Economics Letters 117 (2012) 259–262

Contents lists available at SciVerse ScienceDirect

Economics Letters

journal homepage: www.elsevier.com/locate/ecolet

# Flattening of the Phillips curve and the role of the oil price: An unobserved component model for the USA and Australia

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ARTICLE INFO

*Article history:*
Received 8 March 2011
Received in revised form
17 May 2012
Accepted 21 May 2012
Available online 26 May 2012

*JEL classification:*
C2
C12
E3

*Keywords:*
Unobserved component model
USA
Australia
Flattening Phillips curve
Oil price

ABSTRACT

We used the unobserved component model of Harvey (1989, 2011) to estimate the Phillips curve for the USA and Australia, augmenting it with the oil price. Our results show that while the coefficient of demand pressure and the intercept decreased, the coefficient of the oil price increased. Therefore, the oil price is likely to play a significant role in future inflation rates.



## 1. Introduction

Recent studies have found that since the late 1990s the Phillips curve (PC) has become flatter in countries like the USA, Canada and Australia; see Beaudry and Doyle (2000), Roberts (2006), Williams (2006), Mishkin (2007) and Kuttner and Robinson (2010). While the reasons for this are not well established, it has both positive and negative policy effects. Higher output levels can be achieved without increasing inflation by large amounts, but it would be costly to reduce entrenched inflation rates.

Previous studies have concentrated on the changes in the coefficient of the output gap (GAP) and have neglected the changes in the intercept and coefficients of other variables. This paper includes the oil price as an additional explanatory variable and employs the structural time series models of Harvey (1989, 2011) to analyze the coefficients of the GAP, the oil price, and the level component.[1] The results for the US and Australia show that while the coefficient of the GAP and the intercept decreased, the coefficient of the oil price increased. The downward shift of the intercept and the GAP coefficient is consistent with the observed period of "Great Moderation" since the early 1980s; see Cogley et al. (2010) and Fuhrer (2009). However, an increase in the oil price coefficient implies increased dependence on energy prices, and if this continues, it will be more difficult to control the inflation dynamics.

The rest of the paper is as follows. Section 2 presents specifications, Section 3 contains results, and Section 4 makes conclusions.

## 2. Model specification

Our specification of the PC is adapted from Harvey (2011),[2] with the GAP ($y^{gap}$) as the driving force and the oil price as an additional

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1 The level component is equated to the intercept in the classical regression model. While the intercept is fixed in the classical regression, it is allowed to change over time in the time series structural models; see Commandeur and Koopman (2007).

2 Notice that (1) differs from the specifications used for the new Keynesian and hybrid new Keynesian Phillips curves in that neither $\pi_{t-1}$ nor its expected one period ahead rate ($E_t\pi_{t+1}$) are present. However, Harvey (2011) shows that under some assumptions Eq. (1) is consistent with a backward-looking behavior and a forward-looking dynamic. As for the lagged term, it is sufficient to observe that

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doi:10.1016/j.econlet.2012.05.022

explanatory variable; see Fuhrer (1995) and Blanchard and Gali (2007).

$$\pi_t = \mu_t + \gamma_t + \psi_t + \phi_{1,t} y_t^{\text{gap}} + \phi_{2,t} \text{oil}_t + \varepsilon_t, \quad \varepsilon_t \sim N\left(0, \sigma_\varepsilon^2\right), \; t = 1, \ldots, T. \tag{1}$$

Observed series of inflation ($\pi_t$) is decomposed into trend ($\mu_t$), cycle ($\psi_t$), and seasonality ($\gamma_t$) components. Oil is the cyclical component of the oil price. $y^{\text{gap}}$ and oil are obtained through the univariate trend–cycle decomposition. The component $\mu_t$ is specified as random walk plus noise model:

$$\mu_t = \mu_{t-1} + \eta_t \quad \eta_t \sim N\left(0, \sigma_\eta^2\right). \tag{2}$$

The seasonal component $\gamma_t$ has the following trigonometric form:

$$\gamma_t = \sum_{j=1}^{[s/2]} \gamma_{j,t} \tag{3}$$

where $s$ is the seasonal length (for quarterly data, $s = 4$) and each $\gamma_{j,t}$ is generated by:

$$\begin{bmatrix} \gamma_{j,t} \\ \gamma_{j,t}^* \end{bmatrix} = \begin{bmatrix} \cos\lambda_j & \sin\lambda_j \\ -\sin\lambda_j & \cos\lambda_j \end{bmatrix} \begin{bmatrix} \gamma_{j,t-1} \\ \gamma_{j,t-1}^* \end{bmatrix} + \begin{bmatrix} \omega_{j,t} \\ \omega_{j,t}^* \end{bmatrix}, \quad \begin{matrix} j = 1, \ldots, [s/2] \\ t = 1, \ldots, T. \end{matrix} \tag{4}$$

In (4), $\lambda_j = 2\pi j/s$ is the seasonal frequency in radians, and $\omega_t, \omega_t^*$ are NID seasonal disturbances with zero mean and common variance $\sigma_\omega^2$.

The statistical specification of the cycle, $\psi_t$,[3] is given by the following:

$$\begin{bmatrix} \psi_t \\ \psi_t^* \end{bmatrix} = \rho_\psi \begin{bmatrix} \cos\lambda_c & \sin\lambda_c \\ -\sin\lambda_c & \cos\lambda_c \end{bmatrix} \begin{bmatrix} \psi_{t-1} \\ \psi_{t-1}^* \end{bmatrix} + \begin{bmatrix} \kappa_t \\ \kappa_t^* \end{bmatrix}, \quad t = 1, \ldots, T \tag{5}$$

where $\rho_\psi$ (in the range $0 < \rho_\psi \leq 1$) is a damping factor; $\lambda_c$ is the frequency, in radians, in the range $0 \leq \lambda_c \leq \pi$; $\kappa_t, \kappa_t^*$ are NID disturbances with zero mean and common variance $\sigma_\kappa^2$.

The coefficients ($\phi_{1,t}$ and $\phi_{2,t}$) are assumed to vary over time according to a smoothing spline process:

$$\left(\phi_{i,t} - \phi_{i,t-1}\right) = \left(\phi_{i,t-1} - \phi_{i,t-2}\right) + u_{i,t} \qquad u_{i,t} \sim N\left(0, \sigma_{u_i}^2\right). \tag{6}$$

Estimation for the US and Australian PCs in (1)–(6) are in Table 1. For the Australian PC, the seasonal component $\gamma_t$ is ignored because it was found to be statistically insignificant. Inclusion of $\gamma_t$ did not change the results.

(excluding for simply the oil price) all models that combine inflation and the output gap of the type $\pi_t = \mu_t + \phi y_t^{\text{gap}} + \varepsilon_t, \varepsilon_t \sim \text{NID}\left(0, \sigma_\varepsilon^2\right)$ can be written as $\pi_t = E_{t-1}(\mu_t) + \phi y_t^{\text{gap}} + v_t, v_t \sim \text{NID}\left(0, \sigma_v^2\right)$, where $v_t = \varepsilon_t + \eta_t$ and $E_{t-1}(\mu_t)$ are weighted averages of past observations, corrected for the $y^{\text{gap}}$ effect. Moreover, since $\pi$ is commonly found to be I(1) over very long horizons (see Russell (2011)) with $y^{\text{gap}}$ being stationary by construction, $\mu_t$ captures the long-run forecast and can be considered as a measure of core inflation. Harvey (2011, Appendix A) shows that a hybrid new Keynesian Phillips curve reverts back to a simple PC, without expectations or dynamics, assuming that $y^{\text{gap}}$ is driven by an AR(1) process with root $|\phi| < 1$.

3 Inserting the cycle into the formula gives a smaller equation standard error. But more important, $\mu$ is much less erratic.

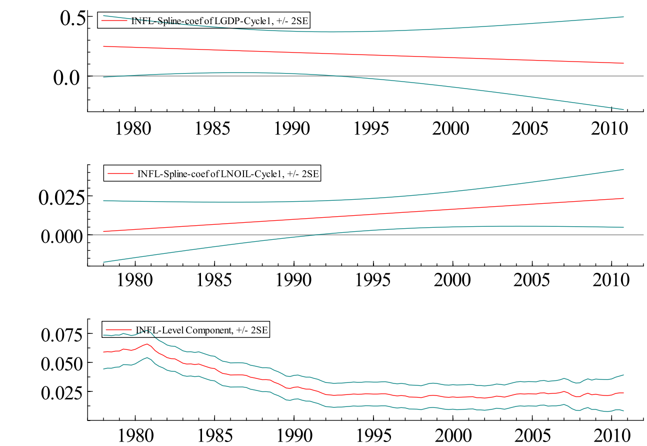


**Fig. 1.** Coefficients with 2SEs of the US Phillips curve. Panel 1: GAP ($\phi_1$); Panel 2: oil price ($\phi_2$); Panel 3: level component ($\mu$).

## 3. Results

Table 1 shows the results (with the STAMP software) for the US and Australia PCs for 1978Q1–2010Q3.[4] The results show that the models are well determined and the use of time-varying parameters is justified. When coefficients in Model A are allowed to vary over time (in Model B), the measures of the goodness of fit are better.

In US, the time evolution of the coefficients of the output gap[5] and of the oil price and the level component (all from Model B) with their two standard deviation bands, respectively, are shown in the three panels of Fig. 1. As can be seen, the coefficient of the GAP and the level component have decreased over time, which has positive effects on the inflation policy. However, this is partly offset by the increase in the coefficient of the oil price. The decline in the level component is due to the decline in core inflation. This highlights the explicit announcements of lower target rates of inflation by the Fed since the early 1980s. The decline in the coefficient of the GAP, which has been more rapid since the 1990s, may be due to the effects of globalization and the belated effects of other liberalization policies. The increase in the coefficient of the oil price is somewhat surprising as it occurs despite several energy saving policies.[6] As our measure of inflation is based on the GDP deflator,[7] it is likely that the share of energy expenditures in total private expenditures may have increased due to an inelastic demand for oil; see Cooper (2003). Real energy prices have increased more steeply since the late 1990s. This may have caused this coefficient to show an upward trend, implying that the oil price is an important determinant of future inflation.

In Australia (See Fig. 2), the coefficient of the GAP shows a declining pattern similar to the US, which lends support to the argument that this is due to some common factors such as the effects of globalization (e.g. the availability of cheap consumer goods from China) and market liberalization policies. The decline in the level coefficient is constant up to the late 1990s, but has shown a slight increase since then, perhaps due to the introduction of the general goods and services tax in 2000 and the skill shortages caused by the high export demand for natural resources. The

4 We focused on the past 30 years because large outliers are detected by STAMP prior to 1978. In addition, diagnostic tests are more robust if we start from 1978.

5 The output gap is insignificantly different from zero from the 1990s onwards for the US and Australia. This is not new and is similar to the Kuttner and Robinson (2010) result.

6 For example, the Energy Tax Act of 1978 and the Energy Policy Act of 1992.

7 The results are very similar if we use CPI as a measure of inflation.

**Table 1**
Phillips curve estimation results of various models.

| | $\phi_1$ | $\phi_2$ | PEV | $R^2$ | $Q$ | $N$ | $H$ |
|---|---|---|---|---|---|---|---|
| $\pi_t = \mu_t + \psi_t + \gamma_t + \phi_1 y_t^{gap} + \phi_2 \text{oil}_t + \varepsilon_t$ | | | | | | | |
| Model A | | | | | | | |
| USA | 0.235* | 0.013* | 8.53E−05 | 0.320 | 0.128 | 0.018 | 0.941 |
| Australia[a] | 0.456* | 0.041* | 8.10E−04 | 0.535 | 0.241 | 0.221 | 0.738 |
| $\pi_t = \mu_t + \psi_t + \gamma_t + \phi_{1,t} y_t^{gap} + \phi_{2,t} \text{oil}_t + \varepsilon_t$ | | | | | | | |
| Model B | | | | | | | |
| USA | (See plots) | (See plots) | 8.44E−05 | 0.339 | 0.173 | 0.012 | 0.962 |
| Australia[a] | (See plots) | (See plots) | 7.00E−04 | 0.606 | 0.140 | 0.122 | 0.917 |

Notes: PEV = Prediction Error Variance; $R^2$ = Coefficient of determination ("seasonally" adjusted goodness of fit for the US since we have a seasonal component); $N$ = Normality statistic (Bowman–Shenton statistic with the correction of Doornik–Hansen); $H$ = Heteroskedasticity test; $Q$ = Box–Ljung $Q$-statistic. For $Q$, $N$, and $H$ test we report $p$-value. The proper lag lengths in $Q$ and the degree of freedom are selected automatically by STAMP. $h$'s in $H(h)$ test are selected by STAMP according to the number of observations.
[a] In Australia the seasonal component is not included.
* Significant at 5%.

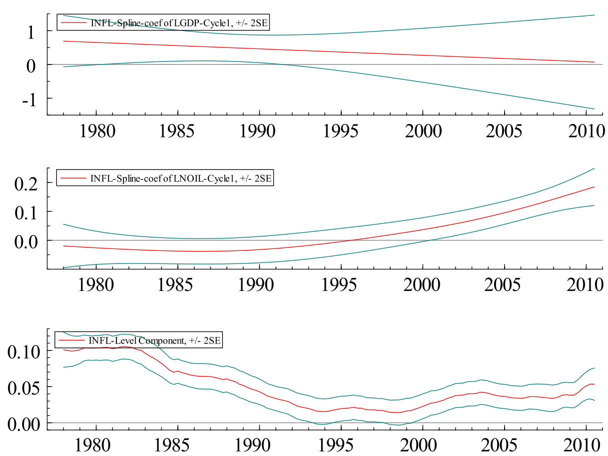


**Fig. 2.** Coefficients with 2SEs of the Australian Phillips curve. Panel 1 GAP ($\phi_1$); Panel 2: oil price ($\phi_2$); Panel 3: level component ($\mu$).

increase in the coefficient of oil is similar to the US pattern. Therefore, the oil price in Australia is also likely to play a significant role in inflation in the future.

## 4. Conclusions

This paper followed the unobservable component approach of Harvey (1989, 2011) to estimate the Phillips curves for the US and Australia. Our specifications included oil prices as an additional explanatory variable. We found that in both countries, while the long-term level coefficient of inflation (core inflation) and the coefficient of demand pressure have shown downward trends, the coefficient of the oil price has shown an upward trend. The positive effects on the inflation policy due to the declines in the level component and the output gap coefficient seem to be the result of a strong commitment by monetary authorities to lower inflation targets and possibly liberalization policies (i.e., capital account openness[8]). The increase in the coefficient of the oil price could be due to a gradual increase in the relative price of energy and the relatively inelastic demand for energy. This implies that energy prices are likely to play a significant role in determining future rates of inflation. Therefore, strategies to reduce dependence on oil might be important for the future inflation policy.

Some issues that could be subject to the future investigation include: a comparison of the output gap with that of other measures, inclusion of import prices, exchange rate influences and extension to other countries.

[8] See Gruben and McLeod (2002) on this point.

## Appendix. Data appendix

| Definitions and data source: 1978Q1–2010Q3 | | |
|---|---|---|
| Variable | Definition | Source |
| *Australian data* | | |
| $\pi$ | Annualized rate of change of GDP deflator: $(\ln p_t - \ln p_{t-1}) \times 4$. | Reserve Bank of Australia (RBA). |
| $y$ | Natural log of real GDP. | RBA. |
| $y^{gap}$ | Output gap obtained through univariate trend–cycle decomposition: $y_t = \mu_t + \psi_t + \varepsilon_t,\ \varepsilon_t \sim N(0, \sigma_\varepsilon^2),\ t = 1, \ldots, T$ where $\mu_t$ is an integrated random walk, $\varepsilon_t$ is white noise, and $\psi_t$ is a time varying trigonometric cycle with frequency associated with the length of the cycle (in our case 3 as used by Harvey, 2011). | Authors' elaboration. |
| *US data* | | |
| $\pi$ | Annualized rate of change of GDP deflator: $(\ln p_t - \ln p_{t-1}) \times 4$. | Federal Reserve Economic Data. (FRED). |
| $y$ | Natural log of real GDP. | FRED. |
| $y^{gap}$ | Output gap obtained through univariate trend–cycle decomposition. | Authors' elaboration. |
| Oil | Cyclical component of natural log of oil price (West Texas Intermediate (US$/BBL)) obtained through univariate trend–cycle decomposition as used for $y^{gap}$. Different specifications do not change the results. | Authors' elaboration. |

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