Property Rights, Technological Innovation and Economic Growth: A Cross Country Analysis

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Background

- **Long-run (per capita) growth is determined by rate of growth of technology**
- **Technology Growth is Endogenous**
  - **Romer (1990):** technological growth takes place due to efforts by researchers and entrepreneurs responding to economic incentives
    - infrastructure, institutions and Property Rights play crucial role determining economic growth through technological innovation

Motivation

- **Literature identified nonlinear relationship among Intellectual Property Rights (IRP), Total Factor Productivity (TFP) and Economic Growth:** Impact of IPR and TFP on growth rate of rich country is different than that of poor countries
    - **Thompson and Rushing (1996 & 1999):** IPR improves TFP and promotes growth for rich countries
    - **Falvey et. al. (2006):** IPR has positive impact on growth for rich and poor countries and no impact on growth for middle income countries
    - **Haydaroğlu (2015):** IPR promotes growth for EU and OECD countries
    - **Park and Ginrate (1997):** IPR improves research capital; a measure of TFP but has no impact on growth

Objective

- **This paper identifies probable sources leading to the nonlinear relationship among IPR, TFP and Growth**
  - *we have used Romer (1987, 1990a, 1990b) to identify probable sources of nonlinearity*
- **Identifying appropriate sources of nonlinearity and accordingly incorporating them into the estimation process is important to avoid omitted variable bias**
  - *we have used endogenous regime switching model of Maddala and Nelson (1975) $\longrightarrow$ producing unbiased estimates by incorporating different sources of nonlinearity in an otherwise Barro (1991) type cross sectional growth model.*

- **Romer (1990): Economic Incentives Leading to Growth through Technological Innovation**
  - **Increasing Return to Scale and Innovation:** Technology of Ideas associated with IRS $\longrightarrow$ Falling AC and MC curve (MC<AC) $\Rightarrow$ Marginal Cost pricing under perfectly competition is not possible
  - **Monopolistic Competition:** Labour and Capital paid less than their marginal products $\longrightarrow$ profit to entrepreneurs $\longrightarrow$ providing fund for R&D
  - **Property Rights and Patent:** gives monopoly Power to researchers and entrepreneurs to cover the initial fixed cost incurred $\longrightarrow$ inducing R&D activities leading to economic growth by technological innovation.
- **Helpman (1992):** Stringent IPR increases (decreases) welfare for North (South) by encouraging (discouraging) innovation (imitation)

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

An Application

- **Suppose, the unobserved ambience of undertaking R&D activities by researchers and entrepreneurs of country i depends on,**

$$\gamma^{'} Z_i - \epsilon_i$$

  - Z_i: observed country specific factors (infrastructure, institutions, IPR)
  - γ: corresponding weights
  - ϵ_i: unobserved country specific factors

- **Define an indicator variable I_i such that, it takes a value 1 for innovation driven rich countries and 0 otherwise**

$$\begin{aligned} I_i &= 1 \text{ when } \gamma^{'} Z_i - \epsilon_i \geq 0 \\ &= 0 \text{ when } \gamma^{'} Z_i - \epsilon_i < 0 \end{aligned}$$

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

An Application

- **Corresponding growth equations for countries belonging to Group 1: innovation driven rich countries with better ambience of undertaking R&D activities and Group 2: rest of the poor non-innovation driven countries**

$$g_{1i} = \beta_1^{'} X_{1i} + u_{1i}, \text{ when } I_i = 1 \tag{1}$$

$$g_{2i} = \beta_2^{'} X_{2i} + u_{2i}, \text{ when } I_i = 0 \tag{2}$$

$$(u_{1i}, u_{2i}, \epsilon_i) \sim N(0, \Sigma), \Sigma = \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{1\epsilon} \\ & \sigma_2^2 & \sigma_{2\epsilon} \\ & & 1 \end{pmatrix}$$

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

An Application

- g_{1i} **and** g_{2i}**:** average annual growth for countries belonging to Group 1 and Group 2
- X_{1i} **and** X_{2i}**:** control variables influencing growth rate for countries belonging to Group 1 and Group 2 (Barro, 1991)
- u_{1i} **and** u_{2i}**: error term but not necessarily random**

- **Conditional expectation of equation (1) and (2) gives,**

$$E\left(g_{1i} \middle| X_{1i}, I_i = 1\right) = \beta_1^{'} X_{1i} + E\left(u_{1i} \middle| \gamma^{'} Z_i \geq \epsilon_i\right)$$
$$= \beta_1^{'} X_{1i} - \sigma_{1\epsilon} W_{1i} \quad (3)$$

$$E\left(g_{2i} \middle| X_{2i}, I_i = 0\right) = \beta_2^{'} X_{2i} + E\left(u_{2i} \middle| \gamma^{'} Z_i < \epsilon_i\right)$$
$$= \beta_2^{'} X_{2i} + \sigma_{2\epsilon} W_{2i} \quad (4)$$

$$W_{1i} = \frac{\phi_i}{\Phi_i}, W_{2i} = \frac{\phi_i}{1 - \Phi_i}$$

- **Φ_i is the distribution function of standard normal and ϕ_i is the density function of standard normal evaluated at $\gamma^{'} Z_i$**

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

An Application

- **Equation (3) and (4) gives,**

$$g_{1i} = \beta_1' X_i - \sigma_{1\epsilon} W_{1i} + \eta_{1i}, E\left(\eta_{1i}\right) = 0 \quad (5)$$

$$g_{2i} = \beta_2' X_i + \sigma_{2\epsilon} W_{2i} + \eta_{2i}, E\left(\eta_{2i}\right) = 0 \quad (6)$$

- $\sigma_{1\epsilon} = cov\left(u_{1i}, \epsilon_i\right), \sigma_{2\epsilon} = cov\left(u_{2i}, \epsilon_i\right)$

- **Comparing equation (1) and (2) with equation (5) and (6)**

$$u_{1i} = -\sigma_{1\epsilon} W_{1i} + \eta_{1i}$$
$$u_{2i} = \sigma_{2\epsilon} W_{2i} + \eta_{2i}$$

- **Technological innovation induced by R&D activities affecting growth if**

$$\sigma_{1\epsilon} \neq 0 \textbf{ and } \sigma_{2\epsilon} \neq 0$$

- **Omitted variable bias:** $\sigma_{1\epsilon} \neq 0$ and $\sigma_{2\epsilon} \neq 0$ but we estimate equation (1) and (2) instead of equation equation (5) and (6)

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

Three Sources of Nonlinearity

- $\sigma_{1\epsilon} \neq \sigma_{2\epsilon} \Rightarrow$ **impact of TFP on growth is nonlinear**
- $\beta_1 \neq \beta_2 \Rightarrow$ **impact of** X_1 **and** X_2 **on growth is nonlinear**
- W_1 **and** W_2 **are nonlinear function of infrastructure, institutions and IPR (captured in** Z**) through** ϕ **and** Φ

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

Full Sample Estimation

- **Can we do a full sample estimation instead of estimating equation (5) and (6) separately?**

$$
\begin{aligned}
E\left(g_i\right) &= \Phi_i E\left(g_{1i} \middle| X_{1i}, I_i = 1\right) + \left(1 - \Phi_i\right) E\left(g_{2i} \middle| X_{2i}, I_i = 0\right) \\
g_i &= \beta_1^{'}\left(\Phi_i X_{1i}\right) + \beta_2^{'}\left[\left(1 - \Phi_i\right) X_{2i}\right] \qquad (7) \\
&\quad + \left(\sigma_{2\epsilon} - \sigma_{1\epsilon}\right)\phi_i + \omega_i \\
E\left(\omega_i\right) &= 0
\end{aligned}
$$

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

Full Sample Estimation

- **Equation (7) can capture differential impact of X_{1i} and X_{2i} on growth rate through $\beta_1 \neq \beta_2$**
- **Equation (7) cannot capture differential impact of technological innovation of economic growth as it cannot identify $\sigma_{2\epsilon}$ and $\sigma_{1\epsilon}$ separately**
  - *we need separate estimation of equation (5) and (6)*

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

An Application

- **Estimation of equation (5) and (6) involves 2 steps**

1. **Estimate a Probit model:** gives $\widehat{\gamma}$, $\widehat{\phi}_i$, $\widehat{\Phi}_i \longrightarrow \widehat{W}_{1i}$ and $\widehat{W}_{2i}$
2. Estimate **equation (5) and (6) separately by OLS using** $\widehat{W}_{1i}$ and $\widehat{W}_{2i}$

Estimation of Probit Model

- **There are 2 Issues:**

1. We need prior classification of countries belonging to Group 1 and Group 2$\Rightarrow$ exogenous sample separation
2. We need to identify Z_i representing infrastructure, institutions and IPR

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

- **Identify countries belonging to Group 1 and Group 2 using Global Competitive Index (GCI)**
  - **Global Competitive Index (GCI):** Divides countries in three groups depending on their income level → Innovation Driven, Efficiency Driven and Factor Driven
- **Countries belonging to Group 1 are** *Innovation Driven with* $I_i = 1$
- **Countries belonging to Group 2 are non-innovation driven (***Efficiency Driven and Factor Driven) with* $I_i = 0$

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

Exogenous Sample Separation

- **Total Factor Productivity (Penn World Table 9.1):** gives a measure of TFP of different countries relative to US → *correctly measures country specific TFP relative to US after controlling for differences due to changes in factor prices and input shares (see, Feenstra, et. al., 2015)*
    - **calculate** $d_i = \frac{TFP_i}{TFP_{\text{max}}}$ **separately for 2007 and 2009** → **gives distance of country** i **from global technology frontier**
        - we find $d_i \in (0, 0.47]$ for all innovation driven countries given by GCI ⇒ **rich countries closer to global technology frontier innovate as suggested by the Schumpeter's Theory of Creative Destruction**
- **Interpretation:**
    - **division of countries in Group 1 and Group 2 according to their distance from the Global Technology Frontier**

- **Calculated for different countries based on average of 3 components given below $\rightarrow$ broadly represents institutions influencing innovation**
  - **Legal and Political Environment (LP):** calculated as average of (i) Judicial Independence, (ii) Confidence in Courts, (iii) Political Stability and (iv) Control of Corruption
  - **Physical Property Rights (PPR):** calculated as average of (i) Protection of Physical Property Rights, (ii) Ease of Registering Property and (iii) Access to Loans
  - **Intellectual Property Rights (IPR):** calculated as average of (i) Protection of Intellectual Property Rights, (ii) Patent Protection, (iii) Copyright Piracy Protection and (iv) Trademark Protection
- **IPRI** $\in (0, 10)$ **represents country specific intellectual property rights and institutions**
  - 10 represents strongest property rights protection and *vice-versa*

The Endogenous Regime Switching Model (Maddala and Nelson, 1975)

Exogenous Sample Separation

- **We have estimated our model for the period 2007-2017**
    - **No inter group transition of countries:** Innovation driven rich countries belonging to Group 1 and Non-innovation driven poor countries belonging to Group 2 in the beginning of 2007 remain in their respective group till the end of 2017

Estimation of Probit Model for 2007-2017

Stage 1

- $Z_i = \left(\overline{R\&DtoGDP}_{07-17,i}, \overline{IPRI}_{07-17i}\right)', \gamma = (\gamma_1, \gamma_2)'$
- Indicator variable $I_i \sim Ber\ (\Phi_i)$

$$\begin{aligned} I_i &= 1 \text{ with probability } \Phi_i \\ &= 0 \text{ with probability } (1 - \Phi_i) \end{aligned}$$

- Estimate γ by MLE$\longrightarrow$ **estimated probability of innovation** $\widehat{\Phi}_i = \Phi\left(\widehat{\gamma}' Z_i\right)$

Results of Probit Model for 2007-2017

- **Estimated Probit model for 2007 with 64 countries (27 innovation driven and 37 non-innovation driven)** $\rightarrow$ country specific probability of innovation $\widehat{\Phi}_i = \Phi\left(\widehat{\gamma}' Z_i\right)$
  - **estimated coefficient associated with** $\overline{IPRI}$ $(\widehat{\gamma}_1)$: 1.407
  - **estimated marginal effect of** $\overline{IPRI}$: 0.096 (3.58) $\Rightarrow$ one unit rise in $\overline{IPRI}$ increases **average probability of innovation** by 9.6% (statistically significant at 1% level)
  - **estimated coefficient associated with** $\overline{R\&DtoGDP}$ $(\widehat{\gamma}_2)$: 2.059
  - **estimated marginal effect of** $\overline{R\&DtoGDP}$: 0.141 (3.37) $\Rightarrow$ one unit rise in $\overline{R\&DtoGDP}$ increases **average probability of innovation** by 14.1% (statistically significant at 1% level)
- **Pseudo-**$R^2 = 0.82$

Results of Probit Model for 2007-2017

- **Calculate,**

$$\widehat{W}_{1i} = \frac{\widehat{\phi}_i}{\widehat{\Phi}_i},$$

$$\frac{\partial \widehat{W}_{1i}}{\partial z_{ki}} = -\left[\frac{\widehat{\Phi}_i \times \left(\widehat{\gamma}' Z_i\right) + \widehat{\phi}_i}{\left(\widehat{\Phi}_i\right)^2}\right] \widehat{\phi}_i \widehat{\gamma}_k < 0 \text{ (as } \widehat{\gamma}_l > 0\text{)} \tag{8}$$

- **Calculate,**

$$\widehat{W}_{2i} = \frac{\widehat{\phi}_i}{1-\widehat{\Phi}_i}, \frac{\partial \widehat{W}_{2i}}{\partial z_{ki}} = \left[\frac{\widehat{\phi}_i - \left(1-\widehat{\Phi}_i\right) \times \left(\widehat{\gamma}' Z_i\right)}{\left(1-\widehat{\Phi}_i\right)^2} \right] \widehat{\phi}_i \widehat{\gamma}_k$$

$$\frac{\partial \widehat{W}_{2i}}{\partial z_{ki}} \gtreqless 0 \text{ according as, } \widehat{\phi}_i - \left(1-\widehat{\Phi}_i\right) \times \left(\widehat{\gamma}' Z_i\right) \gtreqless 0 \quad (9)$$

- **We find** $\frac{\partial \widehat{W}_{2i}}{\partial z_{ki}} > 0$ **for all non-innovation driven countries**

OLS Estimation of Equation (5) for 2007-2017

Stage 2

- **Dependent Variable:**
  - **average annual growth rate of innovation driven countries belonging to Group 1** (g_{1i})
- **Control Variable** (X_i)**: based on Barro (1991)**
  - initial income $(\log(GDP_{2007}))$
  - human capital (average investment to GDP from 2007-2017)
  - savings rate (average investment to GDP from 2007-2017)
  - trade openness (average trade to GDP from 2007-2017)
  - constant

- **Number of Countries belonging to Group 1:** 27
  - estimated coefficient of initial income $\left(\widehat{\beta}_{11}\right)$: -0.192 (-4.5) $\Rightarrow$ poor countries in Group 1 grows faster in long-run (significant at 1% level) $\Rightarrow$ **conditional convergence**
  - estimated coefficient of human capital $\left(\widehat{\beta}_{12}\right)$: 0.024 (4.24) $\Rightarrow$ **better human capital promotes long-run growth (significant at 5% level)**
  - estimated coefficient of savings rate $\left(\widehat{\beta}_{13}\right)$: $0.539 = (1.42)$ $\Rightarrow$ higher investment promotes long-run growth (non-significant) $\Rightarrow$ **countries are in steady state**
  - estimated coefficient of trade openness $\left(\widehat{\beta}_{13}\right)$: $0.071 = (5.89)$ $\Rightarrow$ better trade to GDP ratio promotes long-run growth (significant at 1% level)
- $\overline{R}^2 = 0.68$

OLS Estimation of Equation (5) for 2007-2017

Stage 2

- **Estimated coefficient of** $\widehat{W}_{1i}$ ($\widehat{\sigma}_{1\epsilon}$)**:** 0.146 (11.67)
- **Equation (8) gives** $\frac{\partial \widehat{W}_{1i}}{\partial z_{ki}} < 0$ **and equation (5) gives**

$$\frac{\partial \widehat{g}_{1i}}{\partial z_{ki}} = -\widehat{\sigma}_{1\epsilon} \frac{\partial \widehat{W}_{1i}}{\partial z_{ki}} > 0$$

  - **better ambience for undertaking R&D activities promotes long-run growth through technological innovation for innovation driven rich countries**

OLS Estimation of Equation (6) for 2007-2017

Stage 2

- **Dependent Variable:**
  - **average annual growth rate of non-innovation driven countries belonging to Group 2** (g_{2i})
- **Control Variable** (X_i)**: based on Barro (1991)**
  - initial income $(\log(GDP_{2007}))$
  - human capital (average investment to GDP from 2007-2017)
  - savings rate (average investment to GDP from 2007-2017)
  - constant

OLS Estimation of Equation (6) for 2007-2017

Stage 2

- **Number of Countries belonging to Group 2:** 37
  - estimated coefficient of initial income $\left(\widehat{\beta}_{21}\right)$: -0.134 (-2.67) $\Rightarrow$ poor countries in Group 2 grows faster in long-run (significant at 5% level) $\Rightarrow$ **conditional convergence**
  - estimated coefficient of human capital $\left(\widehat{\beta}_{22}\right)$: 0.0242 (1.56) $\Rightarrow$ better human capital has no significant impact for long-run growth non-innovation driven countries
  - **estimated coefficient of savings rate** $\left(\widehat{\beta}_{23}\right)$**:** 1.717 (6.17) $\Rightarrow$ **higher investment promotes long-run growth (significant at 1% level)** $\Rightarrow$ **countries are in transition**
- $\overline{R}^2 = 0.54$

OLS Estimation of Equation (6) for 2007-2017

Stage 2

- **Estimated coefficient of** $\widehat{W}_{2i}$ $(\widehat{\sigma}_{2\epsilon})$**:** -0.046 (-0.46) $\Rightarrow$ $\widehat{\sigma}_{2\epsilon}$ **is of correct sign but non-significant**

$$\frac{\partial \widehat{g}_{2i}}{\partial z_{ki}} = \widehat{\sigma}_{2\epsilon} \frac{\partial \widehat{W}_{2i}}{\partial z_{ki}} < 0$$

  - **better ambience for undertaking R&D activities has no impact on economic growth for non-innovation driven poor countries**

Estimation of Variance for 2007-2017

- **Lee and Trost (1977):**

$$E\left(\eta_{1i}^2 \middle| I_i = 1\right) = \sigma_1^2 - \sigma_{1\epsilon}^2 W_{1i}\left[\left(\gamma^{'} Z_i\right) + W_{1i}\right] \tag{10}$$

$$E\left(\eta_{2i}^2 \middle| I_i = 0\right) = \sigma_2^2 + \sigma_{2\epsilon}^2 W_{2i}\left[\left(\gamma^{'} Z_i\right) - W_{2i}\right] \tag{11}$$

- **Equation (10) and (11) show errors of equation (5) and (6) are heteroscedastic $\Rightarrow$ should be estimated by GLS**
- **White's test and Glesjer test:** errors of equation (5) and (6) **homoscedastic $\Rightarrow$ can be estimated by OLS**

Estimation of Variance for 2007-2017

Issues Related to GLS

- **Source of heteroscedasticity in equation (10) and (11) are** $W_{1i}\left[\left(\gamma' Z_i\right) + W_{1i}\right]$ **and** $W_{1i}\left[\left(\gamma' Z_i\right) + W_{1i}\right]$ **respectively**
  - η_{1i} and η_{2i} homoscedastic when $\sigma^2_{1\epsilon}$ and $\sigma^2_{2\epsilon}$ in equation equation (10) and (11) are zero
- Regress $\widehat{\eta}^2_{1i}$ on a **constant** and $-\widehat{W}_{1i}\left[\left(\widehat{\gamma}' Z_i\right) + \widehat{W}_{1i}\right]$
  - $\widetilde{\sigma}^2_{1\epsilon} = 0.023\ (0.45) \Rightarrow \sigma^2_{1\epsilon}$ is **statistically non-significant** $\Rightarrow$ homoscedastic error of equation **(5)**
- Regress $\widehat{\eta}^2_{2i}$ on a **constant** and $\widehat{W}_{2i}\left[\left(\widehat{\gamma}' Z_i\right) - \widehat{W}_{2i}\right]$
  - $\widetilde{\sigma}^2_{2\epsilon} = 1.954\ (0.54) \Rightarrow \sigma^2_{2\epsilon}$ is **statistically non-significant** $\Rightarrow$ homoscedastic error of equation **(6)**
- **Equation (5) and (6) can be estimated efficiently by OLS**

Estimation of Variance for 2007-2017

- **Following Lee and Trost (1977):**
  - **Regress** $\left(\widehat{\eta}_{1i}^2 + \widehat{\sigma}_{1\epsilon}^2 \widehat{W}_{1i}\left[\left(\widehat{\gamma}' Z_i\right) + \widehat{W}_{1i}\right]\right)$ **on a constant**
    $\rightarrow \widehat{\sigma}_1^2 = 0.008\ (1.62)$
  - **Regress** $\left(\widehat{\eta}_{2i}^2 - \widehat{\sigma}_{2\epsilon}^2 \widehat{W}_{2i}\left[\left(\widehat{\gamma}' Z_i\right) - \widehat{W}_{2i}\right]\right)$ **on a constant**
    $\rightarrow \widehat{\sigma}_2^2 = 0.012\ (4.87)$

Estimated Variance-Covariance Matrix for 2007-2017

- **Estimated Variance-Covariance Matrix**

$$\widehat{\Sigma} = \begin{pmatrix} 0.008 & \sigma_{12} & 0.146 \\ & 0.012 & -0.046 \\ & & 1 \end{pmatrix}$$

- σ_{12} **cannot be identified in this model**

Robustness

- **We have estimated our model for the period 2009-2017 with 79 countries (31 innovation driven and 48 non-innovation driven)**
    - we got identical results

Conclusion

- **Capital accumulation is the only factor promoting economic growth for the non-innovation driven poor countries belonging far away from the global technological frontier**
- **Economic growth for the innovation driven rich countries is independent of physical capital accumulation as they already reached their steady state**
- **Conditional convergence prevails for both innovation driven rich countries and non-innovation driven poor countries**
- **Better human capital and better ambience for undertaking R&D activities promotes economic growth through technological innovation only for the innovation driven rich countries belonging closer to the global technological frontier**

Thank You