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Estimation of the Phillips Curve Using Regional Data

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There are two identification problems that can occur when the Phillips curve is estimated using time-series data. First, inflation expectations and labor market conditions are correlated to cost-push shocks (error term of the Phillips curve), causing an endogeneity problem in the estimating equation. Next, if a central bank conducts an optimal monetary policy under the theoretical assumption that the Phillips curve holds, the inflation rate observed in actual data reflects only the impact of cost-push shocks.

According to recent studies, if the Phillips curve is estimated using regional panel data, even when a central bank carries out an optimal monetary policy, regional demand shocks are not fully offset, making it possible to estimate the relationship between demand shocks and prices. In addition, since cost-push shocks can be controlled through fixed effects, the endogeneity in the estimating equation can be significantly mitigated.

The analysis results of this paper are as follows. First, the job openings rate and the consumer price index (CPI) in Korea vary widely by region. While the nationwide job openings rate has a higher concentration in some ranges, the regional job openings rate shows more of a normal distribution. Second, the slope of Korea's Phillips curve varies significantly depending on whether cost-push shocks are controlled. When such shocks are not controlled, the slope of the Phillips curve is only 0.01. When they are controlled, however, the slope rises to 0.56. These findings imply that labor market conditions and prices are still closely correlated.

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Ⅰ. Introduction

Since the economist Alban William Phillips (1914-1975) showed that there is an inverse relationship between nominal wage growth and the unemployment rate, using data for England from 1861 to 1957, the Phillips curve has been widely used as a tool to analyze the relationship between macroeconomic conditions and inflation.[1)]

Since those days, central banks have shown keen interest in the magnitude of the relationship (slope of the Phillips curve) between inflation and macroeconomic conditions, in addition to the nature of the relationship itself. While a Phillips curve with a flat slope means that the sensitivity of inflation to changes in economic conditions is not large, a steep Phillips curve indicates higher sensitivity of inflation to changes in economic conditions. The implications of the slope of the Phillips curve are thus significant for central banks in implementing monetary policy.

In this regard recently, controversies concerning the flattening of the Phillips curve that manifested after the Great Recession have persisted, mostly in the U.S. The slope of the Phillips curve had been steep, due to the Volcker disinflation period, among other reasons, until the early 1980s, but from the mid-1980s, it began to gradually flatten. After the Great Recession, researchers found that the relationship between economic conditions and prices weakened considerably. Identifying the causes of this development is, therefore, at the center of controversies surrounding the Phillips curve.[2)]

After the Great Recession, despite a very low unemployment rate in the U.S., prices did not rise much, leading some to argue that the slope of the Phillips curve no longer had any significance. This development is referred to as the "missing reinflation." Lee, Chang, and Choi (2022) also found that the relationship between Korea's economic conditions and inflation has moderated remarkably, as in the U.S., since the 2000s.

While various factors have been pointed to as the cause of the flattening of the Phillips curve,[3)] the identification problem of the Phillips curve is said to be one of them. Mavroeidis, Plagborg-Møller, and Stock (2014) indicated that the estimation of the Phillips curve using time-series data could cause significant bias in the regression coefficient due to low volatility, among other factors. Hazell et al. (2022) and McLeay and Tenreyro (2020) both estimated the Phillips curve using regional data to circumvent the

1) The Phillips curve was initially used to identify the relationship between nominal wages and unemployment. Recently, its use has been expanded to analysis of the relationship between economic conditions and prices. The economic indicators most commonly used to estimate the Phillips curve are the GDP gap, unemployment gap, short-term unemployment rate, job openings rate, and so on. For cases of estimating the Phillips curve using various indicators, see Stock and Watson (2020).

2) Recent research into the Phillips curve in the U.S. shows that there is a consensus as to the flattening slope of the Phillips curve. Depending on the study, however, there are huge variations in the magnitude of such flattening.

3) The relationship between the labor market and inflation is said to be weakened by various factors, such as the increase in e-commerce, improved productivity driven by the deployment of unmanned automation technologies and systems, technological development, and the transmission of foreign prices to domestic prices amid the process of globalization.

various identification problems of time-series data, empirically proving that the flattening of the Phillips curve after the Great Recession could be largely due to identification problems.[4)]

Based on these previous studies, this paper estimates the Phillips curve using the job openings rate and CPI by region in Korea. The remainder of this paper is structured as follows. Chapter II introduces the various identification problems that can arise in estimating the Phillips curve using time-series data and outlines the necessity of using regional data. Chapter III reviews the status of the labor market and inflation by region. Chapter IV discusses the Phillips curve estimation methodologies and results using regional data. Lastly, Chapter V summarizes the results of this research and suggests implications.

Ⅱ. Identification problems and necessity of using regional data

(Endogeneity of monetary policy)

McLeay and Tenreyro (2020) proved theoretically that inflation is determined by cost-push shocks if a central bank implements an optimal monetary policy, under the assumption that the inverse relationship between inflation and labor market slack holds. In this case, the inflation observed through actual data reflects only the impact of cost-push shocks, thus making it difficult to identify a Phillips curve that estimates the impact of demand shocks on prices.

Specifically, suppose that a central bank has a New Keynesian Phillips curve, as shown in Equation (2), as a constraint and implements an optimal monetary policy that minimizes the weighted sum of the two squared terms: the degree to which the unemployment rate deviates from the natural rate of unemployment (unemployment gap) and inflation (Equation (1)). In this case, inflation is expressed as the function of the cost-push shocks alone by the result of optimization (Equation (3)). Inflation being determined purely by the cost-push shocks means that it is determined through an exogenous statistical process regardless of the economic variable s.[5)] In the equation below, π_t is inflation, x_t is the unemployment gap (or GDP gap), λ is the weight for unemployment gap, and u_t is the cost-push shocks that follow the AR (1) process (regression coefficient, ρ).[6)]

$$\min \pi_t^2 + \lambda x_t^2 \qquad (1)$$

(Central bank's loss function)

4) As for the various identification problems that can emerge in estimating the Phillips curve using time-series data, refer to the next chapter, "Identification problems and necessity of using regional data."

5) Using macroeconomic models and empirical analysis, Forbes, Kirkham, and Theodoridis (2017), Smets and Wouters (2007), and King and Watson (2012) all showed that the inflation rate can be exogenously determined.

6) Equations (1) to (3) assume that a central bank performs discretionary monetary policy. Even if a central bank performs monetary policy by commitment, there is no change in the finding that inflation is a function of cost-push shocks. For details, refer to McLeay and Tenreyro (2020).

$$s.t.\ \pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \quad (2)$$

(Phillips curve)

$$\pi_t = \frac{\lambda}{\kappa^2 + \lambda(1-\beta\rho)} u_t \quad (3)$$

(Inflation determination)

(Endogeneity of estimating equation)

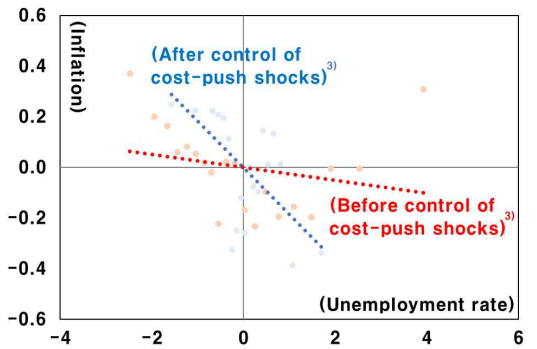
Next, if the Phillips curve is estimated using time-series data, as in Equation (2), significant bias in the estimated coefficients can occur due to the endogeneity of the estimating equation. In Equation (2), inflation expectations and the unemployment gap (or GDP gap) are variables for the demand side, and the impact of cost-push shocks is reflected in the error term (u_t). Since inflation expectations and the unemployment gap are influenced by cost-push shocks as well, the slope (κ) of the Phillips curve cannot be consistently estimated if time-series data are used. So far, the attempts that have been made to solve this endogeneity problem by controlling various additional variables (foreign prices, labor productivity, etc.) have been ineffective in mitigating endogeneity because the variables to be controlled vary with time (Gordon 2013; Christiano, Eichenbaum, and Trabandt 2015).

(Necessity of using regional data)

To overcome the endogeneity problems involved in estimating the Phillips curve using time-series data, some recent studies have used regional panel data. First, regarding the endogeneity of monetary policy, even if a central bank performs an optimal monetary policy, demand shocks in individual regions are not offset completely because monetary policy is operated in response to economy-wide conditions. Thus, using regional data, it is possible to estimate the relationship between regional demand shocks and prices that are not fully offset by an optimal monetary policy.

Second, as for the endogeneity of the estimating equation, if the two-way fixed effects model is estimated using regional panel data, the relationship between the labor market slack and prices can be identified by considering variation only within a particular region ("within variation"). This means that the impact of cost-push shocks common to an entire economy can be controlled by the consideration of year fixed effects. Hazell et al. (2022) empirically demonstrated that the inclusion of time fixed effects in estimating the Phillips curve of the U.S. has a significant effect on the slope of it (see <Figure 1>).

<Figure 1> Estimation of Phillips curve using regional data: the case of the U.S.[1)2)]



Notes: 1) After estimating residual terms are reorganized into 20 bins to plot a binned scatterplot of the slope of the Phillips curve.
2) Analysis period: 1991-2018
3) Cost-push shocks are controlled by year dummies.

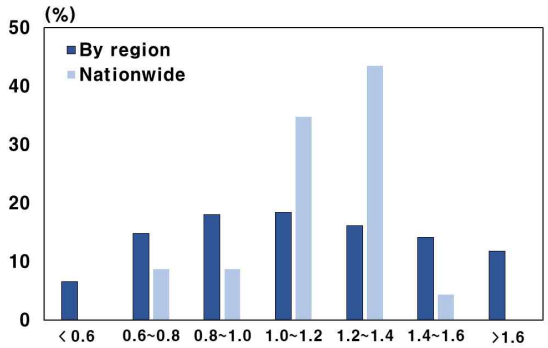
Source: Reorganized Figure V from Hazell et al. (2022)

Ⅲ. Characteristics of regional data

To estimate the Phillips curve, we used the semi-annual job openings rate and CPI from 2013 to the first half of 2022 in 16 regions of Korea (except Sejong). In Korea, the volatility of the unemployment rate is so small that it does not effectively reflect the condition of the labor market,[7] and recent studies have found that the job openings rate is more suitable than the un-employment rate for estimating the Phillips curve (Domash and Summers 2022). Therefore, we used the job openings rate as the indicator of labor market conditions.

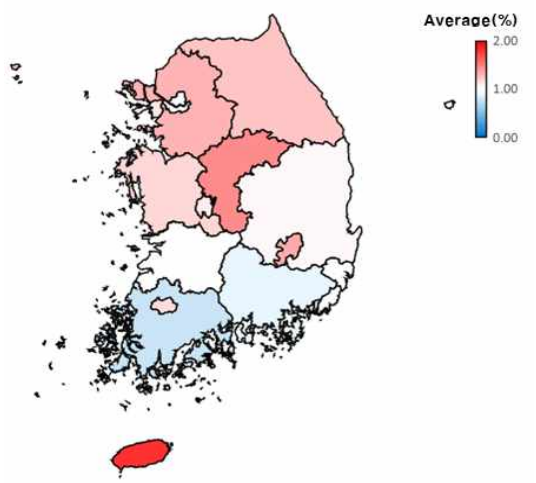
One of the advantages of using regional data instead of time-series data for estimating the Phillips curve is that regional data can mitigate the problem of the low volatility of time-series data. For the job openings rate, while the nationwide job openings rate has a higher density between 1.0% and 1.4%, the job openings rates of certain regions show a nearly normal distribution, allowing us to measure the impact of labor market conditions on prices more precisely (see <Figure 2>). Notably, there are no data below 0.6% nor above 1.6% in the nationwide job openings rate, but in terms of the job openings rates of regions, 6.6% and 11.8% of the data, respectively, are distributed in those domains. Furthermore, the average job openings rate varied widely by region. In the analysis period, the average job openings rate in Jeonnam is 0.77%, the lowest recorded, while the rate in Jeju is 1.81%, the highest, with the difference between the two regions amounting to 1.04%p (<see Figure 3>).

<Figure 2> Distribution of job openings rate[1)]



Note: 1) Semi-annual data from 2013 to the first half of 2022.
Source: Labor Force Survey at Establishments.

<Figure 3> Job openings rate by region[1)]



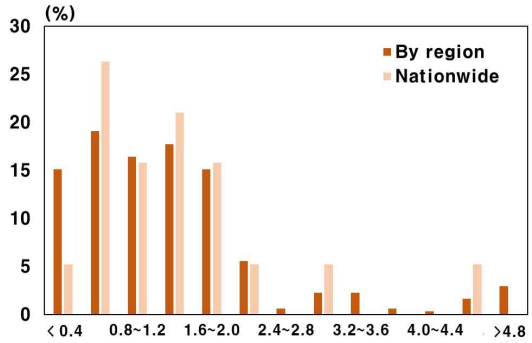
Note: 1) Semi-annual data from 2013 to the first half of 2022.
Source: Labor Force Survey at Establishments.

Next, similar to the job openings rate, region-level CPIs also shows a wider distribution than the national CPI. While 78.9% of nationwide CPIs is clustered

7) Korea's unemployment rate is significantly lower and less volatile than that of the U.S. This seems to be due to differences in the definition of unemployed and in the flexibility of the two labor markets. For details, refer to Box 1 "Comparison of unemployment rates between Korea and the U.S."

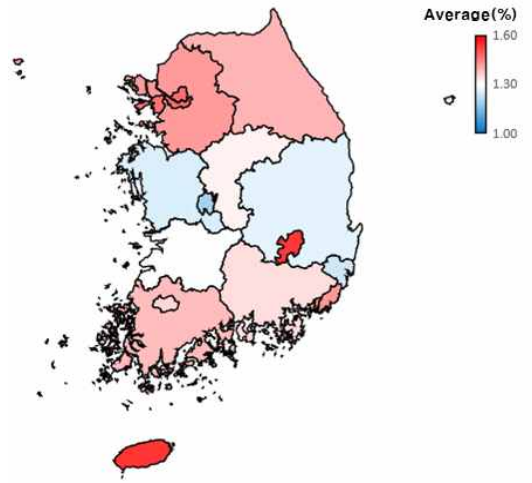
between 0.4% and 2.0%, only 68.4% of region-level CPIs are distributed in that range, showing a lower concentration of distribution (see <Figure 4>). Moreover, the average CPI of 16 regions shows different levels. In the analysis period, the CPI of Daejeon is the lowest at 1.19%, and the CPI of Jeju was the highest at 1.54%, with the difference in CPI between the two regions being as much as 0.35%p (<see Figure 5>).

<Figure 4> Distribution of CPI[1)]



Note: 1) Semi-annual data from 2013 to the first half of 2022.
Source: Labor Force Survey at Establishments.

<Figure 5> CPI by region[1)]



Note: 1) Semi-annual data from 2013 to the first half of 2022.
Source: Labor Force Survey at Establishments.

IV. Methodology and estimation results

(Methodology)

To estimate the Phillips curve in Korea, we conducted a panel analysis referring to the methodologies of Hazell et al. (2022) and McLeay and Tenreyro (2020). In the panel regression analysis using regional data, region fixed effects and year fixed effects are added to the independent variables, unlike a time-series regression analysis.

First, as the differences between the labor markets in regions, which do not change over time, are more likely to be related to factors other than economic ones, bias in the estimation of regression coefficients can occur if this is not controlled when estimating a short-term Phillips curve.[8)] To address this problem, in the panel regression analysis, region fixed effects are included to control for time-invariant regional differences.

Next, year fixed effects control for cost-push shocks. The labor market of the entire economy is affected by cost-push shocks, and regional labor markets are correlated to the labor market of the entire economy. Moreover, region-level CPIs are directly impacted by the cost-push shocks of the entire economy, indicating that if cost-push shocks are not controlled, an endogeneity problem could emerge. To address this, the New Keynesian Phillips curve is modified by adding year fixed effects, like Equation (4):

8) McLeay and Tenreyro (2020) said that when estimating the Phillips curve using regional data, the regional equilibrium unemployment rate needs to be controlled.

$$\pi_{i,t} = \pi_t + \beta E_t(\pi_{i,t+1} - \pi_{t+1}) + \kappa(x_{i,t} - x_t) + \hat{u}_{i,t}$$
$$= \beta E_t \pi_{i,t+1} + \kappa x_{i,t} + (\pi_t - \beta E_t \pi_{t+1} - \kappa x_t) + \hat{u}_{i,t}$$
..... (4)

In Equation (4), $x_{i,t}$ is not correlated to $\widehat{u_{i,t}}$. Rather, it is correlated to cost-push shocks for the entire economy $(\pi_t - \beta E_t \pi_{t+1} - \kappa x_t)$. Unless this is considered, bias could occur in the estimation. To solve this problem, cost-push shocks are controlled by including time fixed effects that control for change over time.

Under this theoretical background, this paper accounts for the following four equations to estimate the Phillips curve for Korea.

$$\pi_{i,t} = \alpha + \gamma \frac{1}{4} \sum_{k=1}^{4} \pi_{i,t-k} + \beta V_{i,t} + \epsilon_{i,t} \quad (5)$$
(Pooled OLS)

$$\pi_{i,t} = \alpha_i + \gamma \frac{1}{4} \sum_{k=1}^{4} \pi_{i,t-k} + \beta V_{i,t} + \epsilon_{i,t} \quad (6)$$
(Model incorporating region fixed effects)

$$\pi_{i,t} = \alpha + \gamma \frac{1}{4} \sum_{k=1}^{4} \pi_{i,t-k} + \beta V_{i,t} + \delta_t + \epsilon_{i,t} \quad (7)$$
(Model incorporating year fixed effects)

$$\pi_{i,t} = \alpha_i + \gamma \frac{1}{4} \sum_{k=1}^{4} \pi_{i,t-k} + \beta V_{i,t} + \delta_t + \epsilon_{i,t} \quad (8)$$
(Model incorporating both region and year fixed effects)

Here, $\pi_{i,t}$ is the CPI inflation (annualized) for region i at time t, α_i is the region fixed effects, $\frac{1}{4}\sum_{k=1}^{4} \pi_{i,t-k}$ is the average inflation for the past two years, $V_{i,t}$ is the job openings rate, and δ_t is the year fixed effects. In Korea, as there are no data on inflation expectations by region, the average inflation rate for the past two years is used instead. In addition, the dummy variable for the first half is included as an independent variable.

The use of various estimation methods, as in equations (5) through (8), is to identify what impact each type of fixed effect has on Korea's Phillips curve. Equation (5) does not allow for region nor year fixed effects. Equations (6) and (7) allow for either region or year fixed effects, and Equation (8) allows for both region and year fixed effects.

(Phillips curve estimation results)

The estimation results show that the slope of Korea's Phillips curve varies significantly depending on whether year fixed effects (to control for cost-push shocks) are introduced. In cases where neither region nor year fixed effects are considered and only region fixed effects are considered, the slope of the Phillips curve is much flatter (see <Table 1>).

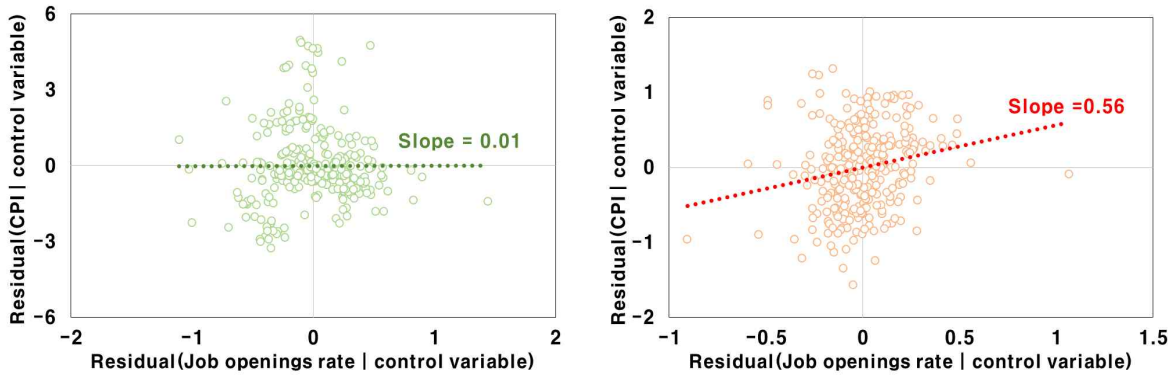
<Table 1> Estimation results of the Phillips curve using regional data

	Pooled OLS	Fixed effects model		
		Region	Year	Region & Year
Job openings rate	0.06	0.01	0.35***	0.56**
	(0.08)	(0.12)	(0.12)	(0.25)
Number of observations	288	288	288	288
R^2	0.12	0.12	0.88	0.89

Notes: 1) All models include the average inflation rate for the past two years and the dummy variable for the first-half periods.
2) Figures in parentheses are regional cluster standard errors.
3) *** and ** indicate a significance level of 1% and 5%, respectively.

<Figure 6> Slope of the Phillips curve: comparison of scatterplots[1)]

Before controlling for cost-push shocks[2)] | After controlling for cost-push shocks[2)]



Notes: 1) The horizontal axis shows the residuals of the regression analysis, with the job openings rate as the dependent variable and other variables as the independent variables. The vertical axis indicates the residuals of the regression analysis, with CPI as the dependent variable, and other variables, except for the job openings rate, as the independent variables.

2) "Before controlling for cost-push shocks" refers to a model that considers only region fixed effects, and "after controlling for cost-push shocks" refers to a model that considers both region and year fixed effects.

Source: Authors' estimations.

On the other hand, in cases where both region and year fixed effects are considered and only year fixed effects are considered, the slope of the Phillips curve is relatively steep with statistical significance, exhibiting a remarkable difference in the results when cost-push shocks are not controlled and when they are controlled for (see <Figure 6>).[9)] In particular, if both region and year fixed effects are considered, a 1%p rise in the job openings rate can lead to a 0.56%p rise in the CPI inflation, indicating that labor market conditions have a large effect on CPI inflation.[10)]

V. Conclusion

This paper estimates the Phillips curve using regional data from across Korea based on recent studies that have suggested that the two endogeneity problems -- the endogeneity of the estimating equation and the endogeneity in monetary policy -- in estimating the Phillips curve using time-series data can be mitigated by using panel data.

As for regional data, the CPI and the job openings rate differ significantly by region. In terms of job openings rate, which indicates labor market conditions, while the nationwide job openings rate had high density in some ranges, regional data shows a nearly normal distribution. Thus, the

9) Hazell et al. (2022) and McLeay and Tenreyro (2020), using regional data in the U.S., found that year fixed effects are closely related to the slope of the Phillips curve.

10) However, it is to be noted that, given the characteristics of the fixed effects model, these findings are estimation results based on "within variation" and do not represent the relationship between the job openings rate and the inflation rate for all of Korea.

regional job openings rates are more appropriate for identifying the relationship between labor market conditions and inflation.

The Phillips curve estimated based on regional panel data shows that the slope of Korea's Phillips curve is significantly affected by the control of cost-push shocks. If cost-push shocks are not controlled, the slope of the Phillips curve is much flatter. If the cost-push shocks are controlled, on the other hand, the Phillips curve has a relatively steep slope, suggesting that labor market conditions in Korea are closely related to prices. These findings point to the possibility that the recent studies showing that Korea's Phillips curve has flattened were greatly influenced by the identification problems.

However, many studies looking into the determinants of the slope of the Phillips curve are currently being carried out, and it is known that the slope of the Phillips curve is also affected by a variety of factors other than such identification problems. Therefore, consistent studies into the factors affecting the slope of the Phillips curve are required.

<Box 1>

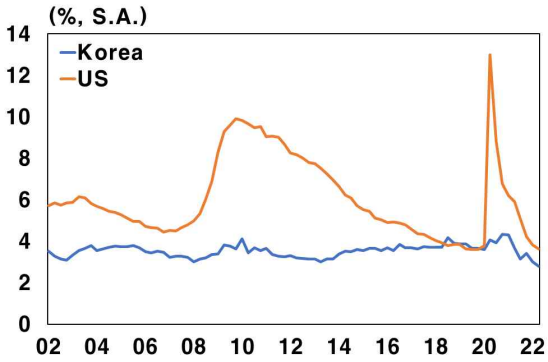
Comparison of unemployment rates in Korea and the U.S.

The unemployment rate in Korea is lower and less volatile than that in the U.S. This seems to be attributed to (i) different definitions of the unemployed, and (ii) differences in labor market flexibility.

First, both Korea and the U.S. define unemployed persons as those who are not working during the survey period, have engaged in job-seeking activities over the past four weeks, and who are immediately available for employment. Additionally, the U.S. classifies temporary layoffs as unemployed persons. These different definitions of the unemployed between the two countries become more prominent during crises (see <Figure A-1>). The share of temporary layoffs among unemployed persons in the U.S. surged from 13.9% before the pandemic (fourth quarter of 2019) to 27.9% in the fourth quarter of 2020.

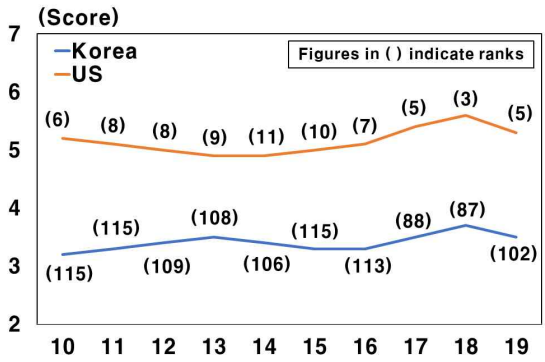
Next, the flexible labor market in the U.S. seems to be one of the factors that increases the volatility of the unemployment rate. While employment and layoff flexibility in the U.S. ranked fifth among 141 countries as of 2019, Korea ranked 102nd (see <Figure A-2>). The OECD indicator for the strictness of employment protection for regular contracts was 1.30 for the United Sates and 2.37 for Korea. This means that, while firms in the U.S. can adjust their employment in response to changes in the economy, the dismissal of regular employees is not easy to do in Korea, leading to less fluctuation in the unemployment rate.

<Figure A-1> Trends in unemployment rates in Korea and the U.S.



Sources: BLS, Economically Active Population Survey.

<Figure A-2> Employment and layoff flexibility scores,[1] ranks



Note: 1) Scores range from 1 to 7, with a 1 meaning "impeded by regulation," and a 7 meaning "flexibly determined by employers."
Source: World Economic Forum.

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