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The Effect of Inflation and Real Wages on Productivity: New Evidence from a Panel of G7 Countries

Paresh Kumar Narayan

and

Russell Smyth

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Editorial Team:

For more information on the Discussion Paper Series or contribution please contact:

Associate Professor Paresh Kumar Narayan
Griffith Business School
Department of Accounting, Finance and Economics
Griffith University
PMB 50
Gold Coast Mail Centre 9726
PH: (07) 5552 8056
Fax: (07) 5552 8068

Or

Jo Burling or Julie Carlisle
Griffith Business School
Department of Accounting, Finance and Economics
Griffith University
PMB 50
Gold Coast Mail Centre 9726
PH: (07) 55528994
FAX: (07) 5552 8068

or email:
P.Narayan@griffith.edu.au
J.Burling@griffith.edu.au
J.Carlisle@grifith.edu.au

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Corresponding author

Paresh Kumar Narayan
Griffith Business School
Department of Accounting, Finance and Economics
Gold Coast Campus
Griffith University
PMB 50 Gold Coast MC
Queensland 9726
Australia
Telephone +(617) 5552 8056
Fax +(617) 5552 8068
E-mail: P.Narayan@Griffith.edu.au

Russell Smyth
Professor of Economics
Department of Economics
Faculty of Business and Economics
Monash University
E-Mail: Russell.Smyth@buseco.monash.edu.au.

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ABSTRACT

This paper examines the effect of inflation and real wages on productivity within a panel unit root and panel cointegration framework for the G7 countries over the period 1960 to 2004. The main contribution of the paper is to provide panel long-run estimates of the effect of inflation and real wages on productivity in the G7 countries over this period. The paper finds that for the panel as a whole a 1 per cent increase in real wages generates a 0.6 per cent increase in productivity while the effects of inflation on productivity are statistically insignificant for most of the individual countries and for the panel as a whole.

Keywords: Panel Unit Root; Panel Cointegration; Productivity; Inflation.

JEL Classification: C23; E31; J24.

1. Introduction

Over the last two decades there have been several studies that have examined the relationship between inflation and productivity growth. Studies for various countries include Jarret and Selody (1982), Buck and Fitzroy (1988), De Gregorio (1992), Smyth (1995), Cameron *et al.* (1996), Freeman and Yerger (1998, 2000), Hondroyiannis and Papetrou (1998), Bitros and Panas (2001), Dritsakis (2004), Mahadevan and Asafu-Adjaye (2005) and Tsionas (2003, 2003a). The findings from these studies have been mixed. Some studies have found a negative relationship between inflation and productivity growth (see eg. Buck and Fitzroy, 1988; De Gregorio, 1992; Smyth, 1995). However, other studies have found no significant relationship between the variables (see eg. Cameron *et al.* 1996; Freeman and Yerger, 1997; Hondroyiannis and Papetrou, 1998).

There are several problems that have plagued studies on this topic. First, much early research on inflation and productivity growth assumed the relationship to be unidirectional, running from exogenous productivity growth to inflation (Freeman and Yerger, 2000). Several authors have argued that the correlation between inflation and productivity is 'spurious', resulting from cyclical movements between the two variables (Freeman and Yerger, 1998; Hondroyiannis and Papetrou, 1998; Christopoulos and Tsionas, 2005). As Tsionas (2003a) noted a second problem is that until recently most studies on this topic have failed to first examine the unit root properties of the variables. A third issue is that recently a large number of studies have begun testing long-standing macroeconomic hypotheses using panel unit root and/or panel cointegration tests. To this point, however, there are few such studies examining the relationship between inflation and productivity. Christopoulos and Tsionas (2005) used a panel unit root and panel cointegration framework to examine the relationship between inflation and productivity in 15 European countries over the period 1961 to 1999. Their main findings were that in the long-run there was a negative equilibrium relationship between inflation and productivity growth. Strauss and Wohar (2004) examined the long-run relationship between inflation, productivity and real wages at the industry level for a panel of 459 U.S. manufacturing industries over the period 1956 to 1996 using Granger causality. Their major results were that in the long-run inflation Granger causes productivity, while there was bidirectional Granger causality between productivity and real wages.

Compared with the large literature examining the relationship between inflation and productivity, there are relatively few studies on the inflation-wage nexus. Mehra (1991) examined the relationship between inflation and productivity adjusted wages and found that in the long-run inflation had a positive effect on per-unit labour costs. In more recent studies, Mehra (1993, 2000) reexamined his earlier result and found a bidirectional relationship between these variables in the long-run. There are few studies that have examined the relationship between inflation, productivity and real wages. In addition to the Strauss and Wohar (2004) study discussed above, Hondroyiannis and Papetrou (1997) examined the relationship between inflation, productivity and wages in Greece over the period 1975 to 1992 and found that inflation had a negative effect on productivity, but there was no clear-cut effect of wages on productivity. Other related studies include Wakeford (2004) who examined the relationship between productivity, unemployment and wages in South Africa, Mahadevan and Asafu-Adjaye (2006) who investigated the relationship between inflation, productivity and the money supply in nine Asian countries and Sonmez-Atesoglu and Smithin (2006) who examined the relationship between productivity, real wages and economic growth for the G7 countries from 1960 to 2002.

The objective of this paper is to examine the effect of inflation and real wages on productivity for the G7 countries over the period 1960 to 2004 using recent methodological advances in panel unit root and panel cointegration testing to avoid power distortions in small samples. In particular, for the first time in the literature, we provide long-run panel estimates for the effect of inflation and real wages on productivity in the G7 countries over this period. There are a number of avenues through which an increase in the inflation rate could adversely affect productivity growth (Jarret and Selody, 1982, pp. 361-362; Hondroyiannis and Papetrou, 1997, pp. 235-236). First, inflation may affect labour productivity by causing an inefficient mix of factor inputs. Second, inflation distorts the informational content of price signals and if price signals are distorted, managers may be more likely to choose sub-optimal factor input mixes. Third, increasing uncertainty about inflation can reduce productivity by inducing firms to increase their inventories of unproductive buffer stocks and reduce their expenditure on long-term basic research. Fourth, inflation reduces incentives to work or the ability to do productive work. Fifth, inflation erodes tax reductions for depreciation and raises the rental price of capital which causes a reduction in capital accumulation and, therefore, in labour productivity. In addition to inflation, changes in real wages can also lead to changes in productivity. According to efficiency wage theory, a rise in real wages may induce higher worker productivity by increasing the opportunity cost of job loss. At the macroeconomic level, an increase in real wages will raise the unit cost of labour and thus cause substitution from labour to capital. The substitution from labour to capital could raise the marginal (and hence average) labour productivity (Wakeford, 2004).

The paper is set out as follows. Section II discusses the data. Section III explains the econometric methodology and presents the results. We proceed in three stages. First we establish the stationarity properties of the variables using the panel unit root tests proposed by Breitung (2000), Im *et al.* (2003) and Maddala and Wu (1999). Second, we ascertain whether there is a long-run equilibrium relationship between inflation, productivity and real wages using the panel cointegration test suggested by Pedroni (1997, 1999). Third, we calculate the long-run estimates using panel fully-modified ordinary least squares (FMOLS). Foreshadowing our main results, the Pedroni (1997, 1999) panel cointegration test suggests the existence of a unique cointegration vector when productivity is the endogenous variable. In terms of the long-run estimates we find that for most countries and for the G7 panel as a whole an increase in real wages have a statistically significant positive effect on productivity while for most countries and for the G7 panel as a whole inflation has a statistically insignificant effect on productivity.

2. Data

The study employs data on productivity (proxied by output per hour in the manufacturing sector), real wages (proxied by hourly compensation in the manufacturing sector measured in $US) and the price level (proxied by the consumer price index) for the G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) over the period 1960 to 2004. Data on productivity and wages were obtained from the United States Department of Labour, Bureau of Labour Statistics, downloaded from http://stats.bls.gov/. Data on the price level was obtained from the International Financial Statistics published by the International Monetary Fund.

3. Econometric methodology and empirical results

3.1. Panel unit root test

We started through testing for the presence of a unit root in the three variables using the panel unit root tests proposed by Breitung (2000), Im *et al.* (2003) and Maddala and Wu (1999). Breitung (2000) develops a panel version of the Augmented Dickey-Fuller (ADF) unit root test where appropriate variable transformations are used to correct for cross-sectionally heterogeneous variances that allows for efficient pooled ordinary least squares (OLS) estimation. A limitation of the Breitung (2000) test, however, is that it assumes that all countries converge towards the equilibrium value at the same speed under the alternative hypothesis. The *t*-bar test proposed by Im *et al.* (2003) has the advantage over the Breitung (2000) test that it does not make this assumption and thus is less restrictive. There are two stages in constructing the Im *et al.* (2003) t-bar test statistic. The first step is to calculate the average of the individual ADF t-statistics for each of the countries in the panel. The second step is to calculate the standardized t-bar statistic:

$$\text{t-bar} = \sqrt{N}\left(t_{\alpha} - \kappa_{t}\right) \big/ \sqrt{\nu_{t}} \qquad (1)$$

where N is the size of the panel, t_{α} is the average of the individual ADF t-statistics for each of the countries and κ_t and ν_t are respectively estimates of the mean and variance of each $t_{\alpha i}$. Im *et. al.* (2003) provided Monte Carlo simulations of κ_t and ν_t and tabulate exact critical values for the t-bar statistic for various combinations of N and T.

A potential problem with the t-bar test involves cross-sectional dependence. When there is cross-sectional dependence in the disturbances, the t-bar test is no longer applicable. However, Im *et al* (2003) suggested that in the presence of cross-sectional dependence, the data can be adjusted by subtracting the cross-sectional means and then applying the t-bar statistic to the transformed data. The standardized demeaned t-bar statistic converges to a standard normal in the limit.[1] The existing evidence suggests that the demeaning procedure does dramatically reduce cross-sectional dependence even in instances where the observed data are highly correlated (see eg. Luntiel, 2001; Smyth, 2003).

Maddalla and Wu (1999) criticize the Im *et al.* (2003) test on the basis that in many real world applications, cross correlations are unlikely to take the simple form proposed by Im *et al.* (2003) that can be effectively eliminated by demeaning the data. Maddala and Wu (1999) propose a panel unit root test developed from Fisher (1932). The test essentially combines the p-values of the test statistic for a unit root in each residual cross-sectional unit. The test is non-parametric and has a chi-square distribution with $2N$ degrees of freedom, where N is the number of cross-sectional units or countries. Using the additive property of the chi-squared variable, the following test statistic can be derived:

$$\lambda = -2\sum_{i=1}^{N} log_e \pi_i \qquad (2)$$

Here, π_i is the p-value of the test statistic for unit i. An important advantage of this test is that it can be used regardless of whether the null is one of integration or stationarity.

INSERT TABLE 1

The results for the three panel unit root tests are reported in Table 1. All three tests suggest the same finding. The log-levels of the three variables are found to be non-stationary, while the first difference of the log-levels of the three variables is found to be stationary. This implies that productivity, real wages and CPI are integrated of order one.

3.2. Panel cointegration

On the basis of the panel unit root test results we proceed to testing for cointegration using the panel cointegration test suggested by Pedroni (1997, 1999). The starting point for the Pedroni test is to estimate of the following panel cointegration regression model:

$$\ln Prod_{i,t} = \alpha_i + \beta_i \ln Wage_{i,t} + \phi_i \ln CPI_{i,t} + \varepsilon_{i,t} \qquad (3)$$

for $t = 1,...,T; \quad i = 1,...,N;$ where T refers to the number of observations over time and N refers to the number of countries in the panel. The Pedroni test entails several steps. First, after estimation we store the residuals $\hat{\varepsilon}_{i,t}$. Second, we difference the original data series for each country, and compute the residuals for the differenced regression:

$$\Delta \ln Prod_{i,t} = \beta_i \Delta \ln Wage_{i,t} + \phi_i \Delta \ln CPI_{i,t} + \eta_{i,t}. \qquad (4)$$

Third, we calculate $\hat{L}^2_{11i}$ as the long run variance of $\hat{\eta}_{i,t}$ using any kernel estimator. Fourth, using the residual $\varepsilon_{i,t}$ of the original cointegrating equation, we estimate the appropriate autoregressive model. For the non-parametric statistics, we estimate $\hat{\varepsilon}_{i,t} = \hat{\psi}_i \hat{\varepsilon}_{i,t-1} + \hat{\kappa}_{i,t}$ and use the residuals to compute the long run variance of $\hat{\kappa}_{i,t}$, denoted $\hat{\sigma}^2_i$. The term λ_i (see below) is computed as $\hat{\lambda}_i = 1/2\left(\hat{\sigma}^2_i - \hat{s}^2_i\right)$, where s^2_i is just the simple variance of $\hat{\kappa}_{i,t}$. For the parametric statistics we estimate $\hat{\varepsilon}_{i,t} = \hat{\psi}_i \hat{\varepsilon}_{i,t-1} + \sum_{k=1}^{K_i} \hat{\psi}_{i,k} \Delta\hat{\varepsilon}_{i,t-k} + \hat{\mu}^*_{i,t}$, and use the residuals to compute the variance of

$\hat{\mu}^{*}_{i,t}$, denoted as $\hat{s}^{*2}_{i}$. We construct the following group test statistics, and then apply the appropriate mean and variance adjustment terms reported in Pedroni (1999: Table 2).

Group ρ-statistic:

$$\tilde{Z}_{\rho} = TN^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{\varepsilon}^{2}_{i,t-1}\right)^{-1}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t} - \hat{\lambda}_{i}\right) \tag{5}$$

Group t-statistic (non-parametric)

$$\tilde{Z}_{t} \equiv N^{-1/2}\sum_{i=1}^{N}\left(\hat{\sigma}^{2}_{i}\sum_{t=1}^{T}\varepsilon^{2}_{i,t-1}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\varepsilon}^{*}_{i,t-1}\Delta\hat{\varepsilon}^{*}_{i,t} - \hat{\lambda}_{i}\right) \tag{6}$$

Group t-statistic (parametric)

$$\tilde{\tilde{Z}}_{t} \equiv N^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{s}^{*2}_{i}\varepsilon^{*2}_{i,t-1}\right)^{-1/2}\sum_{t=1}^{T}\hat{\varepsilon}^{*}_{i,t-1}\Delta\hat{\varepsilon}^{*}_{i,t} \tag{7}$$

where $\hat{\sigma}^{2}$ is the pooled long run variance for the non-parametric model given as $1/N\sum_{i=1}^{N}\hat{L}^{-2}_{11i}\,\hat{\sigma}^{2}_{i}$; $\hat{\lambda}_{i} = 1/2\left(\hat{\sigma}^{2}_{i} - \hat{S}^{2}_{i}\right)$, where $\hat{L}_{i}$ is used to adjust for autocorrelation in panel parametric model, $\hat{\sigma}^{2}_{i}$ and $\hat{S}^{2}_{i}$ are the long run and contemporaneous variances for individual i and $\hat{S}^{2}$ obtained from the individual ADF-test of $\varepsilon_{it} = \eta_{i}\varepsilon_{it-1} + \mu_{it}$; S^{*2} is the individual contemporaneous variance from the parametric model; $\hat{\varepsilon}_{it}$ is the estimated residual from the parametric cointegration, while $\hat{\varepsilon}^{*}_{it}$ is the estimated residual from the non-parametric model and $\hat{L}_{11,i}$ is the estimated long run variance matrix for $\Delta\hat{\varepsilon}_{it}$ and L_{i} is the ith component of the lower-triangular Cholesky decomposition of matrix $\mathbf{\Omega}_{i}$ for $\Delta\hat{\varepsilon}_{it}$ with the appropriate lag length determined by the Newy-West method.

INSERT TABLE 2

The results of the panel cointegration tests are reported in Table 2. We, in turn, treat each of the variables in our model as endogenous. The objective is to ascertain which variable when endogenous leads to a panel cointegration relationship among the variables. In Panel A, we have results for the case when productivity is the endogenous variable, in Panel B we present results for the case when wages is the endogenous variable, and in Panel C we have results for the case when CPI is the endogenous variable. We find that when productivity is the endogenous variable, all the three test statistics suggest that the variables are cointegrated at the 5 per cent level of significance. When wage is the endogenous variable, only one of the three test statistics suggest that the variables are cointegrated, while in the case where we treat CPI as endogenous none of the three test statistics suggest that the variables are cointegrated. Taken together, these results suggest that a single cointegrating vector exists and that when modelling productivity, wages and CPI in a panel framework productivity should be treated as the endogenous variable.

3.3. Panel long-run estimates

Having established that there is a single cointegrating vector and that productivity is the endogenous variable when there is a long-run equilibrium relationship we proceed to the panel long-run estimators using panel FMOLS. For the FMOLS estimator, consider a cointegrated system for a panel of $i = 1,2,...,N$ countries over time $t = 1,2,...,M$:

$$Y_{it} = \alpha_{it} + \beta X_{it} + \varepsilon_{it} \tag{8}$$

$$X_{it} = X_{it-1} + \varepsilon_{it}$$

where $Z_{it} = (Y_{it}, X_{it})' \sim I(1)$ and $\varpi_{it} = (\varepsilon_{it}, \mu_{it})' \sim I(0)$ with long run covariance matrix $\mathbf{\Omega}_i = L_i L_i'$, where L_i is the lower triangular decomposition of $\mathbf{\Omega}_i$ which can also be decomposed as $\mathbf{\Omega}_i = \mathbf{\Omega}_i^0 + \mathbf{\Gamma}_i + \mathbf{\Gamma}_i'$, where $\mathbf{\Omega}_i^0$ is the contemporaneous covariance and Γ_i is a weighted sum of autocovariances. The panel FMOLS estimator for coefficient β is:

$$\beta_{NT}^* = N^{-1}\sum_{i=1}^{N}\left(\sum_{i=1}^{T}\left(X_{it} - \overline{X}_i\right)^2\right)^{-1}\left(\sum_{i=1}^{T}\left(X_{it} - \overline{X}_i\right)Y_{it}^* - T\hat{\tau}_i\right)$$

where

$$Y_{it}^* = \left(Y_{it} - \overline{Y}_i\right) - \frac{\hat{L}_{21i}}{\hat{L}_{22i}}\Delta X_{it}, \quad \hat{\tau}_i \equiv \hat{\Gamma}_{21i} + \hat{\mathbf{\Omega}}_{21i}^0 - \frac{\hat{L}_{21i}}{\hat{L}_{22i}}\left(\hat{\Gamma}_{22i} + \hat{\mathbf{\Omega}}_{22i}^0\right)$$

The results for the panel long-run estimators using panel FMOLS are reported in Table 3. With the exception of Canada, real wages have a statistically significant positive effect on productivity in the G7. The effect of wages on productivity is the largest in the United States, where a 1 per cent increase in the wage rate increases labour productivity by around 1.4 per cent. The United Kingdom ranks second in the G7 in terms of the effect of wages on productivity with a 1 per cent increase in wages increasing labour productivity by around 0.7 per cent, followed by Japan where a 1 per cent increase in real wages increases productivity by about 0.6 per cent. In France, Germany and Italy an increase in the wage rate seems to have a fairly similar impact on productivity. A 1 per cent increase in the wage rate increases labour productivity by around 0.4 per cent. As far as the impact of inflation on labour productivity is concerned, we find that except for the United Kingdom, inflation has a statistically insignificant effect on labour productivity. In the United Kingdom a 1 per cent increase in the CPI reduces labour productivity by around 0.4 per cent. The panel long-run elasticities reported in the last row of Table 3 suggest that a 1 per cent increase in wages increases G7 labour productivity by around 0.6 per cent. This result is statistically significant at the 1 per cent level. On the other hand, while inflation has a negative effect on labour productivity, it is statistically insignificant.

INSERT TABLE 3

4. Conclusion

Previous studies have reached mixed conclusions regarding the effect of inflation and real wages on productivity. This study has applied recent developments in panel unit root and panel cointegration testing to examine the effect of inflation and real wages on productivity in a panel of G7 economies over the period 1960 to 2004. The findings from Pedroni's (1997, 1999) panel cointegration test indicated there was a unique cointegration vector when productivity was the endogenous variable. The FMOLS long-run estimates suggested that an increase in real wages had a statistically significant positive effect on increasing productivity for all countries except Canada with a 1 per cent increase in real wages generating an increase in productivity between 0.4 per cent and 1.4 per cent for individual countries and a 0.6 per cent increase in productivity for the panel as a whole. On the other hand, there is little evidence that inflation has any effect on productivity. The only G7 country for which inflation had a statistically significant negative effect on productivity in the long-run over the timeframe was the United Kingdom where a 1 per cent increase in inflation reduced labour productivity by around 0.4 per cent.

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Table 1: Panel unit root tests

Variables (in logs)	Breitung (2000) t-test	Im *et al.* (2003) t-bar test	Maddala and Wu (1999) test
$\ln Prod$	-0.2365	0.8710	17.2478
	(0.4065)	(0.8081)	(0.2432)
$\Delta \ln Prod$	-4.5699***	-12.4225***	137.836***
	(0.0000)	(0.0000)	(0.0000)
$\ln Wage$	-1.2675	2.6870	3.7276
	(0.1025)	(0.9964)	(0.9969)
$\Delta \ln Wage$	-4.8148***	-6.6226***	65.5316***
	(0.0000)	(0.0000)	(0.0000)
$\ln CPI$	0.0207	2.3719	3.8396
	(0.5083)	(0.9912)	(0.9964)
$\Delta \ln CPI$	-1.9065**	-2.1206**	32.5767***
	(0.0283)	(0.0170)	(0.0000)

Note: Figures in parenthesis are p values. *** (**) denotes statistical significance at the 1(5) per cent level.

Table 2: Pedroni (1997, 1999) panel cointegration test

Panel A: $\ln \Pr od$ is endogenous	Statistics
Group rho-statistics	2.0450**
Group pp-statistics	2.2426**
Group adf-statistics	1.8992**
Panel B: $\ln Wage$ is endogenous	
Group rho-statistics	0.38176
Group pp-statistics	0.2698
Group adf-statistics	-2.4049***
Panel C: $\ln CPI$ is endogenous	
Group rho-statistics	1.6430
Group pp-statistics	1.0598
Group adf-statistics	-0.0096

Note: *** (**) denotes statistical significance at the 1(5) per cent level.

Table 3: FMOLS long-run elasticities

	$\ln Wage$	$\ln CPI$
USA	1.38***	-0.99
	(2.36)	(1.45)
Canada	0.22	0.25
	(1.09)	(1.10)
Japan	0.59***	-0.35
	(5.24)	(-1.22)
France	0.41**	0.20
	(2.12)	(0.76)
Germany	0.39***	-0.04
	(3.50)	(0.10)
Italy	0.40***	0.03
	(6.32)	(0.44)
UK	0.71***	-0.41**
	(3.81)	(-1.84)
G7 Panel	0.59***	-0.19
	(9.24)	(0.88)

Note: Figures in parenthesis are t-statistics. *** (**) denotes statistical significance at the 1(5) per cent level.

ENDNOTES

[1] Im *et al* (2003) assumed that $\varepsilon_{it} = \theta_t + \nu_{it}$ where θ_t is a time-specific common effect which indicates the degree of dependence across countries and ν_{it} are i.i.d. idiosyncratic random effects. While cross sectional demeaning will introduce dependence across the demeaned error terms, the tests will remain asymptotically valid provided that the ν_{it} are rendered uncorrelated.