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Panel Causality and Cointegration between Productivity and Unemployment

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Abstract

This paper empirically investigates the link between productivity and unemployment in a panel of 19 OECD countries between 1970 and 2010. By means of recently developed panel data econometric methods, we find that unemployment and productivity are non-stationary in levels and they are cointegrated for the panel as a whole. In terms of causality, the stronger directional relationship runs from unemployment to productivity. Furthermore, the long-run effect seems to be generally positive, therefore favouring of those theories which suggest that prolonged recessions foster long-run productivity improvements.

Keywords: Granger causality, panel cointegration, FMOLS

JEL Classification: C32, E32, J21, O40, O57

1. Introduction

Productivity is important as it determines our living standards, that is, when economists refer to productivity, at the broadest level, they are referring to an economy's ability to efficiently convert inputs into outputs. Nobel Prize winner Paul Krugman in his "The Age of Diminishing Expectations" (1994) stated: "Productivity isn't everything, but in the long run it is almost everything". For obvious reasons, macroeconomists devote a lot of their attention to productivity variables, in order to date productivity slowdowns and revivals as well as to account for their causes and consequences.

The empirical literature dealing with productivity distinguishes (historically) between the 1948 – 1973 period—the Golden Age—and the post-1973 period, characterized by a productivity slowdown. By far the most common explanation for such a slowdown is the oil price shocks (Griliches, 1988; Fisher, 1988; Dolmas et al. 1999). There are, however, other explanations for the post-1973 productivity slow-

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down[1] and the current paper is particularly interested in those related to labour market conditions, such as (but not limited to), e.g., the increase of female labour force participation (Bowman, 1991) and an increase in the growth rate of labour inputs (Romer, 1987).

In this paper we aim to investigate the empirical relationship between (labour) productivity and unemployment in a panel of 19 advanced (OECD) countries between 1970 and 2010. There exists a plethora of theoretical papers relating these two variables (see section 2); however the empirical evidence is still small or inconclusive. Our main objective is to check for the (in-)existence of a stable long-run relationship between productivity and unemployment for the panel as a whole. To that end, we rely on recent panel data techniques, such as panel unit root tests, panel cointegration, panel Granger-causality tests and Fully Modified OLS estimators.

Our findings suggest that unemployment and labour productivity are non-stationary in levels and stationary in first differences. Results from panel cointegration tests reject the null of no-cointegration. In terms of causality, the stronger relationship runs from unemployment to productivity. Long-run cointegration estimates seem to suggest a positive co-movement between the unemployment and productivity.

The structure of the paper is as follows. Section 2 reviews the literature. Section 3 outlines the econometric methodology. Section 4 presents and discusses our main results. The last section concludes.

2. Literature Review

In terms of theoretical contributions, a recent paper by Barnichon (2010) shows that, by means of a New-Keynesian search model of unemployment with nominal rigidities and variable labour effort, technology shocks can generate a positive unemployment-productivity correlation whereas non-technology shocks tend to do the opposite. Moreover, the author argues that the correlation between unemployment and productivity changed in the mid-1980s from significantly negative to significantly positive.[2] Despite the existence of a variety of factors that are likely to influence this relationship (e.g. interest rates, hiring and firing costs, income taxation, non-labour costs, unemployment benefits, saving behaviour), one can distinguish between two opposite views on whether periods of economic expansion lead to higher productiv-

[1] We can refer to the growth of the underground economy and income under-reporting (Fichtembaum, 1989); demand constraints (Walker and Vatter, 1989); under-measurement of output in the services sector (Griliches, 1994); price mis-measurement (Nakamura, 1995; Gordon, 1996); a decrease of energy consumption (Beaudreau, 1998).

[2] Other studies in the same line include the pioneering work by Gali (1999) and Basu et al. (2004) followed by more recent papers due to Chang and Hong (2006), Holly and Petrella (2008) and Gali and Gambetti (2009).

ity in the long-run. The first is that during times of low economic activity we have smaller productivity (King and Rebelo, 1988 and Stiglitz, 1993).[3] On the other hand, the New-Schumpeterian approach does not support the view that unemployment is negatively correlated with output (Caballero and Hammour, 1994).

Empirically, the strict focus on the correlation between these two series has led to mixed results. Earlier studies (for the US economy or a small set of advanced countries) based on the neo-Marxian hypothesis that average labour productivity is significantly related to labour market conditions is attributed to Weisskopt et al. (1983) and Weisskopt (1987). Taking a broader view, Bean and Pissarides (1993) examined cross-country correlations for the OECD economies between 1955 – 1985 between unemployment and labour productivity. There is no clear correlation except over the period 1975 – 85 where a weak negative coefficient appears to be significant. However, such cross-sectional analyses are fragile in nature since country-specific effects can weaken underlying relations (due to different institutional and economic factors which are unrelated to productivity). Looking at time series data for a particular country seems more reasonable, especially if we take into account the relative constancy of institutions within each nation over time. Caballero (1993) looks at quarterly time series evidence from the US and UK between 1966 and 1989. The author uses a Hodrick-Prescott filter to remove the high-frequency components, however the evidence found is not conclusive. For medium frequencies, both countries showed up with a positive relation between the two variables under scrutiny.[4] Brauninger and Pannenberg (2002) take a generalised augmented Solow-type model to state that unemployment reduces long-run productivity. They then confirm this theoretical result empirically with a panel of 13 OECD countries between 1960 and 1990. Muscatelli and Tirelli (2001) applied structural time series models to 11 OECD countries between 1955 and 1990 and found evidence in favour of those theories predicting a negative co-movement between unemployment and productivity.

3. Methodology

3.1 Panel Unit Roots

We implement three different types of panel unit root tests: two first generation tests, namely the Im et al. (2003) test (IPS); the Maddala and Wu (1999) test (MW) and one second generation test—the Pesaran (2007) CIPS test. The latter is associated with the fact that previous tests do not account for cross-sectional dependence of the contemporaneous error terms and failure to consider it may cause substantial size distortions in panel unit root tests (O'Connell, 1998 and Pesaran, 2007).

[3] Stadler's (1990) learning-by-doing model emphasizes the link between employment and growing productivity through human capital investments.

[4] Other approaches have used Vector Autoregressive (VAR) models but these ended up having mixed results as well (see Saint-Paul, 1997 for a review).

3.2 Panel Cointegration and Panel Causality

We then move to the panel cointegration test proposed by Pedroni (2004). This is a residual-based test for the null of no cointegration in heterogeneous panels. Two classes of statistics are considered in the context of the Pedroni test. The first type is based on pooling the residuals of the regression along the within-dimension of the panel, whereas the second type is based on pooling the residuals of the regression along the between-dimension of the panel. For the first type, the test statistics are the panel *v*-statistic, the panel ρ-statistic, the panel PP-statistic, and the panel ADF-statistic. These statistics are constructed by taking the ratio of the sum of the numerators and the sum of the denominators of the analogous conventional time-series statistics across the individual members of the panel. The tests for the second type include the group ρ-statistic, the group PP-statistic, and the group ADF-statistic. They are simply the group mean statistics of the conventional individual time series statistics. All statistics have been standardised by the means and variances so that they are asymptotically distributed $N(0,1)$ under the null of no cointegration. As one-sided tests, large positive values of the panel ρ-statistic reject the null hypothesis of no cointegration. For the remaining statistics, large negative values reject the null. See Pedroni (2004) for a detailed discussion.

Assuming that productivity and unemployment are cointegrated (to be confirmed in Section 4), one thus needs to estimate the cointegrating coefficients to investigate the long-run relationship between them. In view of the fact that the OLS estimator is a biased and inconsistent estimator when applied to cointegrated panels (Lee et al., 2008), we utilize the "group-mean" panel fully modified OLS estimator (FMOLS) developed by Pedroni (2000, 2001). The FMOLS estimator not only generates unbiased and consistent estimates of the parameters in relatively small samples, but it controls for the likely endogeneity of the regressors and serial correlation. Pedroni (1999) shows via small sample Monte Carlo simulations that the bias (and sampling variance) of the group mean FMOLS estimator (based on the "between" dimension of the panel) is very small "… even in extreme cases when both the N and T dimensions are as small as N=10 and T=10 and become minuscule as the T dimension grows larger" (p. 23). And, in general, provided that T exceeds N (which is clearly the case in this study), Pedroni shows that the small sample properties of both the estimator and the associated t-statistic are extremely well-behaved "… even in panels with very heterogeneous serial correlation dynamics, fixed effects and endogenous regressors" (p. 24). Pedroni (2000) showed that the FMOLS approach can be used to draw an inference about cointegration with heterogeneous dynamics. Moreover, the resulting estimates can be interpreted as long-run elasticities. In the present case, individual estimates and standard errors for $H_0 : \beta_i = 0$ in the equation below are reported, as well as the overall panel results.[5]

[5] We thank Peter Pedroni for providing his RATS code.

$$prod_{it} = \alpha_i + \beta u_{it} + \varepsilon_{it}\,. \tag{1}$$

where $prod_{it}$ is the log of productivity and u_{it} the log of unemployment. ε_{it} is a standard i.i.d. disturbance term.

Once a long-run relationship between productivity and unemployment has been established, we turn to the issue of panel Granger causality. We follow Canning and Pedroni's (2008) approach. Since in each country the series $prod_t$ and u_t are individually non-stationary but together, generally speaking, are cointegrated, we know from the Granger representation theorem that these series can be represented in the form of a dynamic error correction model (ECM). In line with Canning and Pedroni (2008) we estimate the following ECM:

$$\begin{aligned} \Delta prod_{it} &= c_{it} + \lambda_{1i}\hat{e}_{it-1} + \sum_{j=1}^{K}\phi_{11ij}\Delta prod_{it-j} + \sum_{j=1}^{K}\phi_{12ij}\Delta u_{it-j} + \varepsilon_{1it} \\ \Delta u_{it} &= c_{it} + \lambda_{2i}\hat{e}_{it-1} + \sum_{j=1}^{K}\phi_{21ij}\Delta u_{it-j} + \sum_{j=1}^{K}\phi_{22ij}\Delta prod_{it-j} + \varepsilon_{2it} \end{aligned} \tag{2}$$

where $\hat{e}_{it} = prod_{it} - \hat{\alpha}_i - \hat{b}_t - \hat{\beta}_i u_{it}$ is the disequilibrium term and it represents how far our variables are from the equilibrium relationship and the error correction mechanism estimates how this disequilibrium causes the variables to adjust towards equilibrium in order to keep the long-run relationship intact. The Granger representation theorem implies that at least one of the adjustment coefficients λ_{1i} or λ_{2i} must be non-zero if a long-run relationship between the variables is to hold. According to Canning and Pedroni (2008) one can test hypotheses about long-run effects by testing restrictions on the estimated coefficients in the dynamic ECM. Hence, a test for the significance of λ_{1i} (λ_{2i}) for any one country can be interpreted as a test of whether shocks or innovations in unemployment (productivity) have a long-run effect on productivity (unemployment) and a test for the sign of the ratio $-\lambda_{1i}/\lambda_{2i}$ can be interpreted as a test of the sign of the long-run effect of shocks or innovations to unemployment on productivity.

In the following Section we discuss our main findings.

4. Empirical Results

Our data for a set of 19 advanced economies comes from the OECD Stat. The two main variables of interest are unemployment and (labour) productivity measured as output per worker.

In Tables 1.a and 1.b we report the outcome for the full sample of three panel unit root tests: two first generation type, namely IPS and MW and one second generation type, namely CIPS. They show that that the null hypothesis of unit roots for the

panel data for unemployment and labour productivity cannot be rejected when variables are taken in levels. These results strongly indicate that the variables are non-stationary in the level and stationary in first differences.

Table 1a

First Generation Panel Unit Root Tests

Im, Pesaran and Shin (2003) Panel Unit Root Test (IPS) (a)

Full	**Un-employment**		**Labour productivity**
in levels			
lags	*[t-bar]*	*lags*	*[t-bar]*
2.00	-2.42***	0.89	5.20

Maddala and Wu (1999) Panel Unit Root Test (MW) (b)

Full	**Un-employment**		**Labour productivity**	
lags	p_λ	*(p)*	p_λ	*(p)*
in levels				
0	33.42	0.68	34.14	0.64
1	32.00	0.74	58.40	0.01
2	23.54	0.96	47.45	0.14
in first differences				
0	216.69	0.00	318.27	0.00
1	258.16	0.00	224.05	0.00
2	129.94	0.00	164.69	0.00

Notes: All variables are in logarithms. (a) We report the average of the country-specific "ideal" lag-augmentation (via AIC). We report the t-bar statistic, constructed as $t-bar = (1/N)\sum_i t_i$ (t_i are country ADF t-statistics). Under the null of all country series containing a nonstationary process this statistic has a non-standard distribution: the critical values are –1.73 for 5%, –1.69 for 10% significance level—distribution is approximately *t*. We indicate the cases where the null is rejected with **. (b) We report the MW statistic constructed as $p_\lambda = -2\sum_i \log(p_i)$ (p_i are country ADF statistic p-values) for different lag-augmentations. Under the null of all country series containing a nonstationary process this statistic is distributed $\chi^2(2N)$. We further report the p-values for each of the MW tests.

Table 1b

Second Generation Panel Unit Root Tests

Pesaran (2007) Panel Unit Root Test (CIPS)

Full	**Un-employment**		**Labour Productivity**	
lags	p_λ	*(p)*	p_λ	*(p)*
in levels				
0	0.51	0.69	2.27	0.98
1	-1.76	0.03	2.44	0.99
2	0.80	0.78	3.74	1.00
in first differences				
0	-8.35	0.00	-12.91	0.00
1	-7.65	0.00	-6.69	0.00
2	-4.18	0.00	-4.84	0.00

Notes: All variables are in logarithms. Null hypothesis of non-stationarity. We further report the p-values for each of the CIPS tests.

We are now in condition to explore the (in-)existence of a long-run stable relationship between our two variables of interest. Table 2 shows the outcomes of Pedroni's (1999) cointegration tests between unemployment and productivity. We use four within-group tests and three between-group tests to check whether the panel data are cointegrated. The columns labelled within-dimension ("panel") contain the computed value of the statistics based on estimators that pool the autoregressive

Table 2

Pedroni (2004) Panel Cointegration Tests (Productivity and Unemployment)

Dep. Var.	**Labour Productivity**	
	No trend	**trend**
Panel v	0.48	0.52
Panel ρ	–1.13*	–0.61
Panel PP	–1.49*	–2.03*
Panel ADF	–1.49*	–2.39*
Group ρ	–0.61	–0.04
Group PP	–1.81*	–2.13*
Group ADF	–2.71*	–3.39*

Notes: The null hypothesis is that there is no cointegration. An asterisk (*) indicates rejection at the 10% level or better.

coefficient across different countries for the unit root tests on the estimated residuals. The columns labelled between-dimension ("between") report the computed value of the statistics based on estimators that average individually calculated coefficients for each country. Except for the ν-statistic test, the results of the within-group tests and the between-group tests show that the null hypothesis of no cointegration can be rejected. Therefore, unemployment and productivity are cointegrated for the panel of all countries in our sample.

We then estimate the cointegrating vector (equation 1) using the FMOLS estimator. Table 3 shows the coefficients obtained with this estimator. The estimated coefficient for the pool of all countries is 0.06 (statistically significant at the 1% level). As before, it seems that in general the greatest share of results point to a positive long-run co-movement between the levels of unemployment and productivity, despite the cases of Belgium and Sweden which are associated with negative coefficient estimates. Hence, there is evidence in favour of those theories which suggest that prolonged recessions, which typically are associated with increases in unemployment figures, foster long-run productivity improvements, and have long-run positive effects on productivity. This is in line with Caballero and Hammour's (1994) neo-Schumpeterian findings that show that recessions stimulate efficiency gains by causing less efficiency firms to exit. This in turn leads to faster productivity growth if the entry rate of new, more efficient, firms is not too low during recessions. Other models also emphasize the smaller opportunity cost of reorganization activity in terms of lost production during recessions (Hall, 1991), which encourages firms to adopt reorganizing investments. These models predict a positive correlation between unemployment and productivity growth.

Table 3

Panel Estimates of the Cointegrating Relationship: FMOLS in Pedroni (2000, 2001) (Productivity and Unemployment)

Country\Dep. Var.	**FMOLS**	
	Labour Productivity	
\	β	*s.e.*
Australia	0.11	0.08
Austria	0.23***	0.03
Belgium	-0.41***	0.09
Canada	0.12***	0.04
Denmark	0.19*	0.11
Finland	0.02	0.06
France	0.16***	0.03

Greece	0.25*	0.13
Ireland	0.50***	0.12
Italy	0.12**	0.05
Japan	0.02	0.02
Netherlands	0.16	0.10
Norway	-0.26	0.16
Portugal	0.08***	0.03
Spain	-0.00	0.00
Sweden	-0.08***	0.03
Switzerland	-0.11	0.08
United Kingdom	0.01	0.06
United States	0.14	0.27
Panel	0.06***	0.01

Notes: The regression is $prod_{it} = \alpha_i + \beta u_{it} + \varepsilon_{it}$ as discussed in the main text. *s.e.* stands for standard errors.
*, **, *** denote significance at 10, 5 and 1% levels.

Finally, turning to the Pedroni causality tests, one should note first that despite the fact that these tests can be implemented on a country-by-country basis[6], in practice the reliability of these various point estimates and associated tests for any one country is likely to be poor given the relatively short time sample over which the data are observed. Therefore, our tests will be panel based. In particular, we want to know more about the pervasiveness of a long-run causal effect in the panel rather than simply finding that there is at least some long-run causality present in at least one specific country. To this end, we use both a group mean based test[7] and a lambda-Pearson based test[8]. The combination of the group mean and the lambda-Pearson can be particularly informative when the underlying parameters of interest are heterogeneous. For instance, when $\bar{t}_{\lambda_1}$ fails to reject he null while P_{λ_1} succeeds in rejecting the null, this can be interpreted as a situation in which we do not reject that the average value for λ_{1i} is zero, even though we reject that it is pervasively zero in the panel.[9]

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6 Results are available upon request.

7 The group mean test is based on the sample average of the individual country λ_{1i} tests and will allow us to ask whether the long-run causal effect is zero on average for the panel. The group mean panel estimate is computed as $\bar{\lambda}_1 = N^{-1}\Sigma^N_{i=1}\hat{\lambda}_{1i}$ and the group mean panel test for the null of no long-run causal effect from unemployment to productivity is computed as $\bar{t}_{\lambda_1} = N^{-1}\Sigma^N_{i=1}t_{\lambda_{1i}}$, where $t_{\lambda_{1i}}$ is the individual country test for the null that $\lambda_{1i} = 0$.

8 The lambda-Pearson panel tes uses the p-values associated with each of the individual country t tets to compute the accumulated marginal significance associated with these. It takes the form $P_{\lambda_1} = -2\Sigma^N_{i=1}\ln p_{\lambda_{1i}}$, where $\ln p_{\lambda_{1i}}$ is the log of the p-value associated with individual country i's t test for the null that $\lambda_{1i} = 0$.

Hence, the results for each of these panel tests for the direction of long-run causality and the sign of the long-run causal effect as described before in Table 4. Results are reported for the panel as a whole.

Table 4

Panel Long-run Causality (Pedroni)—Full Sample

Panel A: labprod	$\lambda_1 : u_{it} \rightarrow prod_{it}$			$\lambda_2 : prod_{it} \rightarrow u_{it}$			$-\lambda_1/\lambda_2$
	Estimate	**Test**	**p-value**	**Estimate**	**Test**	**p-value**	**median**
Group mean	–0.21	–1.26	(0.10)	–0.53	–0.61	(0.27)	–1.04
Lamba-Pearson		77.45	(0.00)		53.95	(0.04)	(0.82)

Note: For the full sample considered above there are two rows, one for the group mean based test, and one for the lambda-Pearson based test. Columns 2 – 4 report these for tests based on the parameter λ_1, which reflected the presence or absence of long-run causality running from productivity to unemployment. The second column reports the panel point estimaet, which exists only for the group mean, not for the lambda-Pearson. The third column reports the corresponding panel test statistics an the fourth column repors the p-value for outcome of the panel test statistic. The next three columns repeat this same pattern for analogous tests based on the parameter λ_2, which reflects the presence or absence of long-run causality running from unemployment to productivity. Finally, the last column reports the group median point estimate of the sign ratio in the first row, with the simulated standard error reported in parenthesis in the second row.

In examining the details of Table 4, the first note goes to the λ_{1i} parameters as reported in columns 2 through 4 which indicate that long-run causality that runs from unemployment to productivity (p-values lower than 10%). The results hold pervasively among individual countries and on average for the entire panel (based on the group-mean and Lamba-Pearson tests). Nevertheless, the group median sign ratio test in column 8 indicates that the effect is mixed (insignificant coefficient).

Furthermore, turning to λ_{2i}, we cannot reject the hypothesis that productivity has a zero average long-run effect globally (group mean tests). At the same time, we do rule out that the long-run effect of productivity is pervasively zero, although the sign of the effect is mixed, so that the average is still zero. The implication of these results is that changes in productivity do not appear to induce permanent changes in long-run unemployment. On average the marginal long-run impact is zero.

All in all, results point to causality from unemployment to productivity, even though the final result is of mixed sign as to the effect of unemployment on productivity.

[9] This can occur when the value for λ_{1i} is significantly positive for some fraction of the panel and significantly negative for another fraction of the panel. In this case, we can say that a long-run causal effect is present, even if for some members of the panel it is positive while for others it is negative.

5. Conclusion

This paper has empirically studied productivity and unemployment time series in a set of 19 OECD countries between 1970 and 2008, applying recently developed panel data econometric methods. We applied first and second generation panel unit root tests, panel cointegration tests and we used FMOLS estimate the long-run coefficient while dealing with heterogeneity problems.

The empirical finds reported in the paper reveal that unemployment and labour productivity are non-stationary in levels (but stationary in first-differences) and results of the Pedroni panel cointegration tests reject the null of no-cointegration. In terms of causality the stronger relationship runs from unemployment to productivity. Long-run cointegration estimates seem to suggest positive co-movement between the levels unemployment and productivity. These results suggest that periods of economic slack should be viewed by policy makers as opportunities to allow firms to reorganize themselves internally, prioritize investment and stimulate efficiency even if such industry-wide restructuring implies letting "weaker" non-productive firms exit the market in a "creative-destruction" fashion. Policy makers should therefore avoid the temptation of granting across-the-board support (e.g. subsidies, tax credits, etc.) before careful examination of the market's composition and characteristics.

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