University of Victoria
Department of Economics

Econometrics Working Paper EWP0704

ISSN 1485-6441

AN UPDATED ASSESSMENT OF THE LUCAS SUPPLY CURVE

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June 2007

Abstract

Previous empirical work that assessed the theoretical results of Lucas (1972) is updated by incorporating recent data, utilizing advancements in time series methods and bootstrapping results. Specifically, the two-stage method of Ball *et al.* (1988) and others is used, but the functional form used in the first stage is such that the data are stationary. In comparison to using the traditional first stage functional form, coefficient estimates are smaller in absolute value, but still significant.

Keywords: Inflation; Output inflation; Output; Phillips curves

JEL Classifications: E12; E31

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An Updated Assessment of the Lucas Supply Curve

1 Introduction

Lucas (1972) introduced a theoretical aggregate supply curve with far reaching impacts. The importance of this result made it the subject of extensive empirical assessment in the years following its publication. The methodological norm in that literature is a two-stage method first used by Lucas (1973) and more recently by Ball *et al.* (1988). In the first stage log real GDP, $y_{i,t}$, is regressed on itself lagged and the change in log nominal GDP, $\Delta x_{i,t}$, for each country i separately. The coefficient on the change in log nominal GDP, τ_i, is a measure of real responsiveness to nominal changes. In the second stage a cross section regression of τ_i on $\sigma_{\Delta x_i}$ (the standard deviation of $\Delta x_{i,t}$) is fitted. The theory of Lucas (1972) dictates that the coefficient on $\sigma_{\Delta x_i}$ should be significantly negative as real responsiveness decreases in nominal volatitlity. Lucas (1973) concludes that this is indeed the case.

Ball *et al.* (1988) expand upon the above method slightly by including a trend term in the first stage. Additionally, they argue that in theory τ should not fall below zero, implying that the relationship should be non-linear. To explore this they fit two second-stage regressions, one that is linear in $\sigma_{\Delta x_i}$, and another that is quadratic. Using their full sample, they find that the coefficients are significant in both cases.

Since the above mentioned work was published it has become a well known result in the time series literature that regressions involving non-stationary and non-cointegrated data are spurious (Granger and Newbold, 1974). The above mentioned work is then spurious since y is non-stationary and not cointegrated with Δx_i.[1] Other work in this area since Ball *et al.* (1988) also falls subject to this problem (Giorgioni, 2001; Hess

[1] The hypothesis that y has a unit root could not be rejected at the 5% significance level for any country in the sample based on an augmented Dickey-Fuller (ADF) test. It could be rejected at the 10% significance level only for Denmark, the Netherlands and the United Kingdom. The null hypothesis that the residuals from regression of y on Δx_i have a unit could not be rejected at the 10% significance level for any country.

and Shin, 1999; Lammertsma *et al.*, 1997; Katsimbris *et al.*, 1996; Christensen and Paldam, 1990).

The traditional two-stage analysis is repeated in this paper, but using a first-stage regression in which the data are in a stationary form. To ensure the results are accurate, second-stage coefficient confidence intervals and p-values are bootstrapped. For the sake of comparison, the analysis is also carried out using the first-stage specification of Ball *et al.* (1988). The results show that second-stage coefficient estimates are reduced when non-stationarity is accounted for, but the significance of the results is largely unaffected.

2 Method

Annual data from 47 countries spanning the years 1960 to 1999 retrieved from the United Nations Statistical Database are included in the sample.[2] Observations are all in U.S. dollars with real GDP having base year 2000. ADF tests indicated that the logarithms of all series in the sample are $I(1)$. As real and nominal GDP diverge there are no cointegrating relationships.

In the first-stage of the analysis the following equation was estimated for each country i:

$$\Delta y_{i,t} = \alpha_i + \eta_i \Delta y_{i,t-1} + \tau_i \Delta x_{i,t} + \upsilon_{i,t}. \tag{1}$$

It can be shown that the interpretation of τ_i in this equation is equivalent to its interpretation in previous studies. In the second stage of the analysis two regressions were fit, the first being τ_i on $\sigma_{\Delta x_i}$, and the second including $\sigma^2_{\Delta x_i}$ as an additional regressor. Confidence intervals and p-values for the estimated coefficients in the second stage were bootstrapped using 10,000 repetitions. The method was repeated using the first-stage specification of Ball *et al.* (1988).

[2] Data matrices Matrices 22918 and 22919. Argentina(62-99), Australia, Austria, Belgium, Brazil, Canada, Chile, Columbia, Costa Rica, Denmark, Dominican Republic, Ecuador, El Salvador, Finland, France, Greece, Guatemala, Hong Kong, Iceland, India, Ireland, Israel, Italy, Jamaica, Japan, South Korea, Kuwait(63-99), Luxembourg, Mexico, Denmark, Nicaragua, Norway, Netherlands, New Zealand, Pakistan, Panama, Peru, Philippines, Puerto Rico, South Africa, Singapore, Spain, Sweden Switzerland, Tunisia(60-98), United Kingdom, United States, Venezuela.

3 Results and Discussion

A scatter plot of τ_i vs. $\sigma_{\Delta x_i}$ looks very similar to figure 6.1 of Romer (2006, p.238) or figure 2 of Ball *et al.* (1988). Table 1 gives the results of the stage two regressions.

None of the 90% confidence intervals cover zero, implying that one-sided tests at the 5% significance level would reject a null hypothesis that the coefficient is zero for any regressor. The quadratic model has a better fit independent of which first-stage model is used.

Under the stationary first-stage model all regression coefficients are smaller in absolute value, however, there are limited differences in terms of significance. The only noteworthy difference is that the p-value of the quadratic term coefficient in the stationary model is larger by an order of ten than that of the same coefficient in the Ball *et al.* (1988) model. Bootstrapping the results has its greatest impact in the linear second-stage models. Based on the regression p-values the coefficients are significant at a 5% level, whereas based on the bootstrapped p-values they are not.

There is some evidence in favour of a quadratic relationship in the results above. The bootstrapped p-value of the test for joint significance in the stationary quadratic model is smaller than the p-value for the stationary linear model. This in combination with the larger $\overline{R}^2$ favours the quadratic specification.

4 Conclusion

The general conclusion of this paper is that spurious regressions in previous studies did not yield misleading results. Though estimated marginal effects are somewhat weaker, the significance of the coefficient estimates is robust to using a first-stage model in which the data are stationary. Though the results have not been altered in any great manner, future research of this type should, out of principle, use a first-stage regression with data in a stationary form.

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Table 1: Second Stage Regression Results

Regressor	Stat Lin. Model	Stat Quad. Model	BMR Lin. Model	BMR Quad. Model
constant	0.156	0.218	0.199	0.315
$\sigma_{\Delta x_i}$	-0.297 {0.0245} (0.0506) [-0.471,-0.071]	-0.964 {0.0253} (.0184) [-1.629,-0.298]	-0.324 {0.0193} (.0596) [-0.488,-0.063]	-1.476 {0.0023} (.0024) [-2.174,-0.731]
$\sigma^2_{\Delta x_i}$		0.993 {0.0997} (0.0694) [0.088,1.973]		1.354 {0.0119} (0.0062) [0.548,2.174]
$\overline{R}^2$ prob(F)	0.088	0.123 0.0049	0.096	0.200 0.00033

Results corresponding to τ estimated from regression of stationary data are in the first two columns. Results corresponding to τ estimated using the Ball *et al.* (1988) specification are in the last two columns. Dependent variable: τ_i bootstrapped p-values in parentheses; regression p-values in braces; bootstrapped 90% confidence intervals in square brackets; prob(F) is bootstrapped.