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Intellectual property, research intensity, and scale effect☆

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ABSTRACT

This study revisits a multi-country Ricardian model with a continuum of goods by incorporating the "standing-on-shoulder" and "stepping-on-toes" effects into technology-accumulated formation to allow externalities of both knowledge spillovers and duplication of research efforts. Being more in harmony with real practice, and even though all the merits of the trade model remain valid, this study demonstrates the scale effect in research intensity: the larger a country is, the greater the country's research intensity is.

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1. Introduction

Using a multi-country Ricardian model with a continuum of goods, Eaton and Kortum's (2001) trade model shows that a country's research intensities are invariant to the size of the country, whereas all countries share a common research intensity (relative to the population growth rate). Here, the ratio of researchers in total employment measures the research intensity in a country. However, in real practice, the research intensity varies substantially across countries, even among OECD countries. Empirically, Lo and Yang (2015) use a panel dataset for 64 countries over the period of 1996–2009 to show that the country's size matters: the larger the country is, the greater its research intensity is.

The scale also matters in firm-level research activities. Many studies suggest that large size firms tend to be more innovative, because they can use more resources and employ a broad group of researchers (Cohen & Klepper, 1996; Kafouros, 2005; Kafouros, 2006; Kotabe, Srinivasan, & Aulakh, 2002; Lichtenberg & Siegel, 1991). Thus, research activities are more efficient in translating scientific knowledge into new products in large firms than in smaller firms (Mansfield, 1968). Lin and Lee (2006) also argue that research intensity and commercialization of knowledge assets are complementary in enhancing firm performance. Generally, large firms have scale advantages in using this commercialization.

For a country as a whole, Romer's growth model also implies a scale effect in the research intensity. Having the knowledge spillovers externality, the technology accumulated formation in Romer's (1990) growth model increases not only with the country's involved researchers but also the country's current technology stock, leading to the so-called "standing-on-shoulder" effect. The standing-on-shoulder effect also appears in firm-level data. Kafouros (2008) investigates the relationship between research activities and corporate performance and suggests that the returns to research activities for low-tech firms are significantly higher than those for technologically dynamic firms.

Conversely, the simplification of the technology accumulated formation in Eaton and Kortum's trade model increases only with a country's researchers involved in R&D, thus neglecting the standing-on-shoulder effect. As a result, the scale effect disappears in Eaton and Kortum's (2001) trade model.

In addition, the technology accumulated formation in Eaton and Kortum's (2001) trade model also neglects the stepping-on-toes effect, which is an externality that indicates duplication of research efforts. The stepping-on-toes effect is more likely when too many people engage in this process, and especially when bureaucracy takes place. The phenomenon appears in historical data. As Jones (1995) argues, research is an essential input to the production function of ideas. Although authors of the most variable ideas patent them, patents count may provide a simple measure of the technology stock. According to the patents issued, the technology stock increases from around 25,000 patents in 1900 to around 96,000 in 1991 in the U.S. This trend represents a four-fold increase in the last century. As for the inputs into the production of ideas (i.e., researchers), Jones (1995) documents that the number of scientists and engineers devoted to research activities increases from around 200,000 in 1950 to about one million in 1990 in the U.S. This rise also represents a four-fold increase, but during a forty-year

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period. France, West Germany, and Japan presented a similar pattern. That is, the fact that the accumulation of technology (in the form of patents granted) increases at almost half rate (four-fold increase during the forty-year period vs. four-fold increase in a century) of researchers in the most advanced countries (e.g., the U.S., Japan, France, and Germany) provides evidence of the stepping-on-toes effect.

To establish harmony in real practice, this study revisits Eaton and Kortum's (2001) trade model by simply incorporating the standing-on-shoulder and stepping-on-toes effects into their technology accumulated formation to allow for externalities of both knowledge spillovers and duplication of research efforts. As a result, although all of the merits of Eaton and Kortum's (2001) trade model remain, this study demonstrates the scale effect in research intensity: the larger a country is, the greater is the country's research intensity.

Section 2 redesigns Eaton and Kortum's (2001) model by adding the standing-on-shoulder effect to the technology accumulated formation. Section 3 demonstrates how a country's intellectual property protection affects the country's research intensity. Section 4 presents the concluding remarks.

2. The model

Following Eaton and Kortum's (2001) probabilistic model, a firm from country i draws its productivity $z_i(\omega)$ from a Fréchet distribution $F_i(z)=e^{-T_i z^{-\theta}}$, in which the parameter θ reflects the amount of variation within the productivity distribution of a continuum of goods to govern the comparative advantages within this continuum. Eaton and Kortum (2001) presume $T_i(t)\equiv\phi_i\int_0^t r_iL_i(s)ds$ to denote the accumulated technology of country i that represents the absolute advantage of the country, in which ϕ_i denotes the research productivity of researchers and r_i is country i's research intensity. Firms in a country with a higher level of T tend to have a higher probability of drawing a more efficient productivity. This model includes two sectors in an N countries world, in which labor is the only factor of production and is in inelastic supply as L_i, $\forall i\in\{1,.....N\}$. A firm in a country employs an idea from researchers to produce a variety of the final good. Labor is freely mobile between research and production sectors.

The technology accumulated function in Eaton and Kortum's (2001) model is seemingly an oversimplified version of Romer's (1990) model that neglects the standing-on-shoulder effect. This study revisits Eaton and Kortum's (2001) probabilistic model by simply restoring the standing-on-shoulder effect. In addition, to be more realistic, the study also incorporates the stepping-on-toes effect into the mode, as Jones (1995) suggests.

Similar to Romer's (1990) and Jones (1995) model, this research regulates the technology accumulated function as

$$\dot{T}_i(t)\equiv\phi_i T_i(t)^{\lambda}(r_iL_i(t))^{\eta}, \tag{1}$$

where $0<\eta\le1$, which Jones names the stepping-on-toes effect, to indicate that the duplication of research efforts is more likely to occur when too many people engage into the research and especially when bureaucracy takes effect. Here, $0<\lambda<1$ denotes the standing-on-shoulder effect (Jones), capturing whether an economy has well-protected intellectual property rights. Here, intellectual property refers to all the intangible assets resulting from research activities, including industrial patents, copyrighted works, software patents, and trademarks. Researchers widely acknowledge that a country government encourages innovation by ensuring optimal protection of intellectual property rights, because entrepreneurs assure that they will capture satisfactory private returns from the social returns that their innovations produce (Jones, 1995). With an enforceable legal system protecting patents and copyrights, entrepreneurs are more willing to invest in research activities and unveil their innovations in the form of patent applications, allowing all researchers to study freely the innovations the patent application describes. Protection of intellectual property ends up encouraging knowledge spillovers, that is, the standing-on-shoulder effect increases with a greater λ.

Romer presumes an extreme value $\lambda=1$ (everyone freely applies all patents), whereas Eaton and Kortum presume another extreme as $\lambda=0$ (no standing-on-shoulder effect). This study follows Jones to take the middle and presume $0<\lambda<1$, which is the main assumption in this model. Both Romer (1990) and Eaton and Kortum (2001) presume the stepping-on-toes effect as $\eta=1$, whereas Jones (1995) argues $0<\eta<1$ because of historical evidence. This model also applies this assumption.

In (1), the probability of the fraction of goods that country n buys from country i is time-invariant in equilibrium, implying that $\frac{\dot{T}(t)}{T(t)}=\frac{\eta}{1-\lambda}g_L$, where g_L is the population growth rate. With the solution of the differentiation equation in (1), the accumulated technology of country i is as

$$\begin{aligned}T_i(t)&=\left[(1-\lambda)\phi_i\int_0^t(r_iL_i(s))^{\eta}ds\right]^{\frac{1}{1-\lambda}}\\&=\left(\frac{(1-\lambda)\phi_i}{g_L}\right)^{\frac{1}{1-\lambda}}(r_iL_i)^{\frac{\eta}{1-\lambda}}.\end{aligned} \tag{2}$$

2.1. The utility function

As in Eaton and Kortum (2001), the utility function of a representative consumer in each country is a Cobb–Douglas function across the continuum of final goods:

$$U=\exp\int_0^1\ln y_i(\omega)d\omega.$$

The price of good ω in country n from country i is $p_{in}(\omega)=\frac{c_id_{in}}{z(\omega)}$, where d_{in} is the geographical barriers from country i to n. As in the Eaton and Kortum (2001, 2002) model, $d_{ii}=1$ and $d_{in}>1$ if $n\neq i$. The geographical barriers also obey the triangle inequality: for any three countries i, k, and n, $d_{in}\le d_{kn}d_{ik}$. The goods in country n that come from country i have a price distribution $G_{in}(p)=1-e^{-T_i(c_id_{in})^{-\theta}p^{\theta}}$. Therefore, the price distribution in country n is $G_n(p)=1-\Pi_{i=1}^N(1-G_{in}(p)=1-e^{-\Phi_np^{\theta}}$, in which $\Phi_n\equiv\sum_{i=1}^N T_i(c_id_{in})^{-\theta}$. With the Cobb–Douglas preferences, the price index of the final goods in country n is:

$$P_n=e^{\eta_e/\theta}\Phi_n^{-1/\theta}. \tag{3}$$

where $\eta_e\equiv-\int_0^{\infty}\ln(x)e^{-x}dx$ is Euler's constant. The probability that country i is the cheapest source of a particular good exporting to country n is:

$$\pi_{in}=\frac{T_i(w_id_{in})^{-\theta}}{\sum_{k=1}^N T_k(w_kd_{kn})^{-\theta}}, \tag{4}$$

which also represents the fraction of goods that country n buys from i.

2.2. The research activities

The third sector is the research sector. At a point of time t, a firm in country i employs an idea from researchers. Suppose that an idea has an efficiency $z(\omega)$ and that the idea is the best idea applied to a particular good ω.

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