The Expectations-Augmented Philips Curve – Applications in Hong Kong

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1. **Introduction**

The nexus between inflation and unemployment is one of the most widely studied relationships in macroeconomics. Since the discovery of the original Philips curve (PC) by William Philips (1958), generations of macroeconomists have attempted to exploit the toolkit for the implementation of optimal monetary policies. Subsequent economic crises have brought the traditional curve under closer scrutiny. Phelps (1967) and Friedman (1968) criticised the PC by positing that the presented trade-off might occur only in the short-run. Moreover, it is the "natural rate" of unemployment at which inflation remains stable. If the government aggressively pushes down unemployment below equilibrium, individuals would adapt their expectations accordingly and the temporary trade-off would disappear. Incorporating expectations gives the PC its expectations-augmented form.

Since the adoption of inflation-targeting among central banks, many studies have observed a reduction in the backward-looking element in the PC. In contrast, expectations have become anchored, as was recorded by Bernanke (2010) and the IMF (2013) among others. An alternative narrative posited that the central bank's commitment to an inflation target has helped fixated the PC and hence prevented inflation from greatly deviating from the target.

This study aims to provide a full account of the PC relationship in Hong Kong, a small open economy with a pegged exchange rate system. The next section reviews the expectations-augmented Philips curve and its core assumptions, drawing links to its applicability in Hong Kong by invoking empirical evidence on the city's inflation persistence. It also introduces the model of anchored expectations. Section 3 examines our data and estimation methods. Section 4 discusses our empirical results. Section 5 concludes.

2. Theoretical discussion

The expectations-augmented PC has its roots from Friedman (1968), who posited in his presidential address to the American Economic Association that the current inflation depends on both expected inflation and the deviation of unemployment from its natural rate. His theory can be expressed as

$$\pi_t = \pi_t^e + \alpha(\mu_t - \mu_t^*) + \epsilon_t\,, \qquad \alpha < 0, \tag{1}$$

where π_t is inflation, π_t^e is expected inflation, μ_t is unemployment, μ_t^* is the non-accelerating inflation rate of unemployment (NAIRU), and ϵ_t is the error term.

This model, like its predecessor, assumes that prices were set by a constant markup above unit labour cost and hence adjust proportionally to wages. This assumption, formulated by Solow and Samuelson (1960), transformed the PC from a wage-change relationship to a price-change relationship that is more useful to policymakers.

Three innovations set this model apart from the original PC, as discussed by Humphrey (1985). First, excess demand in the labour and product markets upon which inflation depends was redefined as the gap between the actual and natural rates of unemployment, $(\mu_t - \mu_t^*)$, rather than just simply an inverse function of the unemployment rate, $x(\mu)$. Second, the introduction of the expectations variable, π_t^e, as the sole shift variable in the equation reflected the view prevalent in the early 70s that changing price expectations was the predominant cause of observed shifts in the PC. This implies the absence of money illusion as economic agents are chiefly concerned with the real purchasing power of wages and prices. Third, the incorporation of an expectations-generating mechanism into PC analysis led to models of adaptive expectations that were widely used. One version could be written as

$$\pi^e = \sum v_i \pi_{-i} \tag{2}$$

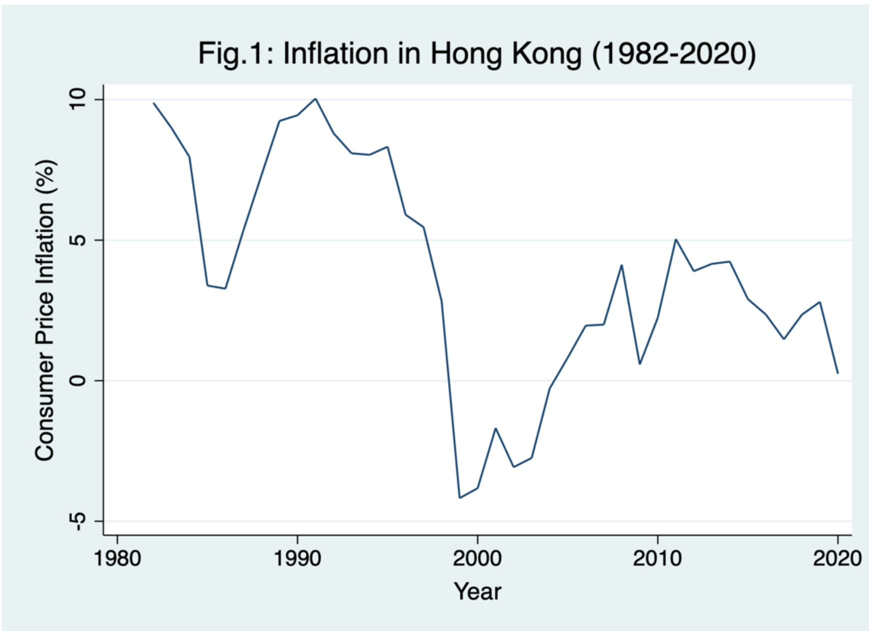
where Σ is the sum of past rates of inflation, v_i denotes the weights attached to them, and the subscript i denotes the corresponding time period. A special case was introduced by Friedman, with expected inflation equal to the inflation in the last period ($v_1 = 1$). Equation (1) thus becomes

$$\pi_t = \pi_{t-1} + \alpha(\mu_t - \mu_t^*) + \epsilon_t\,, \tag{3}$$

This equation is the accelerationist PC that appears in many undergraduate textbooks. It was widely used by policymakers before Lucas (1976) popularised alternative models of rational expectations.

Despite its simplicity, the textbook model's feature of backward-looking expectations is of utmost relevance to Hong Kong. Numerous studies have reported remarkable levels of inflation persistence in the city. Gerlach and Petra-Kristen (2006) attributed Hong Kong's large inflation volatility to its monetary policy framework. The introduction of the currency board in 1983 which pegged the HKD to the USD constrained the Hong Kong Monetary Authority (HKMA)'s ability to adjust the nominal exchange rate in response to deviations from the desired inflation level, thus increasing the persistence of the city's inflation shocks. This argument was reinforced by Gerlach and Tillman (2011) who measured the greatest levels of persistence for Hong Kong among a group of 19 economies. The result is strongly in favour of using equation (3) for our study.

The growing literature on anchored expectations has caused us to incorporate a new element into the textbook model – inflation targets. While there are no explicit targets in Hong Kong, the HKMA is committed to ensuring a low and stable inflation. Active interventions by the government can also be said to have aligned expectations [1].



[1] See Hawkins and Kee (1996)

Figure 1 shows the stabilisation of inflation rates in the post-crisis period, suggesting the use of an alternative model. We derive a simplified version of the model from Ball and Mazumder (2018), which is

$$\pi_t^e = \lambda \pi^T + (1-\lambda)\pi_{t-1} + v_t \quad (4)$$

where expected inflation is a weighted average of the inflation target π^T and the past inflation.

Substituting (4) into (1), we have

$$\pi_t = \lambda \pi^T + (1-\lambda)\pi_{t-1} + \alpha(\mu_t - \mu_t^*) + u_t \,, \quad \alpha < 0, \quad (5)$$

This equation nests two common versions of PC. If the parameter λ is zero, inflation depends on the past inflation with a weight of 1, and we have the accelerationist PC. If λ is one, the lagged inflation term disappears, and we have a version of the original PC with anchored expectations.

3. Data and Methodology

For our study of Hong Kong's inflation-unemployment relationship, we have the following two regression models derived from equation (3) and (5).

Model 1: the accelerationist PC

$$\Delta\pi_t = \beta_0 + \beta_1(\mu_t - \mu_t^*) + \epsilon_t \tag{6}$$

where $\Delta\pi_t = \pi_t - \pi_{t-1}$ and $\beta_1 = \alpha$.

Model 2: PC with both adaptive and anchored expectations

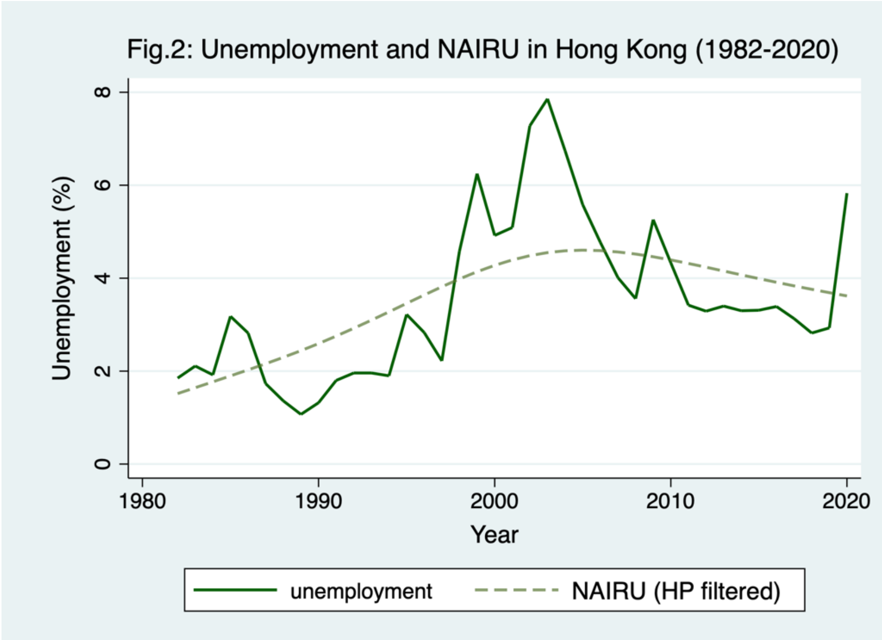
$$\pi_t = \beta_0 + \beta_1\pi_{t-1} + \beta_2(\mu_t - \mu_t^*) + u_t \tag{7}$$

where $\beta_0 = \lambda\pi^T$, $\beta_1 = 1 - \lambda$ and $\beta_2 = \alpha$.

Data is obtained from the World Bank site from 1982-2020. Inflation is measured by the yearly percentage change in the Consumer Price Index (CPI). NAIRU is obtained from the unemployment rate using HF filtering methodology, following Sovbetov and Kaplan (2019). *Table 1* and *fig2* summarise the variables of our dataset.

Table 1: Overview of Mean and Standard Deviation of Variables

Inflation Rate		**Unemployment Rate**		**NAIRU**		**Unemployment Gap**	
Mean	Std Dev.	Mean	Std Dev.	Mean	Std Dev.	Mean	Std Dev.
3.788	0.040	3.496	1.724	3.496	1.015	0.000	1.218



To check for stationarity, we conduct the Augmented Dicky Fuller (ADF) test on inflation π_t and the unemployment gap $\mu_t - \mu_t^*$. We are unable to reject the null that the series are non-stationary at all conventional levels of significance. Thus, we first difference the variables to achieve stationarity. The results are shown in *Table 2*.

Table 2: ADF Unit Root Test Without Trend PP

Variable	**Level**	**1st difference**
$\boldsymbol{\pi_t}$	-1.863	-5.075***
$\boldsymbol{\mu_t - \mu_t^*}$	-2.383	-4.860***

Note: ***, **, * are significance levels of 1%, 5% and 10% respectively at which the unit root test was evaluated.

4. Results and Discussion

Table 3 presents the results of OLS estimation for our two specifications.

Table 3: Regression output

Variable	(1)	(2)
π_{t-1}		0.261* (0.126)
$\mu_t - \mu_t^*$	-0.0167*** (0.00342)	-0.0141*** (0.00249)
C	0.000338 (0.00345)	-0.00120 (0.00248)
N	37	37
$\overline{R^2}$	0.0830	0.8339

Standard errors in parentheses

Note: the 2 models were first differenced before estimated, but the adjusted R-squared reported here refers to the undifferenced model, so they should be treated with caution.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Both models capture an inverse relationship between inflation and unemployment. In model 1, a positive 1% deviation from NAIRU in a given period is associated with a 1.67% decrease in inflation. The figure is 1.41% in model 2. The high magnitude and significance of the coefficient is in striking contrast to the group of countries examined by Sovbetov and Kaplan (2019) and Solomon (2014). This can be explained by Hong Kong's steep aggregate supply curve due to its trade openness and land constraints. It is impossible to expand output beyond its trend without significantly increasing the cost of production. On the contrary, attempts to disinflate the economy would bring a high cost to output and employment.

Once anchored expectations enter the equation, the explanatory power of the variables increases significantly. This is shown by the large improvement in the fitted values of *fig4* compared to *fig3*. The high value of $\lambda\ (= 1 - 0.261 = 0.739)$ demonstrates the importance of the anchor in the formation of expectations. However, past inflationary experience still partly accounts for current expectations. The constancy of λ is a questionable assumption, so we test for a structural break in λ under the hypothesis that expectations shifted from backward-looking to anchored during our sample period.

Table 4: Structural Break Test for λ

Test	Statistic	P-Value
Supremum Wald	20.4756	0.0002
Average Wald	8.0468	0.0001
Average LR	7.8828	0.0001

H_0: no structural break — Full sample: 1983-2020

Exogenous variable: $\mu_t - \mu_t^*$ — Trimmed sample: 1989-2015

Estimated break date	1996
$\lambda^{prebreak}$	0.6086
	(0.2213)
$\lambda^{postbreak}$	0.7911
	(0.1599)

Standard errors in parentheses

The Supremum Wald test identifies a structural break in 1996. This is perhaps unsurprising as the run-up to the Asian Financial Crisis saw inflation moderating from around 10% to 5.5% while unemployment was kept consistently low. An anchoring of expectations, with λ leaping from 0.6086 to 0.7911, helps to explain this unusual trajectory.

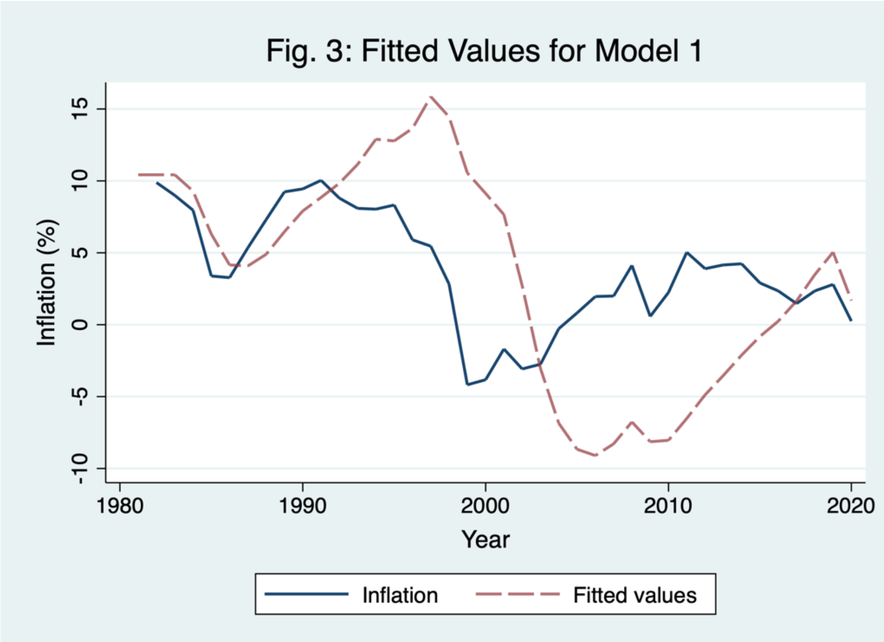


Fig. 3: Fitted Values for Model 1
Inflation (%)
15
10
5
0
-5
-10
1980
1990
2000
2010
2020
Year
Inflation
Fitted values

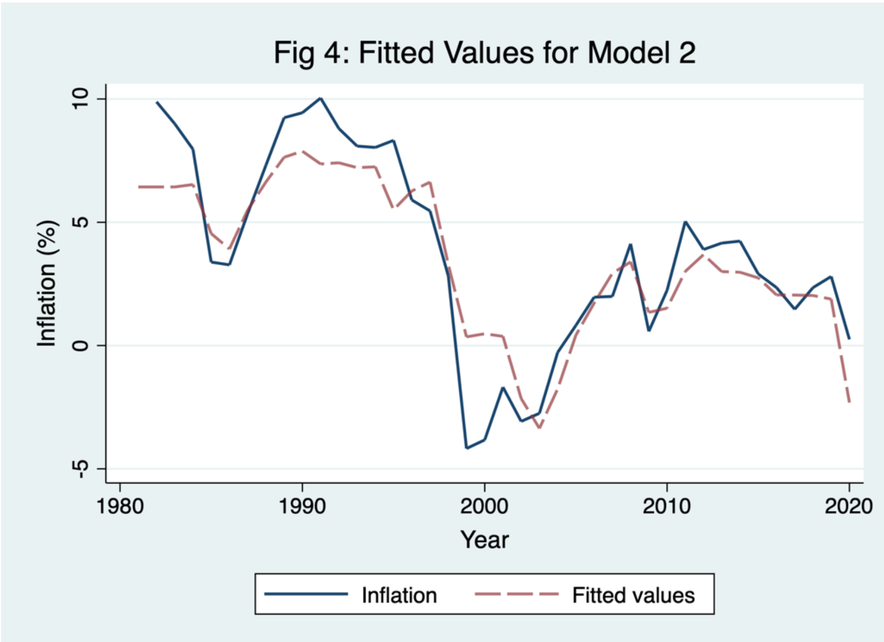


Fig 4: Fitted Values for Model 2
Inflation (%)
10
5
0
-5
1980
1990
2000
2010
2020
Year
Inflation
Fitted values

5. Conclusion

Our results yield two major implications. First, tighter-than-normal monetary policy is required to stabilise inflation due to the steep PC in Hong Kong. Second, more could be done to anchor expectations by demonstrating the central bank's commitment towards inflation control in lieu of its narrow focus on nominal exchange rate fixity.

The above modelling framework could be extended to other small open economies with considerable inflation persistence. The expectations formation process should be studied, and the inflation-unemployment relationship ought to be quantified and exploited for the optimisation of monetary policies.

A possible direction for further study is to develop a model of rational expectations. In the absence of a reliable forecast, one can proxy expected inflation as a function of variables such as exchange rate, money growth and fiscal budget, following empirical work by Solomon (2014). Investigating more sources of expectations allows us to obtain better estimates for the expectations-augmented PC.

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Appendix

Names of the variables stored in STATA

Name	Variable
inflation	π_t
change_inflation	$\Delta\pi_t$
change_inflation_1	$\Delta\pi_{t-1}$
diff_inflation	$\Delta\pi_t - \Delta\pi_{t-1}$
unemployment	μ_t
nairu	μ_t^*
gap	$\mu_t - \mu_t^*$
change_gap	$\Delta(\mu_t - \mu_t^*)$

Unit root test:

```
. dfuller inflation

Dickey-Fuller test for unit root                  Number of obs  = 38
Variable: inflation                               Number of lags =  0

H0: Random walk without drift, d = 0

                                       Dickey-Fuller
                   Test         ———————— critical value —————————
              statistic           1%           5%           10%
─────────────────────────────────────────────────────────────────
 Z(t)            -1.863       -3.662       -2.964       -2.614
─────────────────────────────────────────────────────────────────
MacKinnon approximate p-value for Z(t) = 0.3495.
```

```
. dfuller change_inflation

Dickey-Fuller test for unit root                Number of obs  = 37
Variable: change_inflation                      Number of lags =  0

H0: Random walk without drift, d = 0

                                     Dickey-Fuller
                   Test        ——————— critical value ————————
              statistic          1%          5%          10%
──────────────────────────────────────────────────────────────
 Z(t)            -5.075      -3.668      -2.966      -2.616
──────────────────────────────────────────────────────────────
MacKinnon approximate p-value for Z(t) = 0.0000.
```

```
. dfuller gap

Dickey–Fuller test for unit root          Number of obs  = 39
Variable: gap                             Number of lags =  0

H0: Random walk without drift, d = 0

                                       Dickey–Fuller
                   Test       ——————— critical value ———————
              statistic           1%           5%          10%
————————————————————————————————————————————————————————————
 Z(t)            -2.383       -3.655       -2.961       -2.613
————————————————————————————————————————————————————————————
MacKinnon approximate p-value for Z(t) = 0.1465.

. dfuller change_gap

Dickey–Fuller test for unit root          Number of obs  = 38
Variable: change_gap                      Number of lags =  0

H0: Random walk without drift, d = 0

                                       Dickey–Fuller
                   Test       ——————— critical value ———————
              statistic           1%           5%          10%
————————————————————————————————————————————————————————————
 Z(t)            -4.860       -3.662       -2.964       -2.614
————————————————————————————————————————————————————————————
MacKinnon approximate p-value for Z(t) = 0.0000.
```

Regression: model 1 (undifferenced)

```
. regress change_inflation gap

      Source |       SS           df       MS      Number of obs   =        38
-------------+----------------------------------   F(1, 36)        =      4.35
       Model |  .001633822         1  .001633822   Prob > F        =    0.0442
    Residual |  .013531228        36  .000375867   R-squared       =    0.1077
-------------+----------------------------------   Adj R-squared   =    0.0830
       Total |   .01516505        37  .000409866   Root MSE        =    .01939

------------------------------------------------------------------------------
change_inf~n | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         gap |  -.0053189   .0025511    -2.08   0.044    -.0104928   -.0001449
       _cons |  -.0026017   .0031452    -0.83   0.414    -.0089805     .003777
------------------------------------------------------------------------------
```

Explore Econ 2022

Regression: model 1 (first differenced)

```
. regress diff_inflation change_gap

      Source |       SS           df       MS      Number of obs   =        37
-------------+----------------------------------   F(1, 35)        =     23.75
       Model |  .010424439         1  .010424439   Prob > F        =    0.0000
    Residual |  .015360448        35   .00043887   R-squared       =    0.4043
-------------+----------------------------------   Adj R-squared   =    0.3873
       Total |  .025784887        36  .000716247   Root MSE        =    .02095

------------------------------------------------------------------------------
diff_infla~n | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
  change_gap |   -.016685   .0034235    -4.87   0.000    -.0236351    -.009735
       _cons |   .0003376   .0034478     0.10   0.923    -.0066618     .007337
------------------------------------------------------------------------------
```

Regression: model 2 (undifferenced)

```
. regress inflation inflation_1 gap

      Source |       SS           df       MS      Number of obs   =        38
-------------+----------------------------------   F(2, 35)        =     93.90
       Model |  .047343111         2  .023671555   Prob > F        =    0.0000
    Residual |  .008822937        35  .000252084   R-squared       =    0.8429
-------------+----------------------------------   Adj R-squared   =    0.8339
       Total |  .056166048        37  .001518001   Root MSE        =    .01588

------------------------------------------------------------------------------
   inflation | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
 inflation_1 |    .665301   .0774453     8.59   0.000     .5080786    .8225234
         gap |  -.0110051    .002469    -4.46   0.000    -.0160174   -.0059927
       _cons |    .010317   .0039459     2.61   0.013     .0023065    .0183276
------------------------------------------------------------------------------
```

Regression: model 2 (first differenced)

```
. regress change_inflation change_inflation_1 change_gap

      Source |       SS           df       MS      Number of obs   =        37
-------------+----------------------------------   F(2, 34)        =     16.74
       Model |  .007503286         2  .003751643   Prob > F        =    0.0000
    Residual |  .007620244        34  .000224125   R-squared       =    0.4961
-------------+----------------------------------   Adj R-squared   =    0.4665
       Total |  .015123531        36  .000420098   Root MSE        =    .01497

------------------------------------------------------------------------------------
  change_inflation | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------------+----------------------------------------------------------------
change_inflation_1 |   .2609541   .1257593     2.08   0.046     .0053803    .5165278
        change_gap |  -.0141197   .0024851    -5.68   0.000    -.0191702   -.0090693
             _cons |  -.0011983   .0024777    -0.48   0.632    -.0062336     .003837
------------------------------------------------------------------------------------
```

Explore Econ 2022

Structural break test

```
. eststo: estat sbsingle, breakvars(inflation_1)
────┼─── 1 ───┼─── 2 ───┼─── 3 ───┼─── 4 ───┼───
.........................

Test for a structural break: Unknown break date
Full sample:    1983 thru 2020
Trimmed sample: 1989 thru 2015
Estimated break date: 1996

H0: No structural break

                         Number of obs = 38
───────────────────────────────────────────
             Test     Statistic      p-value
───────────────────────────────────────────
    Supremum Wald       20.4756       0.0002
───────────────────────────────────────────
Exogenous variables: inflation_1 gap
Coefficients included in test: inflation_1
(est2 stored)
```

```
. estat sbsingle, swald awald alr breakvars(inflation_1)
────┼─── 1 ───┼─── 2 ───┼─── 3 ───┼─── 4 ───┼─── 5
.........................

Test for a structural break: Unknown break date
Full sample:    1983 thru 2020
Trimmed sample: 1989 thru 2015

H0: No structural break

                         Number of obs = 38
───────────────────────────────────────────
             Test     Statistic      p-value
───────────────────────────────────────────
    Supremum Wald       20.4756       0.0002
     Average Wald        8.0468       0.0001
       Average LR        7.8828       0.0001
───────────────────────────────────────────
Exogenous variables: inflation_1 gap
Coefficients included in test: inflation_1
```

Explore Econ 2022

Regression after accounting for structural break

```
. regress change_inflation change_inflation_1 change_gap if year<=1995

      Source |       SS           df       MS      Number of obs   =        12
-------------+----------------------------------   F(2, 9)         =      5.58
       Model |  .002015519         2  .001007759   Prob > F        =    0.0265
    Residual |  .001623993         9  .000180444   R-squared       =    0.5538
-------------+----------------------------------   Adj R-squared   =    0.4546
       Total |  .003639512        11  .000330865   Root MSE        =    .01343

------------------------------------------------------------------------------------
  change_inflation | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------------+----------------------------------------------------------------
change_inflation_1 |   .3914429   .2212656     1.77   0.111    -.1090946    .8919805
        change_gap |  -.0170403   .0059979    -2.84   0.019    -.0306086   -.003472
             _cons |  -.0009589   .0039085    -0.25   0.812    -.0098006    .0078828
------------------------------------------------------------------------------------
```

```
. regress change_inflation change_inflation_1 change_gap if year>=1996

      Source |       SS           df       MS      Number of obs   =        25
-------------+----------------------------------   F(2, 22)        =     10.47
       Model |  .005571273         2  .002785636   Prob > F        =    0.0006
    Residual |  .005855095        22  .000266141   R-squared       =    0.4876
-------------+----------------------------------   Adj R-squared   =    0.4410
       Total |  .011426368        24  .000476099   Root MSE        =    .01631

------------------------------------------------------------------------------------
  change_inflation | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------------+----------------------------------------------------------------
change_inflation_1 |   .2089118   .1599092     1.31   0.205    -.1227196    .5405432
        change_gap |  -.0134444   .0029453    -4.56   0.000    -.0195527   -.0073361
             _cons |   -.001474    .003299    -0.45   0.659    -.0083157    .0053677
------------------------------------------------------------------------------------
```