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Labor Market Slack and the Output Gap:

The Case of Korea

By Niels-Jakob Harbo Hansen, Joannes Mongardini, and Fan Zhang

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Abstract

Output gap estimates are widely used to inform macroeconomic policy decisions, including in Korea. The main determinant of these estimates is the measure of labor market slack. The traditional measure of unemployment in Korea yields an incomplete estimate of labor market slack, given that many workers prefer involuntary part-time jobs or leaving the labor force rather than registering as unemployed. This paper discusses a way in which the measure of unemployment can be broadened to yield a more accurate measure of labor market slack. This broader measure is then used to estimate the output gap using a multivariate filter, yielding a more meaningful measure of the output gap.

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I. INTRODUCTION

1.   **Estimates of output gaps are a widely used to inform macroeconomic policy decisions.** The output gap denotes the difference between actual and potential output, where the latter is defined as the maximum level of output an economy can produce without generating inflationary pressures (Okun, 1962). An estimate of the output gap is thus a useful metric for policymakers to decide the appropriate stance of fiscal and monetary policy, with the aim of keeping the economy at its full potential while avoiding inflationary pressures.

2.   **The extent of underutilization of labor market resources (labor market slack) is a key determinant in estimating the output gap.** The degree of labor market slack provides information about whether the economy is operating above or below potential. Tight labor market conditions generally create upward pressure on wage and price inflation, thus requiring a tightening of the policy stance. Conversely, idle labor market resources will lead to underutilized capacity, lower output, and weaker wage and price inflation, which would normally call for an easing of the policy stance.

3.   **In Korea, traditional measures of labor market slack may not fully capture the cyclical conditions in the labor market.** The Phillips curve relationship between inflation and unemployment is relatively weak (Bhattarai, 2016). This could reflect the fact that the traditional measure of unemployment does not truly reflect the full degree of labor market slack for the following two reasons. First, the traditional unemployment rate does not include workers outside the labor force who are ready to work (discouraged workers). Second, it does not include part-time workers who wish to work longer hours (involuntary part-time workers).

4.   **This paper addresses this issue by introducing a broader measure of labor market slack in Korea, by including** discouraged workers. This augmented measure is shown then to have the expected negative relationship with inflation, namely a downward-sloping Phillips Curve.

5.   **The augmented measure is then used to construct a revised output gap estimate.** Output gaps are traditionally estimated using either a production function or filtering methods. The former relies on measures of slack from the production side of the economy, disregarding measures of inflationary pressures arising from the demand side (see e.g. Giorno et al., 1995). Filtering methods, instead, use either univariate or multivariate statistical filters to estimate the output gap. The most commonly-used univariate filter is the Hodrick-Prescott (HP) filter, which smooths out fluctuations in output at business cycle frequencies (De Masi, 1997). The multivariate filter (MVF), instead, uses a system of economic equations from both the demand and supply side of the economy to derive the output gap. Drawing on this literature, this paper uses two MVF models to estimate the revised output gap to ensure that these estimates are robust to model specification. In the first model, the output gap is estimated using a simple production function with the augmented measure of unemployment (see Blagrave et al., 2015) and an estimate of technological innovations. In the second model, both the augmented measures of unemployment and capacity utilization are used to estimate the output gap (Alichi et al., 2017). In both cases, the derived output gap estimates are more

negative than the one derived using a traditional measure of unemployment, which has important policy implications.

6.   **The remainder of the paper is organized as follows.** Section II discusses how to augment the measure of unemployment in Korea with discouraged workers to better capture the extent of labor market slack. Estimates of the output gap using the augmented measure of unemployment are then presented in Sections III-IV using two versions of the MVF. Section V discusses the output gap estimates using both the augmented measure of labor market slack and capacity utilization. Statistical robustness checks are presented in Section VI. Section VII then concludes.

II.   MEASURING LABOR MARKET SLACK

7.   **A measure of slack in the labor market is an essential input in estimating output gaps.** Traditionally, slack in the labor market is measured by the rate of unemployment derived through a labor force survey or registered unemployed. In Korea, only survey data are published, which show that the unemployment rate since 1980 has remained broadly stable around 3-4 percent of the labor force, with only a spike to 7 percent during the Asia crisis in 1998-99. Thus, the unemployment rate has remained relatively stable despite significant volatility in real GDP growth, including during the Global Financial Crisis (Figure 1).

Figure 1: Real GDP Growth and Unemployment Rate, Korea
(Percent)
Latest observation: 2017
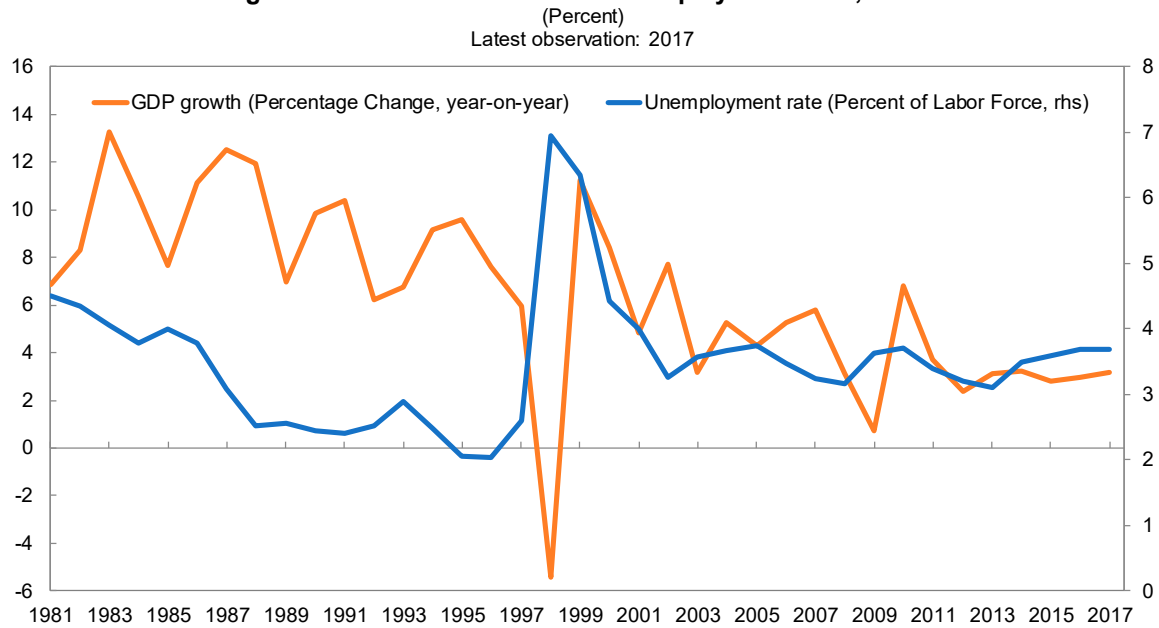
Source: Haver.

8.   **The traditional unemployment rate does not fully capture labor market slack in Korea.** According to the international definition of unemployment, workers are categorized as unemployed if they are (i) without work; (ii) available to start work within two weeks; and

(iii) actively engaged in job searching activities (International Labor Organization, 2018). This definition does not, however, fully capture the degree of slack in the labor market. Indeed, wider definitions include both additional intensive and extensive margins (International Labor Organization, 2018). The additional intensive margin includes persons who are without work but are not able to start working within two weeks or are not actively engaged in job searching activities (discouraged workers). A typical example could be female workers returning from extended maternity leave. The additional extensive margin includes workers who are already employed part-time but want to work more hours (forced part-time workers). A typical example could be workers taking up temporary part-time jobs while waiting for a full-time position in their own field of expertise. The former group is classified as outside the labor force as per the traditional unemployment measure, while the latter group is classified as fully employed, even though these workers work fewer hours than desired and not necessarily in the full-time job they aspire to have.

9.   The poor signal of labor market slack from Korea's traditional unemployment measure is also manifested by its weak correlation with inflationary pressures. The inverse relationship between inflation and labor market slack is traditionally captured by the Phillips curve (Phillips, 1958), where lower cyclical unemployment is associated with upward pressure on wage inflation. As labor is the largest input into the production function, higher wages usually translate into higher price inflation. For most countries, the Phillips curve relation is indeed found to be negative. However, for Korea the relation is weak and not negative for all time periods (Bhattarai, 2016). One interpretation of this result is that the traditional measure of unemployment in Korea does not fully capture the degree of labor market slack.

10.   To address these shortcomings, this section constructs a broader measure of labor market slack to assess cyclical conditions in Korea. This measure is computed by augmenting the traditional measure of unemployment along the extensive margin by adding discouraged workers to the traditional unemployment measure, expressed in percent of the labor force plus discouraged workers. Discouraged workers are workers of the legal working age who want to work and have been looking for a job over the last year but are not currently engaged in a job search. This broader measure of labor market slack is depicted in Figure 2a. This measure hovers around 5 percent and has a variance at business cycle frequency that is around twice as high as the regular unemployment measure (Figure 2b).[2] This augmented measure is similar in nature to the "*Labor Utilization Indicator 2*" published by Statistics Korea, which augments regular unemployment with workers who could potentially be part of the labor force.[3] However, the short time period of this series precludes its use in estimating the output gap.

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[2] The variance of unemployment and augmented unemployment at business cycle frequency is 0.06 and 0.11, respectively. The fluctuations at business cycle frequency are defined as the deviation from a HP-filtered trend with a lambda of 6.25 (a standard coefficient for annual data).

[3] http://kostat.go.kr/portal/eng/index.action. See Appendix A for further discussions on these measures and how they have been constructed.

Figure 2a: Measures of Labor Market Slack
(Percent)
Latest observation: 2017
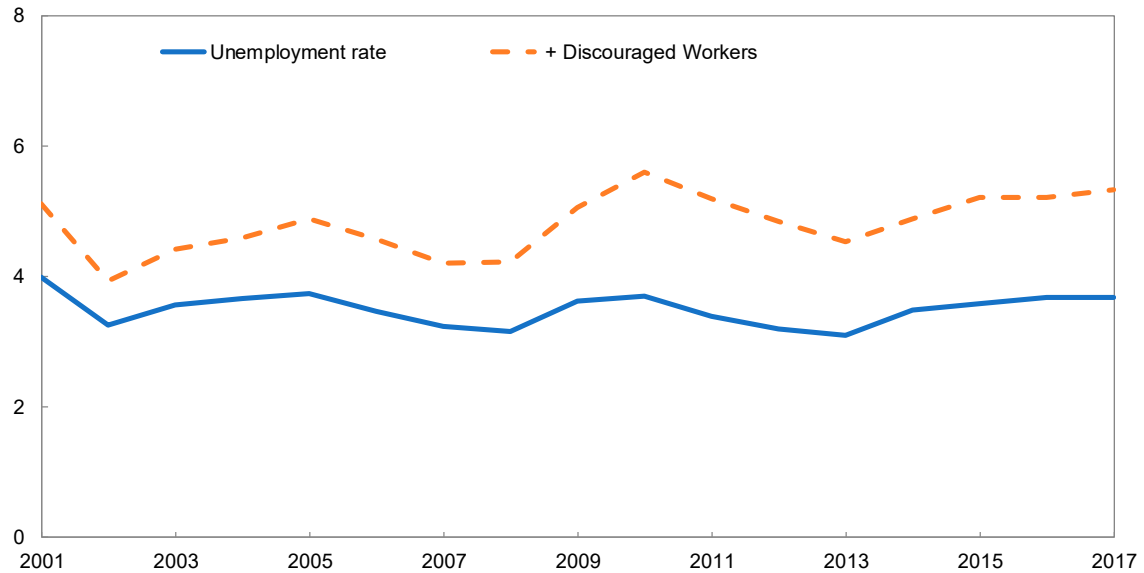
Source: Statistics Korea and authors' estimates.

Figure 2b: Measures of Labor Market Slack
(Deviation from average, Percent)
Latest observation: 2017
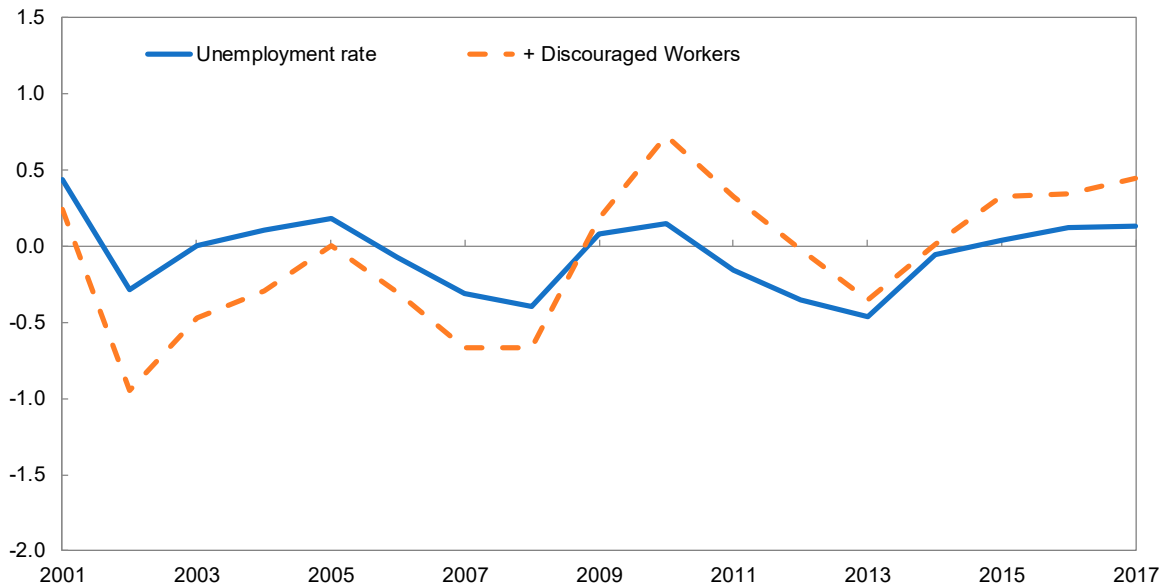
Source: Statistics Korea and authors' estimates.

11.   The broader measure of labor market slack yields a downward-sloping Phillips Curve. Figure 3 shows the relationship between traditional unemployment (top panel) and core inflation compared with the broader measure of labor market slack and core inflation

(bottom panel).[4] Unlike regular unemployment, the broader measure of unemployment yields a negative relationship with inflation since 2001. This suggests that the broader measure provides a better measure of labor market slack, as larger underutilization of labor is associated with a lower rate of inflation.

Figure 3a: Phillips Curve, 2001-18
(Percent)
Latest observation: 2018

y = 0.0086x + 3.4846
R² = 0.0009
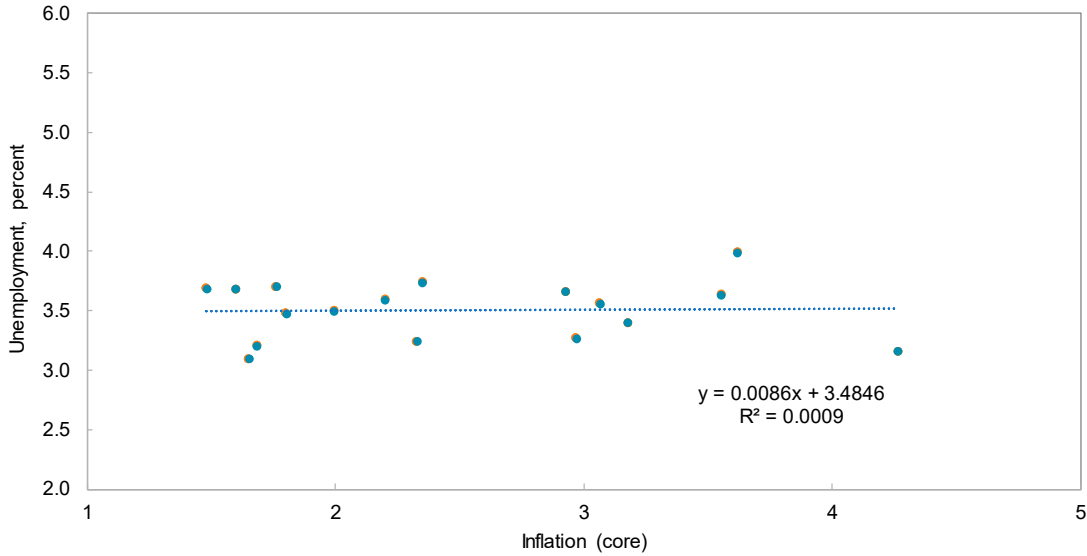
Source: Haver.

Figure 3b: Modified Phillips Curve, 2001-18
(Percent)

y = -0.1846x + 5.2796
R² = 0.1144
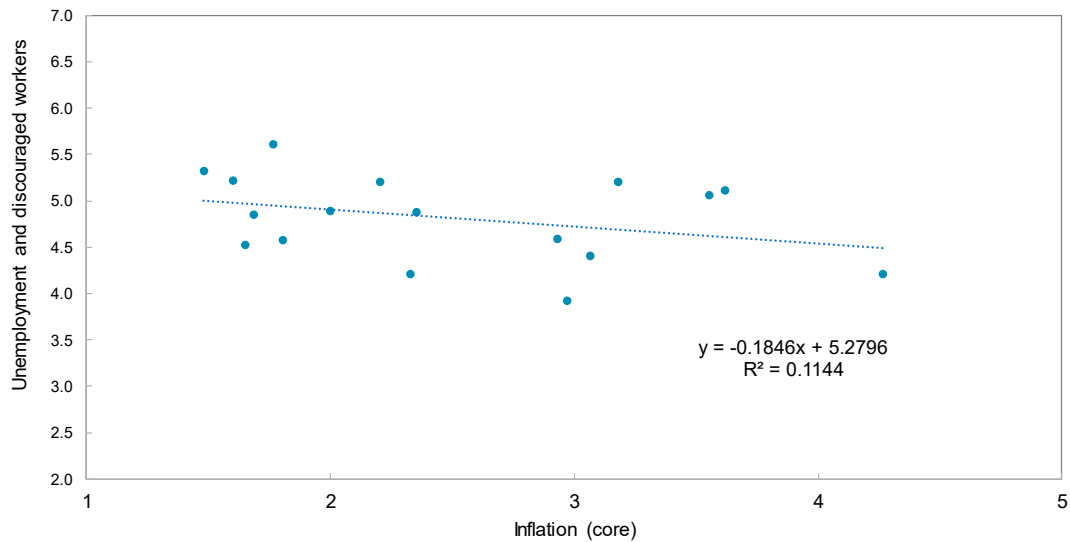
Sources: Statistics Korea and authors' regression results.

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[4] There is a level break in the time series for discouraged workers in 2014. The series was therefore spliced by backing out the levels prior to 2014 using the growth rate of the earlier time series.

III. OUTPUT GAP ESTIMATES USING A MULTIVARIATE FILTER

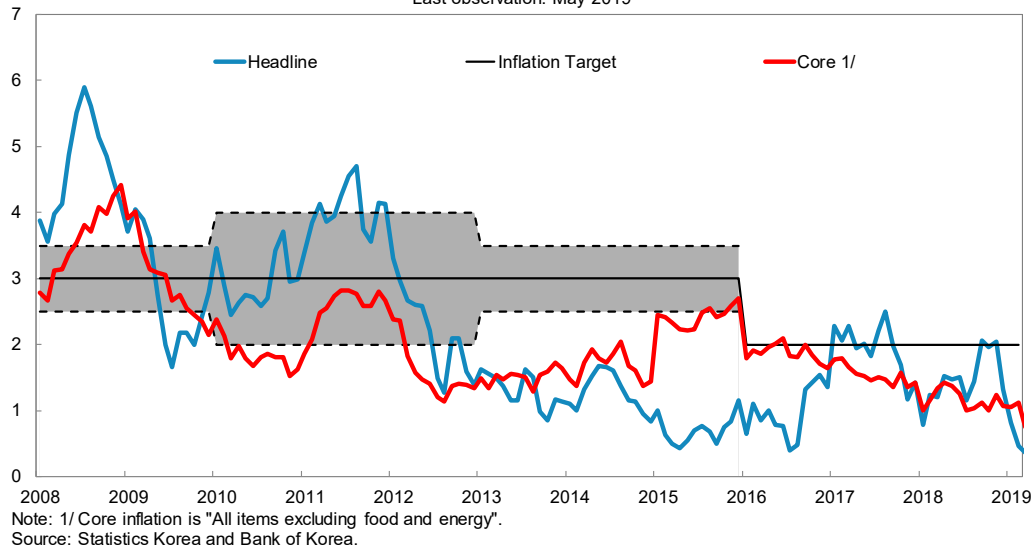**12.** **This section provides estimates of the output gap for the period 2007-2023, using the broader measure of labor market slack constructed in Section II.** We apply the MVF model explained in Appendix B, which is a modified version of the model presented by Blagrave et al. (2015) to include a total factor productivity (TFP) gap to account for spurts of innovation in trend productivity. The model is estimated using annual data from 2001 for the gross domestic product, inflation, employment, TFP, unemployment along with the alternative measures for labor market slack outlined above. Historical data are used up to 2017, extended by the estimate for 2018 and the forecast for 2019-23 in the April 2019 World Economic Outlook. The data sources are presented in Appendix B. The parameters in the model are estimated using Bayesian estimation. The priors for Korea are based on existing estimates from Blagrave et al. (2015). The steady state level for TFP growth (G^{SS}) is set equal to the historical average of 1.5 percent. The steady state level for the structural component of underutilized labor market resources (U^{SS}) is set equal to the historical average of labor market slack, which is 3.4 and 5.5 percent when using regular unemployment and the broader measure described in Section II, respectively.

13. **The broader measure of labor market slack yields a more negative output gap.** Figure 4 shows how the output gap based on the broader measure of labor market slack is generally more negative than the output gap calculated using the traditional unemployment measure. Both measures produce a positive output gap before the Global Financial Crisis (GFC). During the GFC both measures turn negative. However, the augmented measure of labor market slack produces an output gap that is relatively more negative during the GFC and does not turn positive immediately after the GFC. This is consistent with the fact that it took time for the Korean labor market to recover after the GFC. The augmented measure also produces a more negative output gap during recent years suggesting that aggregate demand in the economy has been insufficient to allow the economy to operate at its full potential.

14. **The notion of a negative and persistent output gap is consistent with an extended period of inflation below target.** Both headline and core inflation have mostly been below target since 2012, with brief exceptions (Figure 5). A negative and persistent output gap can have been a driver behind these low inflationary pressures. Specifically, the existence of higher idle capacity in the labor market due to insufficient demand can have contributed to lower wage pressures, and thus lower inflation.

Figure 4: Estimated Output Gaps
(Percent)
Latest observation: 2019
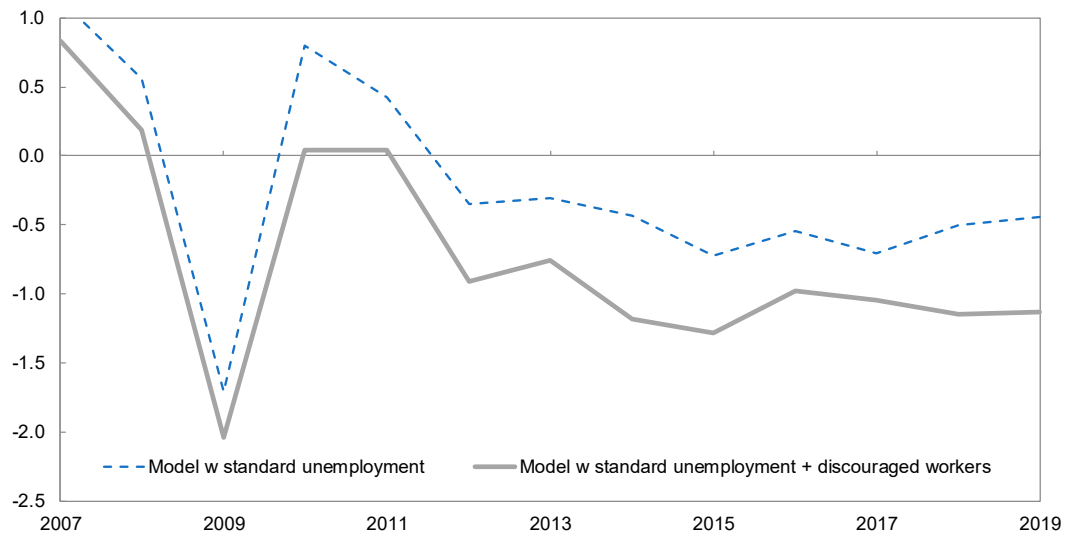
Source: Authors' calculations.

Figure 5. Consumer Price Inflation
(Percent change, year-om-year)
Last observation: May 2019

Note: 1/ Core inflation is "All items excluding food and energy".
Source: Statistics Korea and Bank of Korea.

IV. A MULTIVARIATE FILTER WITH CAPACITY UTILIZATION

15.   This section estimates the output gap using a multivariate filter with both labor market slack and capacity utilization. The model presented in Section III relies on the estimation of a TFP gap. In practice, TFP is unobservable and its estimation subject to large uncertainty. In order to address this issue, this section presents alternative estimates of the

output gap using a multivariate filter without a TFP gap, but which relies on the observed capacity utilization as an extra signal to estimate potential output (Alichi et al., 2017).

16. **The results obtained from the MVF with capacity utilization are broadly consistent with the ones from the previous section.** The model with capacity utilization was estimated using the augmented measure of labor market slack with discouraged workers (Figure 6). After the GFC, the estimated output gap widened to about -2 percent, and quickly closed in 2010 while the unemployment gap remained negative for a longer period. This inconsistency can be explained by a sharp surge in capacity utilization rates immediately after the crisis in response to a sharp rebound in demand, while the labor market improved more slowly. By 2018, the estimated output gap remained negative, following both a deterioration of labor market slack and capacity underutilization in the industrial sector.

Figure 6: Estimated Output Gap using Capacity Utilization
(Percent)
Latest observation: 2018
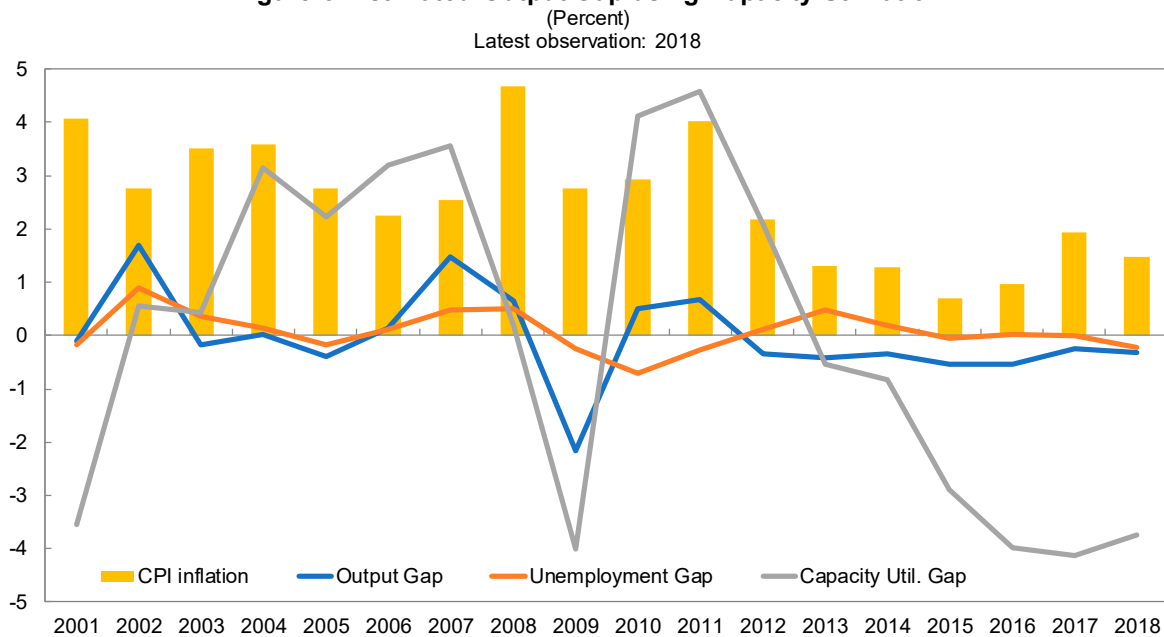
Source: Authors' calculations.

V. UNCERTAINTY IN ESTIMATING THE OUTPUT GAP AND POTENTIAL

17. **Estimates of the output gap are generally subject to significant uncertainty and revisions.** These uncertainties stem from: (i) the choice of model, (ii) model parameters, and (iii) quality and quantity of information used. To assess the robustness of the output gap estimates in the two previous sections, it is useful to construct confidence bands around the estimates of the output gap and compare them with confidence bands associated with a simple Hodrick-Prescott (HP) filter of real GDP growth, following the methodology in Blagrave et al. (2015) and Alichi et al. (2017).

18. **In this section, the confidence bands are constructed using Monte Carlo draws for estimates using the HP filter and the MVF.**[5] They are derived from 1000 draws of all variables from the model for a sufficiently-long period (1000 years) with the first 500 draws discarded to alleviate burn-in bias. An HP filter is applied with a signal-noise ratio of 6.25 to the GDP series in each sample. Deviations of the HP filter estimates of the potential growth and output gap from the assumed true path are then computed for a 77 percent and 98 percent demand shocks, which are typical values in the literature for emerging markets and advanced economies. Similar steps are implemented for the MVF estimates to allow a fair comparison between the two methods. The average 95 percent confidence bands for potential growth and the output gap are shown in Figures 7 and 8.

Figure 7: Confidence Bands for Potential Growth
(Average 95% quantile deviation from mean estimate)
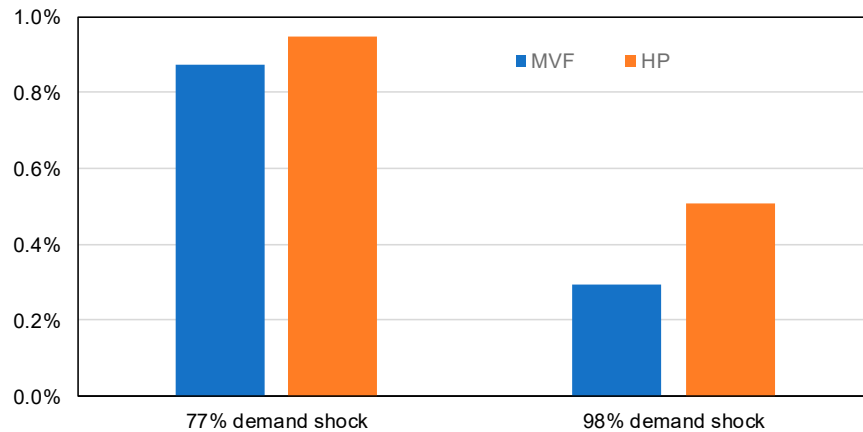
Source: Authors' Monte Carlo simulations.

Figure 8: Confidence Bands for Output Gap
(Average 95% quantile deviation from mean estimate)
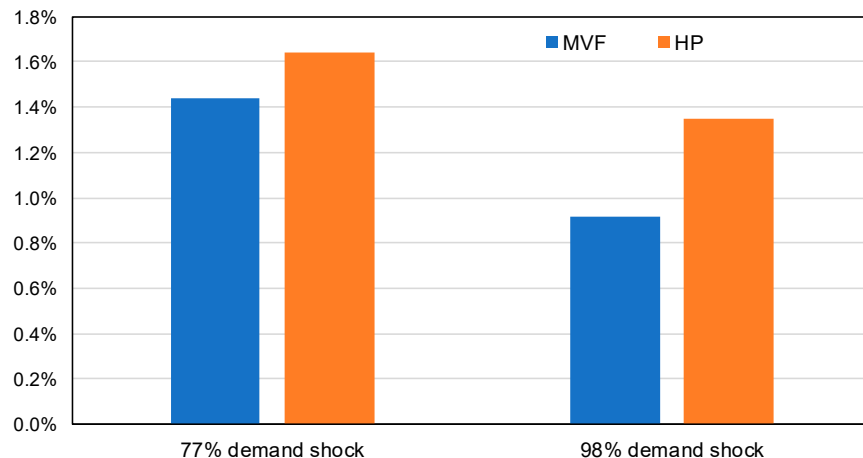
Source: Authors' Monte Carlo simulations.

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[5] Though the multi-variate filter has an analytical covariance matrix, the covariance matrix cannot be used to compare it with that of an HP filter. Accordingly, it is necessary to do the comparison using Monte Carlo simulations and compare the simulated statistical properties of both filters.

19.   The estimates of potential growth and output gap coming from the MVF are subject to significant uncertainty. The standard error around potential growth is more than 0.8 percent for a 77 percent demand shock, but only 0.3 percent for a 98 percent demand shock. Similarly, the standard error around the output gap is 1.4 and 0.9 percent, respectively. This suggests that the estimates should be taken with caution.

20.   The estimates of potential growth and the output gap, however, have smaller confidence bands than those from an HP filter. As shown in the figures, the confidence bands around the estimates of potential output and the output gap from the MVF are narrower than those from an HP filter, regardless of the choice of shocks. This result confirms the theoretical and empirical literature, which demonstrates that a MVF is always superior to a univariate filter, given the richer set of information used to estimate potential output.

VI.   CONCLUSION

21.   This paper presented an augmented measure of labor market slack and its implications for the estimation of the output gap in Korea. Traditionally, labor market slack is measured by the unemployment rate. Although well-defined, this measure does not fully capture the full amount of labor market slack in Korea. Specifically, it does not capture workers outside the labor force that are able and willing to work but are not currently engaged in active job search. To address this, we construct an alternative measure of labor market slack, which augments regular unemployment with discouraged workers. This measure produces the expected negative relationship between unemployment and inflation, namely a downward-sloping Phillips curve, unlike the traditional measure of unemployment.

22.   This broader measure of labor market slack is then used to construct output gap estimates. Two MVF models are used to estimate the output gap in Korea. In the first model, the output gap is tied with labor market slack using a production function and TFP shocks. In the second model, both labor market slack and capacity utilization are used to estimate the output gap.

23.   Using the broader measure of labor market slack has important implications for the estimated output gap. Augmenting unemployment with discouraged workers makes the estimated output gap more negative in recent years. This suggests that there is more idle capacity in the economy than suggested by the standard measure of unemployment. At the same time, the unemployment gap computed using broader measures of labor market utilization display higher variation at business cycle frequency.

24.   These results have significant policy implications. Using the broader measures of labor market slack suggest that the Korean economy has not yet reached a point where inflationary pressures are significant, implying that policies can remain accommodative for a longer.

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Appendix A: Published Broader Measures of Labor Market Slack

1.   Broader measures of labor market slack are published by Statistics Korea, albeit only since the first quarter of 2015. Statistics Korea publishes three alternative measures of labor market slack to complement the traditional unemployment rate. *Labor Underutilization Indicator 1* augments the traditional unemployment measure along the intensive margin, with workers that are working part-time but are willing and able to work longer hours (expressed in percent of the total labor force). *Labor Utilization Indicator 2* augments the traditional unemployment measure along the extensive margin, with workers that are potentially in the labor force. These persons are either unavailable to work but seeking employment, or willing to work but not currently seeking employment. The Utilization Indicator 2 is expressed as a share of the labor force extended with the potential labor force. *Labor Utilization Indicator 3* extends the traditional unemployment measure along both the intensive and extensive margins, with workers that are working involuntary part-time and workers that are potentially in the labor force. The three indicators are depicted in Figure A.1. They lift the measure of labor market slack from around 4 percent to up to 12 percent. However, the period for the measures is too short to make them useful as input to the model presented in section II. The model estimates thus rely on the measure constructed in Section II.

Figure A.1: Official Measures of Labor Market Slack, Korea
(Percent)
Latest observation: July 2018
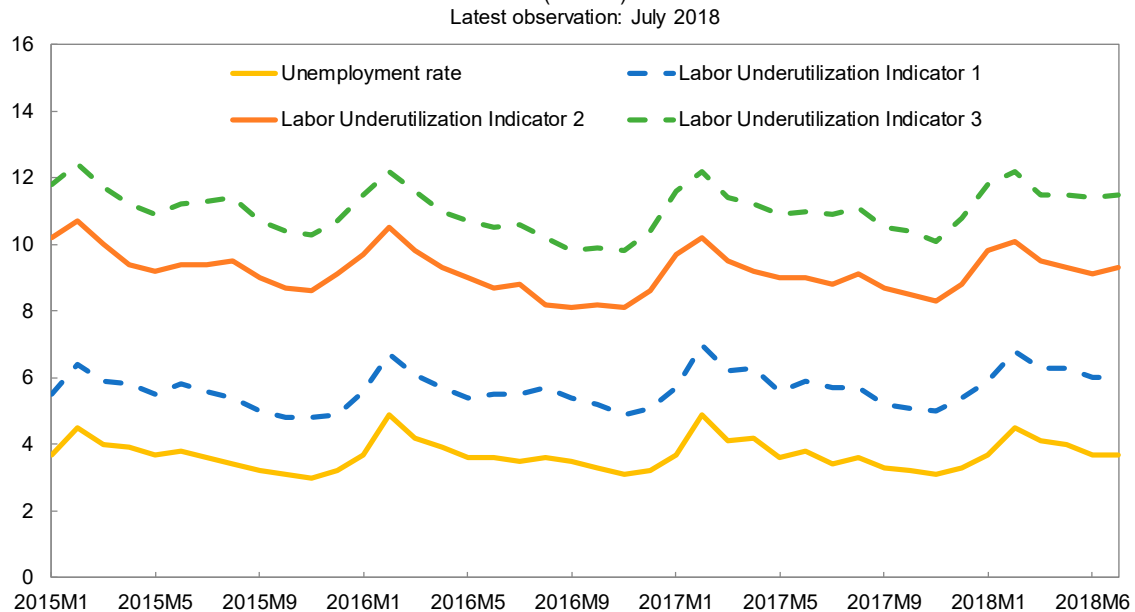
Source: Statistics Korea.

Appendix B: A Multivariate Filter with Labor Market Gaps

1.   This section presents a multivariate filter augmented with a tighter link between the output gap and labor market slack. The filter is a modified version of the MVF presented in Blagrave et al. (2015), modified in three ways. First, an equation is introduced to link output, total factor productivity (TFP), and employment through a production function. This equation then defines the output gap as a combination of the labor market slack and TFP deviations. Second, a series of equations are used to separate trend and cyclical TFP. This is in line with what is done using a pure production function approach (see e.g. Giorno et al., 1995). Third, the model is formulated such that it allows for a flexible representation of labor market utilization ranging from ordinary unemployment to a broader measure of labor market slack as discussed in the main paper.

2.   The filter takes a standard production function as a point of departure. Specifically, output is represented by a Cobb-Douglas production function that takes capital (K), employment (E), and total factor productivity (A) as inputs.

$$Y_t = A_t K_t^\alpha E_t^{1-\alpha}. \tag{1}$$

Equation (1) can be rewritten by replacing employment (E) with the product of the potential labor force (PLF) and the non-employed fraction of this potential labor force (U).

$$Y_t = A_t K_t^\alpha [(1 - U_t)PLF_t]^{1-\alpha} \tag{2}$$

Notice, that the definition of both PLF and U will vary based on the different measures of labor market slack used. When regular employment is used, U is measured by the traditional measure of unemployment. When broader measures are used, as discussed in the previous section, U is measured by the augmented unemployment in percent of the augmented labor force.

3.   The output gap can be written as a function of the TFP gap and labor market slack. We define potential output as the level of GDP achieved when all input variables are at their trend level.

$$\bar{Y}_t = \bar{A}_t K_t^\alpha [(1 - \bar{U}_t)PLF_t]^{1-\alpha} \tag{2}$$

We abstract from cyclical fluctuations in the capital stock, and the potential labor force. That is, we focus on the business cycle variation stemming from TFP and labor market slack. We define the output gap as the percentage difference between actual and potential output

$$y_t = y_t - \bar{y}_t \tag{3}$$

Here lower case denotes a logged variable. Based on equation (2) and (3) the output gap (y) can be written as the sum of the TFP gap (a), and labor market slack (U).[6]

$$y_t = a_t + (1 - \alpha)U_t \qquad (3')$$

Here the output gap (y) is expressed as percent deviation from potential GDP ($\bar{Y}_t$), while the TFP gap (a) is expressed in percent deviation from the trend level of TFP ($\bar{A}_t$). The latter is the long run trend that TFP fluctuates around at business cycle frequency. Finally, the labor market gap is expressed as the deviation (in percentage points) of the degree of underutilization of labor from the structural degree of underutilization ($\bar{U}_t$). When relying on unemployment to measure labor market slack, this will be the NAIRU. In addition, we allow the output gap to be affected by stochastic shocks. That is, we allow the output gap to change temporary without corresponding changes in the TFP or labor market slack.

$$y_t = \phi y_{t-1} + \epsilon_t^Y \qquad (4)$$

This stochasticity represents uncertainty around the output gap estimates. Indeed, the actual output gap is not observed and can only be estimated with a significant degree of uncertainty, which is represented by the error term (ϵ_t^Y) in equation (4).

4.   **The trend component of TFP is modelled as a stochastic process.** This process is governed by a long-term deterministic growth rate (G^{SS}), as well as stochastic shocks that can shift both the TFP level ($\epsilon_t^{\bar{A}}$) or temporary change the growth rate (ϵ_t^G) of TFP.

$$\bar{A}\_t = \bar{A}_{\{t-1\}} + G_t + \epsilon_t^{\bar{A}} \qquad (5)$$

$$G_t = \theta G^{SS} + (1 - \theta)G_{\{t-1\}} + \epsilon_t^G \qquad (6)$$

The stochastic process for TFP is illustrated in Figure A.2. Here G^{SS} is the long-term rate that TFP will grow according to absent any stochastic shocks. $\epsilon_t^{\bar{A}}$ is a stochastic shock that can permanently increase or decrease the level of TFP. Finally, ϵ_t^G is a shock to the growth rate in TFP, which temporarily causes the growth rate of TFP to fall below, or rise above, the long-run growth rate G^{SS}.

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[6] This equation is derived by logging equation (2) and subtracting the expression for potential GDP. we assume that capital is at its structural level.

Figure B.1: Stochastic Process for the Structural Level of TFP
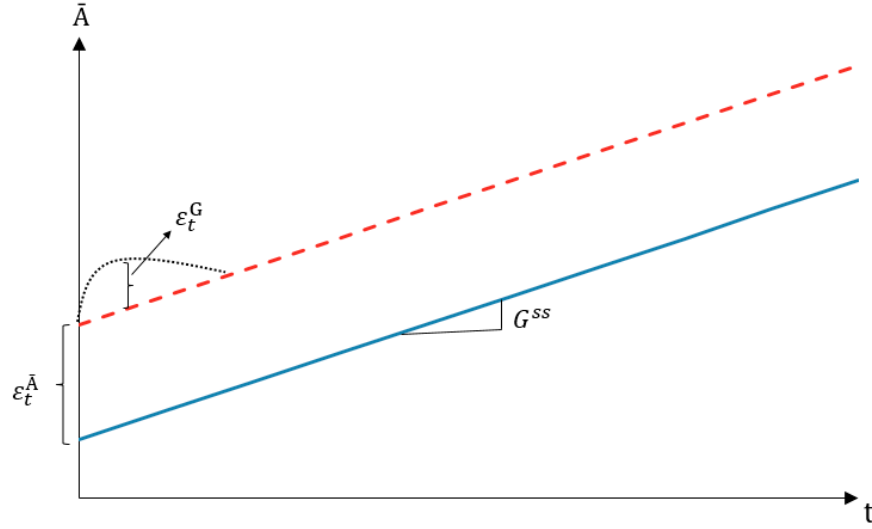
5.   The level of structural underutilization of labor market resources is modelled as a stochastic process. The structural level of labor market underutilization is governed by a long run steady state level, $\bar{U}^{ss}$, which will materialize absent any stochastic shocks. The structural level of labor market utilization is also affected by (1) transitory shocks to the level ($\epsilon_t^{\bar{U}}$), and (2) the realization of a stochastic trend ($g\bar{U}_t$). The stochastic trend is added to allow for more permanent deviations from the long run steady state level. Economically, such deviations can be brought about by a demand shock which creates hysteresis effects as unemployed workers skills are depleted after a prolonged period of unemployment (Blanchard and Summers, 1986). The structural level of underutilization of labor market resources can also increase following a supply shock, which renders the skill set of a certain fraction of the potential labor force obsolete (Braun et al., 2009).

$$\bar{U}_t = \tau_4 \bar{S}^{ss} + (1 - \tau_4)\bar{U}_{t-1} + g\bar{U}_t \quad + \epsilon_t^{\bar{U}} \tag{7}$$

$$g\bar{U}_t = (1 - \tau_3)g\bar{U}_t + \epsilon_t^{g\bar{U}_t} \tag{8}$$

The process for underutilization of labor market resources is illustrated in Figure A.3. Here $\bar{U}^{ss}$ is the steady state level of underutilization which would materialize in the absence of any shocks. $\epsilon_t^{\bar{U}}$ is a stochastick shock which temporarily raises the structural level of underutilization. $g\bar{U}_t$ is a stochastic trend, and shocks to this raises the structural level in a more persistent way.

6.   The labor market gap is defined as the difference between actual and structural underutilization of labor market resources.

$$u_t = \bar{u}_t - u_t \tag{9}$$

$$u_t = \tau_2 u_{t-1} + \epsilon_t^u \tag{10}$$

This means that a positive gap implies that the labor market operates above potential, while a negative gap means it operates below potential (equation 9).[7] In addition, the labor market gap is subject to stochastic shocks representing the uncertainty surrounding the correct level of the gap (equation 10).

7.   A Phillips Curve links the output gap to inflation. As a final equation, a New Keynesian Phillips curve in the filter defines the process for inflation (Gali, 2015).

$$\pi_t = \lambda \pi_{t+1} + (1 - \lambda)\pi_{t-1} + \beta y_t + \epsilon_t^\pi \tag{9}$$

This equation links current, future, and past inflation with the output gap. This captures the idea that a positive output gap (an economy operating above potential) is expected to generate cost pressures, which in turn put upward pressure on CPI inflation as companies pass on the higher costs to their consumers. The existence of both current, future, and past inflation in the equation captures the role of inflation expectations and inertia in the price setting process. The equation also includes a stochastic shock term (ϵ_t^π), which allows for inflation to also be affected by other shocks.

Figure B.2: Stochastic Process for Structural Underutilization of Labor Market Resources

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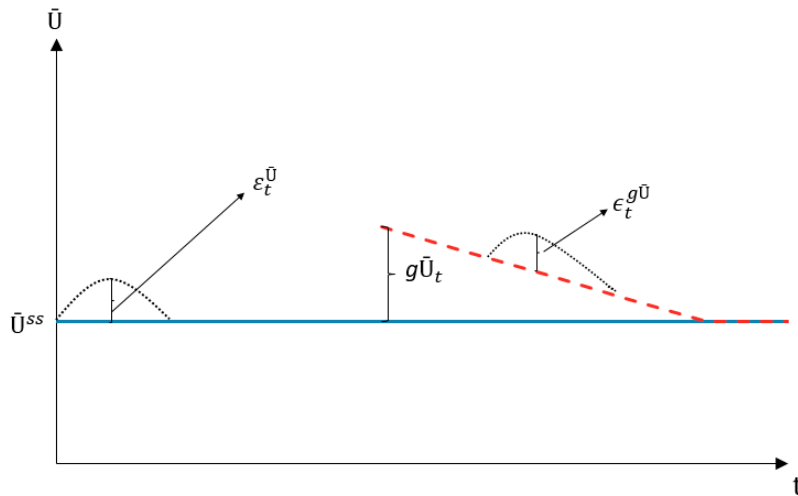
[7] This formulation is done to make the interpretation of the labor market gap consistent with the interpretation of the output gap.

8.   Equations for consensus forecasts are added to improve end-of-sample estimates of inflation expectations. These are as follows:

$$\pi^C_{t+j} = E_t\pi_{t+j} + \epsilon^{\pi^C}_{t+j} , j = 1 \tag{15}$$

$$GROWTH^C_{t+j} = E_t GROWTH_{t+j} + \epsilon^{GROWTH^C}_{t+j} , j = 1, \dots, 5 \tag{16}$$

For output growth expectations, forecasts from Consensus Economics are used five years ahead in term starting from the end of historical observations. Similarly, CPI inflation forecasts from Consensus Economics one year ahead are used. These consensus forecasts $(\pi^C_{t+j}, GROWTH^C_{t+j})$ are benchmarked against model-consistent forward-looking expectations $(E_t\pi_{t+j}, E_t GROWTH_{t+j})$. Their "signaling power" in guiding future paths of output and inflation are determined by the historical standard deviations of the error terms. In practice, adjusting the standard deviations of these error terms can help blend experts' forecasts from various sources and methods. The impact of such tuning can be significant (Alichi et al., 2017).

9.   Below the output gap is estimated using this model along with various measures of labor market slack. Specifically, the model using regular unemployment as well as the broader measures of labor market underutilization discussed in Section II are used. This allow us to gauge how the chosen measure of underutilization affect the estimated output gap.

Appendix C: A Multivariate Filter with Labor Market Gaps and Capacity Utilization

1.   This model relates the labor market slack and the output gap through Okun's law. The output gap is written as a function of the slack in the labor market, which is measured as the gap between the augmented labor market measure and the structural level of labor market slack. Specifically, equation (4) is revised to:

$$y_t = \tau_4 u_t + \phi y_{t-1} + \epsilon_t^Y \tag{4a}$$

As in section III, the augmented measure of labor market slack is used in order to obtain a more accurate signal about the cyclical state of labor market.

2.   Capacity utilization is used to gauge business cycle conditions. Manufacturing constitutes a significant share of the Korean economy. This makes capacity utilization an important business cycle indicator for two reasons. First, industrial capacity utilization provides a measure of capital slack in real time for the manufacturing sector. Second, a large share of the labor force is employed within manufacturing, where capacity utilization also provides a signal about the state of the labor market if capital and labor are complementary inputs. Equations 3,5,6 can therefore be replaced with a system of equations for capacity utilization:

$$\widehat{CAPU}_t = CAPU_t - \overline{CAPU}_t \tag{3a}$$

$$\overline{CAPU}_t = \overline{CAPU}_{t-1} + GROWTH_t^{\overline{CAPU}} + \epsilon_t^{\overline{CAPU}} \tag{5a}$$

$$GROWTH_t^{\overline{CAPU}} = (1 - \delta)GROWTH_{t-1}^{\overline{CAPU}} + \epsilon_t^{GROWTH^{\overline{CAPU}}} \tag{6a}$$

$$\widehat{CAPU}_t = \kappa y_t + \epsilon_t^{\widehat{CAPU}} \tag{6b}$$

$\overline{CAPU}_t$ is the equilibrium rate of capacity utilization, which is determined by a change term $(GROWTH_t^{\overline{CAPU}})$ and a shock term $(\epsilon_t^{\overline{CAPU}})$. The change in the equilibrium capacity utilization rate $(GROWTH_t^{\overline{CAPU}})$ allows some persistence in the dynamic of equilibrium capacity utilization, while subject to some growth shocks $(\epsilon_t^{GROWTH^{\overline{CAPU}}})$. The capacity utilization gap $(\widehat{CAPU}_t)$ is designed to capture slack in the manufacturing sector, meanwhile correlated with the measure of overall economic slack (y_t) and a shock term $\epsilon_t^{\widehat{CAPU}}$.

Parametrization

1. The model contains three types of parameters. First, it contains long-run steady state levels that act as attractors for the structural amount of idle capacity on the labor market and structural TFP growth. Second, it contains a set of model coefficients. Finally, it contains a number of shocks variables.

- **Long run steady state level are computed using long run averages.** For both idle capacity on the labor market and TFP growth, the long run average is used as a the long run attractor in equation (5) and (7), respectively.

- **Model coefficients and shock variables are estimated by Bayesian methods.** The priors are taken from Blagrave et al (2017), and the posteriors presented in Table 2.

Table D.1: Long Run Steady State Levels

Coefficient	Korea
G^{SS}	1.5 percent
$\bar{U}^{SS}$	3.4/5.5/10.7 percent

Table D.2: Model Coefficients [for model with regular unemployment measure]

Coefficient	Prior	Posterior
		Korea
α	0.3	0.3
ϕ	0.6	0.56
θ	0.10	0.13
λ	0.25	0.34
β	0.25	0.29
τ_4	0.10	0.10
τ_3	0.10	0.10
τ_2	0.20	0.25
$\text{Std}(\epsilon_t^Y)$	0.80	0.79
$Std(\epsilon_t^{\bar{A}})$	0.20	0.196
$Std(\epsilon_t^{G})$	0.20	0.198
$Std(\epsilon_t^{\pi})$	0.25	0.466
$Std(\epsilon_t^{\bar{S}})$	0.10	0.09
$Std(\epsilon_t^{g\bar{S}_t})$	0.50	0.49
$Std(\epsilon_t^{u})$	0.49	0.49

Appendix E: Data

1.   The model is estimated using data from the OECD, IMF, and Statistics Korea.
Data on real GDP, inflation, employment, and unemployment is derived from the IMF's
World Economic Outlook. TFP is computed using a production function and data on the
capital stock from the OECD's *Economic Outlook.* Specifically. TFP is backed out using the
production function $Y = AK^{\alpha}L^{1-\alpha}$ along with the OECD data for capital and employment,
and the assumption that $\alpha = 0.3$. Data on discouraged workers and other non-active persons
outside the labor force is taken from Statistics Korea. There is a level break in the time series
for discouraged workers in 2014, why the series have been spliced by backing out the levels
prior to 2014 using the growth rate of the earlier time series.