UNEMPLOYMENT AND PRODUCTIVITY GROWTH: AN EMPIRICAL ANALYSIS OF CAUSALITY

by

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ABSTRACT

In the literature of the past decade, some innovative contributions identified a relation between productivity growth and unemployment. In most unemployment models, productivity growth is considered as an exogenous independent variable. On the other side, the reverse causality from unemployment to productivity growth has been explored in some recent endogenous growth models. In fact, it is likely that growth and employment go hand in hand.

In this paper, I look at panal data from 8 OECD countries over the period 1966-1995, to investigate causality between unemployment and productivity growth. I find some empirical evidence suggesting that there is two-way causation, i. e. a feedback relationship between unemployment and productivity growth. Then I estimate unemployment and growth models where both unemployment and growth are considered as endogenous variables. On balance, the estimated coefficients show a significantly negative relationship between unemployment and productivity growth.

DEDICATION

This paper is dedicated to my great parents, who give me a beautiful world full of love.

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1 INTRODUCTION

Does productivity growth create or destroy jobs? Does equilibrium unemployment have any effect on growth? What is the relationship between growth and unemployment? In the literature, popular views on these questions are mixed.

Gordon (1997) provides a common explanation to the productivity slowdown and high unemployment of the US and the relatively high growth, high unemployment of European countries. He introduces the idea of the UPT (unemployment-productivity trade-off) schedule and distinguishes between policies that move a country along a given schedule and those that shift the schedule. Gordon claims that positive trade-off between growth and unemployment may occur in the short run, generated by structural shocks, like wage shocks, but the trade-off disappears in the long run, through a process of dynamic adjustment.

Pissarides (1990) exhibits a negative correlation between growth and unemployment based on a “capitalization effect”. Suppose that productivity growth occurs throughout the economy. A higher growth rate will then make new hirings more profitable for a firm, because the expected future revenues increase relative to the hiring costs that are incurred today. Thus, higher growth induces lower unemployment.

The negative effect of anticipated growth on unemployment rises when wage setting is affected (Mannning, 1992). Higher anticipated growth means higher future real wages. This raises the value of employment relative to unemployment. So employees are likely to moderate their wage demand to reduce the risk of lay-offs.

Aghion and Howitt (1994) present a model based on the Schumpeterian idea of "creative destruction" and find that if plant is unable to update its technology, in steady state growth path, it becomes unable to cover overhead cost in land due to the increasing price of land. Then, the plant will shut down, forcing its workers into unemployment (direct creative destruction). At the same time, the implied reduction in the benefit to creating a production unit causes vacancies to fall and reinforces the increase in unemployment (indirect creative destruction). However, if plants can upgrade their technology, the "capitalization effect" will reappear. Furthermore, low substitutability across sectors may result in reversing the indirect creative destruction effect and introducing the negative effect of growth on unemployment even in the absence of a capitalization effect.

However, Mortensen and Pissarides (1998) solve the existing conflict in the sign of the effect of growth. When new technology rises, the employer has three choices: continue to produce with the technology embodied in the job when it was created, pay a fixed renovation cost to upgrade its technology and continue producing with the same worker, or close the job down and exit production. They conclude that the sign depends on the size of updating cost. Higher productivity growth induces lower unemployment when renovation costs are low, but that the response of employment to growth switches from positive to negative as the updating cost rises above a unique critical level.

Long run unemployment was totally ruled out by neoclassical growth models. However, Aghion and Howitt (1998) discuss a feedback from unemployment to growth when learning by doing is introduced as a primary source of growth in their model. For example, if the capitalization effect dominates so that an increase in growth reduces unemployment, this will result in more learning by doing and therefore an even stronger capitalization effect.

Daveri and Tabellini (2000) argue that a permanent increase in the employment rate implies a lower capital labour ratio, so capital becomes more productive at the margin, and this induces more investment and a faster growth of per capita income. At the same time, higher employment (lower unemployment) means higher aggregate income in the economy. With a given savings rate, higher employment therefore means higher saving. Eventually, higher aggregate income together with a higher savings rate means more capital accumulation and thus higher growth.

Zagler (1999) constructs a monopolistically competitive economy and finds that the unemployment exhibits an unambiguously negative impact on the long-run growth performance, as employment is reduced both in the manufacturing and innovation sector, the latter leading to a decline in the innovative capacity of the economy and hence slower economic growth. Only if efficiency levels differ across sectors, is there a causal relation from the growth rate to the rate of unemployment.

Bräuninger and Pannenberg (2002) incorporate unemployment into a generalized Solow-type growth model and claim that the long-run level of productivity is reduced if higher unemployment leads to less formal education or less learning by doing.

Finally, not only Aghion and Howitt (1994), but also Bean and Pissarides (1993) consider growth and unemployment in a joint way. Bean and Pissarides build an overlapping generation model where both growth and unemployment are endogenous variables and analyzed the feedback effect that unemployment generates on growth.

In sum, causality from productivity growth to unemployment is adopted when growth is exogenous, whereas in endogenous growth models, unemployment also influences growth. Hence, in this paper, my focus of analysis is the causal relationship between unemployment and productivity growth.

2 GRANGER CAUSALITY TEST

2.1 Granger causality and feedback

From the correlation table below, we can find a negative correlation between growth and unemployment in eight[1] OECD[2] countries, and the size of correlation varies from 0.08 to 0.6.

Table 1 Correlation between growth and unemployment in 8 OECD countries

Australia	Belgium	Canada	France	Japan	Netherlands	Spain	USA
-0.08	-0.53	-0.27	-0.53	-0.57	-0.60	-0.20	-0.19

However, correlation does not necessarily imply causation in any meaningful sense of that word. Granger (1969) develops a simple causal mode as below to decide the direction of the causality between two related stationary time series.

$$X_t = \sum_{j=1}^{m} a_j X_{t-j} + \sum_{j=1}^{m} b_j Y_{t-j} + \varepsilon_t$$

$$Y_t = \sum_{j=1}^{m} c_j X_{t-j} + \sum_{j=1}^{m} d_j Y_{t-j} + \eta_t$$

In this model, Y_t is said to be Granger-caused by X_t if X_t helps in the explanation of movements of Y_t, or equivalently, if the coefficients on the lagged value of X_t are statistically significant, i.e. Y_t Granger-causes X_t if b_j is significant, and X_t Granger-causes Y_t if c_j is significant.

[1] They are Australia, Belgium, Canada, France, Japan, Netherlands, Spain, and United States.
[2] OECD is Organisation for Economic Co-operation and Development.

To test if the data satisfy the assumption of stationary in causal model, I do unit root tests and find that all the productivity growth rates are stationary at 2% level (except 16.7% in Japan and 12.9% in Spain), while all the unemployment rates are non-stationary at 20% (except 5% in United States), which are reinforced by the time trend in unemployment rate from figure 1 in appendix.

However, strictly speaking, the unemployment rate can't have a unit root, since it is bounded between zero and one, and unit root processes diverge to plus or minus infinity with probability one. As a matter of fact, unemployment rates just exhibit an increasing trend during the 30 years (1966-1995) when data are collected in these developed countries, which may be explained by some structural or mechanism change in economy during this period. But, if we have a very long time period, for example, hundreds of years, unit root tests may provide a stationary result. In addition, from a statistical perspective, it may be preferable to use the unit root null distribution even when we know that theoretically the series can't have a unit root. This is because the Dickey-Fuller critical values might provide better small sample approximations than the usual normal asymptotic (that I use in the tests) when the series is highly persistent.

Therefore, I do Granger causality test using original unemployment rates and detrended unemployment rates[3] respectively. Test results in table 2 show that, using detrended unemployment rates, there is two-way causation in most of the countries[4], which is called feedback relationship by Granger (1969), whereas in level form test, Granger causality from unemployment to growth is not significant in most of the countries. However, when I pool the 8 countries data together and test the causality by running the simple causal model using least square method, g_{t-1} is significant in

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[3] Hodrick-Prescott Filter is used to detrend unemployment rates and get stationary time series.
[4] In Australia, the Granger causation is only from growth to unemployment.

predicting u_t, and u_{t-1} is significant in predicting g_t too (reported in column 1 and 2 of table 3). Thus, feedback exists in the pooled data. By the way, neither g_{t-3} nor u_{t-3} is significant, which suggests that two causality lags are enough[5] in tests.

Table 2 P-value (%) in the pairwise Granger causality tests (annual data)

Null Hypothesis	g does not Granger cause u				u does not Granger cause g			
Causality lag	1	1	2	2	1	1	2	2
Australia	0	0	0	2.63	58.7	0.10	13.4	0.19
Belgium	6	2.16	35.5	23.6	5.5	60.6	15.4	34.2
Canada	1.1	1.12	13.1	49.2	58.9	0.02	3.7	0.07
France	2.2	3.84	27.4	62.6	13.8	1.27	40	2.35
Japan	0	0.03	0	1.4	92.5	1.32	32.3	1.42
Netherlands	0	0.55	17.2	17.4	81.9	1.04	92.3	1.85
Spain	0	0.26	2.5	5.48	33	1.58	81.1	22.5
USA	1.3	0.04	9.3	13	6.5	0.02	16.1	0.85

Notes: g is productivity growth, u is unemployment rate in shaded columns, but is detrended unemployment rate in non-shaded columns.

2.2 Instantaneous causality

The more general model with instantaneous causality is

$$X_t + b_0 Y_t = \sum_{j=1}^{m} a_j X_{t-j} + \sum_{j=1}^{m} b_j Y_{t-j} + \varepsilon_t$$

$$Y_t + c_0 X_t = \sum_{j=1}^{m} c_j X_{t-j} + \sum_{j=1}^{m} d_j Y_{t-j} + \eta_t$$

If b_0 is significant, then instantaneous causality is occurring and a knowledge of Y_t will improve the prediction or goodness of fit of the first equation for X_t. From column 3 and 4 in table 3, I find both b_0 and c_0 are significant and thus, instantaneous causality

[5]. The causality lags do have effect on the test results. For example, when I test the null hypothesis that "g does not Granger cause u", the result for France is inversed when the lag is increased from 1 to 2.

exists in two ways[6], which proves my guess that unemployment and growth go hand in hand.

Table 3 Causality tests using pooled data

	1		2		3		4	
Dependent variable	g_t		u_t		g_t		u_t	
g_{t-1}	0.52*** (0.07)	0.51*** (0.06)	-0.1*** (0.03)	-0.08*** (0.02)	0.37*** (0.06)	0.42*** (0.06)	0.009 (0.026)	-0.013 (0.022)
g_{t-2}	0.1*** (0.06)	0.32*** (0.06)	0.13*** (0.02)	0.037* (0.02)	0.28*** (0.05)	0.37*** (0.06)	0.15*** (0.02)	-0.08*** (0.02)
u_{t-1}	0.63*** (0.17)	1.55*** (0.19)	1.32*** (0.07)	0.87*** (0.06)	2.46*** (0.24)	2.56*** (0.24)	1.45*** (0.058)	1.07*** (0.067)
u_{t-2}	-0.55* (0.18)	-0.37* (0.2)	-0.3*** (0.07)	-0.36*** (0.07)	-0.97*** (0.16)	-0.8*** (0.2)	-0.43*** (0.06)	-0.41*** (0.06)
g_t							-0.21*** (0.02)	-0.13*** (0.02)
u_t					-1.39*** (0.14)	-1.16*** (0.19)		

Notes:

1. u_t is unemployment rate in level in shaded columns, but it is detrended in non-shaded columns.
2. *** 1% level of significance. ** 5% level of significance. * 10% level of significance

[6]. Granger (1969) also suggests that in many economic variables, an apparent instantaneous causality would disappear if the economic variables were recorded at more frequent time intervals. I test the instantaneous causality using quarterly data in United States (I didn't find the data for other countries), however, there is still instantaneous causality between unemployment and growth.

3 MODEL

3.1 Unemployment equation

In the literature, exogenous productivity growth is regarded as an explanatory variable in unemployment models as well as other explanatory variables, for instance, labour tax, minimum wage, labour market institution, unemployment benefits etc.

Labour taxes drive a wedge between income if employment (the wage) and if unemployed (income earned in the underground economy or the unemployment benefit). Then, real wage rises and firms cut employment, and as a result, the capital-labour ratio rises for a given capital stock. In the long run, investment is reduced and the economy returns to a new steady state with the same capital-labour ratio, the same real wage, but a permanently lower level of employment and of per capita output (Daveri and Tabellini, 2000).

Dolado et al. (1996) summarizes four propositions about minimum wage: 1) Minimum wage cannot increase employment and generally reduces it. 2) Its adverse employment effects are largest in a small open economy where international competitiveness is most significant. 3) Young workers are most affected. 4) Minimum wage earners do not usually come from the poorest households, so minimum wages do little to alleviate poverty.

In addition, the cross-sectional variation in the unemployment rates is dominated by fixed effect at the country level (Daveri and Tabellini, 2000). For instance, as documented by Nickell (1997), labour market legislation differs markedly across countries but has not changed much since the late 1960s or early 1970s.

Raising unemployment benefits increases the real wage which results in a fall in employment, just like the impact of labour tax on employment.

Finally, by combining the variables above that may influence the equilibrium unemployment rate, I develop the following unemployment equation,

$$Unemployment_{it} = \beta_1\ Labour\ tax_{it} + \beta_2\ Minimum\ wage_{it} + \beta_3\ Unemployment\ benefits_{it}$$

$$+ \beta_4\ Time_t + \beta_5\ Growth_{it} + \beta_{6-13}\ Country\ dummies_i + \upsilon_{it}$$

3.2 Growth equation

Different from in neoclassical growth model, some variables are treated as endogenous in endogenous growth model. Lucas (1988) emphasizes human capital accumulation as an alternative (to technological change) source of sustained growth, and education is one of main sources of human capital accumulation[7]. A greater amount of educational attainment indicates more skilled and more productive workers, which in turn increase an economy's output of goods and services (Barro and Lee, 2000).

Furthermore, raising capital tax reduces the return to investment and there is less incentive to invest and therefore reduce productivity growth. Then, the inclusion of initial per capita income is suggested by the prediction of convergence implied by some formulations of the technology (Daveri and Tabellini, 2000). In addition, initial level of technology as well as other time invariant country effects can be captured by country specific dummy variables, and growth trend is captured by time variable.

Eventually, the growth equation is modeled as below.

$$Growth_{it} = \beta_1\ Capital\ tax_{it} + \beta_2\ Education_{it} + \beta_3\ Initial\ productivity\ level_{it}$$

$$+ \beta_4\ Unemployment_{it} + \beta_5\ Time_t + \beta_{6-12}\ Country\ dummies_i + \varepsilon_{it}$$

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[7] Lucas (1988) distinguishes two sources of human capital accumulation, education and learning-by-doing.

4 DATA

In this paper, I look at annual data from 8 OECD countries, Australia, Belgium, Canada, France, Japan, Netherlands, Spain and United States over the period 1966-1995. The sample size is dictated by the availability of data on minimum wages and tax rates. To remove the effect of cyclical fluctuations, I average each variable over a five-year period and the transformed data have six observations, 1966-70, 1971-75, 1976-80, 1981-85, 1986-90 and 1991-95[8] for each country. Resulted from the availability of minimum wages, I have to use unbalanced panal data in some estimation.

Productivity growth rate: I adopt the growth rate of PPP-adjusted real GDP per capita in 1996 international price because of its comparability across countries. Source: Summers-Heston Data set (PWT 6.1).

Initial productivity level: first-year PPP-adjusted real GDP per capita in each five-year period. It takes the logarithm form in regression because dependent variable is in percentage. Source: Summers-Heston Data set (PWT 6.1).

Unemployment rate: to ensure comparability across countries, I use OECD standardized unemployment rates (seasonally adjusted), which give the numbers of unemployed persons as a percentage of the total labour force. The definition of employment and unemployment conforms to the definition adopted by the 13th Conference of Labour Statisticians (generally referred to as the ILO guidelines) with the exception that employment and unemployment estimates are based on labour force

[8] Tax rate is averaged over six years in the first period, 1965-1970, while standardized unemployment rates are averaged over four years due to the availability of data, 1967-1970.

surveys, which cover only private households and exclude all people living in institutions. Source: OECD Quarterly Labour Force Statistics.

Minimum wage: the real level of the minimum wage may be inappropriate in comparisons across time or between countries with differing productivity: we expect the effect of minimum wages to depend on their level relative to labour productivity. The commonest measure is therefore the minimum wage as a fraction of average earnings (Dolado et al., 1996). In this paper, I use the ratio of minimum wage over median wage. Source: Labour database statistics in OECD's Corporate Data Environment (CDE).

Unemployment benefits: are the OECD summary measures of entitlement benefits-an average of the gross replacement rates of various categories of benefit earners, different in terms of marital status, number of children and unemployment spells. Source: OECD 2002, Benefits and Wages, OECD Indicators.

Tax rates: effective tax rate on labour income is computed as the ratio between total taxes on labour income[9]. Effective tax rate on capital income is computed as the ratio between total taxes on capital income[10]. Source: Mendoza et al. (1997) using the methodology developed by Mendoza, Razin and Tesar (JME, 1994). Original data source: OECD National accounts, OECD Revenue Statistics.

Education: educational attainment is at best a proxy for the component of the human capital stock obtained at schools. I use the percentage of the total population aged 25 and over when the highest educational level attained is second level and over. Source: Barro, Robert J. and Jong-Wha Lee (2000) in their paper "International Data on Educational Attainment: Updates and Implications".

[9] Labour income =an imputation of taxes on wages and salaries from the individual income tax + social security contributions + payroll taxes.
[10] Capital income =an imputation of taxes on the operating surplus of unincorporated enterprises and profits and entrepreneurial incomes + corporate taxes + recurrent taxes on immovable property + taxes on financial and capital transactions.

5 ESTIMATION

5.1 Fixed effect estimators

First, I estimate two simple regressions below respectively using fixed effect method without considering the causality relationship between unemployment and growth (reported in column 1 and 2 of table 4).

$$Unemployment_{it} = \beta_1\ Labour\ Tax_{it} + \beta_2\ Minimum\ wage_{it} + \beta_3\ Unemployment\ benefits_{it} + \beta_4\ Time_t + \beta_{5-12}\ Country\ dummies_i{}^{11} + v_{it}$$

$$Growth_{it} = \beta_1\ Capital\ tax_{it} + \beta_2\ Education_{it} + \beta_3\ Initial\ productivity\ level_{it} + \beta_4\ Time_t + \beta_{5-12}\ Country\ dummies_i + \varepsilon_{it}$$

Fixed effect intercepts are assumed in regression because in unemployment and growth theories, country specific effects exist on long run equilibrium unemployment and productivity growth. Besides, I reject the null hypothesis that all intercept coefficients are equal using Chow test in both equations. More importantly, fixed effect estimators are unbiased no matter whether the intercept is random effect or fixed effect. In addition, random effects estimator should not be used whenever there are a small number of cross-sectional units (Kennedy, 2002) (there are only 8 countries in the sample).

Second, I add 'growth' into unemployment equation as additional regressor and 'unemployment' into growth model assuming they are exogenous (reported in column 3 and 4 in Table4). The Interesting thing is that, in the original annual data, unemployment is non-stationary and growth is stationary. However, in the two regressions, time variable

[11] There are 8 countries and thus 8 country specific dummy variables, and regressions are estimated without intercepts.

Table 4 Unemployment and growth estimation (8 countries)

	1	2	3	4	5	6	7
Method	FE	FE	FE	FE	FE	2SLS	2SLS
Regressand	u	g	u	g	u	u	g
Adjusted R^2	0.816	0.616	0.848	0.666	0.852	-	-
Labour tax rate	0.356 (0.178) 5.5%	-	0.169 (0.177) 34%	-	0.11 (0.094) 23%	0.11 (0.094) 23%	-
Minimum wage	-0.092 (0.07) 20%	-	-0.114 (0.065) 8%	-	-0.109 (0.062) 9%	-0.109 (0.062) 9%	-
Unemployment benefits	0.448 (0.115) 0	-	0.506 (0.107) 0	-	0.52 (0.01) 0	0.52 (0.01) 0	-
Capital tax rate	-	-0.037 (0.056) 51%	-	0.0025 (0.054) 96%	-	-	-0.028 (0.069) 68%
Education	-	0.07 (0.034) 4.6%	-	0.078 (0.032) 1.9%	-	-	0.08 (0.04) 5.18%
Log(Initial productivity)	-	-13.16 (2.95) 0	-	-15.07 (2.85) 0	-	-	-13.77 (4.55) 0.5%
Time	-0.435 (0.48) 37%	0.96 (0.33) 1%	-0.163 (0.45) 72%	1.33 (0.35) 0	-	-	1.18 (.0.52) 3.21%
Unemployment	-	-	-	-0.188 (0.074) 1.6%	-	-	-0.187 (0.083) 3.41%
Growth	-	-	-0.567 (0.216) 1.4%	-	-0.585 (0.207) 0	-0.585 (0.207) 0	-
Number of observations	40	48	40	40	48	40	40

Notes:

1. Fixed effects intercepts not reported. Standard errors in parentheses. The third row in each unit is the P-value for that coefficient. Except column 2 and 4, I use unbalanced panal data.
2. FE: fixed effect estimator. 2SLS: two-stage least square estimators.

is not significant in unemployment equation but is in growth equation. The reasonable explanation is that time and unemployment benefits are highly correlated in unemployment equation, i.e. the correlation in the 8 countries is from 88% to 98% (in Table 5). Whereas, there is no such high multi-collinearity in growth equation, and time trend is accruing after cyclical fluctuation is removed. Therefore I dropped the time variable from unemployment equation, and re-run the regressions (reported in column 5 in table 4).

Table 5 Correlation between time and unemployment benefits

Australia	Belgium	Canada	France	Japan	Netherlands	Spain	USA
0.98	0.95	0.984	0.975	0.987	0.951	0.933	0.883

5.2 Two-stage least square (2SLS) estimators

Hausman (1978) originally proposes a test statistic for endogeneity based upon a direct comparison of coefficient values. Then, Davidson and MacKinnon (1989, 1993) propose another version of the Hausman test. Take growth equation for an example, first, regress unemployment on its instrumental variables, labour income tax, minimum wage, unemployment benefits and other exogenous variables, capital tax, education, initial productivity level, and then retrieve the residuals e_i from the estimation. Second, re-estimate the growth equation with e_i as additional regressor. Then unemployment is endogenous if the coefficient on e_i is statistically significant. Eventually, I find both the endogeneity of unemployment in growth equation (P-value of coefficient on residual is 0%) and that of growth in unemployment equation (P-value of coefficient on residual is 5%), which is consistent with the two-way Granger causality in section 2.

In order to cope with the endongeneity, I use Two-stage Least Square (2SLS) to estimate the two specifications in table 6 (reported in column 6 and 7 of Table 5). These specifications satisfy the order condition for identification, which requires that there be at least as many instruments as there are coefficients in the equation specification, and also satisfies rank conditions because it is impossible to find another linear combination from the two specifications[12].

Moreover, 2SLS estimators are consistent and have small sample properties superior on most criteria to all other estimators. Especially, they are quite robust (i.e. insensitive to the presence of other estimating problems such as multi-collinearity and specification errors) (Kennedy, 1998).

Table 6 Specifications in 2SLS

Regressand	Unemployment	Growth
Regressors	Labour tax, minimum wage, unemployment benefits, country dummies, growth	Capital tax, education, initial productivity, time, country dummies, unemployment
Instrumental variables	Labour tax, minimum wage, unemployment benefits, country dummies, capital tax, education, initial productivity, time	Capital tax, education, initial productivity, time, country dummies, labour tax, minimum wage, unemployment benefits,

Notes:

1. Assume all explanatory variables are predetermined except growth and employment in each specification.
2. Assume the instrumental variables, capital tax, education and initial productivity, have no effect on unemployment rates, and at the same time, labour tax, minimum wage and unemployment benefits have no effect productivity growth.

However, the most undesirable result in table 4 is the wrong sign on the coefficient of minimum wage that is supposed to be positive. After checking the data, I am confident that the wrong sing is resulted from an outlier (or influential) country in sample, Spain, i.e. the correlation between unemployment and minimum wage in Spain is negative (figure 5 in appendix).

[12]. The rank condition is quite awkward to employ and the "impossible to find a linear combination" view of identification can be used to check informally the rank condition for instances in which the order condition holds (Kennedy, 1998).

Therefore, I drop 'Spain' and estimate the equations again (reported in Table 7), where I find significantly negative relationship between unemployment and growth in each regression. All else equal, 1% increase in growth rates leads to 0.52% reduction in unemployment from unemployment equation, and then the reduction in unemployment rates reinforces the increase in growth rates by $(0.38 \times 0.52\%=)$ 0.1976% due to the feedback from unemployment to growth.

In unemployment equation, the sign on minimum wages become positive in all regressions after I drop Spain from the data set, but it is still not significant. It is likely because that minimum wage mainly reduces youth employment rate and has little impact on total unemployment rate. Besides, the criteria and definition[13] of minimum wage are various across these OECD countries. As for the estimated coefficients on labour tax and unemployment benefits, they are both significantly positive as expected. All else equal, 1% increase in labour tax rates results in 0.23% increase in unemployment rates, and 1 unit increase in unemployment benefits gives rise to 0.246% increase in unemployment rates.

In growth equation, capital tax rate is never significant in any regression and even has a positive sign in column 4 where the endogeneity of unemployment is not dealt with in regression. Actually, capital tax mainly has significantly direct effect on investment but not on growth (Daveri and Tabellini, 2000). In addition, the measurement error in capital tax rates is likely to be very large and thus could also account for my non-significant estimates. Finally, the estimated coefficient of education always has expected sign, positive, so is (the log of) initial GDP per capita but with positive sign.

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[13]. In Australia and Netherlands, minimum wage is federal minimum weekly. Belgium and Spain use minimum monthly wage. United States settle federal minimum hourly wage. In Canada they are weighted average of provincial minimum hourly wage. In France they are gross annual equivalent of the hourly minimum wage. Japan uses weighted average of prefectural hourly minimum wages.

Ceteris paribus, if one more percent of population aged 25 and over attains second level and over education, the whole economy productivity growth will increase by 0.077%. Besides, the small estimated coefficient on initial productivity is–11.28, implies a slow convergence to the steady state (Daveri and Tabellini, 2000).

Table 7 Unemployment and growth estimation (7 countries)

	1	2	3	4	5	6	7	8	9
Method	FE	FE	FE	FE	FE	2SLS	2SLS	WTSLS	WTSLS
Regresand	u	g	u	g	u	u	g	u	g
Adjusted R^2	0.846	0.63		0.72	0.849	-	-	-	-
Labour tax rate	0.327 (0.15) 3.7%	-	0.34 (0.14) 2.19%	-	0.23 (0.07) 0.4%	0.23 (0.07) 0.4%	-	0.253 (0.05) 0	-
Minimum wage	0.017 (0.06) 78%	-	0.048 (0.05) 36%	-	0.037 (0.06) 50%	0.037 (0.06) 50%	-	0.06 (0.04) 13%	-
Unemployment benefit	0.239 (0.095) 2%	-	0.19 (0.08) 2.7%	-	0.246 (0.09) 1.5%	0.246 (0.09) 1.5%	-	0.19 (0.06) 0.6%	-
Capital tax rate	-	-0.04 (0.06) 46%	-	0.01 (0.05) 85%	-	-	-0.029 (0.06) 64%	-	-0.06 (0.05) 19%
Education	-	0.066 (0.03) 6%	-	0.07 (0.03) 3%	-	-	0.077 (0.04) 5%	-	0.063 (0.03) 5.2%
Log(Initial productivity)	-	-12.55 (3.1) 0	-	-14.9 (2.96) 0	-	-	-11.28 (5.09) 3.75%	-	-9.36 (4.0) 2.8%
Time	-0.29 (0.40) 46%	0.93 (0.34) 1%	-0.26 (0.34) 45%	1.4 (0.36) 0	-	-	0.99 (0.54) 7%	-	0.78 (0.4) 7.1%
Unemployment	-	-	-	-0.3 (0.11) 1%	-	-	-0.38 (0.12) 0.6%	-	-0.3 (0.09) 0.5%
Growth	-.051 (0.17) 0.7%	-	-0.46 (0.16) 0.7%	-	-0.52 (0.17) 0.6%	-0.52 (0.17) 0.6%	-	-0.457 (0.13) 0.1%	-
Number of observations	34	42	34	42	34	34	34	34	34

Notes:

1. Fixed effects intercepts not reported. Standard errors in parentheses. The third row in each unit is the P-value for that coefficient. Except column 2 and 4, I use unbalanced panal data.
2. FE: fixed effect estimator. 2SLS: two-stage least square. WTSLS is weighted two-stage least square.

Additionally, because of the feedback relationship, I also test the impact of lagged growth on unemployment and lagged unemployment on growth, but neither is significant which may be resulted from the fact that the lagged value is averaged over five years, while feedback is found in annual data.

Finally, the standardized unemployment rate is also likely to be measured with error. Different countries have different methods of recording the unemployed, and even the OECD standardized unemployment rates cannot cover all undetected measurement problems that may actually drive our results.

5.3 Balanced panal data

In order to get a relatively large sample, I use unbalanced data in the regressions above. Actually, there is no big change when I use balanced panal data (4 countries) instead. But the advantage of using balanced panal data is that I can test for the nature of the variance-covariance matrix of error term.

LR test for the equality of the error variances across the N countries, is given by

$$LR = T(N \ln \hat{\sigma}^2 - \sum_{i=1}^{N} \ln \hat{\sigma}_i^2),$$

where $\hat{\sigma}^2$ is the estimate of the assumed-common error variance, and $\hat{\sigma}^2$ is the estimate of the i^{th} country's error variance. This statistic distributed as a chi-square with N-1 degree of freedom.

LM test for the unique off-diagonal elements of the contemporaneous variance-covariance matrix equal to zero, is given by

$$LM = T \sum_{i=1}^{N} \sum_{j=1}^{i-1} r_{ij}^2,$$

where r_{ij}^2 is the square of the correlation coefficient between the contemporaneous errors for the i^{th} and j^{th} countries. This statistic distributes as a chi-square and degree of freedom equals the number of restrictions, i.e. 6 in the balanced panal estimation.

LR and LM statistics are calculated when balanced data are used to estimate following two equations (see table 8).

$$\textit{Unemployment}_{it} = \beta_1 \textit{ Labour Tax}_{it} + \beta_2 \textit{Minimum wage}_{it} + \beta_3 \textit{Unemployment benefits}_{it} + \beta_4 \textit{Growth}_{it} + \beta_{5-8} \textit{Country dummies}_i + v_{it}$$

$$\textit{Growth}_{it} = \beta_1 \textit{Capital tax}_{it} + \beta_2 \textit{Education}_{it} + \beta_3 \textit{Initial productivity level}_{it} + \beta_4 \textit{Time}_t + \beta_5 \textit{Unemployment}_{it} + \beta_{6-9} \textit{ Country dummies}_i + \varepsilon_{it}$$

Table 8 Residual tests

Null hypotheses	Homoskedasticity	No contemporaneous correlation
Statistic	LR	LM
Growth equation	12.88 4.48%	4.85 43.4%
Unemployment equation	13.02 4.27%	6.18 28%
Conclusion	Heteroskedasticity in residuals at 5% level in both equations.	No contemporaneous correlation at 25% level in the two equations.

Notes: the figures beneath the statistics are p-value.

Heteroskedasticity is found in residuals of the two regressions, but contemporaneous correlation is not. Then estimates are not efficient and standard errors are biased if there is heteroskedasticity, and inference results are not reliable any more.

Therefore in order to get efficient estimates and unbiased standard errors, I use weighted two-stage least square (WTSLS) technique to re-estimate[14] the two specifications in table 6 (reported in column 8 and 9 of table 6). As a result, in unemployment equation, all the explanatory variables become more significant than in 2SLS and in growth equation, only capital tax is more significant than before but p-value is over 20%. Generally speaking, there is no big change except the standard errors become smaller and some variable become more significant by using WTSLS.

5.4 Alternative measure of productivity

The measure of productivity in this paper is real GDP per capita. However, due to trends in labour force participation, it might be preferable to use per worker rather than per capita. The latest data available for real GDP per worker is in 1990 in Penn World Table 6.1 (figure 6 in appendix).

I redo Granger causality tests (Table 9 and 10 in appendix) using growth rate of PPP-adjusted real GDP per worker, and find the results are quite robust. Causality from growth to unemployment is significant in most of the countries, but the reverse causality from unemployment to growth is not if level unemployment rates are taken in tests. However, feedback is occurring in detrended unemployment rates and pooled data.

Furthermore, I re-estimate the two equations by two-stage least square[15] using data in 7 OECD countries (Table 11 in appendix). Most of the estimates are robust except that the sign of coefficient on education becomes negative, but it isn't significant at all (P-value is 32%). There still exists a significantly negative relationship between unemployment and growth.

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[14]. Even though heteroskedasticity is found in balanced data, I still use unbalanced panal data to re-estimate the two specifications by WTSLS for the sake of comparability.

[15]. There are no sufficient observations to use weighted two-stage least square.

6 CONCLUSION

I find a feedback relationship and two-way "instantaneous Granger causality" between the unemployment rate and productivity growth using annual data. However, Granger causality does not imply that one variable is the effect or the result of another one, like what causality means in the more common use of the term, but it measures precedence and information content. Therefore, my conclusion about Granger causality in this paper is that unemployment and productivity growth go hand in hand.

Adopting the results in the Granger causality tests, I consider the endogeneity of unemployment in a growth model and of growth in an unemployment model and estimate two equations using two-stage least square. On balance, the estimated coefficients suggest a significantly negative relationship between unemployment and productivity growth. That is, in the sample data, higher growth reduces unemployment rate, and "capitalization effect" dominates "creative destruction". On the other hand, lower unemployment rate induces higher growth, more likely by more learning by doing or education.

APPENDIX

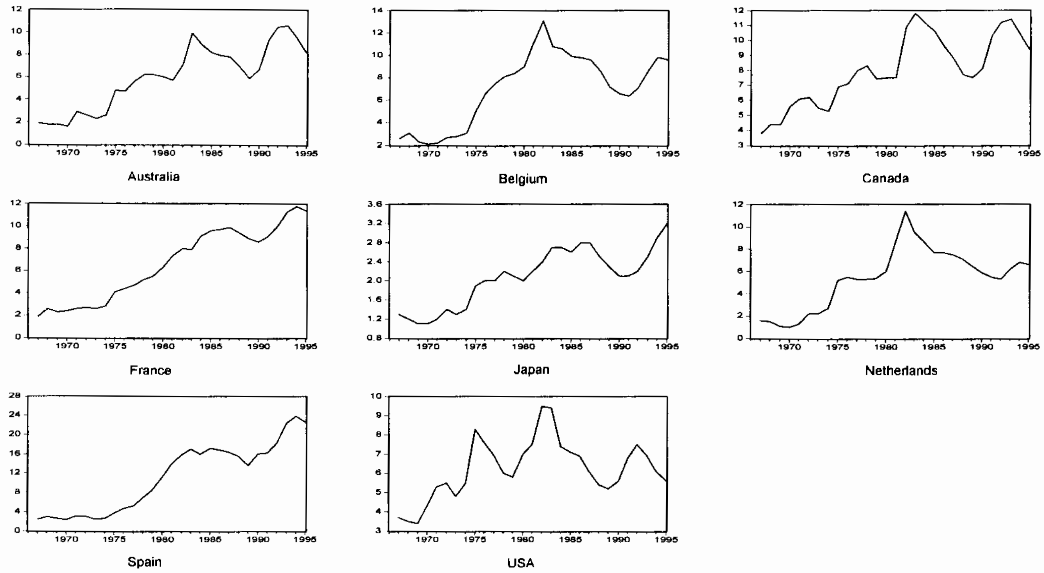

Figure 1 Standardized unemployment rates

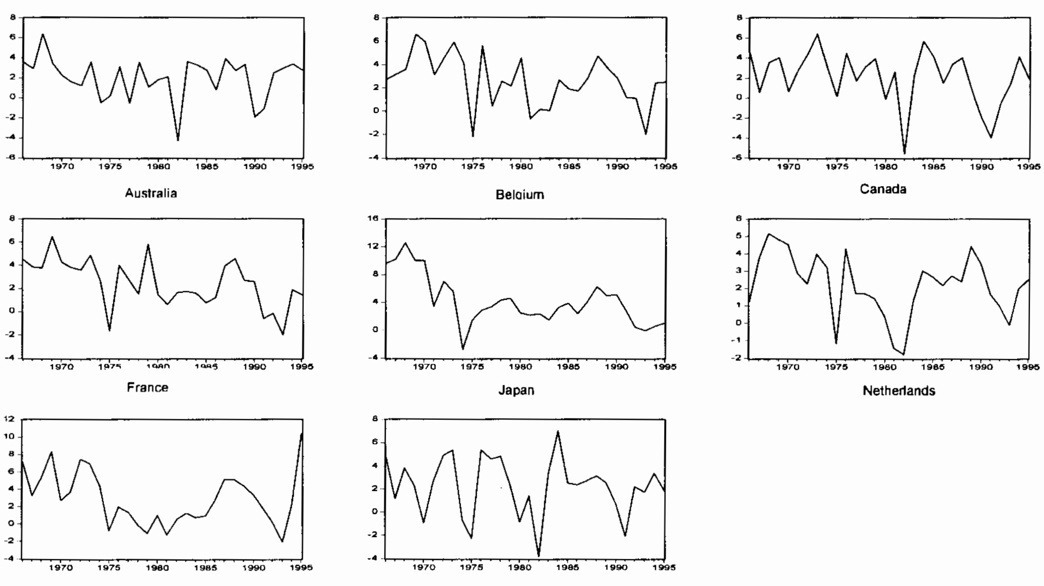

Figure 2 Productivity growth rates

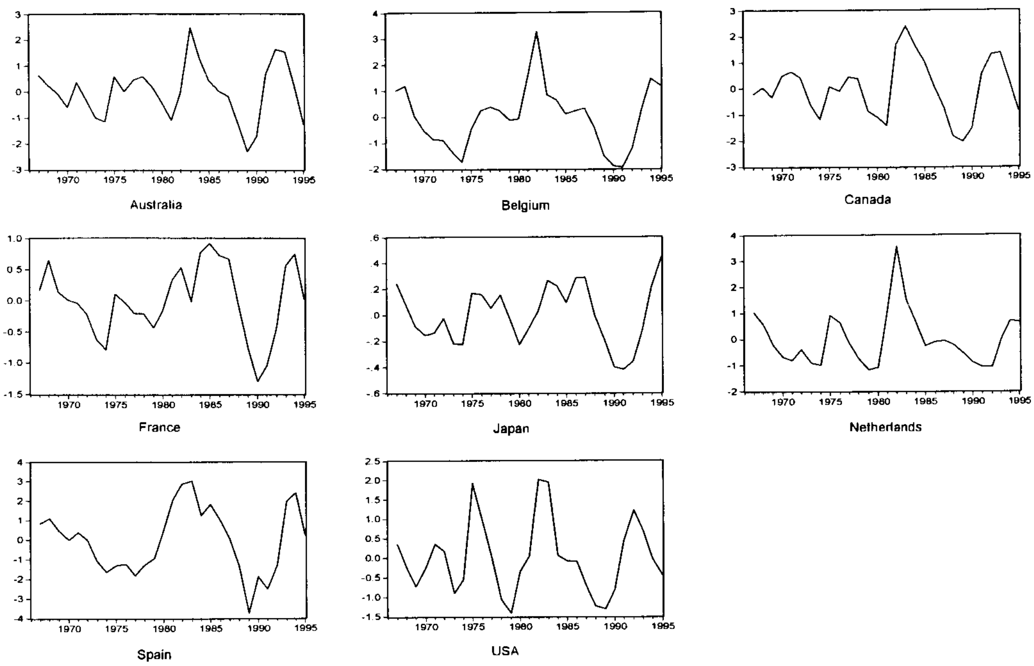

Figure 3 Detrended standardized unemployment rates

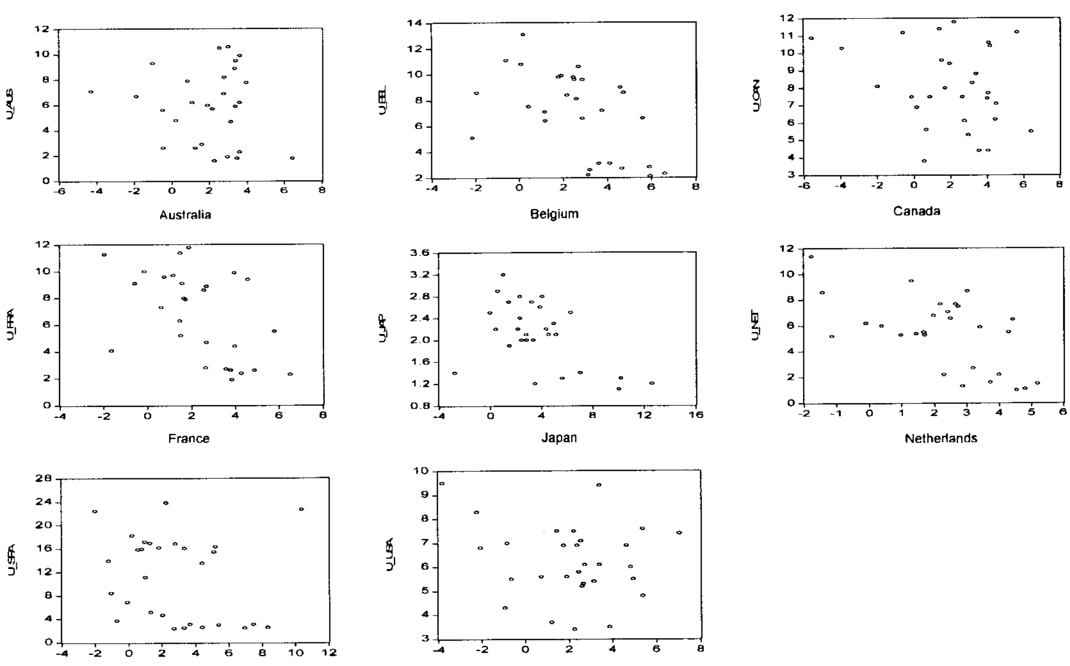

Figure 4 Unemployment-growth scatter plots

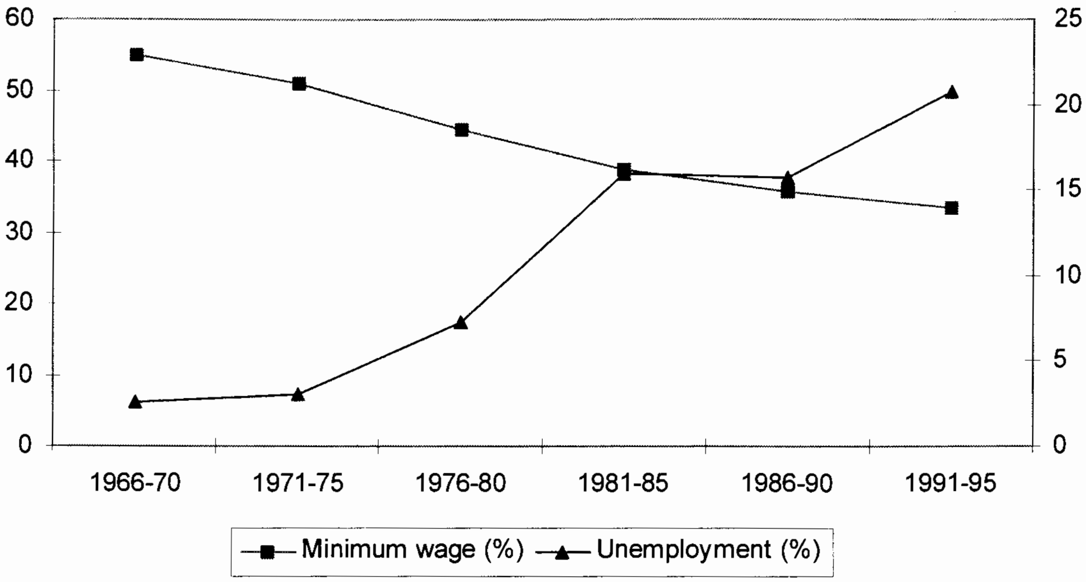

Figure 5 Unemployment-minimum wages in Spain

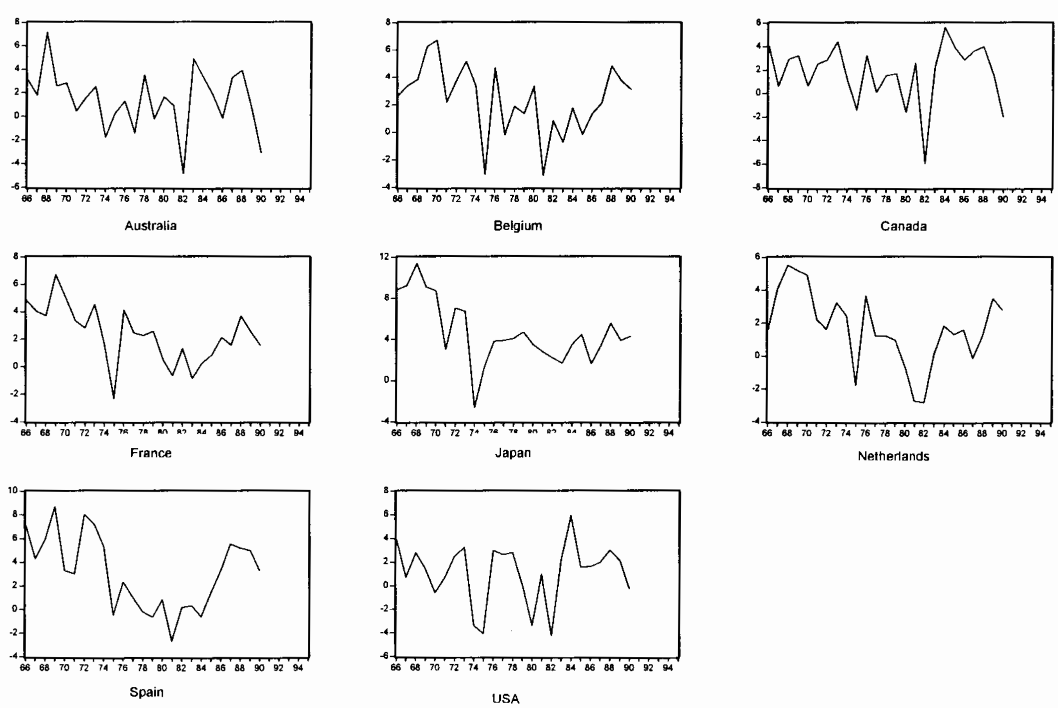

Figure 6 Growth rates of real GDP per worker

Table 9 P-value (%) in the pairwise Granger causality tests (alternative measure of productivity)

Null hypothesis	g does not Granger cause u				u does not Granger cause g			
Causality lag	1	1	2	2	1	1	2	2
Australia	0	0	0.2	3.5	95	0	12	1.8
Belgium	2.5	1.7	19	7.6	4.5	82	18	75
Canada	18	18	55	36	24	0	11	0.4
France	1	10	6.5	27	38	4.7	51	5.3
Japan	0	0	0	4.2	78	5	54	12.6
Netherlands	1	1.8	14	26	76	2.7	99	7.8
Spain	0	1.4	7	14	94	27	76	53
USA	2	0	4	15	10	0	10	1

Notes:

1. Productivity is measured by real GDP per worker.
2. g is productivity growth, u is unemployment rate in shaded columns, but is detrended in non-shaded columns.

Table 10 Granger causality tests using pooled data (alternative measure of productivity)

Dependent variable	g_t		u_t		g_t		u_t	
g_{t-1}	0.43*** (0.07)	0.44*** (0.07)	-0.1*** (0.03)	-0.1*** (0.02)	0.31*** (0.07)	0.33*** (0.068)	-0.005 (0.026)	-0.035 (0.02)
g_{t-2}	0.19*** (0.07)	0.35*** (0.06)	0.11*** (0.025)	0.04* (0.02)	0.34*** (0.06)	0.39*** (0.06)	0.14*** (0.02)	0.07*** (0.02)
u_{t-1}	0.63*** (0.2)	1.4*** (0.24)	1.28** (0.07)	0.8*** (0.07)	2.38*** (0.29)	2.4*** (0.29)	1.4*** (0.07)	0.99*** (0.08)
u_{t-2}	-0.6 (0.21)	-0.32 (0.26)	-0.3*** (0.07)	-0.23*** (0.08)	-0.9*** (0.19)	-0.65*** (0.25)	-0.38*** (0.07)	-0.31*** (0.076)
g_t							-0.19*** (0,02)	-0.12*** (0,02)
u_t					-1.36*** (0.18)	-1.2*** (0.23)		

Notes:

1. Productivity is measured by real GDP per worker.
2. u_t is level unemployment rates in shaded columns, but is detrended in non-shaded columns.
3. *** 1% level of significance. ** 5% level of significance. * 10% level of significance

Table 11 2SLS estimators (alternative measure of productivity)

Regressand	Growth		Unemployment	
Regressors	Coefficient	P-value	Coefficient	P-value
Capital tax	0.0008 (0.07)	0.99	-	-
Education	-0.03 (0.03)	0.32	-	-
Log (initial productivity)	-7.36 (4.35)	0.11	-	-
Time	1.00 (0.32)	0.01	-	-
Unemployment	-0.44 (0.11)	0.00	-	-
Labour tax	-	-	0.27 (0.08)	0
Minimum wage	-	-	0.01 (0.06)	0.83
Unemployment benefits	-	-	0.21 (0.11)	0.06
Growth	-	-	-0.78 (0.2)	0
Number of observations	27		27	

Notes:

1. Productivity is measured by real GDP per worker.
2. Unbalanced panal data from 7 OECD countries.
3. Fixed effects intercepts not reported. Standard errors in parentheses.

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