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# An Empirical Analysis of the Phillips Curve – A Time Series Exploration of Hong Kong

***WANG Dong***

**Abstract**
This paper examines the stationarity and cointegration of inflation and unemployment variables of Hong Kong in a period prior to and after the return of Hong Kong's sovereignty to China on July 1, 1997. The paper separately introduces two ARDL and error correlation models for the long-run and short-run dynamic relationships between inflation and unemployment variables for these two periods after an identification of cointegration. The key findings of this paper include the negative relationship observed between inflation and unemployment in Hong Kong during this time period. Moreover, prior inflation has a significantly negative effect on the current inflation level after 1997. This result might be explained by the change of potential endogenous variables such as the macro environment shocks in the coming years after 1997.

**Key Words:** Inflation, Unemployment, Phillips Curve, Hong Kong, Time Series, Nonstationary, Cointegration, Error Correction Model

## 1. Introduction

Phillips curve provides an empirical relationship between inflation and unemployment, which are two major factors policy makers need to be concerned with when they decide relevant domestic policies for the purpose of internal balance. This empirical relationship between inflation and unemployment may be different depending on the geographical locations, time periods, global economics, or even some major events. In other words, it is necessary to independently study the Phillips curve with a new econometric approach when using a local data set for Hong Kong.

The purpose of this paper is to explore the relationship between inflation and unemployment for Hong Kong from 1982 to 2014. During the period, one of the most significant events was the return of Hong Kong's sovereignty to China on July 1, 1997. Before July 1, 1997, Hong Kong was a colony governed by Great Britain. After 1997, Hong Kong has returned to the People's Republic of China and changed the name to Hong Kong Special Administrative Region (HKSAR). After Hong Kong became a part of China, it still maintained most of the original political, legislative, and economic systems during the British Hong Kong Government period from the protection of the Basic Law.

This event gave us an interest to separately study the Phillips curve of Hong Kong prior and after 1997. This study also rose the following questions. First, can we observe a long-run and a short-run dynamic negative relationship in Hong Kong? Second, should we use two regression models to describe the Phillips curve of Hong Kong prior and after 1997? Doing so would imply that the return of Hong Kong's sovereignty to China significantly changed the original relationship of inflation and unemployment for Hong Kong. In order to solve these questions, an empirical study on the Phillips curve of Hong Kong, including a data description, introduction of the stationary, the cointegration and the error correlation model in the methodology, was conducted. This is followed by an estimation of the results and the conclusion.

## 2. Literature Review

Most recent empirical studies on the Phillips curve have focused on new-Keynesian economics, market imperfections, and the formation of expectations. For instance, one work emphasizes the micro-foundations of sticky price models as an important part of New Keynesian economics and therefore presents new estimates of dealing with expectations about future prices (Roberts, 1995), whereas another panel found that the new-Keynesian pricing model cannot explain the importance of lagged inflation in standard inflation regressions and forward-looking terms play a very limited role in explaining inflation dynamics (Rudd & Whelan, 2005). Besides, one scholar detected Phillips curves for Japan and the United States with the concept of cointegration (Reichel, 2004).

Regarding the empirical research about the Phillips curve of Hong Kong, unfortunately, there are not sufficient studies for analyzing and identifying the potential relationship between inflation and unemployment for Hong Kong. One panel used the data set from Hong Kong found the variables were consistent with the theoretical predictions and finally rejected the new hybrid Keynesian Phillips curve model where only labor costs matter (Genberg & Pauwels, 2005 ). The literature review indicates a furthermore empirical analysis of the Phillips curve of Hong Kong is necessary due to the limited understanding in this field. This analysis is also valuable by providing significant signals for Hong Kong policy deciders to concern and to evaluate the effects of relative policies.

# 3. Data

## 3.1. Data description

This paper uses annual data on unemployment rate and inflation rate from the source of Census and Statistics Department Hong Kong [6]. Table 1 exhibits the annual CPI (**inf**) and unemployment rate (**u**) with three original variables (**inf**, **u**, and **date**) including a time variable (**date**). The time series covers from 1982 to 2014 and comprises 33 observations per variable.

**Table 1.1**

Descriptive statistics of original variables from 1982 to 2014

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| inf | 33 | 4.5 | 4.560085 | -4 | 11.6 |
| u | 33 | 3.733333 | 1.75618 | 1.1 | 7.9 |

*Source: Census and Statistics Department Hong Kong*

We then use the logarithm to regenerate the original variables as elasticity to facilitate the interpretation of the results. Owing to some negative values in the time series data and that variables **inf** and **u** represent the percentage numbers, we therefore divide the original data by 100, and add unity to it before taking logarithm, as shown in equations (3.01) and (3.02). The descriptive statistics will be showed in Table 1.2.

$$linf = ln(1 + \frac{inf}{100}) \tag{3.01}$$

$$lu = ln(1 + \frac{u}{100}) \tag{3.02}$$

Note that these econometric transforming method (3.01) and (3.02) was issued by Patrick Nüß in *An Empirical Analysis of the Phillips Curve - A Time Series Exploration of Germany* (Nüß, 2013).

**Table 1.2**

Descriptive statistics of transformed variables from 1982 to 2014

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| linf | 33 | .0430848 | .0439531 | -.040822 | .1097509 |
| lu | 33 | .0365152 | .0168558 | .0109399 | .0760347 |

CPI measures the level of prices in Hong Kong instead of the inflation. Nevertheless, inflation estimates can be derived by calculating the change in the level of the CPI from one period to another and the yearly growth rates represent the inflation rate of Hong Kong. Therefore, we will use the first difference of the transformed variable **lu** as an explanatory variable and the transformed variable **linf** as a dependent variable in our further discussion.

## 3.2. Sampling method

By definition, unemployment rate refers to the proportion of unemployed persons in the labor force without seasonal adjustment. In this data set, the labor force refers to the land-based non-institutional population aged 15 and over who satisfy the criteria for being classified as employed population or unemployed population, and for a person aged 15 or over to be classified as unemployed, that person should:

[6] http://www.censtatd.gov.hk/home/index.jsp

1. not have had a job and should not have performed any work for pay or profit during the 7 days before enumeration; and
2. have been available for work during the 7 days before enumeration; and
3. have sought work during the 30 days before enumeration (Census and Statistics Department Hong Kong, 2015).

Consumer Price Index (CPI), on the other hand, are a measure of prices paid by consumers for a market basket of Hong Kong consumer goods and services. In this data set, CPI measures the changes over time in the price level of consumer goods and services generally purchased by households. The year-on-year rate of change in the CPI is widely used as an indicator of the inflation affecting consumers (Census and Statistics Department Hong Kong, 2015).

## 4. Methodology

### 4.1. Econometric Approach

In time series analysis, there are six assumptions of the distributed lag model. If some assumptions are violated, the least squares estimators will not be the best linear unbiased estimators (BLUE). One of the assumptions indicates the dependent variable and explanatory variables should be stationary random variables. Many economic variables are nonstationary, including inflation rate and unemployment rate of Hong Kong. It is possible to estimate a regression and discover a statistically significant relationship between two nonstationary variables even if none exists. Such invalid regressions are said to be spurious.

One of the first diagnostic tools for revealing the potential spurious regression problem is a simple time series plot of the data. A time series plot will intuitively disclose the pattern of the data whether it is inclined to be stationary or nonstationary. Another appropriate tool is to separate the data set into two time periods and then compare the two sample means of time series. The logic of the two approaches is that if the time series $y_t$ is stationary, it will be stationary for all values and for every time period. It will also be true that

$$E(y_t) = \mu \tag{4.01}$$
$$var(y_t) = \sigma^2 \tag{4.02}$$
$$cov(y_t, y_{t+s}) = cov(y_t, y_{t-s}) = \gamma_s \tag{4.03}$$

Besides the simple time series plot, there are many unit root tests for determining whether a series is stationary or nonstationary. One test is called the Phillips-Perron (1988) test. Phillips-Perron test has a null hypothesis that the time-series is nonstationary against the alternative hypothesis that it is stationary. This test applies heteroskedasticity and autocorrelation consistent (HAC) standard errors to testify the serial correlation. The advantage of this test is that analysts do not need to select an appropriate model to help decide how to implement the regression.

Besides the Phillips-Perron test, one more test is sometimes recommended. Another popular test is the Dickey-Fuller test. There are three basic taxonomy of the Dickey-Fuller regressions, particularly for “no constant and no trend series” (4.04), “constant, but no trend series” (4.05), and “constant and trend series” (4.06).

$$\Delta y_t = \gamma y_{t-1} + v_t \tag{4.04}$$
$$\Delta y_t = \alpha + \gamma y_{t-1} + v_t \tag{4.05}$$
$$\Delta y_t = \alpha + \gamma y_{t-1} + \lambda t + v_t \tag{4.06}$$

An important extension of the Dickey-Fuller test allows the error term to be autocorrelated. The extended test equation will be

$$\Delta y_t = \alpha + \gamma y_{t-1} + \sum_{s=1}^{m} a_s \Delta y_{t-s} + v_t \tag{4.07}$$

The unit root tests based on (4.07) are referred to as augmented Dickey-Fuller (ADF) tests (Hill, Griffiths, & Lim, 2012). With proper number of lagged first difference terms, the residuals will not be autocorrelated and corresponded to a white noise process $v_t \sim (0, \sigma^2)$ (Gujarati & Porter, 2009).

If the first difference of the dependent variable and explanatory variable are stationary, these variables are claimed to be integrated of order one, and denoted as I(1). Simultaneously, first difference of the two variables are said to be integrated of order zero, I(0). For two nonstationary I(1) variables $\mathrm{y}_t$ and $\mathrm{x}_t$, if their difference $\mathrm{e}_t = y_t - \beta_1 - \beta_2 x_t$ to be I(1) as well, $\mathrm{y}_t$ and $\mathrm{x}_t$ should follow similar stochastic trends and never diverge too far from each other. In this case, $\mathrm{y}_t$ and $\mathrm{x}_t$ are said to be cointegrated (Hill, Griffiths, & Lim, 2012). The cointegration test principle is using the (augmented) Dickey-Fuller test to testify the residuals from the least squares estimation. If the series are cointegrated, the Dickey-Fuller test statistic will be statistically significant and therefore reject the null hypothesis that the residuals are nonstationary (Adkins & Hill, 2011). This cointegration test procedure is called the Engle-Granger test (Engle & Granger, 1987).

Once we identified a nonstationary pattern of the time series data, we should typically not use these variables in regression models in order to avoid the problem of spurious regression. Nevertheless, if $\mathrm{y}_t$ and $\mathrm{x}_t$ are cointegrated and individually integrated of order one, we can estimate a long-run equation with least squares without the spurious regressions. Simultaneously, we can construct a short-run error correction model to catch the short-run dynamic.

For the long-run equation with least squares, an autoregressive distributed lag (ARDL) model is a proper approach that contains both the lagged explanatory variable *x* and the dependent variable *y*. In the general form, with *p* lags of *y* and *q* lags of *x*, an $\mathrm{ARDL}(p, q)$ model can be described as

$$\Delta y_t = \delta + \theta_1 \mathrm{y}_{t-1} + \cdots + \theta_p y_{t-p} + \delta_0 x_t + \delta_1 x_{t-1} + \cdots + \delta_q x_{t-q} + v_t \tag{4.08}$$

To determine the optimal number of lags of the ARDL model, the information criteria AIC and SC would be used.

For the short-run error correction model, we can embed an equation (4.09) between *y* and *x* in a general $\mathrm{ARDL}(1,1)$ framework and an equation (4.10) in a general $\mathrm{ARDL}(1,3)$ framework, which are proven in Appendix A

$$\Delta y_t = -\alpha(y_{t-1} - \beta_1 - \beta_2 x_{t-1}) + \delta_0 \Delta x_t + v_t \tag{4.09}$$

$$\Delta y_t = -\alpha\left(y_{t-1} - \beta_1 - \beta'_2 x_{t-3}\right) + \delta_0 \Delta x_t + (\delta_0 + \delta_1)\Delta x_{t-1} + (\delta_0 + \delta_1 + \delta_2)\Delta x_{t-2} + v_t \tag{4.10}$$

where $\alpha = (1 - \theta_1)$, $\beta_1 = \frac{\delta}{1-\theta_1}$, $\beta_2 = \frac{\delta_0+\delta_1}{1-\theta_1}$, $\beta'_2 = \frac{\delta_0+\delta_1+\delta_2+\delta_3}{1-\theta_1}$.

Advantages of this error correction model include that all the time series are stationary and therefore allow us to analyze with a simple OLS estimation (Harris & Sollis, 2003); simultaneously, we can analyze the dynamics of the cointegrated variables both in short-run and long-run. Moreover, the error correction model allows us to use the Phillips curve to analyze the dynamic effects of the inflation rate and unemployment rate in Hong Kong. The prerequisite for the time series data set for Hong Kong is cointegrated. Consequently, we will apply the methodologies exhibited above for the Hong Kong Phillips curve case in the following.

### 4.2. Limitations of the Approach

In the empirical study of Hong Kong Phillips Curve, we ignore the discussion of non-cointegration if it appeared in our data set. We also do not cover the problems of the spurious regression. Moreover, we do not consider the possibility of the potential heteroscedasticity in our regressions. All these limitations in our methodology may decrease the completeness of our empirical paper. Nevertheless, these drawbacks should not invalidate our time series study of Hong Kong Phillips Curve. In other words, by following the methodology of this empirical paper, we should be able to get BLUE if the data set is cointegrated.

## 5. Estimation Results

This section presents the results, focusing on four key issues:

1. Diagnose the stochastic trends in the data set;
2. Identify the cointegration of the inflation rate and unemployment rate;
3. Construct separated ARDL models for long-run equations between 1982 to 1997 and 1998 to 2014 periods if a cointegration has identified;
4. Embed error correction models for short-run equations between 1982 to 1997 and 1998 to 2014 periods if a cointegration has identified.

### Diagnose the Stochastic Trends in the Data set

Figure 1 presents the time series plots of the data set. The chart at the top left shows a downward trend of the sample means of the dependent variable in the time order. The chart at the top right describes the sample means of the first difference of the explanatory variable in the time order. The bottom left of Figure 1 exhibits the first difference of the dependent variable, and the bottom right of Figure 1 indicates the secondary difference of the explanatory variable. Except the top left chart, other time series plots imply the series appear to be wandering around their sample average which may be constant values.

**Figure 1**
Time series plots

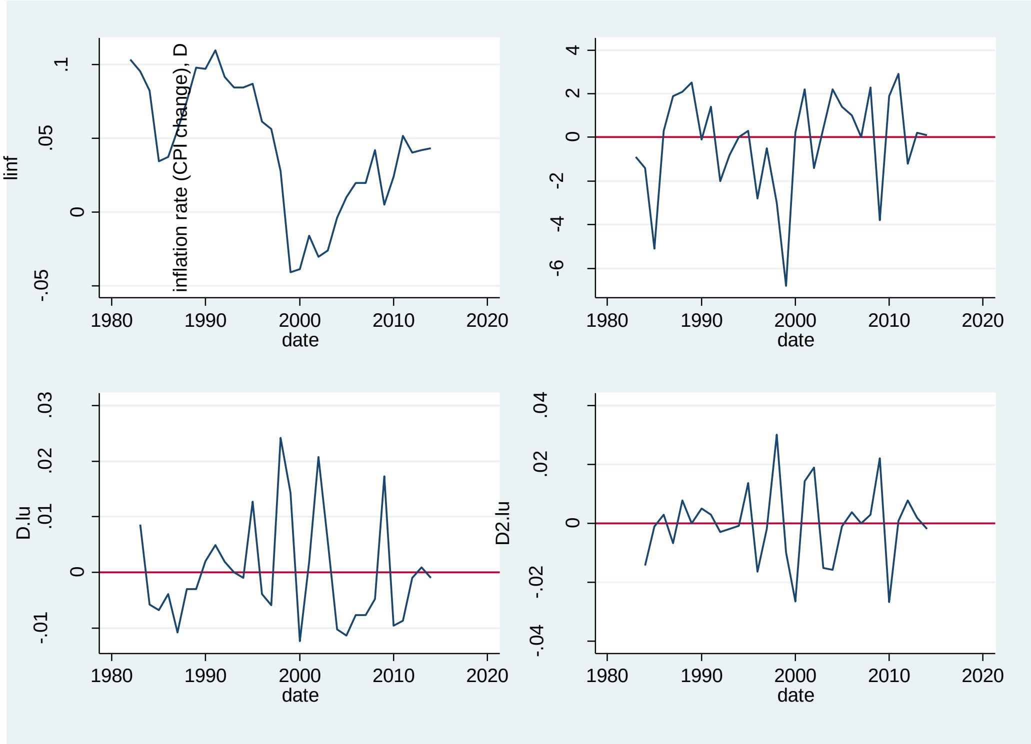


**Table 2.1**
Sample means of time series (1982-1997)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| linf | 16 | .0783338 | .0229781 | .0344014 | .1097509 |
| lu D1. | 15 | -.000907 | .0061683 | -.010758 | .0126769 |
| linf D1. | 15 | -.0031386 | .0186949 | -.0480998 | .0229263 |
| lu D2. | 14 | -.001036 | .0079485 | -.0165604 | .0136578 |

**Table 2.2**
Sample means of time series (1998-2014)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| linf | 18 | .012491 | .0319462 | -.040822 | .0563803 |
| lu D1. | 18 | .0002696 | .0115648 | -.0123166 | .0241674 |
| linf D1. | 18 | -.001002 | .0244771 | -.0684372 | .0279267 |
| lu D2. | 18 | .000162 | .0154123 | -.0267839 | .0300211 |

Table 2.1 and Table 2.2 show the sample means of time-series variables in 1982 to 1997 and 1998 to 2014 two periods. The difference between the dependent variables is 0.6584, and this gap will reduce to $-2.1366 \times 10^{-3}$ when we take the first difference. Relatively, the difference between the explanatory variables in the two periods is $9.5 \times 10^{-5}$, and this gap will increase to $1.198 \times 10^{-3}$. These results implicate that the dependent variable may be nonstationary, and tend to be stationary in the first order difference. Moreover, the explanatory variables probably will not have stochastic trends based on our observation. Therefore, we priori estimate the dependent and explanatory variables are not stationary, and they are stationary in the first order difference. Looking at the sample means of time-series variables is a convenient indicator as to whether a series is stationary or nonstationary. Nonetheless, further hypothesis tests are required.

The first hypothesis test for a unit root is the Phillips-Perron test. The testing result shows in Appendix B. Table B.1 in Appendix B shows the Phillips-Perron testing result of the dependent variable. The p-value (0.7040) of Table B.1 supports our prior estimation that the dependent variable is nonstationary at 10% significance level. In Table B.2, B.3, and B.4, the p-values are significantly lower than 0.01, which indicate that dependent and explanatory variables are stationary in the first order difference at 1% significance level.

Besides the Phillips-Perron test, we also perform the ADF test and the result exhibits in Appendix C. Not surprisingly, the p-value (0.6914) of the dependent variable in the Table C.1 supports our previous estimation that the dependent variable is nonstationary at 10% significance level. Moreover, Table C.2, C.3, and C.4 also show that dependent and explanatory variables are stationary in the first order difference at 1% significance level. Therefore, we can claim that both dependent and explanatory variables are integrated in the first order I(1).

**Identify the Cointegration of the Inflation Rate and Unemployment Rate**

Engle-Granger test shows whether two variables are cointegrated or not. The testing result of the dependent and expanatory vairables are in Table 3.

**Table 3**
The Engle-Granger test

```
      Source |       SS       df       MS              Number of obs =      30
-------------+------------------------------           F(  2,    28) =    2.15
       Model |  .001962402     2  .000981201           Prob > F      =  0.1354
    Residual |  .012779992    28  .000456428           R-squared     =  0.1331
-------------+------------------------------           Adj R-squared =  0.0712
       Total |  .014742394    30  .000491413           Root MSE      =  .02136

------------------------------------------------------------------------------
     D.ehat1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ehat1 |
         L1. |  -.1743541   .0936756    -1.86   0.073    -.3662399    .0175317
         LD. |   .2270078   .1777476     1.28   0.212    -.1370916    .5911072
------------------------------------------------------------------------------
```

The Engle-Granger test indicates that the p-value (0.073) of $\hat{e}$ is lower than 0.1, thus the residuals of the dependent and explanatory variables are stationary at 10% significance level. In other words, the dependent and explanatory variables are cointegrated at 10% significance level. Therefore, we can constitute long-run equations without the spurious regressions.

**Construct Two ARDL Models for the Periods of 1982 to 1997 and 1998 to 2014**
For detection of the optimal lag length, the AIC and the SC were applied.

**Table 4.1**
AIC and SC values for Phillips curve ARDL models from 1982 to 1997

| $(p,q)$ | AIC | SC | $(p,q)$ | AIC | SC | $(p,q)$ | AIC | SC | $(p,q)$ | AIC | SC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1,0) | -8.03 | -7.89 | (1,1) | -7.81 | -7.63 | (1,2) | -8.07 | -7.85 | (1,3) | -8.91 | -8.67 |
| (2,0) | -8.19 | -8.00 | (2,1) | -8.05 | -7.82 | (2,2) | -8.01 | -7.75 | (2,3) | -8.75 | -8.47 |
| (3,0) | -8.15 | -7.93 | (3,1) | -8.01 | -7.75 | (3,2) | -7.97 | -7.66 | (3,3) | -8.59 | -8.27 |

From Table 4.1, we notice that when $p = 1,\ q = 3$, both criteria are at a minimum. Therefore, we conclude that $\mathrm{ARDL}(1,3)$ has the optimal lag length for estimating the Phillips curve of Hong Kong from 1982 to 1997.

**Table 4.2**
AIC and SC values for Phillips curve ARDL models from 1998 to 2014

| $(p,q)$ | AIC | SC | $(p,q)$ | AIC | SC | $(p,q)$ | AIC | SC | $(p,q)$ | AIC | SC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1,0) | -7.96 | -7.82 | (1,1) | -8.22 | -8.03 | (1,2) | -8.11 | -7.86 | (1,3) | -8.07 | -7.78 |
| (2,0) | -8.06 | -7.86 | (2,1) | -8.11 | -7.86 | (2,2) | -7.99 | -7.70 | (2,3) | -7.96 | -7.62 |
| (3,0) | -7.97 | -7.72 | (3,1) | -7.99 | -7.70 | (3,2) | -7.89 | -7.55 | (3,3) | -7.85 | -7.46 |

From Table 4.2, we discover that when $p = 1,\ q = 1$, both criteria are at a minimum. Therefore, we conclude that $\mathrm{ARDL}(1,1)$ has the optimal lag length for estimating the Phillips curve of Hong Kong from 1998 to 2014.

The regression results will be showed in Table D of Appendix D. We can therefore constitute the long-run equations (5.01) for Hong Kong from 1982 to 1997 and equation (5.02) for 1998 to 2014 time period.

$$linf_t = 0.00394 + 0.9021linf_{t-1} - 1.0511\Delta lu_t - 0.9866\Delta lu_{t-1} + 0.2263\Delta lu_{t-2} - 0.3619\Delta lu_{t-3} \quad (5.01)$$
$$linf_t = 0.00359 - 0.8613linf_{t-1} - 1.04847\Delta lu_t - 0.7417\Delta lu_{t-1} \quad (5.02)$$

Notice that all the coefficients except the second and third lags of the equation (5.01) are significant at 5% significance level. The second lag of the equation (5.01) has a positive coefficient. However, since the coefficient is not significant, it may not violate the principle of economics. One important finding is that the coefficient of the first lag of the dependent variable in the equation (5.02) is significantly lower than zero at 0.1% significance level. This result indicates that higher inflation rate last year would tend to reduce the inflation rate of this year from 1998 to 2014.

**Embed Error Correction Models for Short-run Equations**

Cointegration is a relationship between two nonstationary, I(1), variables. The variables share a common trend and tend to move together in the long-run. After we finished series tests, we concluded that both dependent and explanatory variables in our model are I(1) variables and cointegrated. Therefore, we can embed a cointegrating relationship as the short-run error correction model in our ARDL models. The general form of the short-run error correction model for 1982 to 1997 time period will be the equation (4.10), and the general form of the model for 1998 to 2014 time period will be the equation (4.09).

In Appendix E, Table E.1 shows the parameters of the error correction model from 1982 to 1997 time period. The short-run equation of the error correction model will be

$$\Delta y_t = 0.0001619(y_{t-1} - 6.1161 - 17439.39x_{t-3}) + 0.1160\Delta x_t - 1.5213\Delta x_{t-1} - 2.5456\Delta x_{t-2} + v_t \quad (5.03)$$

Table E.2 indicates the ADF test of the residuals for stationarity from 1982 to 1997 time period. The p-value (0.190) of $\hat{e}$ notices that we cannot reject the null hypothesis that the dependent and explanatory variables are cointegrated at 10% significance level from 1982 to 1997. This result indicates that our long-run equation for the Hong Kong Phillips curve from 1982 to 1997 time period may have the spurious regression.

Simultaneously, Table E.3 identifies the parameters of the error correction model from 1998 to 2014 time period. The short-run equation of the error correction model will be

$$\Delta y_t = 0.2818(y_{t-1} - 0.01169 - 7.3141x_{t-3}) - 1.2462\Delta x_t + v_t \quad (5.04)$$

Table E.4 exhibits the ADF test of the residuals for stationarity from 1982 to 1997 time period. The p-value (0.001) of $\hat{e}$ means that we reject the null hypothesis and conclude that the dependent and explanatory variables are cointegrated at 1% significance level from 1998 to 2014.

## 6. Conclusion

The main objective of this study is to investigate the existence and pattern of the Phillips curve for Hong Kong. Under the Phillips-Perron test and the ADF test, inflation and unemployment were considered as integrated in the first order I(1). The paper subsequently evaluated the cointegration of the Phillips curve. Ultimately, this paper constructed the long-run ARDL models and error correction models for Hong Kong prior and after 1997. One important result from this empirical paper is that there is a significant negative relationship between inflation and unemployment can be observed in the long-run prior and after 1997. We also notice that higher inflation rate last year will tend to reduce the current inflation rate after the return of Hong Kong's sovereignty to China on July 1, 1997. Hong Kong has been affected by a variety of significant changes in macroeconomic circumstances after 1997, including the Asian financial crisis in 1998, the outbreak of SARS in 2002, and the subprime mortgage crisis of the United States in 2008. All the macroeconomic changes may retard the development of the Hong Kong economy and the growth rate of the consumer price index. Therefore, for the Hong Kong policy makers, the major concern may not be controlling the inflation rate.

Furthermore, for the period prior 1997, there is not a significant error correction model and therefore there may be spurious regression. The failure of the Phillips curve prior 1997 in Hong Kong may require further research on the historical political and economic background of the Asian Pacific area. In spite of this limitation, this study provides a valid short-run error correction model for Hong Kong after 1997. In this case, the unemployment rate three years before may significantly reduce the current inflation change rate after 1997. In addition, the current unemployment change rate will also retard the inflation change rate. For Hong Kong officials, they may need to be concerned with the policies which will influence the labor market when they constitute relevant policies. In this respect, Hong Kong policy makers should stimulate the economic growth by creating more job positions for Hong Kong citizens and try to increase the commercial communications with other markets such as Mainland China. Moreover, they should take into account the historical policies and economic data up to three years backward.

Finally, we do observe the movement of the relationship of inflation and unemployment after the return of Hong Kong's sovereignty to China. By only focusing on the regression models of two periods, it seems the economic situation of Hong Kong has improved due to the negative impact of last year’s inflation level on this year’s inflation growth and the smaller influence on current inflation caused by the unemployment level.

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## Appendix A: Proof of the Error Correction Model

### The Error Correction Model for the ARDL(1, 1) Model

The $\text{ARDL}(1,1)$ can be written as

$$y_t - \mathrm{y}_{t-1} = \delta + \theta_1 \mathrm{y}_{t-1} + \delta_0 x_t + \delta_1 x_{t-1} + v_t \tag{A.01}$$

First of all, we add the term, $-\mathrm{y}_{t-1}$, to both sides of the equation

$$y_t - \mathrm{y}_{t-1} = \delta + (\theta_1 - 1)\mathrm{y}_{t-1} + \delta_0 x_t + \delta_1 x_{t-1} + v_t \tag{A.02}$$

Second, add the term, $-\delta_0 x_{t-1} + \delta_0 x_{t-1}$, to the right-hand side to get

$$\Delta y_t = \delta + (\theta_1 - 1)\mathrm{y}_{t-1} + \delta_0(x_t - x_{t-1}) + (\delta_0 + \delta_1)x_{t-1} + v_t \tag{A.03}$$

where $\Delta y_t = y_t - y_{t-1}$. We then transform the equation to look like

$$\Delta y_t = (\theta_1 - 1)\left(\frac{\delta}{\theta_1 - 1} + y_{t-1} + \frac{\delta_0 + \delta_1}{\theta_1 - 1} x_{t-1}\right) + \delta_0 \Delta x_t + v_t \tag{A.04}$$

where $\Delta x_t = x_t - x_{t-1}$, and set $\beta_1 = \frac{\delta}{1-\theta_1}$, $\beta_2 = \frac{\delta_0+\delta_1}{1-\theta_1}$, we get

$$\Delta y_t = -\alpha(y_{t-1} - \beta_1 - \beta_2 x_{t-1}) + \delta_0 \Delta x_t + v_t \tag{A.05}$$

where $\alpha = (1 - \theta_1)$. Equation (A.05) is called an error correction equation for a general $\text{ARDL}(1,1)$ model.

### The Error Correction Model for the ARDL(1, 3) Model

The $\text{ARDL}(1,3)$ can be written as

$$y_t - \mathrm{y}_{t-1} = \delta + \theta_1 \mathrm{y}_{t-1} + \delta_0 x_t + \delta_1 x_{t-1} + \delta_2 x_{t-2} + \delta_3 x_{t-3} + v_t \tag{A.06}$$

First of all, we add the term, $-\mathrm{y}_{t-1}$, to both sides of the equation

$$y_t - \mathrm{y}_{t-1} = \delta + (\theta_1 - 1)\mathrm{y}_{t-1} + \delta_0 x_t + \delta_1 x_{t-1} + \delta_2 x_{t-2} + \delta_3 x_{t-3} + v_t \tag{A.07}$$

Second, add the term, $-\delta_0 x_{t-1} + \delta_0 x_{t-1} - (\delta_0 + \delta_1)x_{t-2} + (\delta_0 + \delta_1)x_{t-2} - (\delta_0 + \delta_1 + \delta_2)x_{t-3} + (\delta_0 + \delta_1 + \delta_2)x_{t-3}$ to the right-hand side and transform the equation to look like

$$\begin{gathered}\Delta y_t = (\theta_1 - 1)\left(\frac{\delta}{\theta_1 - 1} + y_{t-1} + \frac{\delta_0 + \delta_1 + \delta_2 + \delta_3}{\theta_1 - 1} x_{t-3}\right) + \delta_0 \Delta x_t + \\ (\delta_0 + \delta_1)\Delta x_{t-1} + (\delta_0 + \delta_1 + \delta_2)\Delta x_{t-2} + v_t\end{gathered} \tag{A.08}$$

where $\Delta y_t = y_t - y_{t-1}$, $\Delta x_{t-s} = x_{t-s} - x_{t-s-1}$ $(s = 0, 1, 2)$.
Set $\beta_1 = \frac{\delta}{1-\theta_1}$, $\beta'_2 = \frac{\delta_0+\delta_1+\delta_2+\delta_3}{1-\theta_1}$, we get

$$\begin{gathered}\Delta y_t = -\alpha\left(y_{t-1} - \beta_1 - \beta'_2 x_{t-3}\right) + \delta_0 \Delta x_t + (\delta_0 + \delta_1)\Delta x_{t-1} + \\ (\delta_0 + \delta_1 + \delta_2)\Delta x_{t-2} + v_t\end{gathered} \tag{A.09}$$

where $\alpha = (1 - \theta_1)$. Equation (A.09) is called an error correction equation for a general ARDL(1,3) model.

## Appendix B: Phillips-Perron Testing Results

**Table B.1**

Phillips-Perron test for the dependent variable

Phillips-Perron test for unit root — Number of obs = 32; Newey-West lags = 3

| | Test Statistic | Interpolated Dickey-Fuller: 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(rho) | -7.045 | -23.396 | -18.432 | -15.936 |
| Z(t) | -1.801 | -4.316 | -3.572 | -3.223 |

MacKinnon approximate p-value for Z(t) = 0.7040

**Table B.2**

Phillips-Perron test for the explanatory variable

Phillips-Perron test for unit root — Number of obs = 31; Newey-West lags = 3

| | Test Statistic | Interpolated Dickey-Fuller: 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(rho) | -24.572 | -23.268 | -18.356 | -15.888 |
| Z(t) | -4.750 | -4.325 | -3.576 | -3.226 |

MacKinnon approximate p-value for Z(t) = 0.0006

**Table B.3**

Phillips-Perron test for the first difference of the dependent variable

Phillips-Perron test for unit root — Number of obs = 31; Newey-West lags = 3

| | Test Statistic | Interpolated Dickey-Fuller: 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(rho) | -26.271 | -17.608 | -12.692 | -10.320 |
| Z(t) | -4.679 | -3.709 | -2.983 | -2.623 |

MacKinnon approximate p-value for Z(t) = 0.0001

**Table B.4**

Phillips-Perron test for the first difference of the dependent variable

49

```
Phillips-Perron test for unit root                Number of obs   =        30
                                                  Newey-West lags =         3
```

| | Test Statistic | Interpolated Dickey-Fuller 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(rho) | -25.865 | -17.540 | -12.660 | -10.300 |
| Z(t) | -9.649 | -3.716 | -2.986 | -2.624 |

MacKinnon approximate p-value for Z(t) = 0.0000

50

## Appendix C: ADF Testing Results

**Table C.1**

ADF test for the dependent variable with drift, trend, and one lag

Augmented Dickey-Fuller test for unit root          Number of obs = 31

| | Test Statistic | Interpolated Dickey-Fuller 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(t) | -1.827 | -4.325 | -3.576 | -3.226 |

MacKinnon approximate p-value for Z(t) = 0.6914

**Table C.2**

ADF test for the explanatory variable with drift, trend, and one lag

Augmented Dickey-Fuller test for unit root          Number of obs = 30

| | Test Statistic | Interpolated Dickey-Fuller 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(t) | -5.096 | -4.334 | -3.580 | -3.228 |

MacKinnon approximate p-value for Z(t) = 0.0001

**Table C.3**

ADF test for the first difference of the dependent variable with drift and no lag

Dickey-Fuller test for unit root          Number of obs = 31

| | Test Statistic | Interpolated Dickey-Fuller 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(t) | -4.690 | -3.709 | -2.983 | -2.623 |

MacKinnon approximate p-value for Z(t) = 0.0001

**Table C.4**

ADF test for the first difference of the explanatory variable with drift and no lag

Dickey-Fuller test for unit root          Number of obs = 30

| | Test Statistic | Interpolated Dickey-Fuller 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(t) | -6.700 | -3.716 | -2.986 | -2.624 |

MacKinnon approximate p-value for Z(t) = 0.0000

## Appendix D: Regression Result of the ARDL Models

**Table D**

ARDL Model of the Phillips Curve in Hong Kong

| | (1)<br>1982-1997 | (2)<br>1998-2014 |
|---|---|---|
| L.linf | 0.90213*** | 0.86125*** |
| | (0.073) | (0.076) |
| D.lu | -1.05109** | -1.04847** |
| | (0.350) | (0.351) |
| LD.lu | -0.98664** | -0.74172* |
| | (0.348) | (0.344) |
| L2D.lu | 0.22632 | |
| | (0.341) | |
| L3D.lu | -0.36187 | |
| | (0.347) | |
| _cons | 0.00394 | 0.00359 |
| | (0.004) | (0.004) |
| N | 29 | 31 |

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

52

## Appendix E: Dynamic Relationship of I(0) Variables

**Table E.1**

Parameters of the error correction model from 1982 to 1997 time period

| Source | SS | df | MS |
|---|---|---|---|
| Model | .001859644 | 4 | .000464911 |
| Residual | .000596802 | 7 | .000085257 |
| Total | .002456446 | 11 | .000223313 |

| | | |
|---|---|---|
| Number of obs | = | 12 |
| R-squared | = | 0.7570 |
| Adj R-squared | = | 0.6182 |
| Root MSE | = | .0092335 |
| Res. dev. | = | -84.85146 |

| Dlinf | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| /alpha1a | -.0001619 | .0000454 | -3.57 | 0.009 | -.0002692 | -.0000546 |
| /beta1a | 6.116136 | 16.88749 | 0.36 | 0.728 | -33.81643 | 46.04871 |
| /beta2a | 17439.39 | . | . | . | . | . |
| /delta0a | .1160133 | .4820205 | 0.24 | 0.817 | -1.023784 | 1.255811 |
| /delta1a | -1.637312 | .4867581 | -3.36 | 0.012 | -2.788312 | -.4863124 |
| /delta2a | -1.024308 | .4793871 | -2.14 | 0.070 | -2.157878 | .1092627 |

Parameter beta1a taken as constant term in model & ANOVA table

**Table E.2**

ADF test of the residuals for stationarity from 1982 to 1997 time period

| Source | SS | df | MS |
|---|---|---|---|
| Model | 11711.8861 | 2 | 5855.94305 |
| Residual | 38204.6581 | 8 | 4775.58226 |
| Total | 49916.5442 | 10 | 4991.65442 |

| | | |
|---|---|---|
| Number of obs | = | 10 |
| F( 2, 8) | = | 1.23 |
| Prob > F | = | 0.3432 |
| R-squared | = | 0.2346 |
| Adj R-squared | = | 0.0433 |
| Root MSE | = | 69.106 |

| D.ehat2 | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ehat2 | | | | | | |
| L1. | -.4149604 | .2898331 | -1.43 | 0.190 | -1.083317 | .253396 |
| LD. | .0316519 | .234929 | 0.13 | 0.896 | -.5100954 | .5733992 |

**Table E.3**

Parameters of the error correction model from 1998 to 2014 time period

| Source | SS | df | MS |
|---|---|---|---|
| Model | .007321304 | 3 | .002440435 |
| Residual | .002849314 | 13 | .000219178 |
| Total | .010170618 | 16 | .000635664 |

| | | |
|---|---|---|
| Number of obs | = | 17 |
| R-squared | = | 0.7198 |
| Adj R-squared | = | 0.6552 |
| Root MSE | = | .0148047 |
| Res. dev. | = | -99.55222 |

| Dlinf | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| /alpha1b | .2818045 | .1308033 | 2.15 | 0.051 | -.0007789 | .564388 |
| /beta1b | .0116872 | .0127789 | 0.91 | 0.377 | -.0159199 | .0392944 |
| /beta2b | -7.314129 | 3.74399 | -1.95 | 0.073 | -15.40253 | .7742689 |
| /delta0b | -1.246233 | .3400802 | -3.66 | 0.003 | -1.980931 | -.511534 |

Parameter beta1b taken as constant term in model & ANOVA table

**Table E.4**

ADF test of the residuals for stationarity from 1998 to 2014 time period

| Source | SS | df | MS |
|---|---|---|---|
| Model | .108087778 | 2 | .054043889 |
| Residual | .090345753 | 15 | .00602305 |
| Total | .198433531 | 17 | .011672561 |

| | | |
|---|---|---|
| Number of obs | = | 17 |
| F( 2, 15) | = | 8.97 |
| Prob > F | = | 0.0027 |
| R-squared | = | 0.5447 |
| Adj R-squared | = | 0.4840 |
| Root MSE | = | .07761 |

| D.ehat3 | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ehat3 | | | | | | |
| L1. | -1.224264 | .2960415 | -4.14 | 0.001 | -1.855262 | -.5932665 |
| LD. | .3826452 | .2100408 | 1.82 | 0.088 | -.0650461 | .8303366 |

## Appendix F: Data Set

*Source: Census and Statistics Department Hong Kong*

| u | inf | date |
|---|---|---|
| 3.6 | 10.9 | 1982 |
| 4.5 | 10.0 | 1983 |
| 3.9 | 8.6 | 1984 |
| 3.2 | 3.5 | 1985 |
| 2.8 | 3.8 | 1986 |
| 1.7 | 5.7 | 1987 |
| 1.4 | 7.8 | 1988 |
| 1.1 | 10.3 | 1989 |
| 1.3 | 10.2 | 1990 |
| 1.8 | 11.6 | 1991 |
| 2.0 | 9.6 | 1992 |
| 2.0 | 8.8 | 1993 |
| 1.9 | 8.8 | 1994 |
| 3.2 | 9.1 | 1995 |
| 2.8 | 6.3 | 1996 |
| 2.2 | 5.8 | 1997 |
| 4.7 | 2.8 | 1998 |
| 6.2 | -4.0 | 1999 |
| 4.9 | -3.8 | 2000 |
| 5.1 | -1.6 | 2001 |
| 7.3 | -3.0 | 2002 |
| 7.9 | -2.6 | 2003 |
| 6.8 | -0.4 | 2004 |
| 5.6 | 1.0 | 2005 |
| 4.8 | 2.0 | 2006 |
| 4.0 | 2.0 | 2007 |
| 3.5 | 4.3 | 2008 |
| 5.3 | 0.5 | 2009 |
| 4.3 | 2.4 | 2010 |
| 3.4 | 5.3 | 2011 |
| 3.3 | 4.1 | 2012 |
| 3.4 | 4.3 | 2013 |
| 3.3 | 4.4 | 2014 |