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Productivity, Wage and Inflation Relationship for a Sample of Developed Countries: New Evidence from Panel Cointegration Tests with Multiple Structural Breaks

Maria Gabriela Ladu[a*] & Marta Meleddu[b*]

[a] PolComIng, University of Sassari & CRENoS,
[b] PolComIng, University of Sassari & CRENoS,

Abstract: This paper examines the long run relationship among real wages, inflation and labor productivity over the period 1960-2011, for 11 developed economies, using a comprehensive set of empirical tests. We present a dual-level analysis: first, we consider the panel properties of the data checking for panel cointegration with structural breaks, allowing also for cross sectional dependence; hence, we examine each country separately and we investigate the properties of the variables through a set of tests, controlling also for structural breaks in order to check for robustness of data. Results do not show evidence of a long run relationship.

Keywords: cointegration, inflation, productivity, structural breaks, unit root, wages

JEL Classification: C50, E23, E31

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1. Introduction

Productivity has been long recognized as a reference point to categorize living standards, material well-being and international competitiveness across countries and across regions within a country. It provides a baseline for governments' socioeconomic decision-making and therefore, its growth has become an essential agenda for many countries. Also for these reasons, several studies examine the relation between productivity growth and real wage and between productivity growth and inflation. From an empirical point of view, on the one hand, inflation and productivity growth are negatively related (Jarret and Selody, 1982). Inflation would diminish the incentive to work, it would distort the informational content of relative price levels, and it would contract tax reductions for depreciation. The theoretical literature predicts that inflation and productivity growth are negatively related as workers purchasing power affects motivation and effort, but also because inflation affects firms' investment plans, impacts capital depreciation rates and produces changes in the techniques of production. On the other hand, real wages and productivity are positively related since higher real wages would enhance the opportunity cost of job loss and would stimulate greater work effort to avoid it. In addition, higher wages increases the marginal productivity of labor (Wakeford, 2004) through capital for labor substitution (see Kumar et al. 1012 for a comprehensive review of related literature).

A noteworthy question is whether a relation exists among the three variables above since they play an important role in productivity growth, inflation adjustment and consumption stimulation policies. Despite the relevance of their role, few studies have examined the connection that may exist among them. Previous literature finds a relationship among real wages, inflation and productivity growth. Specifically, Hall (1986) and Alexander (1993) find evidence that inflation, real wages and productivity have a cointegrating relationship in the UK, and therefore higher wage rates stimulate labor productivity via efficient wages. Strauss and Wohar (2004) observe the long-run relationship between inflation, real wages and productivity for a panel of 459 US manufacturing industries between 1956 and 1996. The authors find that in the long-run inflation Granger-causes productivity, while a bi-directional Granger causality exists between real wages and productivity. Gunay et al. (2005) study the relationship between inflation, real wages and profit margins over 29 Turkish manufacturing sub-sectors over the period 1980 to 1996 and find that mark-ups are positively and significantly affected by real wage costs and inflation. From a between country perspective, Narayan and Smyth (2009) use panel cointegration techniques to examine the relationships between inflation, real wages and productivity growth for the G7 countries over the period 1960 to 2004. They find evidence that, when productivity is the endogenous variable, a cointegration relationship among the three variables does exist. More recently, Kumar et al. (2012) analyze the effect of inflation and real wages on productivity for Australia over the period 1965 to 2007 including tests for structural change. The findings indicate the presence of a structural break and the presence of cointegration between the variables and a positive statistically significant relationship between real wages and productivity growth but no statistically significant relationship between inflation and productivity growth and a weak and negative effect of inflation on productivity in Australia. Granger causality tests revealed a bi-directional causality running between real wages and productivity suggesting that real wages and inflation Granger cause productivity in the long run. In this study, Kumar et al. highlight that most studies use standard time series or panel data techniques but fail to consider structural changes in the cointegrating vector. In addition, cointegration analysis is used with small sample sizes and it is ignored the role of real wages on the relationship between inflation and productivity.

Following this lane, this study further address Kumar et al. (2012) concerns and extends this thread of the literature using a comprehensive set of empirical tests to analyze the relationship between inflation, real wages and labor productivity. The aim is to improve the knowledge of these variables given the complexity of the interaction among them. We present for the first time such a study on a sample of 11 developed countries (United States, Belgium, Canada, Denmark, France, Germany, Italy, Netherlands, Norway, Sweden, United Kingdom) for the period 1960-2011 also controlling for structural breaks. In fact, applied time series analysis and forecasting is built on the assumption of stationarity, which implies that the parameters (mean, variance and trend) are constant over time. However, a structural break occurs if one parameter changes at some point (break date) during the sample period. Therefore, not considering structural changes can lead to unreliability of the model but also to forecasting errors especially if they occur in an unknown timing. This is relevant if one wants to analyze macroeconomics dynamics during the latter part of the last century, when several developed countries faced relevant economic changes.

In this paper, we perform a dual-level analysis on inflation, real wages and labor productivity. First, we consider the panel properties of the data checking for panel cointegration with structural breaks and allowing for cross sectional dependence (Westerlund and Edgerton, 2008). Therefore we examine each country separately and we investigate the properties of the variables through a set of tests, controlling also for structural breaks in order to check for robustness of data.

The rest of the paper is organized as follows. Section 2 discusses the data and methodology used in the analysis. In Section 3, we present various results of unit root tests and panel unit tests. Section 4 reports the cointegration analysis findings for both panel and time series, with and without structural breaks control. Section 5 summarizes and concludes.

2. The Data and the Methodology

To study the relation among real wages, inflation and productivity, we retrieved data from the United States Department of Labor, Bureau of Labor Statistics, downloaded from http://stats.bls.gov/. Specifically, we employ data on output per hour in the manufacturing sector as a proxy for productivity, hourly compensation in the manufacturing sector measured in \$US as a proxy for real wages and the consumer price index as price level. The sample consists of 11 developed countries (United States, Belgium, Canada, Denmark, France, Germany, Italy, Netherlands, Norway, Sweden, United Kingdom) for the period 1960-2011. Following Narayan and Smyth (2009), in order to determine the causality relationship, we estimate three models. The first one considers productivity as the endogenous variable (equation 1), in the second model inflation is the endogenous (equation 2) and in the third model real wages is the dependent variable (equation 3):

$$lnY_{i,t} = \alpha_0 + \alpha_1 lnw_{i,t} + \alpha_2 ln\pi_{i,t} + u_{it} \tag{1}$$

$$ln\pi_{i,t} = \alpha_0 + \alpha_1 lnw_{i,t} + \alpha_2 lnY_{i,t} + u_{it} \tag{2}$$

$$lnw_{i,t} = \alpha_0 + \alpha_1 lnY_{i,t} + \alpha_2 ln\pi_{i,t} + u_{it} \tag{3}$$

where $i=1, \ldots, N$ refers to the countries in the panel, $t=1, \ldots, T$ to the years of observation $lnY_{i,t}$ is the logarithm of productivity, $lnw_{i,t}$ the logarithm of real wages, $ln\pi_{i,t}$ the logarithm of inflation, and u_{it} is the error term.

To analyze the connection among real wages, inflation and productivity, a dual-level analysis is performed. In the first level of the analysis, we apply Levin Lin Chu unit root test (2002), Im, Pesaran, Shin unit root test (2003) and Fisher unit root type tests (Choi, 2001), in order to identify stationarity in the panel for real wages, inflation and labor productivity. Afterwards, panel cointegration is investigated by applying the tests proposed by Pedroni (2000, 2001) and the more recent test proposed by Westerlund (2007). As highlight by Westerlund and Edgerton (2008), these first generation tests do not take into account structural changes and cross-sectional dependence that may occur because of the interrelationship between macroeconomic measures. Therefore, we apply the test proposed by Westerlund and Edgerton (2008) that allows for cross-sectional dependence and unknown structural breaks in both the intercept and slope of the cointegrated regression, which may be located at different dates for different units.

We perform the second level of the analysis in order to check robustness of our data properties. To this aim we implement a set of time series unit root and cointegration tests. We investigate stationarity of our variables applying the Augmented Dickey-Fuller test (Dickey and Fuller, 1979) and the KPSS test (Kwiatkowski, Phillips, Schmidt, and Shin, 1992). However, if there is a shift in the level of the series and it is ignored, the tests may be distorted. Therefore, we apply the unit root test proposed by Lanne, Lütkepohl and Saikkonen (2002) test to account for unknown break date. If no-stationarity issues are present, we apply cointegration tests in order to establish the existence of a long run relationship between the three macroeconomic variables. For time series, we apply the Johansen trace tests (1995), the test proposed by Saikkonen and Lütkepohl (2002) and the Gregory-Hansen procedure (1996) for testing cointegration in the case of level, trend and regime shifts.

2.1 Unit Root Test and Cointegration

We use panel data techniques to investigate the properties of inflation, real wages and productivity. We first check the stationarity of our variables using the Levin Lin Chu unit root test (2002), the Im, Pesaran, Shin unit root test (2003) and the Fisher unit root type tests (Choi, 2001). The Levin Lin Chu unit root test is a panel-based unit root test that allows for individual-specific intercepts, the degree of persistence in individual regression error and trend coefficient to vary freely across individuals. The Im, Pesaran, Shin test is for dynamic heterogeneous panels based on the mean of individual unit root test statistics. In particular it proposes a standardized t-bar test statistic based on the (augmented) Dickey-Fuller statistics averaged across the groups. The Fisher-type test uses p-values from unit root tests for each cross-section. The test is asymptotically chi-square distributed with 2N degrees of freedom. We finally check the cointegration among our variables using three types of tests. The first one is that proposed by Pedroni (2000, 2001). This test allows for a considerable heterogeneity among individual members of the panel. In fact, it includes heterogeneity in both the long run cointegrating vectors as well as in the dynamics associated with short run deviations from these one. Pedroni derives the asymptotic distributions of seven different statistics: four are based on pooling along the within-dimension, and three are based on pooling along the between-dimension. Pedroni calls the within-dimension based statistics as panel cointegration statistics, and the between-dimension based statistics as group mean panel cointegration statistics. The first of the panel cointegration statistics is a type of nonparametric variance ratio statistic. The second is a panel version of nonparametric statistic analogous to the Phillips and Perron rho-statistic. The third statistic is also nonparametric and analogous to the Phillips and Perron t-statistic. The fourth of the panel cointegration statistics is a parametric statistic analogous to the augmented Dickey-Fuller t-statistic. The other three statistics are based on a group mean approach. The first and the second ones are analogous to the Phillips and Perron rho and t-statistic respectively, while the third one is analogous to the augmented Dickey-Fuller t-statistic. Each of the seven statistics are distributed as a N (0,1). Another panel cointegration test applied in this paper is that one proposed by Westerlund (2007). He proposes four new panel tests of the null hypothesis of no cointegration that are based on structural rather than residual dynamics, and therefore do not impose any common factor restriction. These tests are designed to test the null by inferring whether the error correction term in a conditional error correction model is equal to zero. If the null hypothesis of no error correction is rejected, then the null hypothesis of no cointegration is also rejected. Each test is able to accommodate individual-specific short-run dynamics, including serially correlated error terms, non-strictly exogenous regressors, individual-specific intercept and trend terms, and individual-specific slope parameters. Two tests are designed to test the alternative hypothesis that the panel is cointegrated as a whole, while the other two tests the alternative that there is at least one individual that is cointegrated. Westerlund finds that the new tests show both better size accuracy and higher power than the residual-based tests developed by Pedroni. He further shows that this difference in power arises mainly because the residual-based tests ignore potentially valuable information by imposing a possibly invalid common factor restriction.

As a robustness check, we examine, for each country of the sample, the time series properties for real wages, productivity and inflation applying unit roots and cointegration tests. We apply three types of unit root tests. The first one is the Augmented Dickey Fuller (ADF) test (1979), which the null hypothesis is that the variable contains a unit root, and the alternative is that the variable is generated by a stationary process. We perform the ADF test both with constant and constant and trend. The second unit root test we apply is the KPSS test (1992) which is an LM test of the hypothesis that the random walk has a zero variance. The null hypothesis is that an observable series is stationary around a deterministic trend. We perform the KPSS test both with constant and constant and trend. The last unit root test we apply is the that one proposed by Lanne, Lutkepohl and Saikkonen (LLS, 2002). This test allows for a level shift of a very general, possibly nonlinear form at a known point in time and the null hypothesis is unit root.

Whether the analysis of time series properties shows the presence of a unit root in the variables under study, we go further in the analysis performing cointegration tests for each country of our sample. The first one is the Johansen trace test (1995), which is a likelihood ratio type test if the dependent is normally distributed. The null hypothesis of no cointegration is based upon the distribution of the test statistics which depend on the deterministic terms. The second cointegration test we perform for time series is that one proposed by Saikkonen and Lutkephol (2002). This test allows for possible exogenous shifts in the mean of the data-generation process. Finally, we apply the Gregory and Hansen test (1996), which is designed to test the null of no cointegration against the alternative of cointegration in the presence of a possible regime shift. Unlike the two previous cointegration tests, Gregory and Hansen test considers cases where the intercept and/or slope coefficients have a single break of unknown timing.

2.2 Panel Cointegration with Structural Breaks

Both the panel cointegration tests of Pedroni (2000, 2001) and Westerlund (2007), mentioned above, do not take into account the probability of the existence of structural changes in the cointegration relation, which increases with the length of the time series dimension of the panel. Checking for structural breaks avoids size distortions and deceptive inference when testing for cointegration. For this reason in our work we apply the panel cointegration test proposed by Westerlund and Edgerton (2008). Their test allows for heteroskedastic and serially correlated errors, unit-specific time trends, cross-sectional dependence and unknown structural breaks in both the intercept and slope of the cointegrated regression, which may be located at different dates for different units. The test is based on the popular Lagrange multiplier (LM) unit-root tests developed by Schmidt and Phillips (1992), Ahn (1993) and Amsler and Lee (1995) and it has a limiting normal distribution that is free of nuisance parameters under the null hypothesis. In particular, the asymptotic null distribution is independent of the nuisance parameters associated with both the structural break and common factors used to model the cross-sectional dependence. The test allows estimating three models: no break, level break and regime shift and it is implemented using the Campbell and Perron (1991) automatic procedure to select the lag length. The breaks are determined by grid search at the minimum of the sum of squared residuals. The *P*-values are for a one-sided test based on the normal distribution.

3. Empirical Results

3.1 Unit Root Tests

This section presents a set of panel unit root tests carried out for the variables under investigation, that are the logarithm of productivity, the logarithm of real wages, and the logarithm of inflation. Tests are performed on both levels and first differences of the variables and both with constant and with constant and trend. Results show that productivity is stationary with a constant but not if a trend is introduced. This is confirmed by all the set of tests we performed (Table 1). However, when we consider the first difference, the variable is always stationary. Inflation is not stationary when a trend is included in all tests but not with the Fisher Dickey-Fuller type. With this test we cannot reject the null that all panel contain unit root both with constant and with constant and trend. The first difference of inflation is always stationary (constant and constant and trend) but once again not for the Fisher Dickey-Fuller type test. Real wages is not stationary in all tests performed except for the Levin-Lin-Chu test. The first difference is always stationary. Overall, the variables under analysis contain unit root in levels but not in the first difference.

These results are confirmed at the individual level for almost all countries for all the three variables under investigation (Table A1, Table A2 and Table A3 in appendix). Specifically, KPSS test rejects the hypothesis of stationarity for each country of the sample and for both constant and constant and trend. The ADF test rejects the null of unit root always with the exception of productivity in six out of eleven countries (Belgium, Canada, France, Germany, Netherlands and Norway) in the case we test only with the constant. Overall the LLS test rejects the hypothesis of stationarity for productivity, inflation and real wages, in particular when we test with the time trend.

Once verified the stationarity properties of the data, the next step is to check for cointegration in order to establish if a relationship among the three variables exists.

3.2 Cointegration

Results for the Pedroni panel cointegration test (Table 2) show that when real wage is treated as endogenous, four out of seven statistics suggest that a cointegration relationship exists. We do not find any relationship when we treat inflation as endogenous. Unlike Narayan and Smyth (2009), we do not even find cointegration treating productivity as endogenous.

These results are verified by running the Westerlund panel cointegration test (Table 3) where the four statistics are able to accommodate individual-specific short-run dynamics, including serially correlated error terms, non-strictly exogenous regressors, individual-specific intercept and trend terms, and individual-specific slope parameters.

Results shows that when both inflation and real wages are, in turn, treated as endogenous, one out of the four statistics does reject the null of no cointegration. Results also confirm that when productivity is treated as endogenous, a cointegration relationship is not found.

In order to check for robustness we test for cointegration at country level using the Johansen Trace Test and the Saikkonen and Lutkepohl Test (Table A4 in appendix). Both tests reject the null hypothesis of no cointegration among productivity, inflation and real wages, performing the two test both with constant and with constant and time trend.

3.3 Panel Cointegration with Structural Breaks

In this section we illustrate the results of the panel cointegration test proposed by Westerlund and Edgerton (2008) for dependent panel with structural breaks. In fact, not considering structural changes in cointegration analysis can lead to unreliability of the relationship under investigation but also to forecasting errors especially if they occur in an unknown timing. This is relevant if one wants to analyze macroeconomics dynamics during the latter part of the last century, when several developed countries faced relevant economic changes. Furthermore, as Westerlund and Edgerton highlight, the first generation of panel cointegration tests do not take into account the kind of structural breaks that may occur in long periods of time. Another issue that the first generation of panel cointegration tests overlooked is the cross-sectional dependence, very frequent in macroeconomic data. Westerlund and Edgerton derive two statistics, $Z_\tau(N)$ and $Z_\phi(N)$. The first one shows a good performance in almost all the experiments, while the second one is better as T increases. Furthermore, $Z_\tau(N)$ appears very robust against different forms of serial correlations. Westerlund and Edgerton (W&E) test is implemented using the Campbell and Perron (1991) automatic procedure to select the lag length. The authors use three breaks which are positioned at different dates for different units. The null hypothesis of the test is no cointegration in panel data and table 4 shows the results. As in the previous section, we perform the W&E test according to equations (1), (2) and (3). When productivity is treated as endogenous, we find cointegration among the three variables only when we do not control for structural breaks (both $Z_\tau(N)$ and $Z_\phi(N)$ are statistically significant at 5% and 1% respectively). In the level break model and in the regime shift model the test statistics do not reject the null of no cointegration. These results confirm what Narayan and Smyth (2009) found for the G7 countries when not controlling for breaks. When we introduce the breaks in the cointegrating equation, the results are reversed, that is any evidence of cointegration is found. Performing the test for equation 2, where inflation is the endogenous variable, results show a strong evidence of cointegration among the variables under analysis in all models (no break, level break and regime shift), unlike Narayan and Smyth (2009).

Finally, we perform the W&E test for equation 3 where we treat real wages as endogenous. We do not find any cointegration relationship among productivity, real wages and inflation in all models (no break, level break and regime shift) in line with Narayan and Smyth (2009).

We test also for cointegration with structural breaks at country level using the Gregory-Hansen test as a final check (Table A5a, A5b and A5c in appendix). Overall, results confirm what the W&E test highlights. Specifically, when productivity is treated as endogenous, we find cointegration only for Canada and Italy, while when inflation is treated as endogenous, France, Belgium and Netherlands show a long run relationship among the three variables. Furthermore, when real wages is endogenous, only Canada shows a relationship among productivity, wages and inflation.

The W&E test also reports the estimated break dates (Table 5). The median break dates are 1980 for the level break model and 1984 for the regime shift model in the case of productivity treated as endogenous. Conversely, when real wages is the endogenous, the median break dates are 1985 and 1980 for the level break and the regime shift model, respectively. Finally, the median break dates identified are 1978 and 1980 when inflation is the endogenous variable.

4. Conclusions

This work extends the literature on the relationship among productivity, inflation and real wages with the aim to improve the knowledge of these variables given the complexity of the interaction among them. According to Kumar et al. (2012), the analysis of this mutual link can provide policy directions for productivity improvement, inflation control and consumption boosting. Most studies in this field use standard time series or panel data techniques but fail to consider structural changes in the cointegration vector. However, not considering structural changes can lead to unreliability of the model, but also to forecasting errors, especially if they occur in an unknown timing. This can be an issue if the analysis focus on the macroeconomics dynamics of the latter part of the last century, when several developed countries faced relevant economic changes and if the variables are employed for forecasting purposes.

Unlike Kumar et al. (2012), who focus on the analysis of the relationship among the three macroeconomic variables for only one country, this work performs a comprehensive set of empirical tests to analyze the above relationship for a sample of 11 developed countries over the period 1960-2011, not setting any a priori assumption. Different from Narayan and Smith (2009), and following Kumar et al. (2012), we control for the presence of unknown structural breaks, which may be located at different dates for different units, in both the intercept and slope of the cointegrated regression. This type of control is achieved by applying the recent test proposed by Westerlund and Edgerton (2008).

Findings from Pedroni (2000, 2001) and Westerlund (2007) panel cointegration tests suggest a weak cointegration relationship among the three variables under study when real wages is treated as endogenous. Conversely, when inflation is treated as endogenous results from Pedroni test do not show any cointegration relationship while the Westerlund test shows that one out of the four statistics does reject the null of no cointegration.

Unlike Narayan and Smyth (2009), we do not even find cointegration treating productivity as endogenous. This result is confirmed by the Westerlund panel cointegration test. Applying the Westelund and Edgerton test (2008), we find cointegration among the three variables only when we do not control for structural breaks. These results confirm what Narayan and Smyth (2009) found for the G7 countries where the authors do not control for breaks. However, when we introduce the breaks, the results are reversed, that is any evidence of cointegration is found.

From the results obtained it appears that a great care should be paid whenever one wants to consider the dynamics among productivity, real wages and inflation. Findings also show the need to go further on the investigation in order to shed more light on the existence of the connection among the three macroeconomic variables above.

Endnotes

Maria Gabriela Ladu, Research Fellow, PolComIng, University of Sassari & CRENoS, viale Mancini, 5 07100 Sassari (Italy), email: mgladu@uniss.it..

Marta Meleddu, Research Fellow, PolComIng, University of Sassari & CRENoS, viale Italia, 39 07100 Sassari (Italy), email: mmeleddu@uniss.it.

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Table 1. Panel Unit Root tests

Variables	**IPS**	**p-value**	**IPS with trend**	**p-value**	**LLC**	**p-value**	**LLC with trend**	**p-value**	**Fisher Dfuller**	**p-value**	**Fisher Dfuller with trend**	**p-value**	**Fisher PP**	**p-value**	**Fisher PP with trend**	**p-value**
Log Productivity	-4.008***	0.000	2.593	0.995	-9.189***	0.000	-0.789	0.215	74.719***	0.000	13.937	0.904	97.243***	0.000	8.500	0.996
Δ Log Productivity	-14.944***	0.000	-17.518***	0.000	-18.282***	0.000	-17.989***	0.000	90.448***	0.000	123.992***	0.000	300.896***	0.000	346.124***	0.000
Log Inflation	-1.751**	0.039	3.098	0.999	-6.423***	0.000	-0.071	0.472	25.635	0.267	2.875	1.000	36.589**	0.026	0.138	1.000
Δ Log Inflation	-2.526***	0.005	-2.520***	0.006	-2.277**	0.011	-3.432***	0.000	23.678	0.364	25.622	0.268	31.808*	0.081	32.174*	0.075
Log Real Wages	-0.793	0.213	2.049	0.979	-4.931***	0.000	-1.428*	0.077	23.187	0.391	4.909	0.999	26.515	0.230	2.888	1.000
Δ Log Real Wages	-10.572***	0.000	-9.849***	0.000	-11.268***	0.000	-11.388***	0.000	98.637***	0.000	86.282***	0.000	170.009***	0.000	144.541***	0.000

LLC and IPS tests are distributed as N(0,1) under the null hypothesis of non-stationarity. Fisher test is chi-square distributed with 2N degrees of freedom.

Table 2. Pedroni Panel Cointegration Test

	Endogenous Variable		
	Log Productivity	Log Inflation	Log Real Wages
Statistics	Value	Value	Value
Panel v-stat	0.0607	0.188	3.509***
Panel rho-stat	0.8935	0.566	-1.148
Panel pp-stat	0.7771	0.102	-1.343*
Panel adf-stat	0.1353	-0.723	-3.075***
Group rho-stat	1.773	1.807	-0.208
Group pp-stat	1.355	0.920	-0.929
Group adf-stat	0.289	-0.341	-3.671***

Nsecs = 11. Tperiods = 52 . no. regressors = 2
All reported values are distributed N(0.1) under null of unit root or no cointegration.
Panel stats are weighted by long run variances. Critical values at 1%. 5% and 10% are -2.328.-1.645 and -1.282 respectively.

Table 3. Westerlund (2007) Panel Cointegration Test

	Endogenous Variable					
	Log Productivity		Log Inflation		Log Real Wages	
Statistics	Value	P-value	Value	P-value	Value	P-value
Gt	-1.117	1.000	-3.084**	0.014	-3.245***	0.002
Ga	-3.257	1.000	-9.828	0.957	-10.887	0.893
Pt	-3.116	1.000	-8.046	0.306	-8.709	0.107
Pa	-4.348	0.999	-7.760	0.910	-12.579	0.152

Results for H_0: no cointegration, model with constant and trend

Table 4. Westerlund & Edgerton (2008) Panel Cointegration Test with Structural Breaks

	Endogenous Variable											
	Log Productivity				Log Inflation				Log Real Wages			
	$Z_\tau(N)$		**$Z_\phi(N)$**		**$Z_\tau(N)$**		**$Z_\phi(N)$**		**$Z_\tau(N)$**		**$Z_\phi(N)$**	
Model	Value	P-value	Value	P-value	Value	P-value	Value	P-value	Value	P-value	Value	P-Value
No break	-1.995	0.023	-2.461	0.007	-3.635	0.000	-3.037	0.001	1.607	0.946	1.029	0.848
Level break	0.527	0.701	-0.149	0.441	-3.209	0.001	-1.615	0.053	0.288	0.613	0.167	0.567
Regime shift	0.000	0.500	0.475	0.682	-1.538	0.062	-0.675	0.250	2.360	0.991	1.797	0.964

Results for H_0: no cointegration. P-Values are for a one-sided test based on the normal distribution

Table 5. Estimated breakpoints

	Endogenous Variable					
	Log Productivity		Log Inflation		Log Real Wages	
Country	Level break	Regime shift	Level break	Regime shift	Level break	Regime shift
United States	2001	2001	1979	1979	1974	1974
Belgium	1982	1980	1974	1974	1985	1980
Canada	1984	1983	1980	1980	1975	2002
Denmark	1993	1983	1973	1984	1972	1980
France	1967	1969	1979	1986	1974	1980
Germany	2005	1975	1972	1980	1985	1980
Italy	1975	1975	1978	1973	1992	1992
Netherlands	1967	1975	1974	1980	1985	1980
Norway	2005	1974	1980	1980	1992	1974
Sweden	2001	2000	1979	1979	1992	1992
United Kingdom	1974	1995	1974	1974	1979	1992
median	1980	1984	1978	1980	1985	1980

APPENDIX

Table A1. Unit Root tests for the logarithm of productivity

	Intercept included				*Trend and Intercept included*			
Country	**ADF**	**KPSS**	**LLS**	**Break**	**ADF**	**KPSS**	**LLS**	**Break**
United States	1.770	2.60	1.685	2002	-0.423	0.556	-1.395	2002
Belgium	-4.005***	2.527	-4.305***	2007	-0.079	0.654	-1.261	2007
Canada	-2.763*	1.805	-2.105	1984	-1.370	0.327	-1.164	1984
Denmark	-1.294	1.704	-3.367**	1994	-2.011	0.414	-1.044	1994
France	-2.753*	1.783	-2.491	2008	-2.685	0.366	-0.652	2008
Germany	-2.761*	1.767	-3.290**	2006	-2.409	0.303	-1.492	2006
Italy	-2.057	1.724	-4.564***	1994	-1.628	0.410	-0.443	1994
Netherlands	-3.326**	1.757	-3.457**	2008	-1.643	0.389	-1.427	2008
Norway	-2.678*	1.725	-2.693*	1979	-1.916	0.371	-1.013	1979
Sweden	-0.679	1.759	-0.460	2001	-2.940	0.216***	-1.542	2001
United Kingdom	-0.609	1.806	-0.562	1998	-3.322*	0.097***	-3.082**	1998

Model with intercept: ADF Critical values at 1%. 5% and 10% are -3.43,-2.86 and -2. 57 respectively
KPSS Critical values at 1%. 5% and 10% are 0.739, 0.463 and 0.347 respectively
LLS Critical values at 1%. 5% and 10% are -3.48, -2.88 and -2.58 respectively
Model with intercept and trend: ADF Critical values at 1%. 5% and 10% are -3.96, -3.41 and -3.13 respectively
KPSS Critical values at 1%. 5% and 10% are 0.216, 0.146 and 0.119 respectively
LLS Critical values at 1%. 5% and 10% are -3.55, -3.03 and -2.76 respectively

Table A2. Unit Root tests for the logarithm of the inflation rate

	Intercept included				*Trend and Intercept included*			
Country	**ADF**	**KPSS**	**LLS**	**Break**	**ADF**	**KPSS**	**LLS**	**Break**
United States	-1.574	1.781	-1.893	2008	-0.822	0.373	-2.708	2008
Belgium	-1.972	2.575	-2.259	2008	-1.629	0.610	-1.795	2008
Canada	-1.797	2.591	-2.130	1991	-1.695	0.568	-2.526	1991
Denmark	-2.006	1.731	-2.330	1974	-1.294	0.441	-2.552	1974
France	-2.073	2.537	-1.864	1974	-1.903	0.604	-2.256	1974
Germany	-2.148	1.781	-3.327**	2008	-0.879	0.415	-1.507	2008
Italy	-1.987	1.753	-2.739**	2008	-1.818	0.368	-3.094**	2008
Netherlands	-2.914**	1.722	-2.768**	2001	-1.790	0.429	-2.364	2001
Norway	-1.941	1.764	-2.505	2007	-0.767	0.414	-2.156	2007
Sweden	-2.004	1.758	-1.760	1992	-0.725	0.399	-1.837	1992
United Kingdom	-1.559	1.746	-1.631	1990	-1.444	0.398	-1.952	1990

Model with intercept: ADF Critical values at 1%. 5% and 10% are -3.43,-2.86 and -2. 57 respectively
KPSS Critical values at 1%. 5% and 10% are 0.739, 0.463 and 0.347 respectively
LLS Critical values at 1%. 5% and 10% are -3.48, -2.88 and -2.58 respectively
Model with intercept and trend: ADF Critical values at 1%. 5% and 10% are -3.96, -3.41 and -3.13 respectively
KPSS Critical values at 1%. 5% and 10% are 0.216, 0.146 and 0.119 respectively
LLS Critical values at 1%. 5% and 10% are -3.55, -3.03 and -2.76 respectively

Table A3. Unit Root tests for the logarithm of real wage

	Intercept included				*Trend and Intercept included*			
Country	**ADF**	**KPSS**	**LLS**	**Break**	**ADF**	**KPSS**	**LLS**	**Break**
United States	-1.810	2.627	-1.824	2004	-1.087	0.584	-3.052**	2004
Belgium	-1.945	2.437	-2.127	1990	-1.818	0.549	-1.993	1990
Canada	-1.229	2.555	-1.481	1976	-1.936	0.522	-2.603	1976
Denmark	-1.632	2.512	-1.788	1990	-1.793	0.534	-1.873	1990
France	-1.754	2.546	-1.592	1975	-1.503	0.564	-2.118	1975
Germany	-1.823	1.729	-1.731	1991	-1.388	0.390	-1.713	1991
Italy	-2.057	1.724	-1.797	1993	-1.627	0.410	-1.598	1993
Netherlands	-2.390	1.689	-2.597*	1990	-1.682	0.388	-1.079	1990
Norway	-1.545	1.726	-1.739	1993	-1.770	0.379	-1.875	1993
Sweden	-2.046	1.683	-2.237	1993	-2.149	0.367	-2.270	1993
United Kingdom	-1.433	1.769	-1.490	1989	-1.273	0.346	-1.929	1989

Model with intercept: ADF Critical values at 1%. 5% and 10% are -3.43,-2.86 and -2. 57 respectively
KPSS Critical values at 1%. 5% and 10% are 0.739, 0.463 and 0.347 respectively
LLS Critical values at 1%. 5% and 10% are -3.48, -2.88 and -2.58 respectively
Model with intercept and trend: ADF Critical values at 1%. 5% and 10% are -3.96, -3.41 and -3.13 respectively
KPSS Critical values at 1%. 5% and 10% are 0.216, 0.146 and 0.119 respectively
LLS Critical values at 1%. 5% and 10% are -3.55, -3.03 and -2.76 respectively

Table A4. Time series cointegration tests

		Intercept included				*Trend and Intercept included*			
		Johansen Trace Test		***Saikkonen & Lutkepohl Test***		***Johansen Trace Test***		***Saikkonen & Lutkepohl Test***	
Country	**H_0**	**LR**	**p-value**	**LR**	**p-value**	**LR**	**p-value**	**LR**	**p-value**
United States	r0	86.7	0.00	61.56	0.00	94.39	0.00	41.03	0.00
Belgium	r0	98.22	0.00	60.49	0.00	130.54	0.00	75.23	0.00
Canada	r0	53.11	0.00	34.99	0.00	155.4	0.00	52.65	0.00
Denmark	r0	83.52	0.00	45.42	0.00	110.37	0.00	47.53	0.00
France	r0	69.11	0.00	43.30	0.00	79.29	0.00	53.70	0.00
Germany	r0	82.11	0.00	45.64	0.00	96.29	0.00	54.73	0.00
Italy	r0	134.19	0.00	80.45	0.00	156.20	0.00	71.50	0.00
Netherlands	r0	91.64	0.00	67.94	0.00	118.25	0.00	58.71	0.00
Norway	r0	60.76	0.00	44.25	0.00	122.89	0.00	52.21	0.00
Sweden	r0	78.83	0.00	49.50	0.00	80.34	0.00	57.58	0.00
United Kingdom	r0	89.27	0.00	64.17	0.00	113.67	0.00	70.52	0.00

Table A5a. Gregory-Hansen Test for Cointegration with Regime Shifts: *Productivity as endogenous variable*

	Change in Level		*Change in Level and Trend*		*Change in Regime*		*Change in Regime and Trend*	
Country	**Zt**	**Break Date**	**Zt**	**Break Date**	**Zt**	**Break Date**	**Zt**	**Break Date**
United States	-3.22	1971	-4.93	2001	-4.14	1979	-5.09	2000
Belgium	-3.70	1967	-4.08	1968	-3.75	1974	-4.26	1970
Canada	-4.94	1994	-4.76	1969	-5.61	1989	-5.50	1978
Denmark	-3.84	1979	-3.86	1980	-3.93	1981	-3.99	1981
France	-3.60	1997	-4.04	1967	-3.57	1988	-4.66	1986
Germany	-3.83	1998	-3.94	1967	-3.81	1998	-4.36	1986
Italy	-4.55	1967	-4.62	1967	-5.29	1980	-6.89	1981
Netherlands	-4.27	1975	-4.52	1967	-4.44	1975	-4.93	1972
Norway	-3.53	1975	-3.98	1967	-3.98	1973	-4.94	1989
Sweden	-3.78	1996	-3.48	1968	-3.94	1995	-4.13	1977
United Kingdom	-3.73	1975	-4.12	1996	-3.87	1978	-4.77	1995

Table A5b. Gregory-Hansen Test for Cointegration with Regime Shifts: *Inflation as endogenous variable*

	Change in Level		*Change in Level and Trend*		*Change in Regime*		*Change in Regime and Trend*	
Country	**Zt**	**Break Date**	**Zt**	**Break Date**	**Zt**	**Break Date**	**Zt**	**Break Date**
United States	-3.68	1969	-5.02	1967	-3.78	1981	-5.64	1979
Belgium	-3.90	1967	-4.10	1968	-4.63	1981	-5.96	1981
Canada	-3.68	1979	-3.84	1979	-4.04	1979	-4.39	1978
Denmark	-4.25	1979	-4.16	1979	-4.70	1981	-5.62	1981
France	-4.09	1979	-4.55	1981	-6.88	1981	-6.08	1982
Germany	-4.09	1979	-4.07	1979	-4.40	1981	-4.05	1979
Italy	-4.45	1967	-4.30	1967	-4.68	1978	-4.93	1978
Netherlands	-4.42	1977	-4.52	1977	-5.17	1977	-6.16	1980
Norway	-4.11	1981	-3.97	1981	-3.81	1982	-5.57	1982
Sweden	-3.67	1981	-3.17	1980	-3.68	1982	-4.25	1976
United Kingdom	-4.07	1981	-4.29	1996	-4.54	1983	-5.32	1983

Table A5c. Gregory-Hansen Test for Cointegration with Regime Shifts: *Real wage as endogenous variable*

	Change in Level		*Change in Level and Trend*		*Change in Regime*		*Change in Regime and Trend*	
Country	**Zt**	**Break Date**	**Zt**	**Break Date**	**Zt**	**Break Date**	**Zt**	**Break Date**
United States	-3.81	1969	-4.59	1967	-4.37	1980	-4.92	1975
Belgium	-3.82	1981	-4.05	1980	-4.14	1981	-4.64	1982
Canada	-3.17	1981	-4.35	1968	-3.70	1987	-5.81	1984
Denmark	-3.60	1997	-4.04	1967	-3.57	1988	-4.66	1986
France	-4.07	1980	-4.19	1981	-4.77	1981	-4.76	1981
Germany	-4.00	1997	-4.03	1997	-3.93	1997	-4.34	1986
Italy	-3.63	2003	-4.51	1995	-4.25	1998	-4.38	1995
Netherlands	-3.85	1973	-3.88	1997	-4.01	1981	-4.88	1986
Norway	-3.71	1981	-3.92	1973	-4.34	1981	-4.28	1981
Sweden	-3.92	1971	-3.93	1971	-3.91	1979	-4.29	1979
United Kingdom	-4.15	1981	-4.16	1981	-4.52	1978	-4.53	1978

Model with change in level: Critical values at 1%. 5% and 10% are -5.44, -4.92 and -4.69 respectively
Model with Change in Level and Trend: Critical values at 1%. 5% and 10% are -5.80, -5.29 and -5.03 respectively
Model with Change in Regime: Critical values at 1%. 5% and 10% are -5.97, -5.50 and -5.23 respectively
Model with Change in Regime and Trend: Critical values at 1%. 5% and 10% are -6.45, -5.96 and -5.72 respectively