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# Unemployment and Productivity Growth

## An Empirical Analysis within the Augmented Solow Model*

by

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# Unemployment and Productivity Growth

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**Abstract:**. Does a country's level of unemployment have an impact on the long-run growth rate? Incorporating unemployment into a generalised Solow-type growth model yields some answers. In the traditional Solow model, unemployment has no long-run influence on the growth rate and the level of productivity. The long-run level of productivity is reduced if higher unemployment leads to less formal education or to less learning-by-doing. If we allow for endogenous growth, unemployment reduces long-run productivity growth. Using panel data from 13 OECD countries from 1960 to 1990, we find evidence that an increase in unemployment scales down the long-run level of productivity.

Keywords: Growth, Equilibrium Unemployment, Panel Data.

JEL classification: O40, O57, E24.

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## 1. INTRODUCTION

Does a country's level of unemployment have an impact on the long-run growth rate? Persistently high unemployment rates in Europe over the last two decades indicate that unemployment is, at least to a large extent, not a pure business cycle phenomenon. This implies a continuing squandering of labour and of human capital in most European countries. Hence, it seems reasonable to ask, if given levels of unemployment influence long-run productivity growth or the long-run level of productivity itself.

Unemployment is a severe problem in Europe, but not in the US. The decline in productivity growth has however been stronger in the US over the last decades of the 20$^{th}$ century. Between 1979 and 1997 the average rate of unemployment in the US was 6.7% and the average growth rate of labour productivity was 0.9%. In Europe the average rate of unemployment was 9.3% and the average growth rate of labour productivity was 2.2%. These figures might indicate a potential trade-off between unemployment and productivity growth. However, if we look at simple time series plots, the evidence lends at best mild support to this suspicion. Figure 1 shows the development of unemployment and productivity growth in Europe and in the US between 1960 and 1997. It is striking that there has been an increase in the rate of unemployment that goes along with a decline of productivity growth in Europe as well as in the USA.

Gordon (1997) and Bean (1997) argue that this time series evidence shows a causal link running from unemployment to growth.[1] Section 2 formalises this link by introducing unemployment into an augmented Solow growth model. The model nests the standard Solow model as well as endogenous growth models as special cases. Our main argument is that unemployment reduces production and income and thereby the accumulation of physical and human capital via a reduction of savings, spending on education and learning-by-doing. Therefore, unemployment might impinge negatively on productivity and productivity growth in the long run, as in Bean/Pissarides (1993). In section 3 and 4 we put our theoretical model to an empirical test, where section 3 discusses the empirical specification and section 4 presents the results of our estimates using a dynamic panel data framework. The main finding is that unemployment indeed reduces the level of productivity: Taken at face value our results suggest that if unemployment would have remained at the level of 1960 than productivity today would be roughly 10% higher than it is. Section 5 concludes.

## 2. UNEMPLOYMENT IN THE AUGMENTED SOLOW GROWTH MODEL

Employing a simple growth theory framework our focus is on the influence of long-run (equilibrium) unemployment on productivity growth. Following most parts of the literature (e.g. Layard/Nickell/Jackman (1991)) we assume that equilibrium unemployment is determined by the generosity of the unemployment insurance system and by institutional settings, such as the size and power of unions and the bargaining system. [2] Given the empirically reasonable assumption that the return from being unemployed is proportional to the income of the employed and therefore to productivity, these determinants of unemployment are not directly influenced by productivity growth. Hence, equilibrium unemployment is exogenous within our simple theoretical model. Note, however, that within an intertemporal framework there might be an indirect influence of productivity growth on equilibrium unemployment through either an influence on the discount rate or through a creative destruction effect (see Aghion/Howitt (1998) and Pissarides (2000)). Therefore, we will tackle potential endogeneity of unemployment in the empirical part of our paper.

We start with a short-run model. Labour supply measured in efficiency units is given as N. All workers are assumed to be equally efficient. Unemployment reduces labour input in production: $L = (1 - u)N$. Available capital as well as the technological state of the economy is given. Firms use physical capital K and labour L to produce a homogenous output Y. The production function is assumed to be of Cobb-Douglas type: $Y = K^{\alpha}L^{1-\alpha}$ with $0 < \alpha < 1$. Profit maximisation implies that the marginal product of capital equals the interest rate $r = \alpha Y/K$ and the marginal product of an efficiency unit of labour equals the wage for an efficiency unit of labour $w_l = (1 - \alpha)Y/L$.

Efficiency units of labour are composed of raw labour and of human capital H. The size of the workforce is $\overline{N}$ and efficiency of raw labour is E. Consequently, labour supply in efficiency units is given as: $N = H^{\beta} (E\overline{N})^{1-\beta}$, with $0 \leq \beta \leq 1$. Efficiency of raw labour depends on technical progress and on learning-by-doing[3]: $E = \overline{E}[K/(\overline{E}\,\overline{N})]^{\gamma}$, with $0 \leq \gamma \leq 1$. Here $\overline{E}$ denotes the exogenous part of technological progress while physical capital normalised by the size of the workforce $[K/(\overline{E}\,\overline{N})]^{\gamma}$ captures the learning-by-doing effect. The size of the effect depends on $\gamma$: with $\gamma = 0$ there is no learning-by-doing and with $\gamma = 1$ learning-by-doing is proportional to capital per head. The production function is then given by:

$$Y = (1-u)^{1-\alpha} K^{\alpha+\gamma(1-\alpha)(1-\beta)} H^{\beta(1-\alpha)} (\overline{E}\,\overline{N})^{(1-\alpha)(1-\beta)(1-\gamma)} \quad (1)$$

The production function encompasses five special cases. 1) With $\beta = 0$ and $\gamma = 0$ human capital is unproductive and there is no learning-by-doing. Efficiency units of labour depend only on the number of workers and on the exogenous technological state of the economy, as in the traditional Solow growth model. 2) With $\beta = 1$ raw labour is unproductive and labour supply depends only on human capital built up by formal education. Therefore we obtain an endogenous growth model in the spirit of Lucas (1993). 3) With $0 < \beta < 1$ and $\gamma = 0$ we get the augmented Solow model introduced by Mankiw/Romer/Weil (1992). 4) With $\beta = 0$ and $0 < \gamma < 1$ human capital depends on leaning-by-doing and formal education is unimportant. 5) With $\beta = 0$ and $\gamma = 1$ we obtain a complete learning-by-doing effect and raw labour as well as formal education are unimportant. In this case the model is of AK type, as in Romer (1986).

Productivity, defined as production per worker, is given as $P = Y/\overline{L}$, where $\overline{L}$ is the number of employed workers. Insert $\overline{L} = (1-u)\overline{N}$ into the production function and divide by $\overline{L}$ to obtain:

$$P = \frac{\overline{E}}{(1-u)^{\alpha}}\left(\frac{K}{\overline{E}\,\overline{N}}\right)^{\alpha+\gamma(1-\alpha)(1-\beta)}\left(\frac{H}{\overline{E}\,\overline{N}}\right)^{\beta(1-\alpha)} \tag{2}$$

To establish the wage of a worker the labour share is divided by the number of workers $w = w_l\, L/\overline{L}$. Therefore, the wage is proportional to productivity $w = (1-\alpha)P$. Now consider an increase in the rate of unemployment. As an important first result we see that this leads to an increase in productivity and wages and to a reduction of production and of the interest rate.

This result holds for a given capital stock and a given level of labour efficiency. However, labour supply and capital and labour efficiency grow in the long-run. The work force grows with the exogenous rate $n = \hat{\overline{N}}$ and exogenous technological progress leads to growing efficiency $e = \hat{\overline{E}}$. Efficiency units of raw labour supply $\overline{E}\,\overline{N}$ therefore grow at an exogenous rate n + e. The equilibrium rate of unemployment stays constant and therefore labour used in production grows with the same rate as labour supply.

In each period physical capital is augmented by investment $\dot{K} = I$, where the dot denotes the time derivative $\dot{K} = dK/dt$. Since we are interested in consequences of long-run unemployment and not in business cycle effects, we assume that all savings are invested $I = S$. Savings are proportional to income $S = sY$. Hence we have $\dot{K} = sY$. Divide both sides by K and use (1) to obtain the growth rate of physical capital:

$$\hat{K} = s(1-u)^{(1-\alpha)}\left(\frac{H}{K}\right)^{\beta(1-\alpha)}\left(\frac{\overline{E}\,\overline{N}}{K}\right)^{(1-\alpha)(1-\beta)(1-\gamma)} \tag{3}$$

Human capital is augmented by education. Spending on education is proportional to income and therefore we have $\dot{H} = zY$, where z is the educational spending rate. Use the production function to substitute Y and divide by H to obtain the growth rate of human capital:

$$\hat{H} = z(1-u)^{(1-\alpha)}\left(\frac{H}{K}\right)^{-\alpha-\gamma(1-\alpha)(1-\beta)}\left(\frac{\overline{E}\,\overline{N}}{H}\right)^{(1-\alpha)(1-\beta)(1-\gamma)} \tag{4}$$

From (3) and (4) it becomes clear that an increase in the rate of unemployment reduces the growth rates of physical and human capital.

We are interested in the impact of a discrete jump in the equilibrium rate of unemployment. Productivity growth can be obtained from (2) and it is obvious that it is determined by technical progress and growth of physical and human capital per capita. Since these are reduced by unemployment, productivity growth is also reduced.

In the long run the economy converges to the steady state, where capital and production grow with equal rates $\hat{Y} = \hat{K}$. Transform the production function into growth rates to see that from the steady state condition $\hat{Y} = \hat{K}$ and $\hat{\overline{E}} + \hat{\overline{N}} = e + n$ it follows: $\hat{K} = [\beta\hat{H} + (1-\beta)(e+n)]/[1-\gamma(1-\beta)]$. Two cases arise: 1) with $0 \leq \beta < 1$ and $0 \leq \gamma < 1$ the steady state growth rate is determined by the exogenous rate of technological progress and population growth $\hat{Y} = \hat{K} = \hat{H} = n + e$; 2) with either $\beta = 1$ or $\gamma = 1$ we have constant returns to the factors that can be accumulated and therefore a balanced endogenous growth path with $\hat{Y} = \hat{K} = \hat{H}$.

Consider the neoclassical model with $0 \leq \beta < 1$ and $0 \leq \gamma < 1$. In the steady state growth is exogenous and the growth rate of productivity is $\hat{P} = e$. Hence, unemployment has no influence on the long-run growth rate. However, it might influence the level of productivity. In the steady state we have $\hat{K} = \hat{H} = e + n$ and, according to (3) and (4), H/K = z/s. Physical capital per efficiency unit of raw labour $k = K/\overline{E}\,\overline{N}$ and human capital per efficiency unit of raw labour $h = H/\overline{E}\,\overline{N}$ are constant. Use these conditions in equations (3) and (4) to obtain:

$$k = (1-u)^{\frac{1}{(1-\beta)(1-\gamma)}}\left(\frac{s}{e+n}\right)^{\frac{1}{(1-\alpha)(1-\beta)(1-\gamma)}}\left(\frac{z}{s}\right)^{\frac{\beta}{(1-\beta)(1-\gamma)}} \tag{5}$$

$$h = (1-u)^{\frac{1}{(1-\beta)(1-\gamma)}}\left(\frac{z}{e+n}\right)^{\frac{1}{(1-\alpha)(1-\beta)(1-\gamma)}}\left(\frac{z}{s}\right)^{\frac{-(\alpha+\gamma(1-\alpha)(1-\beta))}{(1-\alpha)(1-\beta)(1-\gamma)}} \tag{6}$$

An increase in the rate of unemployment reduces physical and human capital per effective raw labour. Now insert (5) and (6) into (2) to gain:

data framework. An advantageous feature of dynamic panel data models is that we do not have to rely on stochastic assumptions about the initial levels of technology, which has to be done in cross-section data regressions.[4] Initial levels of technology as well as other time invariant country effects are captured by fixed effects. Exogenous technological progress and other time specific common shocks are modelled by fixed (deterministic) time effects.

The general specification of our growth regressions as a dynamic two-way fixed effects model is:

$$y_{c,t} = \delta_0 \, y_{c,t-\tau} + \delta_1 u_{c,t-\tau} + x'_{c,t-\tau}\theta + \mu_c + \eta_t + \varepsilon_{c,t} \tag{8}$$

where $y_{c,t}$ is the log of the dependent variable, $u_{c,t-\tau}$ is the log of the country's lagged unemployment rate, $x'_{c,t-\tau}$ is a vector of the log of lagged variables controlling for observed time variant country characteristics, $\delta_0$, $\delta_1$ and $\theta$ are the parameter(s) (vector) of interest. $\mu_c$ is a fixed country effect, $\eta_t$ is a fixed time effect and $\varepsilon_{c,t}$ is a standard error term with $\varepsilon_{c,t} \sim N(0,\sigma_\varepsilon^2)$, $E(\varepsilon_{c,t},\varepsilon_{j,s}) = 0$, $c \neq j$ or $t \neq s$, $E(\mu_c,\varepsilon_{j,s}) = 0 \; \forall$ r, j, t and $E(x_{c,t},\varepsilon_{j,s}) = 0 \; \forall$ c, j, s, t. Using lagged values of all explanatory variables, any potential endogeneity should be reduced.[5]

Recent Monte Carlo studies (Judson/Owen 1999, Bun/Kiviet 1999) have emphasized that the finite sample properties of different inference techniques for dynamic panel data are still not well understood. We therefore use both the usual least square dummy variable estimator (LSDV) and a GMM-estimator proposed by Arellano/Bond (1991) to estimate equation (8). With respect to the GMM-estimator in a first step equation (8) is first-differenced to wipe out $\mu_c$. This allows us in a second step to exploit all lagged values of $y_{c,t-i\cdot\tau}$ $(i \geq 2)$ as instruments in the first-differenced equation. Moreover, if endogeneity of some other regressors like the saving rate is an issue, these variables might be instrumented using lagged values of $x_{c,t-i\cdot\tau}$ $(i \geq 2)$ as well. However, first-differencing introduces a moving average with unit root in the disturbance $\Delta\varepsilon_{c,t}$. The weighting matrix of the GMM-estimator takes the MA form of $\Delta\varepsilon_{c,t}$ into account.[6] Our IV-estimator hinges upon the assumption that there is no $2\tau$-order serial correlation for the disturbances of the first-differenced equations. Therefore, we employ a robust test of $2\tau$-order correlation suggested by Arellano and Bond (1991). Moreover, standard tests indicate that heteroscedasticity is an issue in our data. Standard errors and all test statistics are therefore robust to general heteroscedasticity.

$$P = \overline{E}(1-u)^{\frac{\beta+\gamma-\beta\gamma}{(1-\beta)(1-\gamma)}}\left(\frac{s}{e+n}\right)^{\frac{\alpha+\gamma(1-\alpha)(1-\beta)}{(1-\alpha)(1-\beta)(1-\gamma)}}\left(\frac{z}{e+n}\right)^{\frac{\beta(1-\alpha)}{(1-\alpha)(1-\beta)(1-\gamma)}} \qquad (7)$$

As an important result we see that for either $\beta > 0$ or $\gamma > 0$ unemployment reduces productivity in the long run. Only if $\beta = 0$ and $\gamma = 0$ there is no effect on the long-run level of productivity. Hence, whenever unemployment effects labour efficiency - either through formal education or through learning-by-doing - an increase in unemployment reduces the long-run level of productivity.

Now consider endogenous growth. With $\gamma = 1$ the model delivers endogenous growth through learning-by-doing. From (3) and (4) we obtain: $\hat{Y} = \hat{K} = \hat{H} = (1-u)^{1-\alpha} s^{1-\beta(1-\alpha)} z^{\beta(1-\alpha)}$. If $\beta = 1$ holds we obtain endogenous growth through formal schooling $\hat{Y} = \hat{K} = \hat{H} = (1-u)^{1-\alpha} s^{\alpha} z^{1-\alpha}$ regardless of the level of $\gamma$. In both cases productivity growth is reduced by an increase in unemployment, since $\hat{P} = \hat{Y} - n$ holds.

Finally, have a brief look at the process of adjustment induced by an increase in the level of unemployment. In the short run the increase in unemployment leads to an increase in capital per worker. Therefore productivity and wages rise, but income is reduced. This leads to a decline in savings and in educational spending. As a result, the growth rates of physical and human capital are reduced and productivity growth is also reduced. The long-run effect depends on the size of the influence of human capital and learning-by-doing in the production function. 1) When human capital does not matter and there is no learning-by-doing, productivity growth returns to the exogenously given levels. What is more, even the level of productivity is not affected in the long run. 2) When raw labour is productive and either human capital is also productive or there is some learning-by-doing, the growth of productivity returns to the exogenous levels. However, the transitory decline in productivity growth reduces the level of productivity in the long run. 3) When there is endogenous growth either through complete learning-by-doing or through human capital accumulation, the growth rate of productivity declines to a new steady state level. Hence, we have a permanent reduction in productivity growth.

## 3. EMPIRICAL SPECIFICATION AND DATA

To test for the impact of unemployment on growth we will augment standard growth regressions by levels and changes of the lagged unemployment rate, as motivated by our theoretical model. To capture dynamic as well as long-run effects we exploit a dynamic panel

Our data set covers 13 OECD countries[7] from three sources. Real GDP per worker as a measure for labour productivity, the investment share of GDP in percentage points as a proxy for the saving rate, capital stock per worker (all three at constant 1985 international prices) and the average population growth are drawn from the Penn World Tables version 5.6.

The unemployment rates are the OECD standardised unemployment rates. Our proxy for the country's stock of human capital is the percentage of secondary school attainment in the total population aged 15 and over, which is drawn from the Barro/Lee (1996) data set. Like most other studies (Temple 1999) we opt for a five year time interval to remove the effects of business cycles, i.e. the lagged unemployment rate is taken as an average over the 5 years preceding $t - \tau$, respectively $y_{c,t} - y_{c,t-\tau}$ are five year differences. Besides the lagged averaged unemployment rate we introduce somewhat ad hoc the change in the averaged unemployment rate $\Delta\, av(u) = av(u_{t-1,t-\tau}) - av(u_{t-\tau-1,t-2\tau})$ and the average annual growth rate of unemployment over the five years preceding t $av(\Delta(u^S))$ to capture short-run dynamics.

However, using 5-year averages leaves us with a small data set with respect to the time dimension. As a check of robustness, we therefore additionally run some regressions with annual data within an error correction framework. Since we have standardised unemployment rates starting in 1964 up to 1997, but only information for the secondary school attainment from 1960 to 1990, we exploit data from 1960 to 1990.[8] Table A in the Appendix provides descriptive statistics for all variables used in the empirical analysis. In our data the log of averaged unemployment is negatively correlated with productivity growth as indicated by an overall correlation coefficient of $\rho = -0.47$ ($p = 0.001$). Country-specific correlation coefficients of unemployment and productivity growth range from –0.83 (Netherlands) up to 0.10 (UK). Except for the UK all country specific correlation coefficients are negative.

## 4. RESULTS

We start with a dynamic analysis of the bivariate relation between the level of productivity and lagged unemployment using LSDV- and GMM-estimators. The underlying argument of our theoretical model is that productivity growth might be reduced by an increase of unemployment via reduced savings and educational expenditures (see equations 3 and 4). Therefore, we also analyse bivariate correlations between lagged unemployment and physical capital and lagged unemployment and human capital per worker. The reason for the parsimonious specification is that due to the potential mechanical correlation between the investment share of GDP in percentage points and GDP itself, the signal in the other explanatory variables of interest might be low conditional on investment (see Barro (1997) and Krueger/Lindahl (1999)). Table 1 displays our results.

Columns 1 and 2 of Table 1 show the results of the LSDV- as well as the GMM-estimator for the productivity equation. The estimated parameters for lagged unemployment are both significantly negative. Hence, we find a negative correlation between lagged unemployment and productivity, which is in line with our theoretical model. In addition, the estimated parameters of the short-run effect of unemployment are significantly negative. Therefore, within our five-year time span the initially positive effect of an increase in unemployment on productivity is totally purged by the following adjustment process. Columns 3 and 4 show the results for capital per worker. The correlation between lagged unemployment and capital per worker is significantly negative and is greater than the negative correlation between labour productivity and unemployment. This provides supportive evidence for the underlying link that an increase in unemployment goes along with a decrease in capital accumulation. Columns 5 and 6 indicate that we do not find any significant correlation between lagged unemployment and human capital measured by the secondary school attainment rate. Only the estimated parameter for the short-run averaged growth rates of unemployment in the LSDV-model is significantly positive, which is not in line with our simple model, but might be explained by the fact that young people might stay in school in the short run when unemployment increases.

With respect to the different Wald statistics (Wald_P, Wald_C, Wald_T) the panel specification of our parsimonious models seems to be appropriate. The BP-statistics indicate that heteroscedasticity is an issue in our data.[9] Considering the $m_2$ statistics, there is no evidence for serial correlation in the disturbances in our underlying model in levels.

In a second step we estimate our extended version of the standard augmented growth regression introduced by Mankiw/Romer/Weil (1992). The following specification can be derived from equations (5), (6), and (7). Instead of employment rates we use unemployment rates to assess the effect of unemployment directly. In addition to the lagged unemployment rate we introduce somewhat ad hoc the change in the averaged unemployment rate $\Delta av(u)$ and the average annual growth rate of unemployment over the five years preceding t $av(\Delta(u^S))$ to capture short-run dynamics:

$$p_{c,t} = \delta_0 p_{c,t-\tau} + \delta_1 u_{c,t-\tau} + \delta_2 \Delta\, av(u) + \delta_3 av(\Delta(u^S)) + \delta_4 [s_k - (n + e + d)] + \delta_5 h + \mu_c + \eta_t + \varepsilon_{c,t} \quad (9)$$

where $s_k$ is proxied by the log of the average investment share of GDP over the 5 years preceding t, h is the log of the secondary school attainment rate as provided by Barro/Lee (1996),[10] (n + e + d) is the log of the average rate of population growth in the relevant 5-year interval plus exogenous technological progress e and depreciation d. In line with large parts of the literature we take (e + d) to be equal to 0.05. Table 2 shows our results.

Column 1 and 2 report LSDV- and GMM- estimates of equation (9). The estimated parameters for $p_{c,t-\tau}$ are both significantly positive and clearly unequal from one. Hence, we observe convergence to the exogenous trend captured in the time effects in our data. The implied convergence rate ranges between 0.11 and 0.12 and is in line with results presented by Islam (1995) and Caselli et al. (1996).

The estimated parameters for the lagged level of unemployment are both significantly negative. Hence we observe a negative impact of the lagged level of unemployment on productivity, as suggested by our model. The implied long-run elasticity of productivity with respect to unemployment is roughly –0.08.[11] This indicates that unemployment does indeed have a remarkable long-run effect on productivity in our data: since unemployment in some countries roughly doubled over the observed period, our estimates imply that their productivity today would be 8% to 10 % higher than it would have been without the increase in unemployment.

The estimated parameters for h are never significantly different from zero. This is again in line with results provided by Islam (1995) and Caselli et al. (1996). This result might be due to measurement error (Krueger/Lindahl 1999). Secondary school attainment rates are clearly a very poor proxy for human capital, in particular if only OECD countries are considered. However if we take the result at face value than we have to conclude that the negative effect of unemployment on productivity is due to a learning-by-doing channel, i.e. higher unemployment means fewer opportunities for learning-by-doing. The estimated parameters for $[s_k - (n + e + d)]$ are positive and significant. The implied shares of capital are equal to 0.23 (LSDV) and 0.32 (GMM), which corresponds to other results (Gollin 1998).

Considering the fit of our regressions, all Wald statistics indicate that our panel specification is appropriate. Again, the test statistic of the Breusch-Pagan test indicates that heteroscedasticity is an issue in our data. Moreover, the $m_2$ statistics give supportive evidence for the validity of the GMM-procedure.

One might argue that endogeneity of both capital shares and of lagged unemployment is an issue in our data, e.g. rapidly growing countries are able to attract more investment. To check for endogeneity we exploit lagged values of all explanatory variables as instruments in the GMM procedure. Column 3 of Table 2 shows that the results remain stable with respect to the convergence parameter and the estimated parameter for the lagged level of unemployment, but that none of the other estimates is significantly different from zero.

Following the empirical growth literature (Temple 1999) and using five year averages to wipe out any cyclical effects leaves us with a panel data set with a small dimension with respect to T. To check for the robustness of our results,[12] we therefore ran some additional regressions using annual data from 1965 up to 1990. Since we do not have annual data on human capital, we restrict ourselves to parsimonious specifications like the one documented in Table 1. We specify ad hoc error correction equations with fixed effects for both labour productivity growth and for growth of capital per worker using the LSDV- and GMM-estimator. To test for cointegration between productivity (capital per worker) and unemployment we compute two residual based tests of the null of no cointegration in panels suggested by Pedroni (1999). With respect to labour productivity both tests reject the null (panel-t:–2.91; group-t:–36.8), with respect to capital per worker only one test rejects the null (panel-t:–0.03; group-t:–2.3).[13] Table 3 displays our results for the ECM estimates.

Column 1 of Table 3 shows that we again observe a significant negative correlation ($\alpha < 0.1$) between lagged unemployment and productivity using the LSDV-estimator.[14] Moreover, with respect to the short-run dynamics we find a positive relationship of productivity growth and the change of unemployment as predicted by our model. The estimated parameter for the lagged level of productivity is significantly negative, which is in line with the results of the cointegration tests. However, column 2 shows that we do not observe any significant relationship between lagged unemployment and productivity growth within the GMM-framework. Hence, based on annual data, we find only partly supportive evidence for a negative long-run correlation of unemployment and productivity.[15] Column 3 and 4 indicate that we observe a significantly negative correlation between lagged unemployment and growth of capital per worker in our data. These results are in line with our estimates presented in Table 1.

## 5. CONCLUSION

To answer the question whether unemployment influences productivity in the long run we incorporate equilibrium unemployment into a generalised augmented Solow-type growth model. The model shows that in a neoclassical framework an increase in equilibrium unemployment reduces the long-run level of productivity if unemployment has an effect on labour efficiency - through either formal education or learning-by-doing. In an endogenous growth frame work unemployment reduces productivity growth. Using data for 13 OECD countries within a dynamic panel data framework we find supportive evidence for the conditional convergence hypothesis which implies neoclassical growth and for a negative impact of the level of unemployment on the level of productivity. However, our empirical analysis does not provide any evidence for an effect of formal schooling on productivity. In terms of our model the negative effect of an increase in unemployment on the level of productivity is therefore due to reduced savings, capital accumulation and learning-by-doing.

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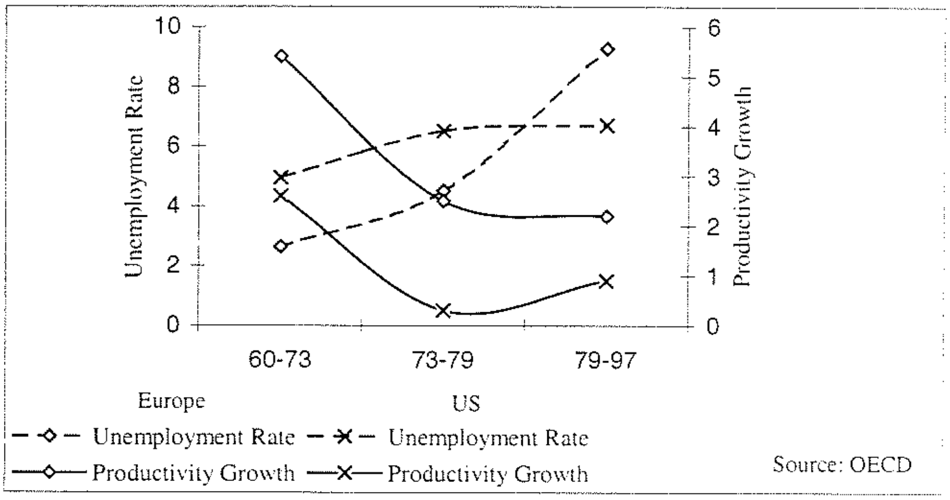


Figure 1: Unemployment and Productivity Growth

## Table 1: Parsimonious Specifications

| | Productivity ($\ln(P_{ct})=p_{ct}$) | | | Capital per worker ($\ln(K/L)_{ct}=k/l_{ct}$) | | | Human Capital ($\ln(h)_{ct}=h_{ct}$) | |
|---|---|---|---|---|---|---|---|---|
| | LSDV | GMM | | LSDV | GMM | | LSDV | GMM |
| $p_{c,t-\tau}$ | 0.578** | 0.600** | $k/l_{c,t-\tau}$ | 0.731** | 0.794** | $h_{c,t-\tau}$ | 0.406** | 0.652** |
| | (0.062) | (0.048) | | (0.043) | (0.044) | | (0.104) | (0.107) |
| $u_{c,t-\tau}$ | -0.040* | -0.040* | $u_{c,t-\tau}$ | -0.081** | -0.058* | $u_{c,t-\tau}$ | -0.029 | -0.170 |
| | (0.016) | (0.018) | | (0.019) | (0.023) | | (0.060) | (0.150) |
| $\Delta av(u)$ | -0.005 | -0.001 | $\Delta av(u)$ | -0.102** | -0.117** | $\Delta av(u)$ | 0.088 | -0.048 |
| | (0.024) | (0.026) | | (0.031) | (0.037) | | (0.058) | (0.092) |
| $av(\Delta(u^s))$ | -0.139* | -0.152* | $av(\Delta(u^s))$ | -0.067 | -0.022 | $av(\Delta(u^s))$ | 0.606** | -0.022 |
| | (0.065) | (0.065) | | (0.083) | (0.066) | | (0.221) | (0.308) |
| $R^2_{adj.}$ | 0.97 | -- | | 0.98 | -- | | 0.89 | -- |
| BP (df) | 7.4 (2) | -- | | 16.7 (3) | -- | | 15.6 (3) | -- |
| Wald_P (df) | 264.8 (13) | -- | | 419.0 (13) | -- | | 87.8 (13) | -- |
| Wald_C (df) | 48.8 (12) | -- | | 85.4 (12) | -- | | 56.0 (12) | -- |
| Wald_X (df) | 155.69 (4) | 233.4 (4) | | 503.3 (4) | 677.0 (4) | | 27.1 (4) | 60.6 (4) |
| Wald_T (df) | 236.10 (5) | 52.6 (4) | | 137.8 (5) | 58.6 (4) | | 53.9 (5) | 11.4 (4) |
| $m_1$ | -- | -2.1 | | -- | -1.7 | | -- | -1.9 |
| $m_2$ | -- | -0.1 | | -- | -1.6 | | -- | -0.8 |

Notes: N(LSDV) = 65 (13 countries * 5 intervals), N(GMM)=52.

Robust standard errors in parentheses. * ($\alpha < 0.05$) ; ** ($\alpha < 0.01$). Test statistics are robust to heteroscedasticity.

Time dummies included in all regression.

BP: Breusch-Pagan test for heteroscedasticity using within residuals ($H_0$: homoscedasticity)

Wald_P: Wald test with $H_0$: no joint significance of country effects; Wald_C: Wald test with $H_0$: identical country effects; Wald_X: Wald test with $H_0$: no joint significance of all independent variables (excluding time dummies), Wald_T: Wald test with $H_0$: no joint significance of time dummies. Degrees of freedom for $\chi^2$-statistics are reported in parentheses.

$m_1$: Test of $\tau$-order correlation of disturbances; $m_2$: Test of $2\tau$-order correlation of disturbances. $H_0$: no *-order correlation. Both tests are distributed N(0,1).

Instruments used in the GMM-estimates are all available lagged values of $y_{c,t-\tau}$, all time dummies and all other explanatory variables.

## Table 2: Standard Growth Regressions

| | LSDV | GMM [a] | GMM [b] |
|---|---|---|---|
| $p_{c,t-\tau}$ | 0.562** | 0.577** | 0.546** |
| | (0.047) | (0.039) | (0.052) |
| $u_{c,t-\tau}$ | -0.031* | -0.030* | -0.037* |
| | (0.016) | (0.014) | (0.014) |
| $\Delta av(u)$ | -0.006 | -0.0003 | -0.015 |
| | (0.025) | (0.029) | (0.030) |
| $av(\Delta(u^s))$ | -0.143* | -0.136* | -0.125 |
| | (0.062) | (0.068) | (0.073) |
| $s_k - (n + e + d)$ | 0.174* | 0.246* | 0.216 |
| | (0.074) | (0.101) | (0.143) |
| h | 0.013 | 0.011 | 0.019 |
| | (0.029) | (0.032) | (0.023) |
| $R^2_{adj.}$ | 0.97 | -- | -- |
| BP (df) | 8.4 (3) | -- | -- |
| Wald_P (df) | 105.7 (13) | -- | -- |
| Wald_C (df) | 69.5 (12) | -- | -- |
| Wald_X (df) | 181.4 (6) | 729.0 (6) | 455.4 (6) |
| Wald_T (df) | 96.1 (5) | 60.9 (4) | 55.7 (4) |
| $m_1$ | -- | -2.0 | -2.1 |
| $m_2$ | -- | 0.6 | 0.8 |

Notes: N(LSDV) = 65 (13 countries * 5 intervals). N(GMM)=52.

Robust standard errors in parentheses. * ($\alpha < 0.05$) ; ** ($\alpha < 0.01$). Test statistics are robust to heteroscedasticity.

Time dummies included in all regression.

BP: Breusch-Pagan test for heteroscedasticity using within residuals ($H_0$: homoscedasticity)

Wald_P: Wald test with $H_0$: no joint significance of country effects; Wald_C: Wald test with $H_0$: identical country effects; Wald_X: Wald test with $H_0$: no joint significance of all independent variables (excluding time dummies). Wald_T: Wald test with $H_0$: no joint significance of time dummies. Degrees of freedom for $\chi^2$-statistics are reported in parentheses.

$m_1$: Test of $\tau$-order correlation of disturbances; $m_2$: Test of $2\tau$-order correlation of disturbances. $H_0$: no *-order correlation. Both tests are distributed N(0,1).

(a) Instruments used in the GMM-estimates are all available lagged values of $p_{c,t-\tau}$, all time dummies and all other explanatory variables. (b) Additionally instrumenting unemployment and both capital shares by lagged values (t-2τ, respectively t - 2iτ with i ≥ ) of relevant variables.

## Table 3: Parsimonious Specifications (annual data)

| | Productivity Growth ($\Delta p_{ct}$) | | | Capital per worker Growth ($\Delta k/l_{ct}$) | |
|---|---|---|---|---|---|
| | LSDV | GMM | | LSDV | GMM |
| $\Delta p_{c,t-1}$ | -- | -- | $\Delta k/l_{c,t-1}$ | 0.100<br>(0.111) | 0.029<br>(0.067) |
| $p_{c,t-1}$ | -0.118**<br>(0.016) | -0.371**<br>(0.126) | $k/l_{c,t-1}$ | -0.089**<br>(0.027) | -0.116**<br>(0.019) |
| $u_{c,t-1}$ | -0.006+<br>(0.003) | -0.022<br>(0.045) | $u_{c,t-1}$ | -0.019**<br>(0.007) | -0.024**<br>(0.008) |
| $\Delta u_{c,t-1}$ | 0.015+<br>(0.008) | 0.044<br>(0.031) | $\Delta u_{c,t-1}$ | -0.008<br>(0.005) | 0.005<br>(0.010) |
| $\Delta u_{c,t-2}$ | 0.020**<br>(0.006) | 0.034<br>(0.024) | $\Delta u_{c,t-2}$ | -- | -- |
| $\Delta u_{c,t-3}$ | 0.018**<br>(0.004) | 0.028+<br>(0.015) | $\Delta u_{c,t-3}$ | -- | -- |
| $\Delta u_{c,t-4}$ | 0.021**<br>(0.005) | 0.028**<br>(0.010) | $\Delta u_{c,t-4}$ | -- | -- |
| $R^2_{adj.}$ | 0.60 | -- | | 0.67 | -- |
| BP (df) | 102.6 (6) | -- | | 418.4 (2) | -- |
| Wald_P (df) | 144.1 (13) | -- | | 176.4 (13) | -- |
| Wald_C (df) | 41.1 (12) | -- | | 93.1 (12) | -- |
| Wald_X (df) | 87.6 (6) | 74.8 (4) | | 39.3 (4) | 186.5 (4) |
| $m_1$ | -- | -2.7 | | -- | -1.7 |
| $m_2$ | -- | 0.1 | | -- | -1.6 |

Notes: N(LSDV) = 286 (13 countries * 22 intervals). N(GMM)=273.
All variables are deviations from period means.
Robust standard errors in parentheses. +($\alpha < 0.1$);* ($\alpha < 0.05$); ** ($\alpha < 0.01$).
Test statistics are robust to heteroscedasticity.
BP: Breusch-Pagan test for heteroscedasticity using within residuals. ($H_0$: homoscedasticity)
Wald_P: Wald test with $H_0$: no significance of country effects; Wald_C: Wald test with $H_0$: identical country effects;
Wald_X: Wald test with $H_0$: no joint significance of all independent variables.
Degrees of freedom for $\chi^2$-statistics are reported in parentheses.
$m_1$: Test of first-order correlation of disturbances; $m_2$: Test of second-order correlation of disturbances.
$H_0$: no *-order correlation.. Both tests are distributed N(0.1).
Instruments used in the GMM-estimates are all available lagged values of $y_{c,t-1}$ and all other explanatory variables.

## APPENDIX

### Table A: Descriptive Statistics

| variable | mean | std.-dev. |
|---|---|---|
| $P_{c,\tau}$ | 10.11 | 0.22 |
| $u_{c,t-\tau}$ | 1.16 | 0.78 |
| $\Delta av(u)$ | 0.29 | 0.34 |
| $av(\Delta(u^5))$ | 0.05 | 0.10 |
| $s_k - (n + e + d)$ | 6.12 | 0.19 |
| $h_{c,\tau}$ | 3.60 | 0.43 |
| $k/l_{c,t}$ | 10.18 | 0.42 |

Note: N = 65 (13 countries * 5 intervals) as in LSDV-procedures.
The countries are Australia, Belgium, Canada, Finland, France, Germany, Italy, Japan, Netherlands, Spain, Sweden UK and USA.

[1] The traditional link between unemployment and productivity is represented in Okuns law. However the focus of Okuns law is on short-run demand dynamics, see Gordon (1979). Neither the slowdown of productivity growth nor the increase in unemployment over the last decades can be explained by such short-run business cycle effects.

[2] Empirical evidence on the determinants of equilibrium unemployment is provided by Bean (1994) and Nickell (1998) among others.

[3] The incorporation of a learning-by-doing channel was stimulated by the suggestion of an anonymous referee.

[4] Standard augmented growth regressions relying on cross-section data have to deal with the problem that the initial level of technical efficiency [E(0)] for each country is unobserved. This introduces an omitted variable bias if one or more regressors are correlated with the initial level of technical efficiency (Caselli et al. 1996, Temple 1999). To solve the problem Mankiw/Romer/Weil (1992) assume that E(0) is a linear function of a stochastic technology shifter, which is independent of all explanatory variables. The dynamic panel data framework has also been used by Islam (1995) and by Caselli et al.(1996).

[5] We will address endogeneity problems in more detail later on.

[6] This is Arellano and Bonds' GMM1-estimator. In most Monte Carlo simulations (Judson/Owen 1999, Kievit 1995) GMM1 outperforms GMM2 if one takes the sample size of our data set into account. All GMM-estimations are carried out using GAUSS and the DPD-tool developed by M. Arellano and S. Bond (Arellano/Bond (1988)).

[7] The countries are Australia, Belgium, Canada, Finland, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, United Kingdom and USA.

[8] This implies that we use the unemployment rate in 1964 as a proxy for the average unemployment rate of the years 1960 to 1964.

[9] In Table 1 we use White estimators to compute robust standard errors. However, the finite sample characteristics of White's estimator are widely unknown (Greene 1997, p. 549). We therefore also compute an alternative estimator recommended by Greene (1997) for the LSDV model. The crucial results with respect to the lagged level of unemployment remain stable but the standard errors are higher, e.g. the estimated standard errors for $u_{c,t-1}$ are in column 1 $s_x = 0.021$ and in column 3 $s_x = 0.023$.

[10] Following previous panel data estimates we use this stock measure for human capital. Flow measures used by Mankiw/Romer/Weil (1992) are not available for 5-year intervals.

[11] Note that using the above mentioned alternative estimator to compute robust standard errors does not change the results qualitatively. However, the standard error for the estimated parameter of lagged unemployment in the LSDV model is then 0.018, which implies a significance level of only 10%.

[12] We also check for the impact of different ways of five-year averaging the data by means of changing the starting year (e.g. 1961 instead of 1960). Our main results with respect to unemployment and convergence remain stable.

[13] Following Pedroni's (1999) terminology we compute the panel t-statistic (parametric) and the group t-statistic (parametric), where we include country specific deterministic time trends in the panel cointegration regression. The values of the test statistics have to be compared to the appropriate tail of the normal distribution.

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[14] This result holds when we use the above mentioned different robust estimator of the standard error.

[15] Daveri/Tabellini (2000) find a significantly negative relationship between unemployment and productivity growth in their study using five year averages of the data. Note that using productivity growth implies that they impose the restriction $\delta_0 = 1$ in equation (9).

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