The Economics of European Regions: Theory, Empirics, and Policy

Dipartimento di Economia e Management

Co-funded by the Erasmus+ Programme of the European Union

Project funded by
European Commission Erasmus + Programme –Jean Monnet Action
Project number 553280-EPP-1-2015-1-IT-EPPJMO-MODULE

Davide Fiaschi Angela Parenti[1]

December 3, 2019

[1] davide.fiaschi@unipi.it, and angela.parenti@unipi.it.

Technological spillovers and growth

Consider the Mankiw-Romer-Weil (1992) production function:

$$Y_i = A_i K_i^{\alpha} H_i^{\beta} L_i^{1-\alpha-\beta}, \tag{1}$$

where Y_i is the **GDP** of region i, A_i the **technological progress**, K_i the **stock of physical capital**, H_i the **stock of human capital**, and L_i the **number of worker**.

GDP per worker $y_i \equiv Y_i/L_i$ is therefore:

$$y_i = A_i k_i^{\alpha} h_i^{\beta}, \tag{2}$$

where $k_i \equiv K_i/L_i$ and $h_i \equiv H_i/L_i$.

Expressing Eq. (2) in growth rates (e.g., $g_{y_i} \equiv \Delta y_i / y_i$):

$$\log\left(1 + g_{y_i}\right) = \log\left(1 + g_{A_i}\right) + \alpha \log\left(1 + g_{k_i}\right) + \beta \log\left(1 + g_{h_i}\right) \tag{3}$$

Differential GDP per worker growth among regions is expressed as **heterogeneity** in g_{A_i}, g_{k_i}, and g_{h_i}.

Growth rate of technology g_{A_i}

Romer, 1986: *local* learning by doing and *uniform* diffusion of knowledge:

$$A_i = \varphi\left(k_i, K\right), \tag{4}$$

where k_i is **regional knowledge** and K **aggregate knowledge** and they are proxied by the level of **physical capital per worker**.

Ertur and Koch, 2007: *local* learning by doing and *local* diffusion of technology:

$$A_i = A_0\left(1+g\right)^t k_i^{\theta} \Pi_{j=1}^{R} A_j^{\rho w_{ij}}, \tag{5}$$

where ρ measures the **intensity** of spatial technological spillovers and w_{ij} the **proximity** between region i and region j.

Ertur and Koch, 2011: *local* diffusion of technology and *local absorptive capacity*:

$$\dot{A}_{it} = \lambda \prod_{j=1}^{R} \left(\frac{A_{jt}}{A_{it}}\right)^{\rho_i w_{ij}} s_{it}^{R\&D}\left(A_{it}^{\max} - A_{it}\right), \tag{6}$$

where ρ_i measures the **absorptive capacity** of region i of taking technology from abroad, $A_{it}^{\max}$ is proxy for technological frontier, and $s_{it}^{R\&D}$ the **share of income invested in R&D**.

Growth rate of technology g_{A_i} (cont.)

Consider the following general formulation:

$$A_i = \Omega_i k_i^{\theta} \Pi_{j=1}^{R} A_j^{\lambda_i^A w_{ij}} \Pi_{j=1}^{R} k_j^{\lambda_i^k w_{ij}}. \quad (7)$$

where Ω_i is a region specific effect. Solving for the level of technological progress:

$$\begin{aligned} \log \mathbf{A} &= \left(\frac{\alpha}{\alpha+\theta}\right)\left[\mathbf{I} - \left(\frac{\alpha\boldsymbol{\lambda}^{\boldsymbol{A}} - \boldsymbol{\lambda}^{\boldsymbol{k}}}{\alpha+\theta}\right)\mathbf{W}\right] \times \\ &\times \left[\log \boldsymbol{\Omega} + \left(\frac{\theta + \boldsymbol{\lambda}^{k}\mathbf{W}}{\alpha}\right)(\log \mathbf{y} - \log \mathbf{h})\right], \end{aligned} \quad (8)$$

where $\mathbf{A}$, $\boldsymbol{\lambda}^{\boldsymbol{A}}$, $\boldsymbol{\lambda}^{\boldsymbol{k}}$, $\mathbf{y}$, $\mathbf{h}$ are $1 \times R$ vectors.

Therefore, the growth rate of technological progress is:

$$\log(1 + \boldsymbol{g}_{\boldsymbol{A}^M}) \equiv \boldsymbol{G}_{\boldsymbol{A}^M} = \boldsymbol{G}_{\boldsymbol{\Omega}^M} + \theta \boldsymbol{G}_{\boldsymbol{k}^M} + \boldsymbol{\lambda}^{\boldsymbol{A}} \boldsymbol{W} \boldsymbol{G}_{\boldsymbol{A}^M} + \boldsymbol{\lambda}^{\boldsymbol{k}} \boldsymbol{W} \boldsymbol{G}_{\boldsymbol{k}^M}. \quad (9)$$

Growth rate of capital g_{k_i}

In an open economy the growth rate of physical capital g_{k_i} depends on the **inflows an outflows of capital**, which can be modelled as:

$$\dot{K}_i = \sum_{j=1}^{N} \eta^k \left(\overset{+}{r_i}, \overset{-}{r_j}, \overset{+}{K_i}, \overset{+}{K_j}, \overset{-}{\bar{r}}, \overset{-}{d_{ij}^k} \right), \tag{10}$$

where N is the **number of regions**, r_j is the **return on physical capital** of region j, $\bar{r}$ **the international reference return on capital**, and d_{ij}^k is a measures of the **frictions** in the capital flows from region j to region i.
Assume that:

- the **marginal rule of determination** of real return on physical capital holds, i.e.:

$$r_i = \frac{\partial y_i}{\partial k_i} = \alpha A_i k_i^{\alpha-1} h_i^{\beta}. \tag{11}$$

Convergence process of r_i

From Eq. (10) it is possible to take an approximation of the convergence process of r_i to $\bar{r}$ as the following:

$$r_i = \left(1 - \phi^k\right) \log r_{i,-\tau} + \phi^k \log \bar{r} + \eta_i, \tag{12}$$

where:

- $\tau > 0$ is the time lag in the convergence process;
- $\phi^k \in (0, 1)$ is the parameter measuring the **frictions** in capital mobility of region i ($\phi^k = 1$ no frictions);
- η_i is a random component reflecting **idiosyncratic shocks** to region i.

Growth rate of human capital g_{h_i}

In an open economy the growth rate of human capital g_{h_i} depends on **migration**, In an open economy the growth rate of physical capital g_{k_i} depends on the **inflows an outflows of human capital**, which can be modelled as:

$$\dot{H}_i = \sum_{j=1}^{N} \eta^h \left(\overset{+}{e_i}, \overset{-}{e_j}, \overset{+}{H_i}, \overset{+}{H_j}, \overset{-}{\bar{e}}, \overset{-}{d_{ij}^h} \right), \tag{13}$$

where e_j is the **return on human capital** of region j, $\bar{w}$ **the international reference return on capital**, and d_{ij}^h is a measures of the **frictions** in the human capital flows from region j to region i.
Assume that :

- the **marginal rule of determination** of return on human capital holds, i.e.:

$$e_i = \frac{\partial y_i}{\partial h_i} = \beta A_i k_i^{\alpha} h_i^{\beta - 1}. \tag{14}$$

Convergence process of e_i

From Eq. (13) it is possible to take an approximation of the convergence process of e_i to $\bar{e}$ as the following:

$$e_i = (1 - \phi^e) \log e_{i-\tau} + \phi^e \log \bar{e} + \epsilon_i, \quad (15)$$

where:

- $\tau > 0$ is the time lag in the convergence process;
- $\phi^e \in (0, 1)$ is the parameter measuring the **frictions** in labour mobility of region i;
- ϵ_i is a random component reflecting **idiosyncratic shocks** to region i.

Key issue

- **What about regional labour markets**? We can have a $\bar{e}_i$...

Aggregate behaviour of R small economies

- Assume the existence of an **aggregate production function** such that:

$$\bar{y} = \bar{A}\bar{k}^{\alpha}\bar{h}^{\beta}, \tag{16}$$

where $\bar{A}$, $\bar{k}$, and $\bar{h}$ are the **average** technological progress, physical and human capital per worker.

- Also assume that:

$$\bar{r} = \frac{\partial \bar{y}}{\partial \bar{k}}, \tag{17}$$

and

$$\bar{e} = \frac{\partial \bar{y}}{\partial \bar{h}}. \tag{18}$$

Aggregate behaviour of R small economies (cont.)

Then, the **deviation** of capital growth rate of region i with respect to the average growth rate, $g_{k_i^M} \approx g_{k^i} - \bar{g}_k$ follows:

$$\begin{aligned} \log\left(1 + g_{k_i^M}\right) &= \gamma_0 \log\left(1 + g_{A_i^M}\right) + \gamma_1 \log\left(1 + g_{\bar{r}}\right) + \\ &+ \gamma_2 \log A^M_{i-\tau} + \gamma_3 \log y^M_{i-\tau} + \gamma_4 \log h^M_{i-\tau} + \tilde{\eta}_i, \end{aligned} \tag{19}$$

while **deviation** of human capital growth rate, $g_{h_i^M} \approx g_{h^i} - \bar{g}_h$:

$$\begin{aligned} \log\left(1 + g_{h_i^M}\right) &= \delta_0 \log\left(1 + g_{A_i^M}\right) + \delta_1 \log\left(1 + g_{\bar{r}}\right) + \\ &+ \delta_2 \log A^M_{i-\tau} + \delta_3 \log y^M_{i-\tau} + \delta_4 \log h^M_{i-\tau} + \tilde{\epsilon}_i, \end{aligned} \tag{20}$$

where $g_{A_i^M} \approx g_{A^i} - \bar{g}_A$, the elements of γ and δ are complex function of α, β, ϕ^k, ϕ^k, and $\tilde{\eta}_i$ and $\tilde{\epsilon}_i$ are linear transformation of η_i and ϵ_i.

The growth rate of GDP per worker g_{y_i}

Taking all together, we get:

$$\boldsymbol{G}_{\boldsymbol{y}^M} = \boldsymbol{c} + \boldsymbol{\lambda} \boldsymbol{W} \boldsymbol{G}_{\boldsymbol{y}^M} + \mu_0 \boldsymbol{y}^{\boldsymbol{M}}_{-\boldsymbol{\tau}} + \mu_1 \boldsymbol{\lambda} \boldsymbol{W} \boldsymbol{y}^{\boldsymbol{M}}_{-\boldsymbol{\tau}} + \mu_2 \boldsymbol{h}^{\boldsymbol{M}}_{-\boldsymbol{\tau}} + \mu_3 \boldsymbol{\lambda} \boldsymbol{W} \boldsymbol{h}^{\boldsymbol{M}}_{-\boldsymbol{\tau}} + \boldsymbol{e},$$

where $\boldsymbol{c}$ collects **fixed and time effects** (e.g. $\log(1 + g_{\bar{r}})$, $\boldsymbol{G}_{\boldsymbol{\Omega}^M}$, ...), $\boldsymbol{\lambda}$ is a (linear) function of $\boldsymbol{\lambda}^{\boldsymbol{A}}$ and $\boldsymbol{\lambda}^{\boldsymbol{k}}$, the elements of μ are function of γ and δ.

Taking the standard approximation $\log(1 + x) \approx x$:

$$\boldsymbol{g}_{\boldsymbol{y}^M} \approx \boldsymbol{c} + \boldsymbol{\lambda} \boldsymbol{W} \boldsymbol{g}_{\boldsymbol{y}^M} + \mu_0 \boldsymbol{y}^{\boldsymbol{M}}_{-\boldsymbol{\tau}} + \mu_1 \boldsymbol{\lambda} \boldsymbol{W} \boldsymbol{y}^{\boldsymbol{M}}_{-\boldsymbol{\tau}} + \mu_2 \boldsymbol{h}^{\boldsymbol{M}}_{-\boldsymbol{\tau}} + \mu_3 \boldsymbol{\lambda} \boldsymbol{W} \boldsymbol{h}^{\boldsymbol{M}}_{-\boldsymbol{\tau}} + \boldsymbol{e}, \quad (21)$$

At the end we get an econometric model very similar to a **Spatial Durbin Model**, but with **fixed and time effects** and possibly **spatial autocorrelated errors**, and, more importantly, with $\boldsymbol{\lambda}$ as a vector of coefficients reflecting **regional absorbing capacities**.

Econometric model

Inspired by theoretical model we estimate the following econometric model for the (relative) growth of GDP per worker:

$$
\begin{aligned}
g_{y^M,it} &= c_i + d_t + \lambda(1 + \delta AC_i)\mathbf{W}_i \mathbf{g}_{y^M,t} + \mu_0 \log y^M_{it-\tau} + \\
&+ \mu_1 \lambda(1 + \delta AC_i)\mathbf{W}_i \log \mathbf{y^M}_{t-\tau} + \mu_2 \log h^M_{it-\tau} + \\
&+ \mu_3 \lambda(1 + \delta AC_i)\mathbf{W}_i \log \mathbf{h^M}_{t-\tau} + \epsilon_{it}.
\end{aligned} \tag{22}
$$

The estimation of this model is not standard for the presence of $\lambda(1 + \delta AC_i)$.