present study considers both education and post-education behaviors.

## IV. Intuitive Criterion

There are infinitely many separating and pooling equilibria in the standard job market signaling model (where there is no post-education work stage). However, Cho and Kreps (1987) show that only the Riley separating equilibrium (and no pooling equilibria) satisfies their Intuitive Criterion, which currently is the standard equilibrium refinement criterion, and is hence reasonable. Recently, Alos-Ferrer and Prat (2012) show that certain pooling equilibria can satisfy the Intuitive Criterion if there is learning by the market (or employers). If there is a post-education work stage, as in this paper, pooling equilibria are more likely consistent with the Intuitive Criterion. These points are elaborated below.

### A. *Separating Equilibrium*

Consider initially the standard job market signaling model. Let $(e^l, e^h)$ be a non-Riley separating equilibrium such that $e^l = 0$ and $e^h > e(h)$, where $e(h)$

is given by (3). (Note that $e^l$ cannot be positive since otherwise low type agents profitably deviate to zero education). Then, if an agent chooses $e'$ such that, $e(h) < e' < e^h$, the market should *not* believe that the agent is high type since otherwise high type agents profitably deviate to $e'$. However, such a belief is not *intuitive* for the following reason. If low type agents deviate to $e'$, they are worse off even in the best scenario in which the market believes them as high type and hence pays $h$ rather than $l$. If high type agents deviate to $e'$, they are better off in the best scenario. That is, low type agents never deviate while high type agents may deviate. Thus, the market should believe that those who deviate to $e'$ are high type. Therefore, if only the *intuitive* belief is allowed, as required by the Intuitive Criterion, $(e^l, e^h)$ is no longer a separating equilibrium. Nothing changes in this argument even if one introduces a post-education work stage, as there is no uncertainty in types.

## B. *Pooling Equilibrium*

Consider the standard job market signaling model. Let $e_P$ be a pooling equilibrium. Then, there is $e_P^\theta$ such that

$$\mathbb{E}^m[\theta](1+\delta) - C(\theta, e_P) = h(1+\delta) - C(\theta, e_P^\theta)$$

It follows then $e_P < e_P^l < e_P^h$. Suppose that $e_P$ is a pooling equilibrium. Then, the market should *not* believe that the agent who deviates to $e' \in (e_P^l, e_P^h)$ is high type, since otherwise high type agents profitably deviate to $e'$. But this belief is not *intuitive*. By deviating to $e'$, low type agents are worse off even under the best scenario (i.e., the market believes them as high type), while high type agents are better off under the best scenario. Thus, only high type agents may deviate to $e'$, and hence, the market should believe that those who choose $e'$ are high type. If only this type of *intuitive* belief is allowed, $e_P$ is no longer a pooling equilibrium.

However, this is not the case if one adds post-education learning by the market (or employers). After the education choice, the output signal $y_t$ is realized. (To focus on the learning effect, I assume for now that $k = 0$ so that agents do not exert any work effort). By observing $y_1$, the labor market learns (partially) about the hidden type and then adjusts its expectation of the date-2 output $\mathbb{E}^m[\theta \mid y_1]$. High type agents know that their date-1 output will be (stochastically) greater than that of low type agents. Thus, even if types are not revealed in pooling equilibria, high type agents expect larger incomes (i.e., $\mathbb{E}^h\left[\mathbb{E}^m[\theta \mid y_1]\right] > \mathbb{E}^l\left[\mathbb{E}^m[\theta \mid y_1]\right]$). Then, a high type agent's gain from separating himself (by gaining more education than $e_P$) from low type agents is lower than it is when there is no post-education

learning. To see this, note that $e_P^\theta$ is determined via

$$\mathbb{E}^m\left[\theta\right]+\delta\mathbb{E}^\theta\left[\mathbb{E}^m\left[\theta\mid y_1\right]\right]-C\left(\theta, e_P\right)=h\left(1+\delta\right)-C\left(\theta, e_P^\theta\right)$$

If this learning effect ($\mathbb{E}^h\left[\mathbb{E}^m\left[\theta\mid y_1\right]\right]-\mathbb{E}^l\left[\mathbb{E}^m\left[\theta\mid y_1\right]\right]$) is large enough, it follows that $e_P^l > e_P^h$. Then, there is no education level $e'$ such that low type agents are worse off even under the best scenario while high type agents are better off under the best scenario. Thus, this pooling equilibrium satisfies the Intuitive Criterion. (See Alos-Ferrer and Prat (2012) for more details).

If one also considers post-education working (i.e., $k>0$), then the pooling equilibria become more robust with respect to the Intuitive Criterion. By separating himself from low type agents, high type agents lose the work stage surplus $ka_1^*-c(a_1^*)$, which is realized only in pooling equilibria. If this surplus is large enough, high type agents are worse off by separating himself from low type agents (by taking more education than $e_P$) even in the best scenario. That is, for any $e>e_P$, it follows that

$$\mathbb{E}^m\left[\theta\right]+\delta\mathbb{E}^h\left[\mathbb{E}^m\left[\theta\mid y_1\right]\right]+ka_1^*-c\left(a_1^*\right)-C\left(h, e_P\right)>h\left(1+\delta\right)-C\left(h, e\right)$$

The pooling equilibrium $e_P$ then satisfies the Intuitive Criterion.

## V. Conclusion

I revisit Spence's signaling theory of education by providing an integrated model of education and career concerns. Under the absence of post-education career concerns, education as a sorting device improves welfare by mitigating the lemon market problem. Under the presence of post-education career concerns, sorting by education could be detrimental to social welfare, as it eliminates work incentives generated by career concerns.

Although this paper examines the welfare effects of education, one should be careful in drawing educational policy implications directly from the current paper, as the main result is based on several assumptions. Rather, the merit of this paper is that it provides a theoretic framework with which researchers may conduct thought experiments regarding possible dynamics of education, careers, incentives, and policies.

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