Does Labour Productivity Flow Across Industries?: Estimation Robust to Panel Heterogeneity and Cross Sectional Correlation.*

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Abstract

We consider labour productivity convergence between the US and the UK and France, using industry level data. We find evidence of panel heterogeneity, cross sectional correlation and weak evidence of productivity convergence at the industry level.

Keywords: Labour Productivity, Convergence, Panel Estimation, Panel Heterogeneity, Common Correlated Effects.

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1. Introduction

The hypothesis of economic convergence is a primary and particularly active area of research in empirical growth economics. The results up to now are far from being unanimous and they very much depend on the different interpretations of convergence.[1] Additional insights have recently been provided by industry level data. For example, Evans and Karras (1996) and Bernard and Jones (1996) find evidence of both economic convergence and heterogeneity across sectors using panel estimation. In this paper we examine convergence in labour productivity between the United States and the United Kingdom and France using a more detailed sample of industries than previously analysed. Additionally and unlike existing evidence (Evans and Karras, 1996, and Bernard and Jones, 1996) our approach does not impose a one-to-one level relationship, which can be important in differentiating conditional and unconditional convergence. Our empirical analysis is also innovative since we extend results from recent aggregate studies which emphasise panel heterogeneity to the sectoral level and we adopt Pesaran's (2004) Common Correlated Effects estimator, a panel approach robust to residual correlation.

2. Modelling Labour Productivity Convergence

We investigate convergence of the log level of industry labour productivity using an Autoregressive Distributed Lag model (ARDL) as follows:

$$lp_{jit} = \alpha_i + \beta_{0i} lp_{USit} + \beta_{1i} lp_{USi,t-1} + \beta_{2i} lp_{ji,t-1} + u_{jit}, \tag{1}$$

where lp_{jit} is labour productivity in the UK or France for industry i and lp_{USit} is labour productivity in the US for industry i. This ARDL equation has an error correction representation as follows:

$$\Delta lp_{jit} = \alpha_i + \beta_{0i} \Delta lp_{USit} + \lambda \left(lp_{ji,t-1} - \theta lp_{USi,t-1} \right) + u_{jit}, \tag{2}$$

[1] An exhaustive review of the convergence debate can be found in Islam (2003).

This serves as our base estimation equation and imposes a one-to-one level relationship between productivity in the catch up industry and the US where $\theta = 1$. Where $\lambda < 0$ we have evidence of convergence. Equation (2) can also be written as

$$\Delta lp_{jit} = a_i + b_{0i}\Delta lp_{USit} + b_{1i} lp_{USi,t-1} + b_{2i} lp_{ji,t-1} + u_{jit}\,. \qquad (3)$$

Our central results are provided by equation (3). Here we have evidence of convergence where $b_2 < 0$ and we can accept the hypothesis of a level relationship between labour productivity in the US and in the UK or France (i.e. we can reject H_0: $b_1 = b_2 = 0$, henceforth known as Wald Test 1). Additionally we consider whether the assumption that the sum of the coefficients equals zero H_0: $b_1 + b_2 = 0$ (Wald Test 2) and hence whether $\theta = 1$ in (2).

Rejection of this hypothesis suggests that we do not have a one-to-one convergence relationship. This implies that although the countries' labour productivities share a common trend, they do not converge to the same levels (Bernard and Durlauf, 1995; Funk and Strauss, 2003). According to Islam (2003), this is indicative of conditional convergence.

3. Panel Estimation – Heterogeneity and Cross Sectional Correlation

Panel heterogeneity is important in convergence studies and recent empirical analyses have shown that accounting for cross sectional differences significantly affects the speed of convergence (Lee, Pesaran and Smith, 1997, and Phillips and Sul, 2003). Also panel methods based on pooled and fixed effects estimation will lead to biased estimation in the presence of substantial cross section heterogeneity, according to Pesaran and Smith (1995). A Random Coefficients Model is unbiased in dynamic panels with heterogeneity, see Hsiao and Pesaran (2004). Additionally panel studies often inappropriately assume off diagonal terms in the disturbance covariance matrix are zero. This is difficult to sustain when data sets are obviously susceptible to common shocks as, for example, labour productivity is likely to be in a panel of industries in a particular country. The problem is difficult to resolve when the disturbance matrix is rank deficient ($N > T$) since SUR estimation cannot be implemented.[2] The standard approach of cross sectionally de-meaning does not solve this problem in heterogeneous panels since common shocks may impact differently on each cross section.

In this paper we implement Pesaran's (2004) Common Correlated Effects estimator to take account of residual correlation, based on augmenting the panel regression with cross sectional averages of regressors. We use both homogeneous (Pooled, POL, and Fixed Effects, FE) and heterogeneous (Random Coefficient Models, RCM) panel estimators and test explicitly for the most appropriate model in this convergence study using *inter alia* a Hausman test.[3] This approach is not sensitive to correlation between the regressors and the factors that induce residual correlation.

Funk and Strauss (2003), in a paper which abstracts from residual cross sectional correlation, find that panel unit root methods used to study convergence of industry productivity may produce results sensitive to the imposition of a one-to-one convergence relationship. They advocate estimating the convergence relationship although do not do so in an explicit panel setting.[4] Therefore our main contribution is to adopt a panel estimation approach and study the importance of imposing a one-to-one convergence relationship in a detailed industry data set under both panel homogeneity and heterogeneity, whilst fully accounting for common shocks.

4. Data

We measure annual labour productivity at the industry level (ISIC Rev. 3) in the US, the UK and France by dividing constant price gross value added by the total number of hours

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[2] Even when there is not rank deficiency of the covariance matrix SUR assumes, perhaps inappropriately, that factors that induce residual cross sectional correlation are independent of the regressors, Smith and Fuertes (2004).

[3] Under the null of the Hausman test, FE estimation is consistent and more efficient (cross sectional homogeneity), whilst under the alternative the FE estimator is biased due to cross sectional heterogeneity and RCM estimates are more appropriate.

worked (van Ark and O'Mahony, 2005) and converted into US Dollars using 1995 PPPs.[5] This data set provides a more detailed analysis compared to previous work[6] as it covers 55 industries in each country, with a time span from 1979 to 2002 ($T = 24$). The availability of a large cross sectional dimension allows a more in-depth analysis of the impact of industry heterogeneity on convergence.

5. Results

In our baseline results, reported in Table 1, we impose a one-to-one relationship between labour productivity in the US, the UK and France and estimate within a dynamic specification (equation 2). The Common Correlated Effect estimator includes cross sectional averages of industry labour productivity in the UK or France ($CCE1_t$) and the US ($CCE2_t$). In the basic equation, without CCE, a Hausman test accepts the null of panel homogeneity, suggesting the FE estimator is most appropriate for the UK.[7] The significance of the error correction term (λ) implies that the hypothesis of convergence of labour productivity in the UK to the US cannot be rejected at the 5% confidence level and the speed of convergence is 7% per year. For France the speed of convergence is 8% per year for both the FE and RCM estimator without CCE. With CCE the RCM estimator is more appropriate for both the UK and France (the Hausman test statistic rejects panel homogeneity) and the speed of convergence is 15% per year in the UK and 18% in France.

However, as suggested by Funk and Strauss (2003), the assumption of a one-to-one relationship may not be appropriate. We test this explicitly by estimating equation (3), reporting the results in Table 2. For both countries the Hausman test always rejects cross

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[4] It is worthwhile noting that Phillips and Moon (1999) suggest that spurious regressions problems are much reduced in panel setting due to cross sectional averaging.

[5] Crafts and O'Mahony (2001) suggest that France has converged at an aggregate level with the US in terms of labour productivity per hour worked whilst there is evidence of a substantial gap between the US and the UK. Our results are generally consistent with this evidence.

[6] For example, Bernard and Jones (1996) use a sample of 6 industries for 14 OECD countries, while Funk and Strauss (2003) study is based on 21 industries in 16 OECD countries.

sectional homogeneity of coefficients and suggests that the RCM estimates are more appropriate, which we consequently focus on. The correction for cross sectional correlation is important given the significance of the CCE terms. For the UK the estimated speed of convergence is 34% per year and contrasts with the uncorrected RCM estimates of 13% per year. The former is of the order of convergence for aggregate economic activity in a large sample of countries uncovered by Lee *et al.* (1997) and Phillips and Sul (2003). Hence our results are innovative in that we find the same sort of convergence at the industry level. In France, accounting for cross section correlation, increases convergence to 37% per year, from 14%. The Wald Test 1 suggests that there is evidence of a level relationship, and therefore convergence, between productivity in the UK and US and France and US. However, convergence is not one-to-one as we strongly reject the null hypothesis of the Wald Test 2 for both countries, but only if we correct fully for common shocks. This is strong evidence of conditional convergence and highlights the importance of dealing adequately with cross sectional residual correlation.

6. Conclusion

We examine convergence in a panel of industries between the US and the UK and France taking account of panel heterogeneity and cross sectional residual correlation. We find the convergence coefficient, as evidenced by an error correction term, is large and significant. However since our statistical tests confirm that once we correct for cross sectional correlation the coefficient on the technology frontier is not equal to one, our results provide evidence of only conditional convergence.

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[7] Whilst individual fixed effects are significant according to a Likelihood Ratio (LR) test.

Table 1

UK and France convergence to the US

Imposing a one-to-one relationship.

Country	UK						France					
Estimator	POL	FE	RCM	POL	FE	RCM	POL	FE	RCM	POL	FE	RCM
α	**0.019** **(t=5.317)**		0.007 (0.589)	**0.280** **(2.635)**		0.065 (0.376)	**0.025** **(9.167)**		**0.033** **(4.929)**	**0.097** **(2.044)**		0.010 (0.076)
$\beta_0 \Delta lp_{US,it}$	**0.434** **(16.056)**	**0.162** **(5.174)**	0.091 (1.662)	**0.438** **(16.222)**	**0.171** **(5.443)**	**0.134** **(3.492)**	**0.418** **(17.222)**	**0.190** **(6.744)**	**0.147** **(5.160)**	**0.419** **(17.358)**	**0.191** **(6.827)**	**-0.197** **(7.187)**
$\lambda(lp_{j,it-1} - lp_{US,it-1})$	**-0.033** **(-4.735)**	**-0.067** **(-6.227)**	**-0.079** **(-3.495)**	**-0.034** **(-4.898)**	**-0.079** **(-6.918)**	**-0.154** **(-5.638)**	**-0.043** **(-7.893)**	**-0.081** **(-8.883)**	**-0.081** **(-5.461)**	**-0.044** **(-8.135)**	**-0.086** **(-9.419)**	**-0.184** **(-8.893)**
$CCE1_t$				**0.187** **(2.775)**	**0.184** **(3.012)**	0.135 (1.683)				**0.417** **(4.434)**	**0.428** **(5.024)**	**0.352** **(2.943)**
$CCE2_t$				**-0.251** **(-2.729)**	**-0.223** **(-2.685)**	-0.146 (-1.357)				**-0.446** **(-4.288)**	**-0.447** **(-4.753)**	**-0.352** **(-2.504)**
LR		**561.90** **[p=0.00]**			**575.12** **[0.00]**			**600.35** **[0.00]**			**630.84** **[0.00]**	
Hausman Test			3.19 [0.20]			**64.04** **[0.00]**			**501.27** **[0.00]**			**53.98** **[0.00]**

Notes: Results based on equation (2). N=55 and T=24. POL is Pooled Estimation, FE is Fixed Effects estimation and RCM is the Random Coefficient Model estimator. LR is a Likelihood Ratio test which examines significant fixed effects, rejection of the null suggests significant fixed effects. $lp_{j,it-1}$ is the level of labour productivity in the UK and in France. The Hausman test examines equivalence of the RCM and FE estimates. The null hypothesis is slope homogeneity where RCM and FE are both consistent under the null. Under the alternative of slope heterogeneity only RCM estimates are consistent. $CCE1_t$ and $CCE2_t$ are the common correlated effects based on the Pesaran (2004) approach of including cross sectional averages of the regressors to take account of common shocks in heterogeneous panels. $CCE1_t$ is cross sectional averages of industry labour productivity in the UK or France and $CCE2_t$ is the equivalent in the US. T-statistics are in parentheses (). P-values in square brackets [].

Table 2
UK and France convergence to the US

Country	UK						France					
Estimator	POL	FE	RCM	POL	FE	RCM	POL	FE	RCM	POL	FE	RCM
a	**0.067** **(t=5.239)**		0.153 (1.309)	**0.277** **(2.620)**		0.335 (1.026)	**0.054** **(4.218)**		0.190 (1.543)	**0.096** **(2.032)**		0.272 (0.808)
$b_0\Delta lp_{US,it}$	**0.425** **(15.764)**	**0.162** **(5.147)**	**0.102** **(2.490)**	**0.427** **(15.825)**	**0.172** **(5.476)**	0.056 (0.923)	**0.414** **(17.036)**	**0.185** **(6.545)**	**0.135** **(2.669)**	**0.413** **(17.060)**	**0.189** **(6.742)**	**0.107** **(2.013)**
$b_1 lp_{US,it\text{-}1}$	**0.025** **(3.595)**	**0.068** **(5.890)**	**0.080** **(2.232)**	**0.028** **(3.965)**	**0.077** **(6.510)**	0.074 (0.953)	**0.040** **(7.286)**	**0.084** **(9.056)**	**0.095** **(2.561)**	**0.041** **(7.433)**	**0.086** **(9.443)**	0.067 (1.223)
$b_2 lp_{j,it\text{-}1}$	**-0.041** **(-5.682)**	**-0.066** **(-6.184)**	**-0.130** **(-5.017)**	**-0.046** **(-6.161)**	**-0.081** **(-6.892)**	**-0.342** **(-7.640)**	**-0.049** **(-8.130)**	**-0.075** **(-7.556)**	**-0.144** **(-5.903)**	**-0.052** **(-8.574)**	**-0.082** **(-8.050)**	**-0.369** **(9.712)**
$CCE1_t$				**0.197** **(2.939)**	**0.187** **(3.047)**	**0.342** **(2.290)**				**0.422** **(4.499)**	**0.425** **(4.991)**	**0.402** **(2.316)**
$CCE2_t$				**-0.242** **(-2.650)**	**-0.222** **(-2.663)**	-0.182 (-1.104)				**-0.439** **(-4.236)**	**-0.449** **(-4.771)**	-0.179 (-1.020)
LR		**562.03** **[p=0.00]**			**575.70** **[0.00]**			**603.74** **[0.00]**			**631.47** **[0.00]**	
Hausman Test			**25.43** **[0.00]**			**53.40** **[0.00]**			**12.78** **[0.01]**			**70.918** **[0.00]**
Wald Test 1 H_0: $b_1 = b_2 = 0$		**38.87** **[0.00]**	**25.39** **[0.00]**		**48.40** **[0.00]**	**60.98** **[0.00]**		**82.28** **[0.00]**	**34.98** **[0.00]**		**89.277** **[0.00]**	**96.54** **[0.00]**
Wald Test 2 H_0: $b_1 + b_2 = 0$		0.13 [0.72]	1.94 [0.16]		0.55 [0.46]	**8.39** **[0.00]**		3.23 [0.07]	1.86 [0.17]		0.59 [0.44]	**20.13** **[0.00]**

Notes: Results based on equation (3). N=55 and T=24. POL is Pooled Estimation, FE is Fixed Effects estimation and RCM is the Random Coefficient Model estimator. LR is a Likelihood Ratio test which examines significant fixed effects, rejection of the null suggests significant fixed effects. $lp_{j,it-1}$ is the level of labour productivity in the UK and in France. The Hausman test examines equivalence of the RCM and FE estimates. The null hypothesis is slope homogeneity where RCM and FE are both consistent under the null. Under the alternative of slope heterogeneity only RCM estimates are consistent. $CCE1_t$ and $CCE2_t$ are the common effects based on the Pesaran (2004) approach of including cross sectional averages of the regressors to take account of common shocks in heterogeneous panels. $CCE1_t$ is cross sectional averages of industry labour productivity in the UK or France and $CCE2_t$ is the equivalent in the US. T-statistics are in parentheses (). P-values in square brackets [].

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