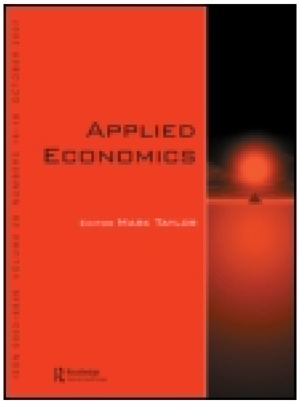

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A New Keynesian IS curve for Australia: is it forward looking or backward looking?

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This article estimates the forward looking, backward looking and an extended version of the New Keynesian IS curve for Australia. The validity of these models is investigated by imposing the constraint on real rate of interest as well as when the constraint is relaxed. Two measures of output gap, namely *GAP1* (constructed using the unobserved components approach) and *GAP2* (constructed using a quadratic trend) are utilized. Our results suggest that the baseline backward looking and forward looking models are overwhelmingly rejected by the data. This evidence strongly supports the extended backward looking model (with *GAP2*) being relevant for monetary policy analysis.

Keywords: New Keynesian IS curve; backward looking; forward looking; Australia

JEL Classification: C2; C12

I. Introduction

Recent research has explored the New Keynesian Investment-Saving (NK-IS) curve, but in most applications the findings are inconclusive. Compared to the New Keynesian Phillips Curve (NK-PC), empirical investigations into the NK-IS curve are limited. Theoretically, both are purely forward looking. While the NK-PC explains inflation to expected future inflation and the output gap, the NK-IS curve links output gap to expected future output gap and the *ex-ante* real interest rate. The failure to attain robust estimates in a purely Forward Looking (FL) model has led many researchers to utilize the hybrid version that incorporates both FL and Backward Looking (BL) elements. Empirically, the BL model often produces estimates that are consistent with the data (Lindé, 2001; Rudebusch, 2002; Goodhart and Hofmann, 2005). Since monetary policy is generally viewed as having mostly short-run real effects on the economy, an investigation into the NK-PC and NK-IS curve yields useful implications on the relevance of monetary policy. Specifically, the estimates of NK-IS curve signify whether the monetary policy will have statistically significant impact on the aggregate demand.

This article utilizes the specifications provided by Goodhart and Hofmann (2005) to estimate the NK-IS curve for Australia over the period 1984Q1–2010Q3. The contribution of this article is threefold. First, we investigate whether the BL model fits the data better than the FL model. This is of special interest because in many studies the estimates of real rate of interest are either wrongly signed or statistically insignificant at the conventional levels; Nelson (2001, 2002) has called this finding the 'IS puzzle'. No attempt has yet been made to assess the NK-IS curve for Australia using country-specific time series data. Second, we explore the validity of the BL and FL models when the real interest rate assumption is relaxed. To this end, nominal interest and inflation rates, in their own right, could also affect the output. We relax this assumption partly due to the perspective of Davidson *et al.* (1978) that it is worth explaining the complete set of existing findings. They

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argued that restrictions derived from economic theories can be valuable in econometric modelling if correctly implemented to restrict the model but not the data. Lastly, we address the issue of stability of the NK-IS curve. For the NK-IS curve to be a good model for policy makers, its structural parameters should not vary in a systematic manner over-time and hence should be stable.

This article is organized as follows. Section II provides a review of the studies that have analysed the NK-IS curve and also offers potential explanations for the IS puzzle. Section III discusses the data and specifications used in this article. Section IV details our empirical results, and Section V concludes.

II. Empirical NK-IS Curve and the Puzzle

Empirical evidence on NK-IS curve

Due to the interest sensitivity of the IS curve, and given that it determines interest rates, monetary policy can steer aggregate demand. The IS curve defines real aggregate demand as a negative function of the real interest rate. In its simplest form, the IS curve is determined by the inter-temporal Euler equation

$$y_t = E_t y_{t+1} - \sigma(i_t - E_t \pi_{t+1}) + \eta_t \quad (1)$$

where y_t is the output gap, $E_t y_{t+1}$ is the current period's expectation of next period's output gap, i_t is the nominal interest rate, $E_t \pi_{t+1}$ is the current period's expectation of next period's inflation rate and η_t is an aggregated demand shock not anticipated by the central bank and hence it is not correlated serially with a statistical mean of zero. Note that the *ex-ante* real interest is used, defined as $i_t - E_t \pi_{t+1}$, and its negative coefficient reflects inter-temporal substitution effects in consumption. Equation 1 is purely forward looking and in empirical applications the pure FL model was found to be inconsistent with the dynamics of aggregate output (see, e.g. Estrella and Fuhrer, 2002). Consequently, Equation 1 is substituted with a hybrid version in order to match the lagged and persistent responses of inflation and output to monetary policy measures that are found in the data, for instance, see Fuhrer and Rudebusch (2004). Fuhrer (2000) showed that such hybrid specification can be theoretically motivated by habit formation in consumption. Fuhrer (2000) and Fuhrer and Rudebusch (2004) estimated the FL model for the USA and found limited evidence that FL expectations are important in output determination. Fuhrer and Rudebusch (2004), in particular, asserted that Generalized Method of Moments (GMM) estimates are problematic due to weak instruments, and that maximum likelihood estimation may be preferable.

With regard to the BL model, Rudebusch and Svensson (1999) have achieved a statistically significant negative coefficient for the real rate of interest. Peersman and Smets (1999) and Angeloni and Ehrmann (2007) attained similar results for the Euro Area and therefore their findings support the BL model. Other studies asserted that additional measures such as monetary aggregates, asset prices, real effective exchange rate, etc., should be included in the BL specification (see, e.g. Nelson, 2001, 2002; Goodhart and Hofmann, 2005; Hafer *et al.* 2007; Hafer and Jones, 2008). Nelson (2001, 2002) estimated the BL model for the UK and the USA and fails to find a significant negative coefficient for the real interest rate. In the case of the USA, Hafer *et al.* (2007) found that movements in real M2 significantly affect changes in the output gap independent of the real federal funds rate. Goodhart and Hofmann (2005) have extended the BL model to include asset prices and monetary aggregates for Group of Seven (G7) countries.[1] They found statistically significant negative impact of real interest rate on aggregate demand for all countries. Recently, Hafer and Jones (2008) found that for six countries (Canada, France, Germany, Japan, the UK and the USA) money, independently of the real rate of interest, exerts a significant impact on the Gross Domestic Product (GDP) gap. By examining the relative role of the real short-term interest rate and real money in predicting future GDP, they found that real money is the more significant policy measure.

The IS puzzle

The empirical failure of the NK-IS curve has created a puzzle, the so called IS puzzle (Nelson, 2001, 2002). Nelson (2001) provided three explanations for this puzzle: (1) simultaneity bias arising from FL aspect of monetary policy; (2) mis-specification caused by the omission of FL elements and (3) misspecification due to the omission of other variables in the IS equation. The first point implies that any attempt to estimate a structural IS curve could be questioned and that the analysis of monetary transmission should focus on the effect of the exogenous or unsystematic component of monetary policy. Partly due to this criticism, a number of studies have used the Vector Autoregressive (VAR) approach to estimate the effect of monetary policy.[2] However, as suggested by Goodhart and Hofmann (2005), the VAR approach provides evidence only for the effect of monetary policy shock which accounts for a negligible share of overall interest rate movements, while nothing is learnt about the effects of systematic monetary policy measures. The latter two explanations imply that the IS puzzle can be solved by choosing an alternative specification of the IS curve. Nelson (2001) argued that omitting FL elements in the empirical IS curve may also produce downward-biased interest rate elasticity. The third point is of our main interest, i.e. other variables besides the short-term real interest rate may influence the aggregate demand.[3]

In extending the IS curve, Goodhart and Hofmann (2005) have utilized the following variables: government spending to GDP ratio, real effective exchange rate, changes in real share price index, changes in real base money, changes in real broad money and the US output gap. The government spending is an important component of the aggregate demand and hence it

[1] These countries are Canada, France, Germany, Italy, Japan, the UK and the USA.
[2] For more details, see Watson (1994) and Stock and Watson (2001).
[3] If other variables besides real interest rate affect the aggregate demand, then the estimated interest rate elasticity in the standard IS curve specification will be biased. For an explanation of this point, see di Giovanni *et al.* (2009).

could play an important role in explaining the output gap. Nelson (2002) reports evidence that real base monetary growth has a significant positive effect on the output gap for the UK and the USA. In open economy extensions of the NK-IS curve (see, e.g. Ball, 1998; Svensson, 2000), the exchange rate appears to be an additional determinant. Further, share prices and broad monetary aggregates may also influence the aggregate demand via wealth effects, for example a change in wealth, caused by a change in asset prices or broad money, induces consumers to change their consumption plans. The US output gap has implications on domestic exports and hence could also influence the aggregate demand.

In our view it is vital to consider the economic significance of the included variables in the IS curve. The considered variables in Goodhart and Hofmann (2005), Nelson (2002), Ball (1998) and Svensson (2000) contribute to the fit and performance of the IS equation. To this end, extending the baseline NK-IS curve may solve the IS puzzle and perhaps the model could be reliably used by policy makers.

III. Data and Specifications

Data

Our sample includes quarterly data for the period 1984Q1–2010Q3. Two measures of output gap are constructed, namely *GAP1* and *GAP2*. *GAP1* is constructed using the unobserved components approach of Harvey (1989, 2011). Harvey's output gap decomposition is based upon the hypothesis that trend and cycle have a separate dynamic structure and therefore the shocks are uncorrelated in this model (Harvey, 2011, p. 8). The value added of this approach is that it can deal with structural breaks. *GAP2* is constructed using a quadratic trend for potential output in which output is assumed to have a quadratic function in time (Ross and Ubide, 2001). This could capture the nonlinear components of the time series.

Other data include inflation rate (π = annualized rate of change of GDP deflator), quarterly average of monthly cash rate (i), oil price (Oil_{price}), total government expenditure to GDP ratio (g), real effective exchange rate (rex), the US output gap (y^{US}), growth in real base money (Δm), growth in real broad money (Δm^b) and growth in real share prices (Δsp). All these data are seasonally adjusted whenever appropriate. Table A1 in the Appendix provides details on the definitions and sources of the data, while Table 1 presents the key descriptive statistics for all variables.

Table 1. Descriptive statistics 1984Q1–2010Q3

Variable	Mean	SD	Min	Max
GAP1	0.001	0.012	−0.026	0.035
GAP2	−0.010	0.029	−0.069	0.040
i	8.085	4.331	3.000	18.257
π	3.677	3.549	−7.473	14.015
Oil_{price}	−0.006	0.195	−0.568	0.527
g	0.350	0.078	0.211	0.540
rex	93.015	10.587	76.487	119.740
y^{US}	3.062	0.119	2.877	3.345
Δm	6.408	5.453	−14.325	21.873
Δm^b	−0.881	6.347	−17.536	17.517
Δsp	5.448	17.488	−45.267	67.454

Note: Min = minimum value and Max = maximum value.

Specification

We follow Goodhart and Hofmann (2005) (see also Fuhrer and Rudebusch, 2004) and specify a hybrid version of the *FL IS* curve as

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \gamma E_t y_{t+1} + \beta \underbrace{(i_t - E_t \pi_{t+1})}_{\equiv R_t} + \varphi x_t + \varepsilon_t \quad (2)$$

where y_t = output gap (*GAP1* or *GAP2*), i_t = nominal interest rate, $E_t\pi_{t+1}$ = expected inflation in the next period, and x_t = a vector of other variables that can influence aggregate demand.[4] The typical x variables we include are Oil_{price}, g, rex, Δsp, Δm, Δm^b and y^{US}.

Further, Equation 2 includes forward looking output expectations to avoid downward biased interest rate elasticity (Nelson, 2001). Following Rudebusch and Svensson (1999), Rudebusch (2002) and Goodhart and Hofmann (2005), our specification for the *BL* model is as follows:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta \underbrace{(i_{t-1} - \pi_{t-1})}_{\equiv R_{t-1}} + \varphi x_{t-1} + \varepsilon_t \quad (3)$$

To avoid the multicollinearity problem in Equations 2 and 3, we first estimate the fully specified model and then progressively eliminate the least insignificant variables until all the retained variables are statistically significant at the conventional levels.[5] However, the main variable of interest – i.e. $(i_t - E_t\pi_{t+1})$ in Equation 2 and $(i_{t-1} - \pi_{t-1})$ in Equation 3 is always retained.

Equations 2 and 3 impose the restriction that it is real interest rate (R), which is crucial in the IS curve. Theoretically, this is pragmatic. The 'modern' view of macroeconomics (Fair, 2002) implies that an increase in the nominal interest rate is expected to discourage investment and consumption spending, while an increase in inflation expectations (nominal interest rates held fixed) lead to an increase in aggregate demand because of a decrease in the real interest rate.

In Equations 2 and 3 the nominal interest rate and inflation are constrained to have the same coefficient; that is,

[4] See Goodhart and Hofmann (2005) and the previous section for an explanation of additional variables that could be used in IS curve estimations.

[5] There are other ways to identify and address multicollinearity. According to Koop (2009), looking at a correlation matrix for explanatory variables can often be helpful in revealing the extent and source of multicollinearity problem. Correlations higher than 0.8 are problematic. Gujarati (2011) estimated the auxiliary regressions for independent variables to verify collinearity in the variables. For each auxiliary regression, it is important to check whether the R^2 is higher than R^2 of the original model. Kumar *et al.* (2012) performed sub-sample estimations to verify the stability of the coefficients.

Table 2. Estimates of the baseline backward looking model 1984Q1–2010Q3

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta \underbrace{(i_{t-1} - \pi_{t-1})}_{\equiv R_{t-1}} + \varepsilon_t$$
(Constraint version)
$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta_1 i_{t-1} + \beta_2 \pi_{t-1} + \varepsilon_t$$
(Unconstraint version)

	Constraint version		Unconstraint version	
	(1) *GAP1*	(2) *GAP2*	(3) *GAP1*	(4) *GAP2*
α_0	0.098 [1.118]	0.190 [2.071]**	−0.018 [0.129]	0.238 [0.728]
α_1	0.848 [17.311]***	0.942 [9.761]***	0.828 [15.824]***	0.943 [1.142]
α_2	–	–	–	–
β	−0.017 [1.166]	−0.045 [1.115]	–	–
β_1	–	–	−0.009 [0.549]	−0.048 [1.259]
β_2	–	–	0.031 [1.606]	0.038 [1.786]*
$\bar{R}^2$	0.737	0.749	0.745	0.719
LM(1)	0.620	0.369	0.524	0.232
LM(4)	0.773	0.400	0.425	0.695
JB	0.116	0.370	0.542	0.437
BPG	0.182	0.246	0.112	0.205

Notes: The absolute *t*-statistics are reported in []. *LM(1)* and *LM(4)* are Lagrange Multiplier tests for first and fourth order serial correlations of the residuals, respectively. *JB* is the Jarque–Bera normality test of residuals. *BPG* is the Breusch–Pagan–Godfrey heteroscedasticity test. *p*-values are reported for *LM(1), LM(4), JB* and *BPG* tests. OLS is used to estimate all equations.
***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

$\beta(i_t - E_t\pi_{t+1}) \equiv \beta_1 i_t + \beta_2 E_t \pi_{t+1}$ with $|\beta_1| = |\beta_2|$. As stated earlier, according to the 'modern' view, it is expected that $\beta_1 < 0$ and $\beta_2 > 0$. However, this restriction is strong and other effects of inflation are also possible (i.e. $\beta_2 < 0$). For example, Davidson *et al.* (1978) found a negative impact of inflation on consumption expenditures. Perhaps this could be interpreted as the effect of price changes on the real balances and in such cases β_2 will be negative. Since there exists alternative explanations on the impact of inflation on output, we tend to estimate the IS curve with and without the constraint on the real rate of interest. We then estimate the following 'unconstraint' versions of Equations 2 and 3:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \gamma E_t y_{t+1} + \beta_1 i_t + \beta_2 E_t \pi_{t+1} + \varphi x_t + \varepsilon_t \tag{2.1}$$

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta_1 i_{t-1} + \beta_2 \pi_{t-1} + \varphi x_{t-1} + \varepsilon_t \tag{3.1}$$

where $\beta_1 < 0$ and β_2 could be positive or negative depending on which effect prevails (i.e. positive effect of inflationary expectations or the real balances effect).

IV. Empirical Results

Baseline backward looking IS curve

We start with the estimates of the baseline BL version of the IS curve.[6] The Ordinary Least Squares (OLS) results for the BL model are presented in Table 2. Columns (1) and (2) present estimates for the constraint version, where it is assumed that the coefficients of i_{t-1} and π_{t-1} are equal but opposite in sign. In columns (3) and (4), we relax this assumption to estimate the unconstraint version. The two measures of output gap viz. *GAP1* and *GAP2* are used in both cases. Due to the multicollinearity problem, y_{t-2} is excluded from all equations.

While all the estimated coefficients have expected signs, neither the estimates of real interest rate (constraint equation in columns (1) and (2)) nor the estimates of nominal interest and inflation rates (unconstraint equation in columns (3) and (4)) are statistically significant at the 5% level. The lagged one-period inflation rate is statistically significant at only 10% level in column (4). Further, the lagged one-period output gap is statistically significant at the 1% level in all cases, except in column (4). The diagnostic test results show no issues of serial correlation, normality and heteroscedasticity. Overall, these results imply that monetary policy does not have a significant link to the real economic activity.

Forward looking IS curve

The baseline BL model we estimated in the preceding subsection may not be structural and therefore we estimate a hybrid FL model as given in Equations 2 and 2.1. The GMM estimates are displayed in Table 3. Hansen's (1982) *J*-test indicates that our selected instruments ($y_{t-1}, y_{t-2}, R_{t-1}, R_{t-2}, oil_{pricet-1}, oil_{pricet-2}$ and intercept) are valid. Columns (1) and (2) present estimates for the constraint version.

[6] The BL model is usually estimated in practice although it is not consistent with the NK-IS curve of most Dynamic Stochastic General Equilibrium (DSGE) models (Hafer and Jones, 2008; Stracca, 2010).

Table 3. Estimates for forward looking model 1984Q1–2010Q3

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \gamma E_t y_{t+1} + \beta \underbrace{(i_t - E_t \pi_{t+1})}_{\equiv R_t} + \varphi x_t + \varepsilon_t$$

(Constraint version)

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \gamma E_t y_{t+1} + \beta_1 i_t + \beta_2 E_t \pi_{t+1} + \varphi x_t + \varepsilon_t$$

(Unconstraint version)

	Constraint version		Unconstraint version	
	(1) *GAP1*	(2) *GAP2*	(3) *GAP1*	(4) *GAP2*
α_0	0.091 [1.454]	0.193 [1.623]	−0.050 [0.228]	0.128 [0.727]
α_1	0.600 [8.332]***	0.600 [6.421]***	0.575 [5.522]***	0.600 [5.735]***
α_2	–	–	–	–
γ	0.480 [5.530]***	0.369 [3.267]***	0.361 [2.270]**	0.363 [2.732]**
β	−0.019 [1.523]	−0.048 [1.711]*	–	–
β_1	–	–	−0.023 [1.171]	−0.048 [1.464]
β_2	–	–	0.070 [1.076]	0.077 [1.050]
φ	–	–	–	–
$\bar{R}^2$	0.834	0.873	0.842	0.872
JB	0.920	0.874	0.889	0.854
J-test	0.529	0.829	0.833	0.564

Notes: The Newey–West adjusted *t*-statistics for serial correlation and heteroscedasticity are reported in []. Instruments are y_{t-1}, y_{t-2}, R_{t-1}, R_{t-2}, $oil_{pricet-1}$, $oil_{pricet-2}$, plus intercept. *J*-test is the Hansen test for instrument validity and rejection implies the instruments are valid. *JB* is the Jarque–Bera normality test of residuals. *p*-values are reported for *J* and *JB* tests. oil_{pricet} is the cyclical component of log oil price obtained by unobserved components approach.
***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

The unconstraint equation estimations are given in columns (3) and (4). Both *GAP1* and *GAP2* are used in the constraint and unconstraint equations but the second lag of respective output gap (y_{t-2}) was statistically insignificant in all cases.

The results show that all the estimates have expected signs and the estimates of the lagged (α_1) and lead (γ) output gaps are statistically significant at the 5% level. However, the constraint coefficient of the real rate of interest (β) is significant at only 10% level in column (2) when this equation is estimated with *GAP2*. The coefficients of nominal interest rate (β_1) and expected inflation rate (β_2) in the unconstraint versions are statistically insignificant at the conventional levels. Moreover, we also utilized the Full Information Maximum Likelihood (FIML) to estimate the FL model; these results are not reported for brevity. The results reveal that real interest rate (nominal interest and expected inflation rates) in the constraint (unconstraint) equations with respect to *GAP1* and *GAP2* are statistically insignificant at the conventional levels. In all the above equations, the estimates of additional x variables (Oil_{price}, g, rex, y^{US}, Δm, Δm^b and Δsp) were statistically insignificant and therefore were excluded to attain the parsimonious models. Results indicate that the baseline and extended versions of FL IS curve are identical; implying that monetary policy is ineffective in steering aggregate demand.

Extended backward looking IS curve

The results attained in the preceding two sub-sections imply that there exists the IS puzzle for Australia. Extending the FL model did not yield any plausible results, therefore we provide an extension into the BL model by including the additional terms such as those described in the data section, in particular, oil price, total government expenditure to GDP ratio, real effective exchange rate, US output gap, growth in real base money, growth in real broad money and growth in real share prices. Table 4 present OLS estimates for the extended IS curve.

The constraint (unconstraint) estimates are given in columns (1) and (2) (3 and 4), respectively. The additional variables that have statistically significant impacts on output gap are one-period lagged growth in base money, broad money and real share prices.[7] These variables have a positive impact on the output gap and this result is not unexpected. In columns (1) to (4), all coefficients have the expected signs and the lagged one-period output gap estimates (α_1) are statistically significant at the 1% level. The constraint coefficient of the real rate of interest (β) is statistically insignificant in column (1) with *GAP1*, but is significant at the 5% level in column (2) when this equation is estimated with *GAP2*. The coefficients of the nominal rate of interest (β_1) and inflation rate (β_2) have expected signs; however, they are statistically significant at the conventional levels only in column (4). Further, their magnitudes in absolute value (in column 4) are close to theoretically expected ones and the application of Wald's test (p-value = 0.27) confirmed this restriction. Thus, estimates of the extended IS curve with *GAP2* in both its constraint and unconstraint versions have produced consistent results and therefore these are our preferred estimates. The diagnostic tests are also reasonable (see the last row in Table 4).

[7] We did attempt to use these variables in natural logarithms but all were statistically insignificant at the conventional levels.

Table 4. Estimates for extended backward looking model 1984Q1–2010Q3

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta \underbrace{(i_{t-1} - \pi_{t-1})}_{\equiv R_{t-1}} + \varphi_{\Delta m}\Delta m_{t-1} + \varphi_{\Delta m^b}\Delta m^b_{t-1} + \varphi_{\Delta sp}\Delta sp_{t-1} + \varepsilon_t$$

(Constraint version)

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta_1 i_{t-1} + \beta_2 \pi_{t-1} + \varphi_{\Delta m}\Delta m_{t-1} + \varphi_{\Delta m^b}\Delta m^b_{t-1} + \varphi_{\Delta sp}\Delta sp_{t-1} + \varepsilon_t$$

(Unconstraint version)

	Constraint version		Unconstraint version	
	(1) *GAP1*	(2) *GAP2*	(3) *GAP1*	(4) *GAP2*
α_0	−0.252 [1.874]*	−0.158 [1.141]	−0.360 [2.062]**	−0.046 [0.283]
α_1	0.837 [13.620]***	0.934 [11.413]***	0.815 [12.734]***	0.912 [11.937]***
α_2	–	–	–	–
β	−0.019 [1.497]	−0.047 [2.809]**	–	–
β_1	–	–	−0.012 [0.839]	−0.054 [3.038]***
β_2	–	–	0.032 [1.553]	0.033 [1.768]*
$\varphi_{\Delta m}$	0.055 [2.816]**	0.054 [2.641]**	0.057 [2.812]**	0.055 [2.722]**
$\varphi_{\Delta m^b}$	0.044 [2.090]**	0.045 [1.924]*	0.042 [2.039]**	0.051 [2.184]**
$\varphi_{\Delta sp}$	0.007 [2.114]**	0.009 [2.510]**	0.006 [1.702]*	0.010 [2.701]**
$\bar{R}^2$	0.763	0.955	0.763	0.955
LM(1)	0.610	0.819	0.526	0.870
LM(4)	0.521	0.480	0.468	0.511
JB	0.938	0.612	0.644	0.830
BPG	0.080	0.345	0.161	0.267

Notes: The absolute *t*-statistics are reported in [ ]. *LM(1)* and *LM(4)* are Lagrange multiplier tests for first and fourth order serial correlations of the residuals, respectively. *JB* is the Jarque–Bera normality test of residuals. *BPG* is the Breusch–Pagan–Godfrey heteroscedasticity test. *p*-values are reported for *LM(1)*, *LM(4)*, *JB* and *BPG* tests.
***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

The plots of actual and fitted values for columns (2) and (4) are more than satisfactory (Figs 1 and 2). These results imply that the IS puzzle unambiguously vanished in the extended IS curve especially when the output gap measure is *GAP2*, and hence monetary policy seems to be a relevant guide for aggregate demand.

Robustness

Since the extended IS curve yields most significant estimates in the constraint and unconstraint versions with *GAP2*, it is therefore important to assess how robust are these results. In the first instance, we subject our preferred extended IS equations (columns (2) and (4)) from Table 4 to stability tests. To this end, we applied the Quandt (1960) and Andrews (1993) structural break tests. The Quandt–Andrews test is a modified version of Chow test that allows for dominant endogenous breakpoints in the sample for an estimated equation. The maximum (max *F*), average (ave *F*) and exponential (exp *F*) test statistics are used in this test. The null hypothesis of no break is rejected if these test statistics are large, however Hansen (1997) derives an algorithm to compute approximate asymptotic *p*-values of these tests. Table 5 reports the Quandt–Andrews breakpoint results.

The results reveal that there exists a structural break during the 1990Q2, 1993Q3 and 1996Q1. For the constraint model with *GAP2*, all test statistics reject the null of no break at the 5% level except the exp and ave LR *F*-statistics. The maximum statistics indicate breaks at 1990Q2 and 1996Q1. In the case of unconstraint model with *GAP2*, only the max LR and exp Wald *F*-statistics reject the null of no break and suggests a break at 1990Q2. Further, a break at 1993Q3 is depicted by the max Wald *F*-statistics but it is statistically insignificant at the conventional levels. The detected break dates are realistic in regard to the economic incidences which Australia experienced in the last decade. During the period 1990–1991, Australia experienced a severe recession that caused shrinkage in the private investment, employment and output growth rate. The year 1996 signifies the introduction of inflation-targeting regime in the performance of monetary policy. The inflation targeting was preliminarily adopted by the Reserve Bank of Australia in 1993, however it was not formally endorsed until 1996.

To assess robustness of the estimates in our extended IS curve, we estimated five variants of the (un)constraint models with *GAP2*, namely (i) sample prior to the recession period 1984Q1–1990Q1, (ii) sample after recession 1992Q1–2010Q3, (iii) sample prior to the inflation-targeting regime 1984Q1–1995Q4, (iv) sample after the inflation- targeting regime 1996Q1–2010Q3 and (v) excluding the global financial crisis of 2007–2010, by ending the sample period in 2006Q4.[8] These equations are estimated using the OLS method and the results

[8] Since our sample starts from 1984, it would be improbable to account for some major changes in the monetary policy that took place in the mid to late 1980s, for example, financial liberalization, the Australian dollar float, and formation of the Australian Stock Exchange Limited. Moreover, the 1997–1998 Asian financial crisis had very minimal impacts on the output growth for Australia, so it is also excluded.

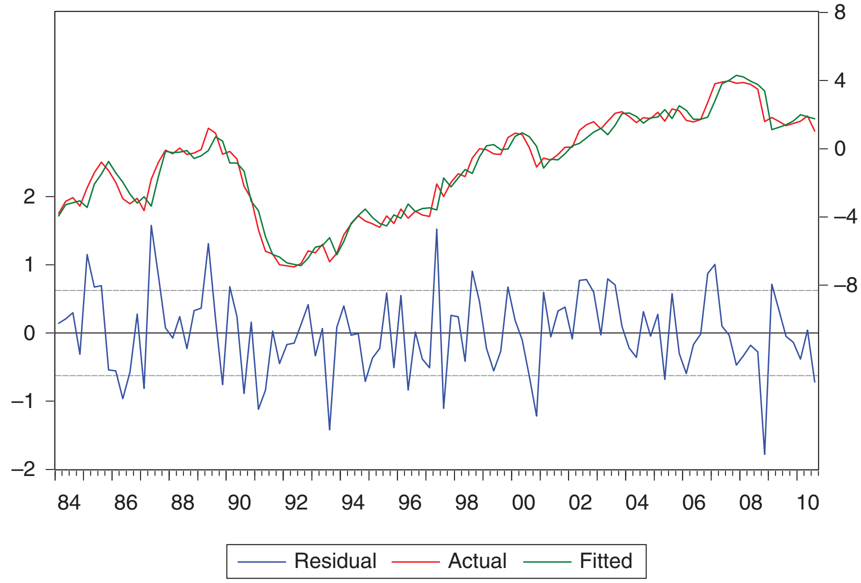

Fig. 1. Actual and fitted values for constraint equation with *GAP2*

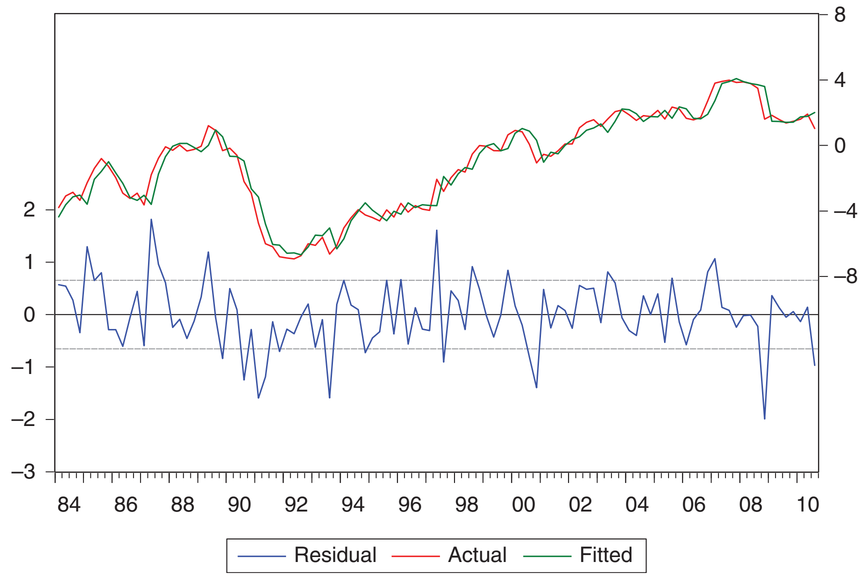

Fig. 2. Actual and fitted values for unconstraint equation with *GAP2*

are reported in Table 6. Overall, the results are found to be pretty robust in the different variants considered. In particular, it is notable that the coefficients of real interest rate in constraint model have expected sign and are statistically significant at the conventional levels. Similarly, the nominal interest and inflation rates have also the expected signs and are significant at the conventional levels except the sample 1996Q1–2010Q3 in which inflation is insignificant. Further, the additional variables (growth in real base money, real broad money and real share prices) have the expected signs and mostly significant at the conventional levels. These results are consistent with our original extended IS curve estimates (see columns (2) and (4) in Table 4). On the basis of these results, we argue that the IS curve is predominantly BL in an extended fashion both before and after the recession (1990–1991). The inflation targeting regime introduced during the 1996 and the global financial crisis of 2007–2010 matters little for the degree of extended BL model.

V. Conclusions

This article has evaluated the BL and FL specifications of the NK-IS curve for Australia over the period 1984Q1–2010Q3. In doing so, we have utilized two measures of output gap viz. *GAP1* and *GAP2*. *GAP1* is constructed using the unobserved components approach of Harvey (1989, 2011), while *GAP2* is computed using a quadratic trend (Ross and Ubide, 2001).

Table 5. Quandt–Andrews structural break tests 1984Q1–2010Q3

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta \underbrace{(i_{t-1} - \pi_{t-1})}_{\equiv R_{t-1}} + \varphi_{\Delta m}\Delta m_{t-1} + \varphi_{\Delta m^b}\Delta m^b_{t-1} + \varphi_{\Delta sp}\Delta sp_{t-1} + \varepsilon_t$$

(Constraint version)

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta_1 i_{t-1} + \beta_2 \pi_{t-1} + \varphi_{\Delta m}\Delta m_{t-1} + \varphi_{\Delta m^b}\Delta m^b_{t-1} + \varphi_{\Delta sp}\Delta sp_{t-1} + \varepsilon_t$$

(Unconstraint version)

	Constraint version with *GAP2*			Unconstraint version with *GAP2*		
Test statistics	Break date	Value	Probability	Break date	Value	Probability
Max LR *F*-statistic	1990Q2	14.217	0.026**	1990Q2	18.029	0.000***
Max Wald *F*-statistic	1996Q1	69.010	0.000***	1993Q3	8.298	0.374
Exp LR *F*-statistic	–	1.388	0.961	–	1.172	1.000
Exp Wald *F*-statistic	–	28.045	0.000***	–	145.941	0.000***
Ave LR *F*-statistic	–	2.552	0.925	–	2.246	0.999
Ave Wald *F*-statistic	–	39.569	0.000***	–	2.367	0.845

Notes: The (un)constraint model with *GAP2* are basically estimates from columns (2) and (4) from Table 4, respectively.
*** and ** denote significance at the 1 and 5% levels, respectively.

Table 6. Robustness

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta \underbrace{(i_{t-1} - \pi_{t-1})}_{\equiv R_{t-1}} + \varphi_{\Delta m}\Delta m_{t-1} + \varphi_{\Delta m^b}\Delta m^b_{t-1} + \varphi_{\Delta sp}\Delta sp_{t-1} + \varepsilon_t$$

(Constraint version)

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \beta_1 i_{t-1} + \beta_2 \pi_{t-1} + \varphi_{\Delta m}\Delta m_{t-1} + \varphi_{\Delta m^b}\Delta m^b_{t-1} + \varphi_{\Delta sp}\Delta sp_{t-1} + \varepsilon_t$$

(Unconstraint version)

	Constraint version with *GAP2*					Unconstraint version with *GAP2*				
	Recession		Inflation targeting regime		GFC	Recession		Inflation targeting regime		GFC
	1984Q1–1990Q1	1992Q1–2010Q3	1984Q1–1995Q4	1996Q1–2010Q3	1984Q1–2006Q4	1984Q1–1990Q1	1992Q1–2010Q3	1984Q1–1995Q4	1996Q1–2010Q3	1984Q1–2006Q4
α_0	0.359	−0.140	−0.321	0.086	0.146	−0.685	0.579	−0.897	0.638	−0.039
	(0.587)	(0.970)	(0.632)	(0.422)	(0.594)	(0.493)	(1.387)	(0.990)	(1.437)	(0.214)
α_1	0.772	0.948	0.940	0.932	0.883	0.705	0.939	0.889	0.907	0.929
	(8.032)***	(26.488)***	(13.427)***	(20.505)***	(14.508)***	(5.629)***	(23.044)***	(9.165)***	(18.615)***	(26.313)***
α_2	–	–	–	–	–	–	–	–	–	–
β	−0.024	−0.049	−0.050	−0.031	−0.086	–	–	–	–	–
	(1.730)*	(2.194)***	(1.953)**	(1.644)*	(1.899)*					
β_1	–	–	–	–	–	−0.033	−0.017	−0.034	−0.025	−0.076
						(2.449)**	(1.729)*	(1.726)*	(1.723)*	(3.782)***
β_2	–	–	–	–	–	0.046	0.016	0.079	0.013	0.074
						(1.784)*	(1.890)*	(2.001)**	(1.481)	(2.776)***
$\varphi_{\Delta m}$	0.024	0.047	0.088	0.007	0.057	0.019	0.017	0.093	0.020	0.065
	(1.462)	(2.131)**	(2.046)**	(1.871)*	(2.032)**	(1.826)*	(1.550)	(2.129)**	(1.719)*	(2.624)***
$\varphi_{\Delta m^b}$	0.136	0.044	0.077	0.002	0.063	0.146	0.026	0.075	0.020	0.067
	(1.731)*	(1.641)*	(1.693)*	(1.456)	(1.811)*	(1.824)*	(1.748)*	(1.590)	(1.678)*	(2.299)**
$\varphi_{\Delta sp}$	0.002	0.010	0.009	0.008	0.011	0.002	0.009	0.007	0.007	0.006
	(1.790)*	(2.070)**	(1.677)*	(1.764)*	(1.989)**	(2.237)**	(1.682)*	(1.707)*	(2.282)**	(1.698)*
..	0.726	0.844	0.801	0.750	0.814	0.805	0.744	0.811	0.742	0.877
LM(1)	0.125	0.684	0.224	0.174	0.142	0.224	0.265	0.850	0.200	0.238
LM(4)	0.443	0.993	0.148	0.583	0.327	0.355	0.423	0.741	0.634	0.640
JB	0.101	0.847	0.071	0.401	0.500	0.123	0.126	0.230	0.541	0.225
BPG	0.129	0.760	0.642	0.655	0.541	0.065	0.238	0.554	0.115	0.124

Notes: *t*-statistics are reported in parentheses. Chow breakpoint test rejects the null of no break at 1996Q1 for unconstraint model with *GAP2*. GFC stands for global financial crisis. All equations are estimated using non-linear least squares. *LM(1)* and *LM(4)* are Lagrange Multiplier tests for first and fourth order serial correlations of the residuals, respectively. *JB* is the Jarque–Bera normality test of residuals. *BPG* is the Breusch–Pagan–Godfrey heteroscedasticity test. *p*-values are reported for *LM(1)*, *LM(4)*, *JB* and *BPG* tests.
***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

The validity of the BL and FL models is investigated by imposing the constraint on real rate of interest and as well as when the constraint is relaxed. The typical NK-IS curve utilizes this constraint, however the unconstraint version could be justified along the lines of Davidson *et al.* (1978), who give a fairly different explanation for the relationship between interest rates and output.

We first estimated the baseline BL and FL models and found statistically insignificant impact of real interest rate on *GAP1* and *GAP2*. The unconstraint versions also did not produce any significant estimates for the nominal interest and inflation rate elasticities. Extending the FL model produced estimates identical to the baseline FL model, therefore in the second stage we provide an extension into the BL model by including additional terms such as oil price, total government expenditure to GDP ratio, real effective exchange rate, US output gap, growth in real base money, growth in real broad money and growth in real share prices. However, only the latter three variables were found to be statistically significant at the conventional levels. The constraint (unconstraint) version with *GAP2* yields plausible estimates for the real interest rate (nominal interest and inflation rates) elasticity.

To assess robustness of the estimates in our extended BL IS curve, we have applied the Quandt–Andrews structural breakpoint tests. The results revealed that there exists a dominant structural break at 1990Q2 and 1996Q1. Both the break dates are expected and highlights the recession which hit the Australian economy during the period 1990–1991 and formal endorsement of the inflation targeting regime in 1996. Consequently, considering these break dates we developed sub-samples to investigate if the extended IS curve is affected due to these structural changes. In addition, we develop a sample which excludes the global financial crisis period 2007–2010. In all cases, we found that the results are consistent with our original extended IS curve results.

Finally, our findings can be reliably used by policy makers. The baseline estimates of the BL and FL model imply that monetary policy is ineffective in steering aggregate demand. However, when the BL IS curve is extended with other variables such as the growth in real base money, real broad money and real share prices, we found that the real interest rate (nominal interest and inflation rates) in the constraint (unconstraint) equations are statistically significant at the conventional levels. To this end, monetary policy has significant real effects in the economy. Moreover, our findings suggest that inflation targeting regime did not contribute to any overwhelming effect on output. The inflation targets are achieved via adjusting the market-based instruments like the short-term interest rates, however this monetary policy process did not create any considerable changes in the aggregate demand. Our results also imply that it is vital to integrate other variables (e.g. growth in real base money, real broad money and real share prices) in the baseline DSGE models used for monetary policy analysis.

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Appendix

Table A1. Definitions and data source: 1984Q1–2010Q3

Variable	Definition	Source
π	Annualized rate of change of GDP deflator: $(\ln p_t - \ln p_{t-1}) \times 400$.	Reserve Bank of Australia (RBA)
y	Output gap obtained with two techniques. *GAP1* is generated by univariate trend-cycle decomposition according to Harvey (1989, 2011). *GAP2* is generated by a quadratic trend (see Ross and Ubide, 2001).	RBA and authors' computations.
i	Quarterly average of the monthly cash rate.	RBA
$Oil_{price}, g, rex, y^{US}$, $\Delta m, \Delta m^b$ and Δsp	Oil_{price} = cyclical component of natural log of oil price (West Texas Intermediate (US\$/BBL)) obtained by univariate trend-cycle decomposition. g = ratio of national real general government final consumption expenditure to real GDP. rex = real effective exchange rate. y^{US} = US output gap (constructed same as y) Δm = year-over-year % change in real base money. Δm^b = year-over-year % change in real broad money. Δsp = year-over-year % change in real share price. Monetary base (broad and narrow) and share prices are deflated by GDP deflator.	RBA, Federal Reserve Economic Database (FED), and authors' computations.