Discussion Paper Series
RIEB
Kobe University

DP2022-32

Cyclical Activity and Inflation under Secular Stagnation: Empirical Evidence Using Data on Japan's Lost Decades

Masahiko SHIBAMOTO

July 4, 2022

Research Institute for Economics and Business Administration
Kobe University
2-1 Rokkodai, Nada, Kobe 657-8501 JAPAN

Cyclical Activity and Inflation under Secular Stagnation: Empirical Evidence Using Data on Japan's Lost Decades*

Masahiko Shibamoto†

July 4, 2022

Abstract

This paper disputes the suspicions about the existence and stability of the trade-off between nominal inflation and the real economy when missing deflation and reinflation under secular stagnation by providing empirical evidence of the stability of this short-run trade-off. To this end, we construct a simple measure of demand-pull pressures, namely the cyclical activity index, using time-series data for a period that includes Japan's secular stagnation. We then quantitatively examine the relationship between inflation and the measured cyclical activity. The empirical results support that the cyclical activity index has a stable and economically meaningful relationship with short-term inflation.

JEL Classification: E31; E32.

Keywords: Inflation; Cyclical activity; Phillips curve; Economic slack; Secular stagnation; Japan.

*This study received financial support from the Japan Society for the Promotion of Science (JSPS KAKENHI Grant Number 20H05633 and 21K01579).

†Correspondence to: Masahiko Shibamoto, Research Institute for Economics and Business Administration (RIEB) and Center for Computational Social Science (CCSS), Kobe University, 2–1, Rokkodai, Nada, Kobe, 657–8501, Japan. E–mail: shibamoto@rieb.kobe-u.ac.jp.

1 Introduction

A short-run trade-off between nominal inflation and the real economy is one of the critical building blocks for understanding business cycles and macroeconomic policy. Since the seminal papers of Fisher (1926) and Phillips (1958), the Phillips curve has been the primary tool that both academics and policymakers rely upon to understand this trade-off. Standard economics textbooks, such as Mankiw (2019), describe the trade-off from the aggregate supply relationship, that is, inflation accelerates when the economy is in a boom and decelerates when it is in a slump. The central banks in many countries discuss their judgments about the current and future state of inflation and the approaches to achieving the policy goal of macroeconomic and inflation stability in terms of the Phillips curve.

The significance of the Phillips curve often exposes it to controversy over its empirical regularity and reliability as a tool for policymaking. The dispute is particularly vigorous when the actual evolution of inflation diverges from the negative relationship with labor market slack.[1] Concerning inflation and the real economy during the prolonged stagnation following the global financial crisis, there are many skeptical views about the stability of the Phillips curve slope, which represents the sensitivity of inflation to the demand-pull pressure. For example, in response to stable inflation with a surge and decline in unemployment, Simon et al. (2013), Blanchard et al. (2015), Hooper et al. (2020), and Del Negro et al. (2020) point out that the Phillips curve would be either irrelevant or be been flattening out in recent years in the U.S. and other advanced economies.[2] This assertion can have a significant implication for a central bank's policy management to achieve macroeconomic stability. If the Phillips curve were to become irrelevant or flatter, it would justify a more aggressive focus of the central bank on employment and the real economy without paying less attention to inflation. Although they are by no means advocating that central banks can manage their policies without considering inflation, Simon et al. (2013), Blanchard et al. (2015), Hooper et al. (2020), and Hazell et al.

[1] In response to the high inflation period that occurred in the 1970s, Friedman (1968) and Phelps (1968) propose a modification of the Phillips curve to an inflation-expectation augmented one. They argue that the Phillips curve relationship is only valid in the short term, considering inflation expectations. Since then, the standard approach has been to understand inflation based on a triangle model of inflation, under which inflation is determined by expected inflation, demand-pull pressures such as the output gap and labor-market slack, and cost-push shocks. For details on the triangle model of inflation, see Gordon (1997) and the references therein.

[2] Some studies argue that the role of the Phillips curve slope has been limited since before the Great Moderation and the global financial crisis. Atkeson and Ohanian. (2001) argue that Phillips curve-based models are not enough for practically forecasting inflation. Hazell et al. (forthcoming) estimate the slope of the Phillips curve for the cross-section of U.S. states and argue that its slope was already small as of the early 1980s and there is limited evidence of its structural change.

(forthcoming) emphasize the importance of inflation expectations being well anchored by policy management rather than the trade-off between inflation and the real economy to achieve price stability.[3]

These facts and discussions are not new in Japan but have plagued the Japanese economy for many years. Figure 1 shows the unemployment rate and 12-month rate of inflation in Japan. On the one hand, while it began to rise after the collapse of asset prices in the early 1990s, Japanese unemployment rose at a growing pace from early 1997 through the mid-2000s. On the other hand, unemployment had been declining steadily for about a decade since the beginning of the 2010s. The labor market slack significantly changed during that period. As a deviation from the full employment level, the unemployment gap was high between the early 1997 and the end of the 2000s, with a maximum above 2%.[4] Then, the unemployment gap shrank in the 2010s, showing that the labor market has been relatively tight since 2015, at less than −0.5% at its tightest. Nevertheless, neither did severe deflation occur in the late 1990s and early 2000s nor did robust inflation in the 2010s. In practice, Japan's inflation has remained stable at a low level of around 0% since the mid-1990s, although there were some temporary rises and falls. As shown in Figure 2, one can see that the unemployment gap and the 12-month rate of inflation since 1997 have been far from what could be explained by the relationships prior to that time. These facts have long raised suspicions among both academics and policymakers about the existence and stability of the trade-off under Japan's secular stagnation.[5] Although many previous studies tackle the Japanese inflation experience over secular stagnation, such as De Veirman (2009), Fuhrer et al. (2012), Okimoto (2019), and Hoshi and Kashyap (2021), most of them presume that the Phillips curve is flattening under secular stagnation and explore the causes behind it.[6]

Although the correlation between inflation and economic slack has weakened, this does not

[3] In practice, policymakers account for policy operations and their relevance in a manner consistent with the academic discussions. For example, Powell (2018) addresses risk factors in achieving inflation stability, following his view that the Phillips curve is flattening under inflation expectations sufficiently anchored by monetary policy.

[4] The Japan Institute for Labour Policy and Training names the unemployment gap "deficient-demand unemployment" and publishes its estimated values. It defines *equilibrium* as the condition in which unemployed and vacant positions exist equally and measures the equilibrium unemployment rate considering the actual unemployment and vacancy rates, given the estimated Beveridge curve relationship.

[5] For example, in an early study, Nishizaki and Watanabe (2000) estimated the nonlinear short-run Phillips curve using Japanese data and concluded that the short-run Phillips curve becomes flatter as inflation approaches zero.

[6] See Hoshi and Kashyap (2021) for a literature review on the price and wage Phillips curve during secular stagnation in Japan. De Veirman (2009), Fuhrer et al. (2012), and Okimoto (2019) argue that the output-inflation trade-off has been limited in Japan since the late 1990s based on their empirical results.

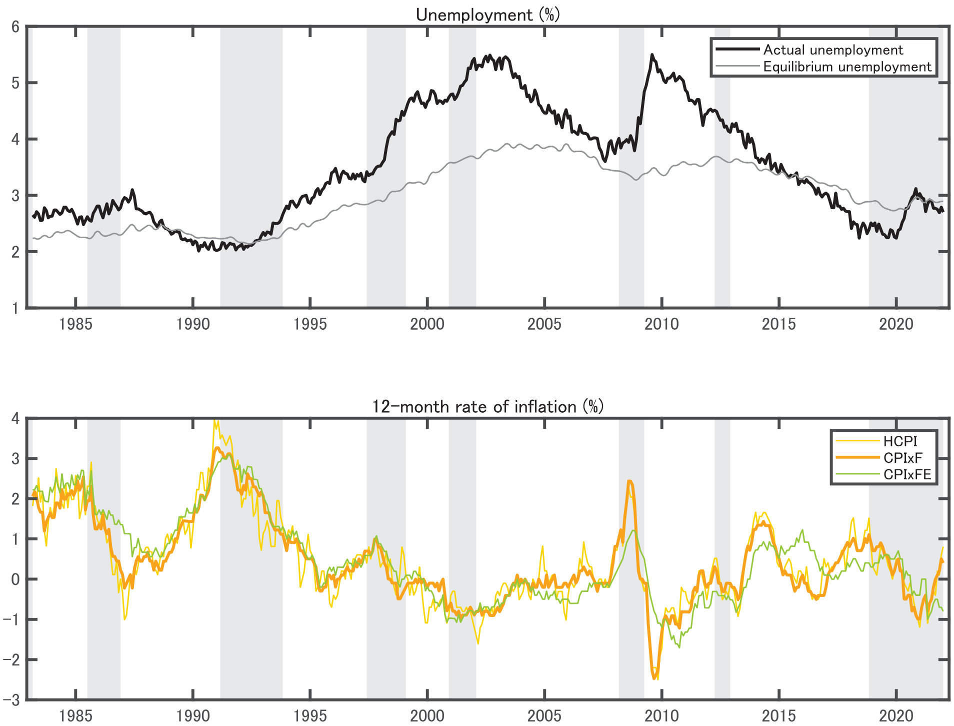

Figure 1: Unemployment and inflation in Japan

Notes: The sample period is from February 1983 to December 2021. The upper panel shows the actual and equilibrium unemployment rates. The equilibrium unemployment rate is constructed by the Japan Institute for Labour Policy and Training. The lower panel shows the 12-month inflation rate. HCPI: consumer price index (CPI), all items (headline CPI). CPIxF: CPI, all items excluding fresh foods. CPIxFE: CPI, all items excluding food and energy. The shaded areas show periods of recession in Japan, as defined by the Cabinet Office.

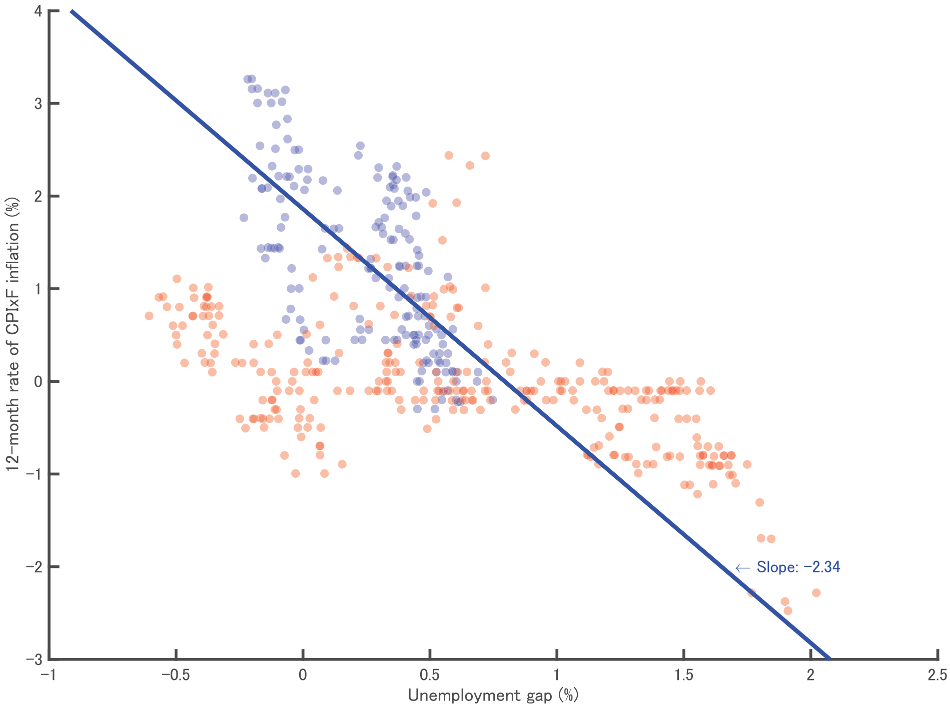

Figure 2: Missing deflation and reinflation since 1997 in Japan: Scatter plot of the unemployment gap and inflation

Notes: The horizontal axis plots the unemployment gap (percent), as the difference between the actual unemployment rate and the equilibrium unemployment rate constructed by the Japan Institute for Labour Policy and Training. The vertical axis plots the 12-month rate of CPIxF inflation (percent). The blue and red circles indicate scatter plots using subsamples from February 1983 to April 1997 and from May 1997 to December 2021, respectively. The blue solid line indicates the fitted values for the inflation regression on the constant and the unemployment gap based on an ordinary least squares estimation using subsamples from February 1983 to April 1997. CPIxF: Consumer price index, all items excluding fresh foods.

necessarily suggest that the short-run trade-off causality has disappeared or become limited. While both academics and policymakers commonly accept the slope of the Phillips curve to be characterizing the extent of a trade-off between inflation and demand-pull pressure at the business cycle frequency, empirical studies usually evaluate the relationship between inflation and economic slack. Economic slack can include a stochastic trend, reflecting the prolonged stagnation in developed countries after the global financial crisis and that in Japan since the late 1990s. Even if a stochastic trend shifts the long-run level of economic slack, it will not affect inflation without being reflected in demand pressure. In this case, we should regard the change in stochastic trend as a persistent shift in the short-run trade-off rather than a change alongside it. Such factors influence inflation in a way that looks like offsetting the influence of economic slack along the short-run trade-off. Consequently, when analyzing the relationship between economic slack and inflation during the secular stagnation period, there is the potential issue that the short-run trade-off would be spuriously overseen even if it exists.

This study thus re-examines the existence and stability of the short-run trade-off during secular stagnation. To this end, we construct a simple measure of the demand-pull pressure as a composite index of indicators summarizing the labor market and economic activity at business cycle frequencies, namely the cyclical activity index, for approximately 40 years since the early 1980s in Japan. Subsequently, we quantitatively examine the relationship between inflation and measured cyclical activity, including the possibility of a structural change in this relationship under secular stagnation.

This paper contributes to the literature by providing new empirical evidence and presenting the standard but essential perspective regarding inflation and the real economy during secular stagnation. The empirical results support that the cyclical activity index has an economically meaningful relationship with short-term inflation. Quantitatively, a one-unit increase in the cyclical activity index corresponding to a 1% in unemployment decelerates CPI inflation by approximately 2% in the case of Japan's secular stagnation. Further, the relationship is stable throughout the sample period, both before and during secular stagnation. Our finding suggests that the short-run trade-off is well-functioning, even under secular stagnation, but can be masked by underlying a stochastic trend in the economic slack. This implies that policymakers should make their policies conditional on this trade-off to achieve macroeconomic stability during secular stagnation, even if neither severe deflation nor robust inflation occur in practice.

The rest of this paper is organized as follows. Section 2 explains the econometric methodology used for measuring the cyclical activity index and estimating the short-run Phillips curve. Section 3 presents the empirical results of applying our empirical framework. Section 4 concludes the paper. The Appendix provides detailed definitions of the variables with data sources and additional analyses.

2 Econometric methodology

2.1 Empirical model

We begin by specifying the short-run Phillips curve, which describes the relationship between inflation and economic activity at business cycle frequencies. Assume variable π_t represents the inflation for month t. Following the literature, such as Gordon (2013), Ball and Mazumder (2011), Stock and Watson (1999, 2009, 2020), we consider the following linear regression model for the short-run Phillips curve:

$$\tilde{\pi}_t = \alpha + \beta \tilde{x}_t + \epsilon_t^{\pi}, \tag{1}$$

where $\tilde{\pi}_t$ represents the short-term inflation, which captures the change in inflation over the course of the business cycle, $\tilde{x}_t$ represents the unobservable measure of cyclical activity in the economy at month t, and ϵ_t^{π}, with a mean of zero and a variance of σ_ϵ^2, represents the deviation component from the short-run Phillips curve.

Following Stock and Watson (2020), we use a one-sided filter to eliminate the long-run trend and a high-frequency noise underlying the macroeconomic variables. Particularly, in case of inflation, we apply the monthly observation of inflation, π_t, to the following year-over-year change filter that concentrates the gains at business cycle frequencies:

$$\tilde{\pi}_t \equiv b(L)\pi_t, \tag{2}$$

where $b(L) = (1 - L^{12})(1 + L + L^2 + \cdots + L^{11})/12$. That is, $\tilde{\pi}_t$ is a year-over-year change in the 12-month moving average inflation for month t.

Next, we consider the model under which we extract a cyclical component of $\tilde{x}_t$ as a common factor from a variety of variables in the labor market and from real economic activity. Assume $\tilde{y}_t$ is a $K \times 1$ vector consisting of observed filtered activity measures. The observed variables, $\tilde{y}_t$, are presumed to be related to a common factor, $\tilde{x}_t$, through the following observation equation:

$$\tilde{y}_t = \lambda_1 + \lambda_x' \tilde{x}_t + \xi_t, \tag{3}$$

where ξ_t is a $K \times 1$ vector of mean-zero idiosyncratic components. λ_1 and λ_x are $K \times 1$ vectors of intercept and slope coefficients, respectively. Assuming the first variable in $\tilde{y}_t$ is filtered unemployment $\tilde{u}_t$, we restrict the first element in the slope coefficient vector λ_x to be equal to one in the factor model (3). Under this restriction, a one-unit increase in common factor $\tilde{x}_t$ corresponds to a one-percent increase in filtered unemployment.

We construct the composite index of filtered activity measures as common factor $\tilde{x}_t$ that satisfies factor model (3). Specifically, we adopt the principal component approach to estimate the unobserved composite index. We first calculate the first principal component, pc_t, using standardized filtered activity measures. Then, we consider the following regression to scale and sign the factor to filtered unemployment, $\tilde{u}_t$:

$$\tilde{u}_t = \gamma_1 + \gamma_{pc} pc_t + v_t, \tag{4}$$

where γ_1 and γ_{pc} are the intercept and slope coefficient, respectively, and v_t is an error term. Given the estimate of γ_{pc}, we compute the composite index as $\tilde{x}_t = \hat{\gamma}_{pc} pc_t$. We refer to the composite index of $\tilde{x}_t$ as the cyclical activity index.

2.2 Data

As the measure of inflation, we consider $\pi_t = 1200 \log(P_t/P_{t-1})$, where P_t is the monthly price index. We use the consumer price index (CPI) for all items less fresh food (CPIxF) as the benchmark proxy of P_t. As alternative price indexes, we also use the CPI for all items (headline CPI, HCPI) and the CPI for all items less fresh food and energy (CPIxFE). Additionally, we consider the wage inflation to be calculated using the hourly wage (Wage/h) as a proxy of P_t.

To construct a vector $\tilde{y}_t$ consisting of the year-over-year change filtered measures, we use six time series of the labor market and three time series of real economic activity. The six labor variables are unemployment rate, employment-population ratio, vacancy ratio, job opening ratio, unemployment insurance beneficiaries, and overtime worked hour index. The three real variables are the 3-month lag of the industrial production index, the 3-month lag of the capital utilization index, and the tertiary industry activity index.[7] See the Appendix for more detailed information on these variables.

Our dataset covers the period from February 1983 to December 2021. The sample starts with the trough of the ninth business cycle, as defined by the Cabinet Office. We omitted the periods when inflation in the Japanese economy was relatively high due to the high economic growth in the postwar period and the oil shocks of the 1970s.

3 Empirical results

3.1 Measuring cyclical activity index

We measure the cyclical activity index in four steps. In step 1, we construct a dataset on time series, $\{y_1, \cdots, y_T\}$, consisting of six labor market variables and three real economic variables. Then, in step 2, we apply the series to the year-over-year-change filter $\tilde{y}_t \equiv b(L)y_t$, that is, we calculate a year-over-year change in their 12-month moving average at month t. In step 3, we calculate the first principal component using standardized filtered measures with zero mean and unit variance. In step 4, we regress equation (4) and scale and sign the principal component to filtered unemployment. Consequently, the cyclical activity index is a composite index, that is, a weighted average of the year-over-year change in the 12-month moving average of real activity measures.

Table 1 shows the empirical results for factor model (3) by ordinary least squares (OLS) regression. The composite index explains much of the variation in filtered measures in the table.[8] We find that the composite index explains around 68% of the variation in unemployment over the business cycle frequency. This result suggests that the composite index, which summarizes common features of the labor market and economic activity, adequately captures the business cycle fluctuations in unemployment. In the following analysis, we consider the composite index as a measure of cyclical activity.

Next, we document the time series of cyclical activity. Specifically, we compare the measured cyclical activity index with labor market slack.

[7] Preliminary analysis confirms that three-month lags have stronger correlations with the other variables than the contemporaneous values of industrial production and the capacity utilization indices. This result is consistent with the stylized fact that labor market variables, including the unemployment rate, are lagging indicators in the business cycle.

[8] The employment-population ratio and tertiary industry activity are explained to a lesser degree, given the large share explained by the idiosyncratic components.

Table 1: OLS estimation results for the factor model

Regressand	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Estimates of									
λ_1	0.02	0.15	0.03	0.01	-0.01	0.00	0.01	-0.01	0.03
	(0.03)	(0.06)	(0.02)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)
λ_x	1	-0.82	-0.97	-0.54	0.38	-0.18	-0.19	-0.21	-0.11
	(0.09)	(0.14)	(0.07)	(0.05)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
R^2	0.68	0.30	0.80	0.87	0.78	0.69	0.82	0.79	0.34

[1] Unemployment (%, MA(12), yoy)
[2] Employment/population (%, MA(12), yoy)
[3] Vacancy (%, MA(12), yoy)
[4] Job opening/applicant (ratio, MA(12), yoy)
[5] Unemployment insurance beneficiaries (log, MA(12),yoy)
[6] Overtime worked hour (log, MA(12), yoy)
[7] Industrial product (lagged 3-month, log, MA(12), yoy)
[8] Capital utilization (lagged 3-month, log, MA(12), yoy)
[9] Tertiary industry activity (log, MA(12),yoy)

Notes: This table shows the ordinary least squares (OLS) results of the year-over-year change filtered indicator described in the upper header on the composite index of indicators and constant term in equation (3). We obtain the composite index by scaling and signing the first principal component calculated using the nine standardized indicators to the year-over-year change filtered unemployment. The numbers between parentheses are Newey and West (1987) heteroskedasticity and autocorrelation robust standard errors for least squares with a 12-month lag truncation. The sample period is from February 1983 to December 2021.

For comparison with the cyclical activity index, we consider two proxies typically used as labor market slack. First, we use the unemployment gap, calculated as the difference between the actual and equilibrium unemployment rates presented in Section 1. Second, following Stock and Watson (1999), we measure detrended unemployment as the deviation of the actual unemployment rate from the trend estimates based on the one-sided version of the Hodrick–Prescott (HP) filter. We use a value of the HP smoothing parameter for monthly unemployment series equal to 6400×3^4 adjusted by multiplying the parameter of 6400 applied to quarterly data by Gordon (2013) with the fourth power of the frequency observation ratio proposed by Ravn and Uhlig (2002).[9]

Figure 3 shows the measured cyclical activity index and the labor market slack from February 1983 to December 2021 in Japan. The thick solid line in the figure represents the monthly time series of a calculated cyclical activity index. The thin solid and dotted lines indicate the measures of the unemployment gap and detrended unemployment, respectively.

By comparing the cyclical activity index with the unemployment gap and detrended unemployment, we can visually confirm its two distinctive properties. First, the cyclical activity index correlates highly with detrended unemployment but less so with the unemployment gap. The former is an entirely natural and expected feature. The cyclical activity index is intended to measure the degree of temporary stagnation or overheating in the labor market and the real economy. However, the cyclical activity index can be inherently different from the unemployment gap, thus aiming to measure the difference between the unemployment measured in real-time and the equilibrium level representing the full utilization of productive resources.

Second, while the cyclical activity index behaved similar to the unemployment gap and detrended unemployment before the secular stagnation period, it behaved differently during the secular stagnation since the mid-1990s. As mentioned in the introduction, the unemployment gap has behaved quite differently before and during the secular stagnation. Namely, it expanded persistently from the mid-1990s to the mid-2000s, then declined persistently until just before the global financial crisis. Subsequently, it rose sharply again during the global financial crisis and has been shrinking slowly since then.[10] While not as large as the unemployment gap, detrended

[9] Gordon (2013) shows that the reason for not choosing the typical HP quarterly parameter of 1600 is that the trend would be extremely variable in response to actual movements, which would be at odds with the estimates of the time-varying non-increasing inflation rate of unemployment (NAIRU) by Staiger et al. (2001). Shimer (2005) and Miyamoto (2011) employ a value of the parameter of 10^5, which yields a smoother trend when extracting business-cycle-frequency fluctuations in quarterly unemployment.

[10] This may partly reflect structural factors such as the increasing mobility of the Japanese labor market since

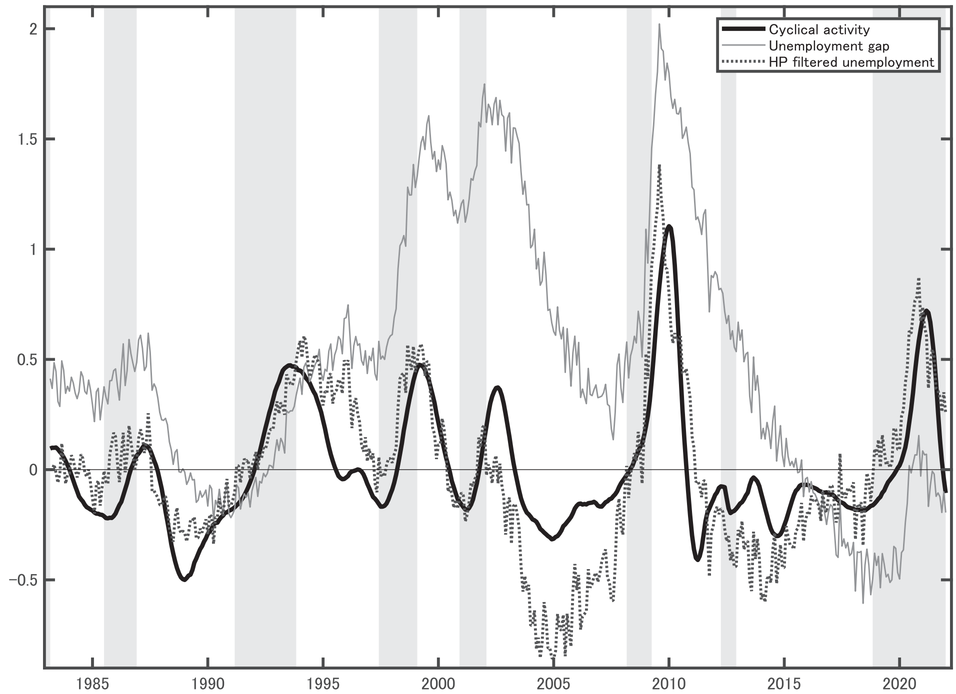

Figure 3: Cyclical activity, unemployment gap, and detrended unemployment

Notes: The sample period is from February 1983 to December 2021. Cyclical activity is the composite index of the year-over-year-change filtered indicators of the labor market and economic activity from factor model (3). The unemployment gap is the difference between the actual unemployment rate and the equilibrium unemployment rate constructed by the Japan Institute for Labour Policy and Training. HP filtered unemployment is the difference between the actual unemployment rate and the smoothed series by the one-sided HP filter with smoothing parameter 6400×3^4. The shaded areas show periods of recession in Japan, as defined by the Cabinet Office.

unemployment also shows periods of persistent movement during the secular stagnation. In particular, detrended unemployment has fluctuated more during secular stagnation. For example, it has slowly declined from its peak in the late 1990s to a maximum of approximately -1% in 2005. On the other hand, there does not appear to be any structural change in the time series of the cyclical activity index before and during the secular stagnation. Specifically, the cyclical activity index tended to rise sharply during recessions and decline moderately during expansions throughout the sample period.

We can re-affirm the properties of the cyclical activity index from the descriptive statistics. Table 2 reports the Pearson correlation coefficients of the cyclical activity index with the unemployment gap or the detrended unemployment from February 1983 to December 2021 and by subsamples from February 1983 to April 1997 and from May 1997 to December 2021. The table shows that the correlation between the cyclical activity and detrended unemployment is relatively high, with a coefficient of approximately 0.8, whether over the entire sample period or subsample periods. By contrast, the correlation between cyclical activity and the unemployment gap is moderate, with a coefficient of approximately 0.4. Table 3 reports the standard deviation of the cyclical activity index, unemployment gap, and detrended unemployment for the entire sample period and by subsamples. The table shows that the variances of the cyclical activity index do not differ much regardless whether it is in a secular stagnation period, with a standard deviation of approximately 0.3.[11] By contrast, the variances of the unemployment gap and detrended unemployment are higher during the secular stagnation period, with the standard deviation of the unemployment gap being around 2.6 times higher than before the stagnation period and the standard deviation of the detrended unemployment being around 1.7 times higher. Note that the standard deviations of the unemployment gap and detrended unemployment before the stagnation are comparable to that of the cyclical activity index, mirroring the fact that the cyclical activity index exhibited a similar behavior to the unemployment gap and the detrended unemployment over this period.

the late 1990s.

[11]The variances of the cyclical activity index are relatively small compared to similar measures in the U.S. For example, the standard deviation of the U.S. unemployment gap, measured by unemployment minus CBO's current estimate of the natural rate of unemployment from the first quarter of 1983 to the first quarter of 2019, is approximately 1.5.

Table 2: Correlation of the cyclical activity index with the unemployment gap or detrended unemployment

		Cyc-A
Full sample:1983m2–2021m12	Gap-U	0.39
	HP-U	0.78
Subsample:1983m2–1997m4	Gap-U	0.37
	HP-U	0.82
1997m5–2021m12	Gap-U	0.40
	HP-U	0.81

Notes: This table reports the Pearson's correlation coefficients of the cyclical activity index (Cyc-A) with the unemployment gap (Gap-U) or the HP filtered unemployment (HP-U) over the sample period from February 1983 to December 2021 and by subsamples from February 1983 to April 1997 and from May 1997 to December 2021. We obtain Cyc-A by scaling and signing the first principal component calculated using the nine standardized indicators to the year-over-year change in filtered unemployment. Gap-U is the difference between the actual unemployment rate and the equilibrium unemployment rate constructed by the Japan Institute for Labour Policy and Training. HP-U is the difference between the actual unemployment rate and the smoothed series by the one-sided HP filter with smoothing parameter 6400×3^4.

Table 3: Standard deviations of cyclical activity index, unemployment gap, and detrended unemployment

	Cyc-A	Gap-U	HP-U
Full sample:1983m2–2021m12	0.28	0.59	0.38
Subsample:1983m2–1997m4	0.25	0.26	0.24
1997m5–2021m12	0.30	0.69	0.43

Notes: This table shows the standard deviation of the cyclical activity index (Cyc-A), unemployment gap (Gap-U), and HP filtered unemployment (HP-U) over the sample period from February 1983 to December 2021 and by subsamples from February 1983 to April 1997 and May 1997 to December 2021. We obtain the cyclical activity index by scaling and signing the first principal component calculated using the nine standardized indicators to the year-over-year change in filtered unemployment. The unemployment gap is the difference between the actual unemployment rate and the equilibrium unemployment rate constructed by the Japan Institute for Labour Policy and Training. HP filtered unemployment is the difference between the actual unemployment rate and the smoothed series by the one-sided HP filter with smoothing parameter 6400×3^4.

3.2 Estimating short-run Phillips curve

Table 4 provides the results of the short-run Phillips curve (1) estimated by OLS. It also reports the results for the *sup*-Wald test proposed by Andrews (1993) and Hansen (1996) based on the hypothesis that the slope coefficient in the regression is stable over the sample period. The first column shows the estimated slopes of the curve using the cyclical activity index. The second and third columns show the result when using the unemployment gap and HP filtered unemployment, respectively, as a regressor in equation (1). The upper panel shows the results for the entire sample period, from February 1983 to December 2021. The lower panel shows the results in two subsample periods, February 1983–April 1997 and May 1997–December 2021.

The cyclical activity index has an economically meaningful relationship with short-term inflation. As shown in Table 4, a one-unit increase in cyclical activity index corresponding to a 1% increase in unemployment decelerates CPI inflation by approximately 1.74%, which is statistically significant at the 1% level. The estimated slope of the Phillips curve -1.74 is relatively steep compared with previous studies in the U.S., such as Ball and Mazumder (2011).[12]

We also find that the short-run Phillips curve relationship is stable over time, including before and during the secular stagnation period. As shown in Table 4, the *sup*-Wald test statistic is 1.72, which indicates that conventional significance levels do not reject the null hypothesis of the structural stability of the slope coefficient in the regression against the alternative of structural shift at an unknown point in time. The test result suggests that the Phillips curve regression using the cyclical activity index is stable throughout the sample period. Furthermore, even when we run Phillips curve regressions for separate subsample periods before and during the secular stagnation period, there is no significant quantitative difference between the estimates of the slope coefficient. The estimate is -1.95 for the subsample before the secular stagnation period from February 1983 to April 1997 and -1.70 for the subsample during the secular stagnation period from May 1997 to December 2021. Figure 4 shows the scatter plot of the cyclical activity index and the year-over-year change in the 12-month rate of CPIxF inflation, which graphically confirms the stability of the short-run Phillips curve relationship over the sample period.

[12]Ball and Mazumder (2011) report the estimated slope of the Phillips curve to be around -0.5. This result may reflect the relatively rigid labor market in Japan and the fact that unemployment fluctuates less than in the U.S.

Table 4: OLS estimation results for the short-run Phillips curve

	Regressand	Year-over-year change in 12-month rate of inflation (%)		
		CPIxF	CPIxF	CPIxF
	Regressor	Cyc-A	Gap-U	HP-U
Full sample:	1983m2–2021m12			
	Estimate of β	-1.74	-0.33	-1.20
		(0.37)	(0.25)	(0.34)
	Adjusted R^2	0.27	0.04	0.24
	sup-Wald	1.72	19.00	8.93
		[0.86]	[0.00]	[0.04]
Subsample:	1983m2–1997m4			
	Estimate of β	-1.95	-1.76	-1.98
		(0.42)	(0.56)	(0.39)
	Adjusted R^2	0.33	0.30	0.32
	1997m5–2021m12			
	Estimate of β	-1.70	-0.29	-1.07
		(0.50)	(0.28)	(0.43)
	Adjusted R^2	0.27	0.04	0.22

Notes: This table shows the OLS regression results of the year-over-year change in inflation for the constant term and the independent variable, that is, the cyclical economic activity measure (Cyc-A), unemployment gap (Gap-U), or HP filtered unemployment (HP-U). We obtain the cyclical activity index by scaling and signing the first principal component, calculated using the nine standardized indicators to the year-over-year change filtered unemployment. The unemployment gap is represented by the difference between the actual unemployment rate and the equilibrium unemployment rate constructed by the Japan Institute for Labour Policy and Training. HP filtered unemployment is the difference between the actual unemployment rate and the smoothed series by the one-sided HP filter with smoothing parameter 6400×3^4. The numbers between parentheses are Newey and West (1987) heteroskedasticity and autocorrelation robust (HAR) standard errors for least squares with a 12-month lag truncation. The estimated constant term and its standard error are not reported. *sup*-Wald represents a HAR F statistic with the null hypothesis that the regression model is stable throughout the sample period and the alternative hypothesis that there is a structural break in coefficient β at an unknown point in time. The numbers between brackets are the p-values for test statistic *sup*-Wald, computed using the critical values proposed by Andrews (1993) and Hansen (1996). CPIxF: consumer price index, all items excluding fresh foods.

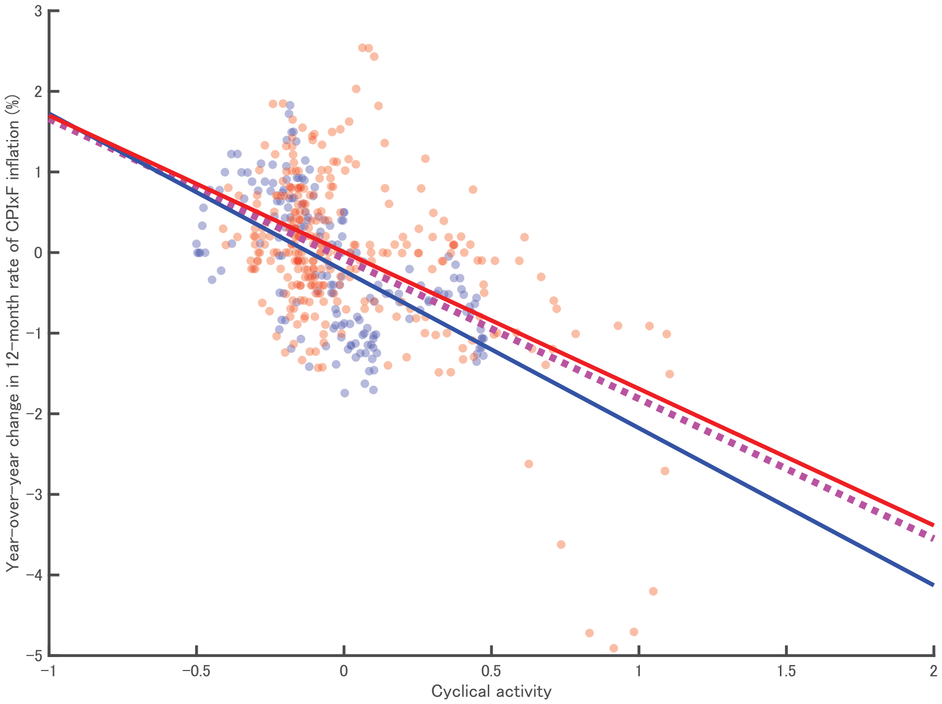

Figure 4: Scatter plot of the cyclical activity and short-term inflation

Notes: The horizontal axis plots the cyclical activity index, which is the composite index of the year-over-year change filtered indicators of the labor market and economic activity from factor model (3). The vertical axis plots the year-over-year change in the 12-month rate of CPIxF inflation (percent). CPIxF: consumer price index, all items excluding fresh foods. The blue and red circles indicate scatter plots using the subsamples from February 1983 to April 1997 and from May 1997 to December 2021, respectively. The dashed line indicates the fitted value for the regression of the change in inflation on constant and the cyclical unemployment based on the OLS estimation using the sample from February 1983 to December 2021. The blue and red solid lines indicate the fitted values for the regression using the subsamples from February 1983 to April 1997 and from May 1997 to December 2021, respectively.

The above results of the Phillips curve regression using the cyclical activity index differ from the ones using the unemployment gap or the detrended unemployment often employed as a measure of labor market slack. As in the second column of Table 4, the relationship between the unemployment gap and inflation appears to have disappeared; the empirical results thus support the possibility of a structural change in the relationship, and the negative coefficient estimate on the unemployment gap during the secular stagnation period is statistically insignificant. Regarding the results of the regression using detrended unemployment, as shown in the third column of Table 4, the slope of the detrended unemployment appears to be flattening, although the relationship with inflation is fairly statistically supported. In particular, the results support the possibility of a structural change in the relationship, with the estimate of the slope of detrended unemployment becoming smaller in the absolute sense during a secular stagnation period. These results suggest that monitoring the unemployment gap or detrended unemployment as demand-pull pressures on inflation could be misunderstood as the trade-off between inflation and the real economy having disappeared or becoming limited.

We argue that it is critical to adequately identify demand-pull pressures to quantitatively understand the short-run trade-off between nominal inflation and the real economy, especially during the secular stagnation period. Of particular significance is the extraction of cyclical activity measures as demand-pull pressures for eliminating stochastic trends that cause persistent shifts in the Phillips curve, in addition to removing idiosyncratic elements among the various economic activity variables. As mentioned in the previous subsection, during Japan's secular stagnation period, the labor market slack has changed dramatically and persistently over a long time. This fact suggests there exists a stochastic trend that is not directly reflected in the cyclical demand-pull pressure but is included in the time-series evolution of labor market slack. If the stochastic trend is positively correlated with the deviation from the short-run Phillips curve, ϵ_t^π, in equation (1) (i.e., if the labor market tightens (slackens), but inflation (deflation) does not occur), it can produce an upward endogenous bias in the estimated coefficient on the slope of the Phillips curve as if the short-run trade-off as a causal relationship would be dead or have flattened. In other words, the short-run trade-off can be masked by a stochastic trend underlying labor market slack during the secular stagnation.

In estimating a model of short-run Phillips curves with labor market slack, a straightforward solution to obtain an unbiased estimator of the coefficient of the slope of the Phillips curve is to run a regression with the demand-pull pressure as an instrumental variable (IV) for the labor market slack. Therefore, we conduct an exercise using the cyclical activity index as an IV for the unemployment gap in a short-run Phillips curve regression for the period including and during secular stagnation.

The cyclical activity index works well to solve the endogenous bias problem in estimating the short-run Phillips curve using the unemployment gap. Table 5 shows the IV regression results of the year-over-year change in CPIxF inflation on the constant term and the unemployment gap using as instruments the cyclical activity index and a constant. The IV estimate of coefficient β is statistically negative both over the entire sample period or the secular stagnation period. There is a less significant quantitative difference in the estimated slopes of -2.15 for the entire sample and -1.86 for the secular stagnation sample. The estimated slope is comparable with the one before secular stagnation shown in Figure 2 and Table 4. The instrument is robust, with first-stage F-statistics of 15.58 and 23.72 for the entire sample and sample of the secular stagnation period, respectively.[13] Furthermore, the Hausman test statistics are 6.04 and 4.61 for the entire sample and sample of secular stagnation period, respectively. This result statistically supports a serious upward endogenous bias in the estimated coefficient on the slope of the short-run Phillips curve using the unemployment gap for the period including and during the secular stagnation by OLS regression.

Finally, we discuss the implications from a summary of Japan's 40-year experience with inflation and labor market slack based on our empirical results for the short-run Phillips curve. Figure 5 shows the relationship between short-term inflation and the unemployment gap. As shown in the scatter plots of $\times$ and the solid line in the figure, the slope of the short-run Phillips curve was stable for around 40 years. However, the Phillips curve shifted to the right in the late 1990s and 2000s, as seen in the scatter plots of the blue circles for the February 1983 to April 1997 sample and the purple circles for the May 1997 to December 2012 sample. It then shifted to the left in the 2010s, as shown by the scatter plots of the light red circles for the sample from January 2013 to December 2021. As a result of these long-term shifts in the Phillips curve during the secular stagnation period, a trade-off between nominal inflation and the real economy simply appears to have spuriously disappeared or been limited, as indicated

[13] To ensure that a weak instrument problem is not present, Stock et al. (2002) and Stock and Yogo (2005) recommend a rule of thumb that requires the F-statistic from the first-stage regression of the two-stage least squares to exceed 10.

Table 5: IV estimation results for the short-run Phillips curve using the unemployment gap

Regressand	Year-over-year change in 12-month rate of inflation (%)	
	CPIxF	CPIxF
Regressor	Gap-U	Gap-U
Sample	1983m2–2021m12	1997m5–2021m12
Estimate of β	-2.15	-1.86
	(0.78)	(0.78)
Wald F	15.58	23.72
Hausman	6.04	4.61
	[0.01]	[0.03]

Notes: This table shows the IV regression results of the year-over-year change in CPIxF inflation on the constant term and the unemployment gap (Gap-U). We use the cyclical activity index as an instrument for the unemployment gap in the IV regression. The unemployment gap is the difference between the actual and the equilibrium unemployment rates constructed by the Japan Institute for Labour Policy and Training. We obtain the cyclical activity index by scaling and signing the first principal component, calculated using the nine standardized indicators to the year-over-year change filtered unemployment. The numbers between parentheses are Newey and West (1987) heteroskedasticity and autocorrelation robust (HAR) standard errors for least squares with a 12-month lag truncation. The estimated constant term and its standard error are not reported. Wald F indicates the HAR F-statistic under the null hypothesis that the coefficients from the first-stage regression of the unemployment gap on the instrument and a constant are both equal to zero. Hausman indicates the HAR statistic on the Hausman (1978) test under the null hypothesis that the OLS and IV estimators of β are consistent, but the OLS estimate is efficient. The numbers between brackets are p-values for the Hausman test. CPIxF: consumer price index, all items excluding fresh foods.

by the dotted line. Instead, as long as a stable trade-off relationship exists, it is not surprising if demand-pull inflation occurs at any time. This summary implies that policymakers should make their policies conditional on the trade-off to achieve the policy goal of macroeconomic stability during periods of secular stagnation, even if neither severe deflation nor robust inflation still occur in practice.

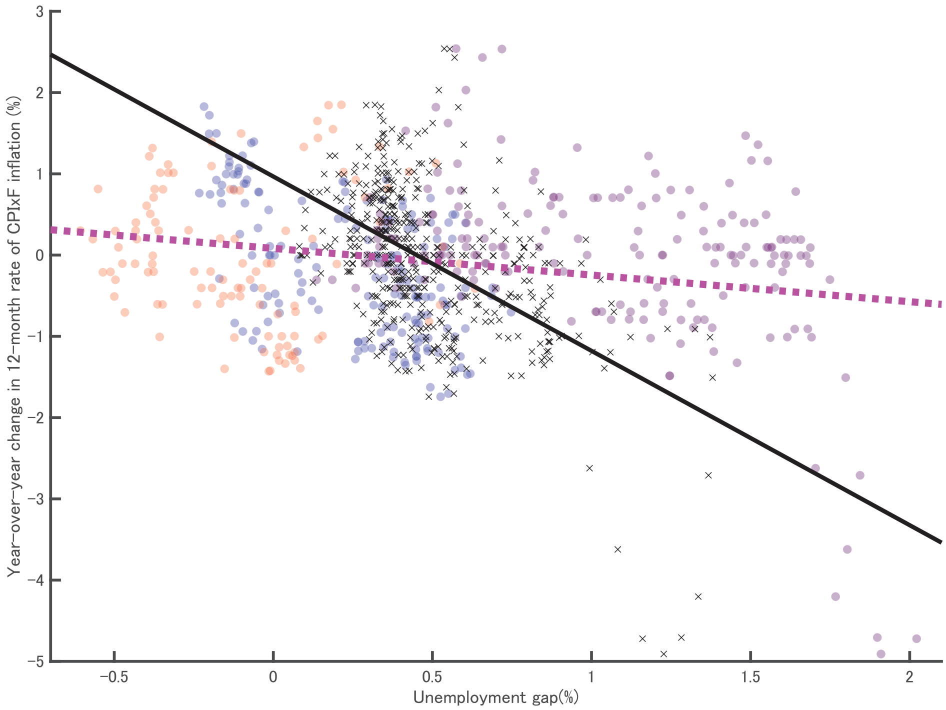

Figure 5: Scatter plot of the unemployment gap and short-term inflation

Notes: The horizontal axis plots the unemployment gap (percent), as the difference between the actual and the equilibrium unemployment rates constructed by the Japan Institute for Labour Policy and Training. The vertical axis plots the year-over-year change in the 12-month rate of CPIxF inflation (percent). The blue, purple, and light red circles indicate scatter plots over the subsamples from February 1983 to April 1997, from May 1997 to December 2012, and from January 2013 to December 2021, respectively. $\times$s indicate scatter plots replacing the unemployment gap with the fitted values for its regression on the constant and the cyclical activity index. The dashed line indicates the fitted value for the regression of the year-over-year change in the 12-month rate of CPIxF inflation on the constant and the unemployment gap based on the ordinary least squares estimation using the sample from February 1983 to December 2021 (slope: -0.33). The solid black line indicates the fitted values for the regression of the year-over-year change in the 12-month inflation rate on constant and the unemployment gap based on the IV estimation (slope: -2.15). We use the cyclical activity index as an instrument for the unemployment gap in the IV regression. CPIxF: consumer price index, all items excluding fresh foods.

4 Concluding remarks

The principal argument of this paper is that there is the potential peril that the existence of a trade-off between nominal inflation and the real economy would be overseen during secular stagnation. This study empirically examines whether the trade-off is well-functioning under secular stagnation. A pivotal issue in quantifying this trade-off is how to measure demand-pull pressures. By constructing the cyclical activity index as a proxy of demand-pull pressures, we find a stable causal relationship between cyclical activity and inflation even during Japan's secular stagnation, when the correlation between economic slack and inflation weakened. Our finding suggests that the demand-pull pressures on deflation and reinflation would be spuriously missing during secular stagnation, as a result the short-run trade-off is masked by a persistent and stochastic trend underlying the economic slack as shifting factors in the Phillips curve such as structural changes in the labor market. It also implies the need for policymakers to keep the short-run trade-off in mind when making judgments about the underlying state of inflation, even under secular stagnation.

There are several limitations and restrictions of the empirical analysis in this study, leaving room for future research in several directions. The first is ascertaining whether analogous mechanisms can be found in other advanced countries. As mentioned in the introduction, it is well known that missing deflation and reinflation were observed in many advanced economies during the long period of stagnation after the global financial crisis. In some of these countries, high inflation was registered after mid-2021 when the COVID-19 crisis had settled down. One reason may be that the central banks have failed to manage inflation expectations in 2021, although, as previous studies such as Simon et al. (2013), Blanchard et al. (2015), Hooper et al. (2020), and Hazell et al. (forthcoming) have pointed out, it has been successful in hitherto anchoring them adequately. Alternatively, as in the findings of this study, the trade-off may well have existed but simply been masked by the presence of stochastic trends during secular stagnation in other countries. If so, it would not be shocking that high inflation occurred, given the sudden increase in demand-pull pressures after the COVID-19 crisis. International comparisons such as constructing a cyclical activity index and examining the stability of the slope of the Phillips curve in other countries are thus crucial in future works.

The second is examining the role of the shift factors in the Phillips curve. This study focuses on quantifying the extent of the short-run trade-off. Therefore, by constructing a cyclical activity index for economic activity, we remove the stochastic trend included in the real economy. Additionally, we remove the stochastic trend included in inflation expectations by measuring short-term inflation at business cycle frequency. However, the shifting factors of the Phillips curve associated with changes in stochastic trends can play an essential role in the business cycle and inflation dynamics, as well as the developments along the Phillips curve.[14]

In particular, it is essential to examine the structural and stochastic change in long-run trends underlying the real economy, including the labor market, to understand the business cycle under secular stagnation. Our results suggest the possibility that the stochastic trends contained in economic slack have been dominant in the dynamics of inflation and the real economy during Japan's secular stagnation. One of the major future research topics is thus clarifying the factors that cause long-term shifts in the Phillips curve due to such stochastic trends.[15]

It is also a research challenge to examine inflation dynamics and business cycles by explicitly addressing the role of inflation expectations. Stock and Watson (2007), Watson (2014), and follow-up studies point out that the anchoring of inflation expectations may have contributed to the declines in real activity and inflation volatility in various advanced countries since the 1980s. Furthermore, the decline in inflation expectations due to less aggressive monetary policy management, which is pointed out by several papers such as Bernanke (2000), Jinushi et al. (2000), Kuttner (2014), and Shibamoto et al. (forthcoming), may pose a severe problem during Japan's secular stagnation.[16] Although beyond the scope of this study, such challenges are

[14] Several papers have pointed out that large output shocks can affect long-run growth and the business cycle. For example, Cerra and Saxena (2008), using panel data for many countries, including advanced, emerging, and developing countries, empirically shows that huge output loss due to financial and political crises tends to cause a persistent decline in growth along with recessions. Further, Shibamoto and Miyao (2008) argue that shifts in both aggregate demand and supply curves lead to significant and permanent effects on output and limited effects on prices after the significant output loss due to the collapse of the asset price bubble in Japan during the early 1990s.

[15] Hoshi and Kashyap (2021), after reviewing previous studies, focus on three reasons why wage inflation has not been responsive to economic slack in Japan. The first is an explanation based on a dual labor market; given the difference in wages paid to regular and non-regular workers, the composition of regular and non-regular workers has been changing in the macroeconomy since the late 1990s. The second is due to downward wage rigidity; firms are more likely to face frictions of being less likely to lower wages when the economy is sluggish, making them reluctant to raise wages even if the economy tightens later in a year. The third is due to the supply side of the labor market; as the population ages, more older workers remain in the labor market as non-regular workers. Consequently, the traditional practice of on-the-job training for employees has dwindled and the supply of highly skilled workers who are relatively well-paid has declined.

[16] Bernanke (2000) shows that money growth was weak in the first half of the 1990s despite the considerable reduction in the broader nominal interest rates. Jinushi et al. (2000) show that the Japanese monetary policy actions during the first half of the 1990s were delayed compared with the "good" Taylor-style policy rule, which they estimated over the pre-bubble period from 1975 to 1985. Kuttner (2014) shows that these actions were not as decisive as the measures taken by the Federal Reserve during the recessions beginning in 2000 and 2007. Shibamoto et al. (forthcoming)'s counterfactual simulation results suggest that the Bank of Japan's reluctance

worthy of consideration in future research.

A Appendix

A.1 Variable definitions

- HCPI: consumer price index, all items (2020 = 100), consumption-tax-adjusted for the period from April 1997 to March 1998 and from April 2014 to March 2015, retrieved from the Ministry of Internal Affairs and Communications in Japan and calculated backward for the period before December 1989 using the monthly change in the index by adding 1.2 in March 1989 to eliminate the influence of the consumption tax from April 1989.

- CPIxF: consumer price index, all items excluding fresh foods (2020 = 100), consumption-tax-adjusted for the period from April 1997 to March 1998 and from April 2014 to March 2015, retrieved from the Ministry of Internal Affairs and Communications in Japan and calculated backward for the period before December 1989 using the monthly change in the index by adding 1.2 in March 1989 to eliminate the influence of the consumption tax from April 1989.

- CPIxFE: consumer price index, all items excluding food and energy (2020 = 100), consumption-tax-adjusted for the period from April 1997 to March 1998 and from April 2014 to March 2015, retrieved from the Ministry of Internal Affairs and Communications in Japan, calculated backward for the period before December 1989 using the monthly change in the index by adding 1.2 in March 1989 to eliminate the influence of the consumption tax from April 1989.

- Wage/h: hourly wage, cash earnings over hours worked, yen. Cash earnings, total-all industries (5 persons or more), yen, retrieved from NIKKEI NEEDS FINANCIAL QUEST. Hours worked, total-all industries (5 persons or more), hour, retrieved from NIKKEI NEEDS FINANCIAL QUEST, retrieved from NIKKEI NEEDS FINANCIAL QUEST.

- Unemployment: unemployment over labor force ratio, percent, retrieved from NIKKEI NEEDS FINANCIAL QUEST.

to cut policy interest rates in response to the post-bubble downturn significantly contributed to the long-lasting recession in the 1990s.

- Equilibrium unemployment: quarterly series of equilibrium unemployment rate constructed by the Japan Institute for Labour Policy and Training, percent, retrieved from Japan Institute for Labour Policy and Training. Interpolated (using linear interpolation under the constraint that the average of three monthly observations within a quarter must equal the quarterly series) to obtain monthly observations.

- Cyc-A: cyclical activity index described in the text.

- Gap-U: actual unemployment minus equilibrium unemployment.

- HP-U: actual unemployment minus the smoothed series by the one-sided Hodrick–Prescott filter with smoothing parameter 6400×3^4.

- Employment/population: total employed person over population ratio, percent. Total employed person, 10,000 persons, seasonally adjusted series, retrieved from NIKKEI NEEDS FINANCIAL QUEST. Population: estimated population at the beginning of the month, 10,000 persons, retrieved from NIKKEI NEEDS FINANCIAL QUEST.

- Vacancy: (Number of effective job openings minus number of job offerings) over labor force ratio, percent. Number of effective job openings, thousands persons, seasonally adjusted series, retrieved from NIKKEI NEEDS FINANCIAL QUEST. Number of job offerings, thousands persons, retrieved from NIKKEI NEEDS FINANCIAL QUEST, seasonally adjusted series obtained using the Census X-12. Labor force, 10,000 persons, seasonally adjusted series, retrieved from NIKKEI NEEDS FINANCIAL QUEST, divided by 10.

- Job opening/applicant: effective job offer ratio, multiplier, seasonally adjusted series, retrieved from NIKKEI NEEDS FINANCIAL QUEST.

- Unemployment insurance beneficiaries: actual number of employment insurance beneficiaries, thousands persons, retrieved from NIKKEI NEEDS FINANCIAL QUEST, seasonally adjusted series obtained using Census X-12, taking the logarithm.

- Overtime worked hour: index of nonscheduled hours worked, all industry (30 persons or more), seasonally adjusted series (2020 = 100), retrieved from NIKKEI NEEDS FINANCIAL QUEST, taking the logarithm.

- Industrial product: index of industrial production, mining and manufacturing, seasonally adjusted series (2015 = 100), retrieved from NIKKEI NEEDS FINANCIAL QUEST, taking the logarithm.
- Capital utilization: index of capital utilization, manufacturing, seasonally adjusted series (2015 = 100), retrieved from NIKKEI NEEDS FINANCIAL QUEST, taking the logarithm.
- Tertiary industry activity: index of tertiary industry activity, seasonally adjusted series (2015 = 100), retrieved from NIKKEI NEEDS FINANCIAL QUEST, taking the logarithm.

A.2 Additional analyses

A.2.1 Preliminary analyses on the cyclical activity measures

First, we present the contemporaneous relationships among the year-over-year change filtered activity measures over the sample period. Table A1 reports the Pearson correlation coefficients between two filtered measures. From the table, the filtered measures are highly correlated. In particular, unemployment is strongly intercorrelated with unemployment insurance beneficiaries and has a strong negative correlation with the employment/population ratio, vacancy, job opening/applicant ratio, overtime worked hours, industrial product, capital utilization, and tertiary industry activity. This result suggests there exist common components characterizing the labor market and economic activity at business cycle frequencies.

Figure A1 plots the nine year-over-year change filtered and standardized indicators of the labor market and economic activity. To simplify the comparison of time-series trends among the indicators in the figure, the employment/population, vacancy, job opening, overtime worked hours, industrial product (lagged 3 months), capacity utilization (lagged 3 months), and tertiary industry activity are multiplied by -1, so they co-vary positively with the unemployment. Additionally, the filtered indicators are standardized to have zero mean and unit variance.

As shown in the figure, most indicators are highly correlated with unemployment. In particular, the filtered unemployment and other filtered indicators show a surge during recessions.

A.2.2 Estimating short-run Phillips curve for alternative inflations

We examine the slope of the Phillips curve for different inflation measures and their stability. Table A2 reports the OLS regression results of the short-run Phillips curve (1) for alternative

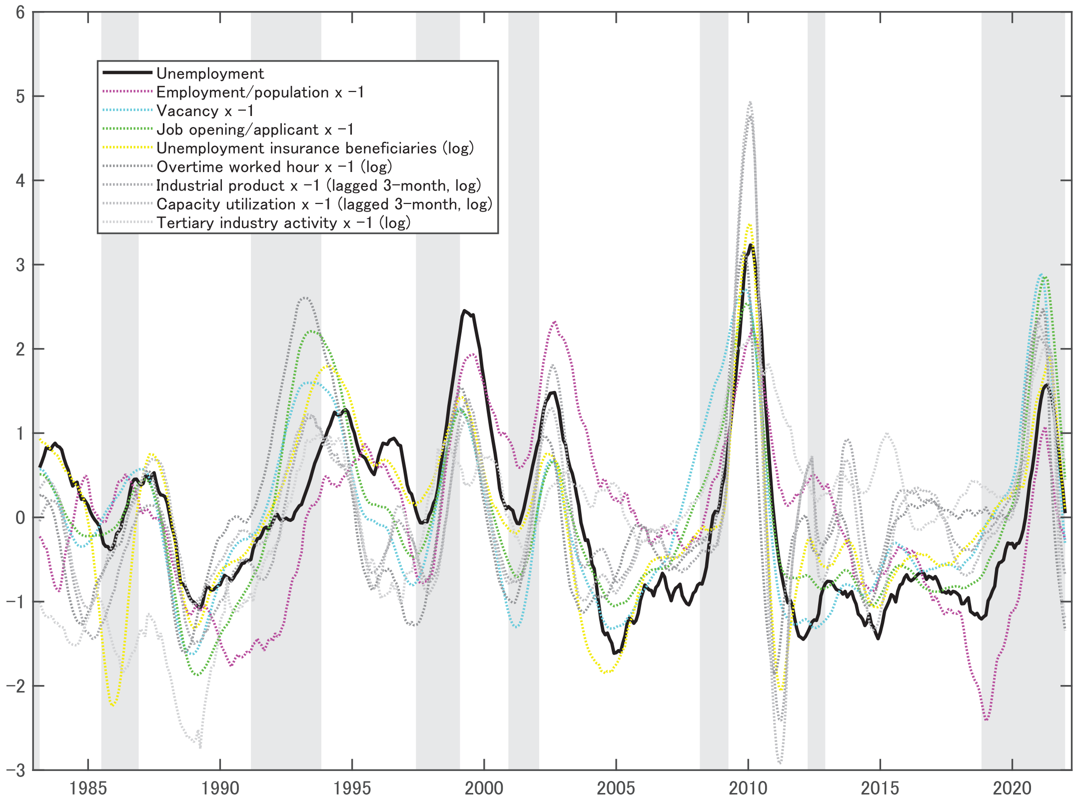

Figure A1: Year-over-year change filtered indicators of the labor market and economic activity

Notes: The sample period is from February 1983 to December 2021. The year-over-year change filtered indicators are listed in the legend. The filtered indicators are standardized to have zero mean and unit variance. The employment/population, vacancy, job opening, overtime worked hours, industrial product (lagged 3 months), capacity utilization (lagged 3 months), and tertiary industry activity are multiplied by −1, so they co-vary positively with unemployment.

Table A1: Correlations among year-over-year change filtered indicators

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
[2]	-0.67							
[3]	-0.71	0.34						
[4]	-0.78	0.50	0.93					
[5]	0.81	-0.35	-0.76	-0.82				
[6]	-0.49	0.18	0.80	0.76	-0.69			
[7]	-0.65	0.47	0.70	0.73	-0.76	0.76		
[8]	-0.65	0.38	0.73	0.72	-0.78	0.80	0.95	
[9]	-0.28	0.40	0.49	0.56	-0.37	0.47	0.57	0.38

[1] Unemployment (%, MA(12), yoy)
[2] Employment/population (%, MA(12), yoy)
[3] Vacancy (%, MA(12), yoy)
[4] Job opening/applicant (ratio, MA(12), yoy)
[5] Unemployment insurance beneficiaries (log, MA(12),yoy)
[6] Overtime worked hour (log, MA(12), yoy)
[7] Industrial product (lagged 3 months, log, MA(12), yoy)
[8] Capital utilization (lagged 3 months, log, MA(12), yoy)
[9] Tertiary industry activity (log, MA(12),yoy)

Notes: This table reports the Pearson's correlation coefficients between two indicators. The sample period is from February 1983 to December 2021.

inflations. The first three columns on the left-hand side of the table are the OLS regression results of the short-run Phillips curve (1) for the HCPI inflation, CPIxFE inflation, and Wage/h inflation, respectively, using the cyclical activity index as the regressor. The three columns on the middle and right-hand side of the table show the results for the alternative inflations using the unemployment gap and detrended unemployment, respectively, as the regressors.

We confirm the robustness of the quantitative assessment of the short-run trade-off in the benchmark model for alternative inflations. In particular, it is robust for other inflations and (1) the cyclical activity index has an economically meaningful relationship with the short-term inflation, (2) the short-run Phillips curve using the cyclical activity index is stable over time, and (3) these results are different from the results using the unemployment gap or detrended unemployment.

Note that there are slight differences in the estimates of the slope of the Phillips curve depending on the inflation measure used. In particular, the slope of the Phillips curve for CPIxFE inflation is relatively flat compared to HCPI or CPIxF inflation. By contrast, the slope of the Phillips curve for Wage/h inflation is relatively steep. This result reflects that the sensitivity of a demand-pull pressure varies by CPI items and that the sensitivity of the demand-pull pressure concerning wages is relatively high compared to prices.

Table A2: Estimation results for the short-run Phillips curve for alternative inflations

Regressand	Year-over-year change in 12-month rate of inflation (%)								
	HCPI	CPIxFE	Wage/h	HCPI	CPIxFE	Wage/h	HCPI	CPIxFE	Wage/h
Regressor	Cyc-A	Cyc-A	Cyc-A	Gap-U	Gap-U	Gap-U	HP-U	HP-U	HP-U
Full sample: 1983m2–2021m12									
Estimate of β	-1.78	-1.34	-3.27	-0.31	-0.25	-0.49	-1.18	-0.91	-1.62
	(0.34)	(0.20)	(0.58)	(0.26)	(0.16)	(0.34)	(0.33)	(0.20)	(0.51)
Adjusted R^2	0.22	0.33	0.11	0.03	0.05	0.01	0.17	0.27	0.05
sup-Wald	2.63	6.33	3.87	12.79	25.12	10.17	12.05	9.94	6.81
	[0.63]	[0.14]	[0.40]	[0.01]	[0.00]	[0.02]	[0.01]	[0.03]	[0.11]
Subsample: 1983m2–1997m4									
Estimate of β	-2.05	-1.67	-4.18	-1.71	-1.42	-1.97	-2.14	-1.61	-3.23
	(0.61)	(0.34)	(1.27)	(0.80)	(0.42)	(1.56)	(0.56)	(0.39)	(1.20)
Adjusted R^2	0.21	0.38	0.13	0.16	0.30	0.03	0.21	0.33	0.07
1997m5–2021m12									
Estimate of β	-1.71	-1.25	-2.96	-0.26	-0.22	-0.43	-1.02	-0.79	-1.38
	(0.45)	(0.26)	(0.60)	(0.27)	(0.18)	(0.33)	(0.41)	(0.23)	(0.56)
Adjusted R^2	0.24	0.32	0.10	0.03	0.05	0.01	0.17	0.26	0.04

Notes: This table shows the ordinary least squares regression results of the year-over-year change in inflation on constant term and the independent variable, that is, cyclical activity index (Cyc-A), unemployment gap (Gap-U), or HP filtered unemployment (HP-U). We obtain the cyclical activity index by scaling and signing the first principal component calculated using the nine standardized indicators to the year-over-year change filtered unemployment. The unemployment gap represent the difference between the actual unemployment rate and the equilibrium unemployment rate constructed by the Japan Institute for Labour Policy and Training. HP filtered unemployment is the difference between the actual unemployment rate and the smoothed series by the one-sided HP filter with smoothing parameter 6400×3^4. The numbers between parentheses are Newey and West (1987) heteroskedasticity and autocorrelation robust (HAR) standard errors for least squares with a 12-month lag truncation. The estimated constant term and its standard error are not reported. *sup*-Wald represents a HAR F statistic with the null hypothesis that the regression model is stable throughout the sample period and the alternative hypothesis that there is a structural break in coefficient β at an unknown point in time. The numbers between brackets are the p-values for test statistic *sup*-Wald computed using the critical values proposed by Andrews (1993) and Hansen (1996). HCPI: CPI, all items (headline CPI). CPIxFE: CPI, all items excluding food and energy. Wage/h: hourly wage.

The results for the slope of the Phillips curve using the unemployment gap are also robust. Table A3 shows the IV regression results of the short-run Phillips curve using the unemployment gap for alternative inflations. We can confirm the benchmark result is robust for alternative inflations and that the cyclical activity index works well to solve the endogenous bias problem.

Table A3: IV estimation results for the short-run Phillips curve for alternative inflations using the unemployment gap

Regressand	Year-over-year change in 12-month rate of inflation (%)					
	HCPI	CPIxFE	Wage/h	HCPI	CPIxFE	Wage/h
Regressor	Gap-U	Gap-U	Gap-U	Gap-U	Gap-U	Gap-U
Sample	1983m2–2021m12			1997m5–2021m12		
Estimate of β	-2.20	-1.66	-4.04	-1.87	-1.37	-3.24
	(0.80)	(0.65)	(1.80)	(0.77)	(0.59)	(1.56)
Hausman	6.30	4.96	4.04	4.97	4.24	3.40
	[0.01]	[0.03]	[0.04]	[0.03]	[0.04]	[0.07]

Notes: This table shows the IV regression results of the year-over-year change in CPIxF inflation on constant term and the unemployment gap (Gap-U). We use the cyclical activity index as an instrument for the unemployment gap in the IV regression. The unemployment gap represents the difference between the actual unemployment rate and the equilibrium unemployment rate constructed by the Japan Institute for Labour Policy and Training. We obtain the cyclical activity index by scaling and signing the first principal component calculated using the nine standardized indicators to the year-over-year change filtered unemployment. The numbers between parentheses are Newey and West (1987) heteroskedasticity and autocorrelation robust (HAR) standard errors for least squares with a 12-month lag truncation. The estimated constant term and its standard error are not reported. Hausman indicates the HAR statistic on the Hausman (1978) test under the null hypothesis that the OLS and IV estimators of β are consistent, but the OLS estimate is efficient. The numbers between brackets are p-values for the Hausman test. HCPI: CPI, all items (headline CPI). CPIxFE: CPI, all items excluding food and energy. Wage/h: hourly wage.

References

Andrews, Donald W. K. 1993. "Tests for Parameter Instability and Structural Change with Unknown Change Point." *Econometrica* 61 (4): 821–856.

Atkeson, Andrew, and Lee E. Ohanian. 2001. "Are Phillips Curves Useful for Forecasting Inflation?" *Quarterly Review* 2–11.

Ball, Laurence, and Sandeep Mazumder. 2011. "Inflation Dynamics and the Great Recession." *Brookings Papers on Economic Activity* spring 337–405, No.17044.

Bernanke, Ben S. 2000. "Japanese Monetary Policy: A Case of Self-Induced Paralysis." In *Japan's Financial Crisis and Its Parallels to U.S. Experience*, edited by Mikitani, Ryoichi, and Adam S. Posen 149–166.

Blanchard, Olivier, Eugenio Cerutti, and Lawrence Summers. 2015. "Inflation and Activity Two Explorations and their Monetary Policy Implications." *IMF Working Papers* 15 (230): .

Cerra, Valerie, and Sweta Chaman Saxena. 2008. "Growth Dynamics: The Myth of Economic Recovery." *American Economic Review* 98 (1): 439–457.

De Veirman, Emmanuel. 2009. "What Makes the Output-Inflation Trade-Off Change? The Absence of Accelerating Deflation in Japan." *Journal of Money, Credit and Banking,* 41 (6): 1117–1140.

Del Negro, Marco, Michele Lenza, Giorgio E. Primiceri, and Andrea Tambalotti. 2020. "What's Up with the Phillips Curve?" *Brookings Papers on Economic Activity* spring (1): 301–357, No.27003.

Fisher, Irving. 1926. "A Statistical Relation between Unemployment and Price Changes." *International Labour Review* 13 (6): 785–792.

Friedman, Milton. 1968. "The Role of Monetary Policy." *American Economic Review* 58 (1): 1–17.

Fuhrer, Jeffrey C., Giovanni P. Olivei, and Geoffrey M. B. Tootell. 2012. "Inflation

Dynamics When Inflation Is Near Zero." *Journal of Money, Credit and Banking* 44 (1): 83–122.

Gordon, Robert J. 1997. "The Time-Varying NAIRU and its Implications for Economic Policy." *Journal of Economic Perspectives* 11 11–32.

Gordon, Robert J. 2013. "The Phillips Curve is Alive and Well: Inflation and the NAIRU During the Slow Recovery." *NBER Working Paper*, No.19390.

Hansen, Bruce E. 1996. "Inference When a Nuisance Parameter is not Identified under the Null Hypothesis." *Econometrica* 64 (2): 413–430.

Hausman, Jerry A. 1978. "Specification Tests in Econometrics." *Econometrica* 46 (6): 1251–1271.

Hazell, Jonathon, Juan Herreño, Emi Nakamura, and Jón Steinsson. forthcoming. "The Slope of the Phillips Curve: Evidence from U.S. States." *Quarterly Journal of Economics.*

Hooper, Peter, Frederic S. Mishkin, and Amir Suf. 2020. "Prospects for Inflation in a High Pressure Economy: Is the Phillips Curve Dead or Is It Just Hibernating?" *Research in Economics* 74 26–62.

Hoshi, Takeo, and Anil K. Kashyap. 2021. "The Great Disconnect: The Decoupling of Wage and Price Inflation in Japan." In *The Political Economy of the Abe Government and Abenomics Reforms*, edited by Hoshi, Takeo, and Phillip Y. Lipscy 170–199, Cambridge University Press.

Jinushi, Toshiki, Yoshihiro Kuroki, and Ryuzo Miyao. 2000. "Monetary Policy in Japan Since the Late 1980s: Delayed Policy Actions and Some Explanations." In *Japan's Financial Crisis and Its Parallels to U.S. Experience*, edited by Mikitani, Ryoichi, and Adam Posen, Washington D.C.: Peterson Institute for International Economics.

Kuttner, Kenneth N. 2014. "Monetary Policy During Japan's Great Recession: From Self-Induced Paralysis to Rooseveltian Resolve." In *Lessons from Decades Lost: Economic Challenges and Opportunities Facing Japan and the United States*, edited by Hanyu, Jiro, and Adam S. Posen 66–80.

Mankiw, N. Gregory. 2019. *Macroeconomics.* Worth Publishers.

Miyamoto, Hiroaki. 2011. "Cyclical Behavior of Unemployment and Job Vacancies in Japan." *Japan and the World Economy* 23 214–225.

Newey, Whitney K., and Kenneth D. West. 1987. "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55 (3): 703–708.

Nishizaki, Kenji, and Tsutomu Watanabe. 2000. "Output-Inflation Trade-Off at Near-Zero Inflation Rates." *Journal of the Japanese and International Economies* 14 (4): 304–326.

Okimoto, Tatsuyoshi. 2019. "Trend Inflation and Monetary Policy Regimes in Japan." *Journal of International Money and Finance* 92 137–152.

Phelps, Edmund S. 1968. "Money-Wage Dynamics and Labor-Market Equilibrium." *Journal of Political Economy* 76 (4): 678–711.

Phillips, A. W. 1958. "The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957." *Economica* 25 (100): 283–299.

Powell, Jerome H. 2018. "Monetary Policy and Risk Management at a Time of Low Inflation and Low Unemployment." October, Speech at the "Revolution or Evolution? Reexamining Economic Paradigms" 60th Annual Meeting of the National Association for Business Economics.

Ravn, Morten O., and Harald Uhlig. 2002. "On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations." *Review of Economics and Statistics* 84 (2): 371–376.

Shibamoto, Masahiko, and Ryuzo Miyao. 2008. "Understanding Output and Price Dynamics in Japan: Why Have Japan's Price Movements Been Relatively Stable Since the 1990s?", Research Institute for Economics & Business Administration Discussion Paper Series No. 219.

Shibamoto, Masahiko, Wataru Takahashi, and Takashi Kamihigashi. forthcoming. "Japan's Monetary Policy: A Literature Review and Empirical Assessment." *Journal of Computational Social Science.*

Shimer, Robert. 2005. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies." *American Economic Review* 95 (1): 25–49.

Simon, John, Troy Matheson, and Damiano Sandri. 2013. "The Dog That Didn't Bark: Has Inflation Been Muzzled or Was It Just Sleeping?" World Economic Outlook: Hopes, Realities, Risks, Washington: International Monetary Fund.

Staiger, Douglas, James H. Stock, and Mark W. Watson. 2001. "Prices, Wages and the U.S. NAIRU in the 1990s." In *The Roaring 90s: Can Full Employment Be Sustained*, edited by Krueger, Alan B., and Robert Solow, New York: Russell Sage and Century Fund.

Stock, James H., and Mark W. Watson. 1999. "Forecasting Inflation." *Journal of Monetary Economics* 44 (2): 293–335.

Stock, James H., and Mark W. Watson. 2007. "Why Has Inflation Become Harder to Forecast?" *Journal of Money, Credit and Banking* 39 (1): 3–34.

Stock, James H., and Mark W. Watson. 2009. "Phillips Curve Inflation Forecasts." In *Understanding Inflation and the Implementations for Monetary Policy: A Phillips Curve Retrospective*, edited by Fuhrer, Jeff, Yolanda K. Kodrzycki, Jane Sneddon Little, and Giovanni P. Olivei, Federal Reserve Bank of Boston.

Stock, James H., and Mark W. Watson. 2020. "Slack and Cyclically Sensitive Inflation." *Journal of Money, Credit and Banking* 52 393–428.

Stock, James H., Jonathan H. Wright, and Motohiro Yogo. 2002. "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments." *Journal of Business and Economic Statistics* 20 (4): 518–529.

Stock, James H., and Motohiro Yogo. 2005. "Testing for Weak Instruments in Linear IV Regression." In *Identification and Inference in Econometric Models: Essays in Honor of Thomas J. Rothenberg*, edited by Andrews, Donald W.K., and James H. Stock 80–108, Cambridge: Cambridge University Press.

Watson, Mark W. 2014. "Inflation Persistence, the NAIRU, and the Great Recession." *American Economic Review* 104 (5): 31–36.