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Abstract

This study investigates the role of international spillovers in generating productivity gains for a panel of 24 OECD countries during the period between 1971-2004. We use recent techniques developed in a common factor framework to characterize the global interdependence implied by international spillovers and the diffusion mechanisms involved. Consistent with some recent studies in this field, the evidence suggests that there are substantial cross-country spillovers mainly related to R&D and human capital variables, which contribute significantly to productivity.

Key words: Productivity, Spillovers, R&D, Human capital, Common factors

JEL Classification: C23, D24, 031

1 Introduction

In spite of the fact that international spillovers have been recognized, the search for international spillovers across countries received more attention with the development of new growth models in an open economy. Indeed, all these models emphasize the importance of international spillovers as a major drive for technological progress. One of the most important contribution in this field has been developed by Grossman and Helpman (1991) with the aid of two canonical models: the love of variety approach due to Romer (1990) and the quality ladders approach due to Grossman and Helpman (1991) and Aghion and Howitt (1992). In these two theoretical frameworks, international spillovers result from foreign knowledge through the channel of trade flows. Another important contribution has been developped by Lucas (1988, 1993) who assumes that international spillovers come from human capital externalities. From an econometric point of view, in an influential paper, Coe and Helpman (1995) who focus on the estimation of international spillovers that come from knowledge, have tested and confirmed the results of these models by using simple econometric techniques. In the last few years, a numerous studies extended this work by analyzing the long terme relationship between total factor productivity and research and developpment (henceforth R&D) and human capital on the basis of advanced econometric tools in panel cointegration tests (Coe et al. (2009), Musolesi (2007), López-Pueyo et al. (2008)).

In this work, we use an alternative econometric approach based on recent techniques developed in common factor framework, which leads to parsimonious econometric structure and is very suitable in modeling these international spillovers effects. Indeed, by spilling over from one country to another, R&D and human capital create co-movement in countries' productivity variables. In such a case, most of the co-variations among these data series are explained by a few underlying common factors, which reflect the effects of international spillovers, and other transmission mechanisms if any. The unexplained component of series movements is due to the country's idiosyncratic factors.

The paper is organized as follows. Section 2 presents our econometric approach. Section 3 discusses the results. Finally, Section 4 concludes.

2 Econometric Approach

2.1 The model

In the econometric model, we consider that the total factor productivity (TFP) variables admit a common factor structure, with r common factors. Using logarithm we have:

$$\ln TFP_{it} = F_t \lambda_i + e_{it}, \tag{1}$$

where $t = 1, \ldots, T$ and $i = 1, \ldots, N$. The vector of time series observations $\ln TFP_{it}$ is a logarithm of total factor productivity for the i-th country, F_t is a $(T \times r)$ matrix representing the factor process, which captures international spillovers received from all other countries. Each country has a specific elasticity λ_i, which measures its relative weight in spillover diffusion, thus λ_i is a $(r \times 1)$ vector of parameters. The $(T \times 1)$ vector e_{it} represents the idiosyncratic component of $\ln TFP_{it}$. This factor model is estimated using the principal components method (Bai and Ng (2002)). If we refer to Coe and Helpman (2009) who consider the total factor productivity as a function of R&D stock and human capital, this idiosyncratic error term can be assimilated to the country i's R&D stock and/or human capital with very limited spillover effects. This econometric approach suggests that cross-sectional correlations in e_{it} are very weak and in addition the cross-country $\ln TFP$ correlations are mostly related to R&D and/or human capital spillovers. In the next sub-section, we present the test used in the empirical part to assess how well the R&D and human capital variables approximate the estimated common factors.

2.2 Comparing estimated and observed spillover sources

The test considered here is the $M(j)$ test (Bai and Ng (2006)) that can be used to test for links between the estimated spillover sources (estimated common factors) and observed sources (observed common factors). Let F^o_{jt} be an element of the vector F^o_t representing the observed common factors. The aim is to test if there is any δ_j such that $F^o_{jt} = \delta^{'}_j F_t$ for all t. It may seem intuitive to regress $\ln TFP_{it}$ on F^o_{jt} and then to assess the explanatory power of F^o_{jt}. If F^o_{jt} is an exact proxy for F_t, then F^o_{jt} should be able to explain $\ln TFP_{it}$. That said, this procedure is not entirely satisfactory because, even though F^o_t is a proxy for F_t, the correlation between them should be very weak if the variance of e_{it} is large. Let $\hat{\gamma}_j$ be the estimated value of γ_j obtained from the least squares regression $F^o_{jt} = \gamma^{'}_j \hat{F}_t + \eta_{jt}$ where η_{jt} is an error term. Bai and Ng (2006) propose to define $\hat{F}^o_{jt} = \hat{\gamma}^{'}_j \hat{F}_t$ and then to test how far the observed factors are from the estimated factors. The test statistic is

$$M(j) = max_{1 \preceq t \preceq T} \left| \tau_t(j) \right| \tag{2}$$

where

$$\tau_t(j) = \frac{(\hat{F}^o_{jt} - F^o_{jt})}{\left(var(\hat{F}^o_{jt}) \right)^{1/2}}. \tag{3}$$

If the idiosyncratic term is cross-sectionally uncorrelated, the variance of $\hat{F}^o_{jt}$ is given[1] by $v\hat{a}r(\hat{F}^o_{jt}) = \frac{1}{N} \hat{\gamma}^{'}_j \hat{V}^{-1} \hat{\Gamma}_t \hat{V}^{-1} \hat{\gamma}_j$, with $\hat{\Gamma}_t = \frac{1}{N} \sum_{i=1}^{N} \hat{e}^2_{it} \hat{\lambda}_i \hat{\lambda}^{'}_i$. It is then possible to use

[1] V is a $r \times r$ diagonal matrix consisting of the r largest eigenvalues of $(\ln TFP)^{'} (\ln TFP)/(NT)$ in decreasing order. The hat sign over the letter indicates an estimated value. $\hat{e}_{it}$, $\hat{\lambda}$ and $\hat{V}$ are obtained from the principal components method, as well as $\hat{F}_t$.

$\hat{var}(\hat{F}^o_{jt})$ and to test the distance between the two curves $\hat{F}^o_{jt}$ and F^o_{jt} , on the basis of the $M(j)$ statistics.

3 Data and Results

We use annual data for 24 countries listed in Coe et al. (2009) from 1971 to 2004. The variables include total factor productivity (TFP) and its principal exogenous variables, which are R&D capital stock and human capital. The R&D (S) corresponds to R&D capital stocks in the business sector. As per Coe et al. (1997, 2009), the human capital variable (H) is included as an additional variable. The latter is a measure of average years of schooling from Barro and Lee (2000).[2]

The latent factors of the 24 annual $\ln TFP$ series are estimated on the basis of principal components analysis, and the number of common factors can be selected by using the BIC_3 criterion defined in Bai and Ng (2002). The $\ln TFP$ data are standardized to be mean zero with unit variances prior to estimation by the method of principal components. The F^o_{jt} variables for $j = 1, 2$, correspond to the cross-section averages of the individual time series $S_{i,t}$ and $H_{i,t}$ respectively denoted by $\bar{S}_t$ and $\bar{H}_t$. They are likewise standardized prior to implementation of the $M(j)$ test. The purpose of the following is to determine if these variables generate significant spillovers and can be considered strong proxies for common factors underlying co-movements in $\ln TFP$ series.

Table 1: Results of the $M(j)$ Test

	Observed factors	
	Domestic R&D ($\bar{S}_t$)	*Human capital* ($\bar{H}_t$)
$M(j)$ statistic	2.385	3.110
Significance	(−)	(−)

Notes: The critical values at the 10%, 5% and 1% thresholds are respectively 3.076, 3.283 and 3.775. (+), (++) and (+++) denote rejections of the null hypothesis, respectively at the 10%, 5% and 1% thresholds. The sign (−) indicates acceptance of the null hypothesis.

Following Moon and Perron (2007), estimations are run on first differences to take into account a possible presence of a unit root. Using the BIC_3 selection criterion, the number of factors in the $\ln TFP$ panel of data is set to 5. $M(j)$ test results are given in Table 1.

The test reveals that R&D capital stock measured by S can be considered exact proxies for latent common factors. Indeed, the critical value at 5% significance level of the $M(j)$ test is 3.283 and cannot reject the null hypothesis that this variable is a common factor. As stressed by a large body of literature in this field (Griffith

[2]For more details about the definition and construction of listed variables, please see Coe et al. (2009).

et al. (2006) at the firms level and Coe and Helpman (1995) at the country level, among others), this implies that R&D accounts significantly for the dynamic of total factor productivity. Moreover, this finding is a strong indication of the presence of spillovers closely linked to R&D through which these spillovers occur.

Furthermore, the evidence supports the human capital variable H as a good proxy. Human capital is generally viewed as a key determinant of total factor productivity, which can also generate spillovers (Ertur and Koch (2007)). Eberhardt et al. (2010) argue that even though R&D is an important source of spillover, significant spillovers may not only represent knowledge externalities but also reflect cross-country dependencies more generally due to a host of other factors, which can be taken into account in a common factor model.

4 Concluding remarks

Consistent with the existing empirical literature such as Coe et al. (2009), the use of recent econometric techniques developed in a common factor framework (Bai and Ng 2006, Lin et al. 2012) indicates that international spillovers resulting from knowledge diffusion through the international trade contribute significantly to total factor productivity growth. Moreover, our results show that international spillovers are also strongly related to human capital externalities.

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