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BUSINESS SERVICES, TRADE, AND RESEARCH INTENSITY*

Chu-Ping Lo

Department of Agricultural Economics, National Taiwan University
Taipei 106, Taiwan
cplo@ntu.edu.tw

and

Chih-Hai Yang**

Department of Economics, National Central University
Taoyuan 320, Taiwan
chyang@mgt.ncu.edu.tw

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Abstract

This paper constructs a theoretical framework of trade to investigate how business services function as a mean of reducing costs and then encouraging research activities. Our theoretical model predicts that a country with a higher degree of business service specialization tends to have higher research intensity and subsequently higher income. Using a panel dataset for 38 countries over the period 1996-2015 to test the theoretical predictions, various robust estimations support our theoretical predictions.

Keywords: trade, technology, research intensity, business services
JEL Classification Codes: F11, F17, O31, O33

I. *Introduction*

The importance of innovation in sustaining economic growth, modeled by the endogenous growth theories,[1] is widely recognized across countries. Thus, most countries have tried to construct a technological environment favoring innovative activities and have adopted various policy measures to encourage private research activities, mainly R&D subsidies and R&D tax

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** Corresponding author.

1 For example, Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992), and Jones (1995).

credits (Becker, 2015). The inter-country variability of research activities depends on a variety of factors - mainly, innovation infrastructure, industrial structure and clustering, human capital, and international trade.

It has also been well documented in literature that there is a positive correlation between financial development and innovation (e.g., Rajan and Zingales, 1998; Aghion, Hemous, and Kharroubi, 2009; Pienknagura, 2010). In addition to financial services, other types of business services specific to firms, such as advertising, legal, accounting, distribution logistics, telecommunications, transport, auditing, tax consultancy, market research, business and management consultancy, educational services, and labor recruitment, are also important ingredients to improve efficiency and quality of the firms (e.g., Bessant and Rush, 1995; Baro, 2008; Shearmur and Doloreux, 2013; Evangelista, et al., 2013).[2] Thus, at the heart of this paper takes the various business services as a whole, rather than financial service along, into account in investigating its impacts on innovation.

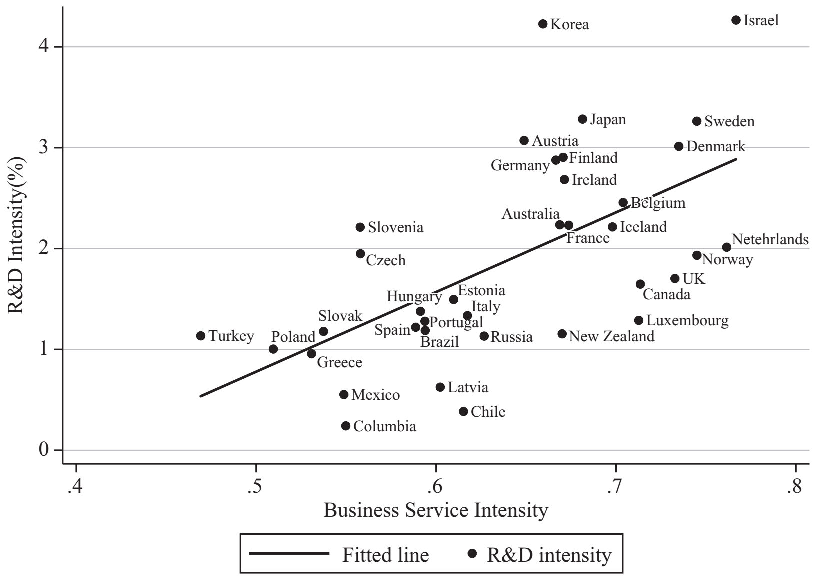
The microeconomics-based models of national competitive advantage and industrial clusters, such as Porter (1990), enumerate the characteristics of the environment in a country's industrial clusters that shape the rate of private sector innovation. Along with economic development, the process inevitably involves the transition of economies from manufacturing to the services sector. This is indeed the case for developed and some developing countries. Not only does innovative activity increase steadily in the services sector itself, but the development of some service industries also serves as a bridge for innovation, such as the business services industry (Czarnitzki and Spielkamp, 2003; Evangelistaa, et al., 2013) and financial sector (Pienknagura, 2010). It implies that services sector development is probably accompanied by an increase in a country's research activity, although this issue is not well examined.

On the other hand, some literature (e.g., Aw *et al*., 2007; Braga and Willmore, 1991; and Lee, 2004) firmly established the empirical regularity that international trade stimulates innovation in studies using micro-level data. The microeconomic consensus, however, seems to be less supported in trade theory from the country-level perspective. Using a multi-country Ricardian model with a continuum of goods, Eaton and Kortum (2001) examine the effect of trade costs on research and the effects of scale and research productivity on relative incomes. They find that research intensities are invariant to the size of the country, whereas all countries share common research intensity (relative to the population growth rate).

However, in practice, research intensity might vary substantially across countries, in terms of business service that is the main concern in this study. Using our sample countries that contains 25 OECD countries and 13 non-OECD countries (see Appendix Table 1), Figure 1 provides a preliminary graphical representation of the relationship between R&D intensity (the R&D expenditure to GDP ratio) and business service intensity (measured by the ratio of business service employments to labor force) without controlling other factors. As depicted in Figure 1, it seems to exhibit a positive relationship between R&D intensity and business service intensity, implying that the development of business services sector might facilitate R&D

[2] Specifically, Bessant and Rush (1995) suggest the important role of consultants in technology transfers, which should help internal innovation. Evangelista et al. (2013) provide empirical evidences on how business services have a positive impact on innovation, while similar results were observed in a survey of 804 manufacturing establishments in Quebec by Shearmur and Doloreux's (2013). Baro (2008) reports that the innovation of firms, due to its interactive, complex, uncertain and thus risky process, depends not only on their internal competencies but also on other external knowledge that various professional business service providers might bring.

FIGURE 1. BUSINESS SERVICE INTENSITY AND R&D INTENSITY, 2015



Note: The selected countries are those used for empirical tests in this study.

activity.

This discrepancy between theory and practice might come from their set-up: all the activities in the Eaton and Kortum (2001, 2002) models take place in the tradable manufacturing sector. However, as is well known, about 70% of jobs in OECD countries are in fact within service industries, including financial, legal, consulting, marketing, distribution, telecommunications, and even public services. Many of these specialized business services are intangible and non-tradable and mostly serve as intermediating facilities to firms in manufacturing industries for production rather than for direct consumption. Furthermore, the variety and values of the businesses also function as a means of reducing costs and other obstacles to innovation in the manufacturing firms (Czarnitzki and Spielkamp, 2003).

This paper therefore aims to model the importance of business services in determining research intensity and further demonstrates how it plays a role in affecting trade and living standards. For this purpose, we extend Eaton and Kortum's (2001) model by adding the business services sector that can facilitate the production of final-goods in the manufacturing sector. Each of these business services demands a group of workers to run a routine set of instructions, while it also requires a fixed amount of workers to deal with complex and tacit tasks. Through being closely interwoven with manufacturing firms, business services providers act in a horizontal fashion to provide an array of specialized business services to the final-goods production.

It is assumed further that business services are symmetrically composited via a Spencer-Dixit-Stiglitz aggregate, so that the cost of composite business services decreases diminishingly with the number of varieties of business services. With diminishing characteristics in the cost of composite business services, a country with a higher degree of business service specialization is better able to raise the returns to firms. We argue that the aggregate business services bundle acts not only as a productivity shifter, but also serves as a probability (a successful idea) shifter. With the love of variety that consumers demand, composite business services can increase the probability of an idea becoming a successful idea in the final-goods markets, thus encouraging research activities. As a result, a country with abundant business services encourages the generation of ideas, leading to higher research intensity than countries that have less business services, thereby increasing its income relative to those other countries. The main implication of this paper is that scale matters: the larger a country is, the greater the country's aggregate business service bundle will be, and hence the greater the country's research intensity and income become as well.

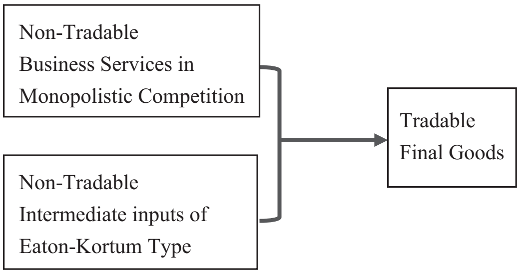
Alvarez and Lucas (2007) have also rewritten the Eaton and Kortum's model (2002) by adding labor services in the final-good production in perfect competition, so do Caliendo and Parro (2015) and Costinot and Rodriguez-Clare (2014) as well. However, in their extensions, the share of business services is exogenous and is the same among all countries, such that scale plays no role in facilitating innovation. Arkolakis (2010) introduces marketing cost into a framework of Melitz (2003) and Chaney (2008), where the marketing cost is positively related to the size of target markets but not host country and is playing no role in either innovation or productivity enhancing. In comparison, in this current paper, the novel ingredient is the endogeneity in the share of business services that is country specific. We presume that the business services sector is in monopolistic competition, allowing a larger country tend to have the greater aggregate business service bundle and then hereby generate more ideas.

Although theoretical frameworks are completely different, our main results are somehow close to Pienknagura (2010), who suggests that financial development, a kind of business services, promotes incomes through the effect it has on investment of research and development (R&D) by firms. Reasonably, an increase in financial development raises the success probability of innovation through its positive impacts on funding innovation and then improving productivity. Pienknagura (2010) thus argues that this credit constraint on financial liquidity has a larger effect on growth and R&D expenditure for firms operating in sectors with higher dependence on external financing.

The main difference of this current paper comparing to Pienknagura (2010) and other empirical papers (e.g., Czarnitzki and Spielkamp, 2003; Evangelistaa, et al., 2013) is that we suggest another channel on how business services promote incomes through its positive impacts on innovation. Considering that a successful innovation of a firm depends not only on its internal research activities but also on other external knowledge, such as advertising, legal, consultancy and market research, among others, various types of professional business services play an important role in successful innovation. We thus argue that the scale effects from the love of business services variety increase the probability of an idea becoming a successful innovation in the final-goods markets, hereby encouraging research activities and then promoting incomes. Another difference comparing to other theoretical frameworks (e.g., Pienknagura, 2010) is that, in our current model, the innovation activity is only to generate new ideas, rather than to improve firm productivity. In addition, extant empirical studies regrading determinants of R&D at the country level (e.g., Masino, 2015; Sameti et al., 2010; Wang, 2010) do not examine the influence of business services on national R&D activity explicitly. This study can fill this gap in related empirical literature.

The remainder of the paper proceeds as follows. Section II presents the model, introducing

FIGURE 2. THE ROLE OF BUSINESS SERVICES



Note: The final good is produced by a Cobb-Douglas production aggregates the Eaton-Kortum type of intermediate inputs with non-tradable business services bundles.

business services into the dynamic Eaton-Kortum model of research and growth. Sections III and IV provide the empirical specifications and results, respectively. Section V offers concluding remarks.

II. *The Model*

In a world with three sectors and N countries, labor is the only factor of production and has an inelastic supply as L_i, $\forall i \in \{1,.....N\}$. The first sector is that of intermediate-goods, the second sector is the research sector, and the third sector is the business services sector. Labor is freely mobile across sectors.

A firm in a country employs an idea from researchers to incorporate a specific intermediate-good with a composite business service in order to produce a variety of final-goods. In this model, consumers value only the final-goods. Thus, both the business services and intermediate goods are non-tradable, while only the final-goods are tradable. Figure 2 illustrates how the three sectors interact.

1. The Business Services Sector

The business services sector in country i consists of N_{iS} varieties of specialized business services in monopolistic competition, which are symmetrically bundled together in Dixit-Stiglitz fashion as:

$$X_{iS} = \left[\sum_{j=1}^{N_{iS}} x_{iS}^{\frac{\eta-1}{\eta}}(j) \right]^{\frac{\eta}{\eta-1}}, \tag{1}$$

where $\eta > 1$ has elasticity of substitution among the specialized business services, x_{iS} is the quantity of a variety of a business service and N_{iS} represents the number of business varieties in country i (e.g., Alvarez and Lucas, 2007; Van Long et al., 2005; Jones and Kierzkowski, 1990). In this model the composite business-service good is not for direct consumption, but is intended to facilitate the production of final goods. These business services are intangible and require proximity to the users. Therefore, we presume that rendering a service provision to distant locations is infeasible so that they are not tradable.[3]

The provision of each specialized business service requires a fixed amount of workers l_0 who establish the program, and the remaining workers execute a routine set of instructions. Hence, the labor requirement for providing a variety of specialized business services is given by $l_i = l_0 + x_{iS}$ in country $i \in N$ and l_0 is common across countries, where we presume that the labor requirement for producing a unit of each variety of business service is one for simplicity. Being similar in the cost functions, as implied in (1), we obtain $x_{iS} = l_0(\eta - 1)$ and $p_{iS} = \eta w_i/(\eta - 1)$, where p_{iS} is the price of x_{iS} and w_i is the wage in country i.[4]

While each business input provider has the same cost function and equates marginal revenue with marginal cost, the unit price of the composite business service goods X_{is} is $P_{iS} = \frac{\eta}{\eta - 1} w_i N_{iS}^{1/(1-\eta)}$ with a markup $\eta/(\eta - 1)$.[5] The more varieties (specialized) of the business service that there are in a country, the lower is the price of the composite business services and the greater the gains that accrue in the presence of positive production externalities to the country's manufacturing sector. In other words, while the business services industry, such as financial services, serves as a bridge for innovation (Czarnitzki and Spielkamp, 2003; Pienknagura, 2010), we argue that the aggregate business service bundle adds the possibility of an idea becoming successful in the final-good markets.

2. The Intermediate-Goods

The intermediate-goods sector has a continuum of goods $\omega \in [0,1]$. we argue that a firm employs a specific technology, obtained from the researchers, to incorporate a specific intermediate good with a bundle of business services to produce the final good. The intermediate goods sector is characterized by perfect competition. However, in the final good production, following Eaton and Kortum's probabilistic model (2001), a firm from country i draws its productivity $z_i(\omega)$ from a Fréchet distribution $F_i(z) = e^{-T_i z^{-\theta}}$ (see Appendix A), where the parameter θ reflects the amount of variation within the productivity distribution of a continuum of goods so that it governs the comparative advantages within this continuum. Here, $T_i(t) \equiv \phi_i \int_0^t r_i L_i(s) ds$ denotes 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 more efficient productivity.

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[3] Note that intermediate-goods in Alvarez and Lucas's (2007) model are all tradable, while some of the intermediate-goods in Caliendo and Parro's (2015) model are not tradable.

[4] Per Krugman's monopolistic competition model (1980), in equilibrium, the unit price for each variety is $p_{iS} = \eta w_i/(\eta - 1)$ and the optimal output for each variety is $x_{iS} = l_0(\eta - 1)$.

[5] With the business service aggregate bundle in Dixit-Stiglitz fashion in equation (1), we obtain the price index of the bundle as $P_{iS} = \left(\sum_j^{N_{iS}} p_{iS}(j)^{1-\eta}\right)^{\frac{1}{1-\eta}}$. Given that each business input provider shares the same cost function and the unit price for one representative variety is $p_{iS} = \eta w_i/(\eta - 1)$, we obtain the unit price of the composite business service goods X_{is} as $P_{iS} = \frac{\eta}{\eta - 1} w_i N_{iS}^{1/(1-\eta)}$.

3. The Final-Goods Production

Together with the composite business services and the intermediate good, the firm produces its final-good via a Cobb-Douglas production function in Bertrand competition as:

$$y_i(\omega)=z(\omega)\left(\frac{x_{im}(\omega)}{1-\alpha_i}\right)^{1-\alpha_i}\left(\frac{X_{iS}}{\alpha_i}\right)^{\alpha_i}, \tag{2}$$

where $x_{im}(\omega)$ is the demand for the intermediate good by firm ω in the country and α_i is country-specific share of business services. For simplicity, let us presume that one unit of labor is required to produce one unit of intermediate goods in country i, $\forall i$, so that their unit product cost is the wage cost for intermediate-good producer ω. Then, the unit cost of input bundled for producing $y_i(\omega)$ is $c_i=\left(\frac{\eta}{\eta-1}\right)^{\alpha_i}\tilde{w}_i$, where $\tilde{w}_i=w_iN_{iS}^{\alpha_i/(1-\eta)}$ denotes the unit production cost. With $\eta>1$, the business services sector helps improve the efficiency of production and the efficiency increases with the measure of the variety of business servicers N_{is}.[6]

In (2), the share of business services is country-specific, and this presumption is based on a fact that only a fraction of contract is ex ante verifiable and contractible in production corporation, and the rest that are unverifiable might lead to possible opportunistic behaviors (Grossman and Hart, 1986; Hart and Morse, 1988). With the incomplete nature of contract, the degree of contractual incompleteness determines the incomplete contract distortions and which are essential to firm organization and technology choices of firms (Grossman and Hart, 1986; Acemoglu, Antràs, and Helpman, 2007; Boehm, 2018). Therefore, Acemoglu, Antràs, and Helpman (2007) argue that a country's fraction of contractible activities is a good measure of the country's quality of contracting institutions. Reasonably, the more the contractible activities in a country, the more varieties of specialized business services are demand and then the less incomplete contract distortions might arise in this country. Therefore, similar to Acemoglu, Antràs, and Helpman (2007) and Boehm (2018), we use the share of business service in the production function (2) to measure the country specific quality of contracting institutions. Nevertheless, in addition to them, it will be clear in the latter on discussion in this paper that a country's abundance in business service helps increase the probability of an idea becoming a successful idea, thereby leading to higher research intensity in that country.

As in the Eaton and Kortum (2001) model, 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 $p_{in}(\omega)=\frac{c_i d_{in}}{z(\omega)}$, where d_{in} is geographical barriers from country i to n.[7] The goods in country n that come from country i have a price

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[6] With the Cobb-Douglas production in (2), the unit cost of $y_i(\omega)$ should be $c_i(\omega)=(w_i)^{1-\alpha}(P_{iS})^{\alpha}$. Given $P_{iS}=\frac{\eta}{\eta-1}w_iN_{iS}^{1/(1-\eta)}$, we thus obtain $c_i=\left(\frac{\eta}{\eta-1}\right)^{\alpha}\tilde{w}_i$ for all ω, where $\tilde{w}_i=w_iN_{iS}^{\alpha/(1-\eta)}$.

[7] As in the Eaton Kortum (2001, 2002) model, we have $d_{ii}=1$ and $d_{in}>1$ if $n\neq i$. The geographical barriers also obey the triangle inequality: for any three countries i, k, and n, $d_{in}\leq d_{kn}d_{ik}$.

distribution $G_{in}(p)=1-e^{-T_i(c_i d_{in})^{-\theta}p^{\theta}}$. Therefore, the price distribution in country n is $G_n(p)=1-\prod_{i=1}^{N}(1-G_{in}(p)=1-e^{-\Phi_n p^{\theta}}$, in which $\Phi_n\equiv\sum_{i=1}^{N}T_i(c_i d_{in})^{-\theta}$. 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 being exported to country n is:

$$\pi_{in}=\frac{T_i(\tilde{w}_i d_{in})^{-\theta}}{\sum_{k=1}^{N}T_k(\tilde{w}_k d_{kn})^{-\theta}}, \tag{4}$$

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

4. 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 to transfer intermediate-goods into the final inputs. Suppose that an idea has efficiency $z(\omega)$ and that the idea is the best one applied to a particular good ω.

Following the Eaton and Kortum (2001) model again, who show that the markup that is conditional on the idea being the best idea follows a Pareto distribution with a parameter θ as $M(\theta)=1-m^{-\theta}$ (see Appendix A). Then, the net profit share from producing the final good is $1-m^{-1}$. Thus, the expected share of the profits from the best idea in a market is:

$$\int_1^{\infty}(1-m^{-1})dM(m)=\frac{1}{1+\theta}.$$

5. Equilibrium

By letting $Y_{in}(t)$ represent the total exports from country i to n at time t, the total profits of firm i around the world are:

$$\sum_{n=1}^{N}\left(\frac{1}{1+\theta}\right)Y_{in}(t)=\frac{1}{1+\theta}Y_i(t), \tag{5}$$

where $Y_i(t)$ denotes the total expenditure of country i under balanced trade. Let r_i denote research intensity while the r_i share of the country's labor are engaged in research activities, such that the surplus $\frac{1}{1+\theta}Y_i(t)$ represents the total profits that is attributed to the researchers, $\forall i$. The remaining $\left(1-\frac{1}{1+\theta}\right)Y_i$ goes to manufacturing workers in the intermediate-goods sector and labor in the business service sector.

Implied in (2), the labor market equilibrium in the business services sector is given by

$$\alpha_i\left(1-\frac{1}{1+\theta}\right)L_i=\eta l_0 N_{is},\ \forall i. \tag{6}$$

Let's define the employment share of business services $\widehat{\alpha}_i=\frac{\eta l_0 N_{is}}{L_i}$ as the business service intensity, which measures the extent to which a country is prosperous in the business service sector. Thus, in (6), we have $\alpha_i=\left(\frac{1+\theta}{\theta}\right)\widehat{\alpha}_i$. With a constant elasticity of substitution parameter η and the fixed cost l_0, *ceteris paribus* (e.g., same labor supply L), the more a country's business services are specialized (larger N_{is}), the larger is the country's business service intensity ($\widehat{\alpha}_i$), and then the more prosperous is the country in the business service sector.

Together with (5) and (6), the labor market equilibrium for manufacturing workers in the intermediate-goods sector in country i is:

$$(1-\alpha_i)\left(1-\frac{1}{1+\theta}\right)Y_{it}=w_{it}\left(1-r_i-\frac{\theta}{1+\theta}\alpha_i\right)L_{it},\ \forall t,^{8} \tag{7}$$

where $w_{it}\left(1-r_i-\frac{\theta}{1+\theta}\alpha_i\right)L_{it}=w_{it}(1-r_i-\widehat{\alpha}_i)L_{it}$ is the total wages incomes of the manufacturing workers. We can rewrite (7) to get $\frac{Y_{it}}{L_{it}}=w_{it}\left(\frac{1-r_i-\frac{\theta}{1+\theta}\alpha_i}{1-\alpha_i}\right)\left(\frac{1+\theta}{\theta}\right)$.

The net present value of a researcher in country i from discovering a successful idea to produce a specific final-good at time is:

$$v_i(t)=w_{it}\left(\frac{g_L}{\theta\rho-g_L}\right)\frac{(1-\alpha_i)}{1-\alpha_i(1+\theta)/\theta}\,\frac{1-r_i}{r_i}. \tag{8}$$

See Appendix B for detail derivation. It is interesting in (8) that the present value of a successful idea in a country is increasing in the country's business intensity. Arbitrage by workers leads to $v(t)=w(t)$ in equilibrium when workers are freely movable across sectors. After some algebra (see Appendix B), we rearrange (8) to obtain the country-specific research intensity as:

$$r_i=\left(\frac{g_L}{\theta\rho}\right)\left(\frac{1-\frac{\theta}{1+\theta}\alpha_i}{1-\alpha_i(1-g_L/\theta\rho)}\right). \tag{9}$$

Note that for the case of without the love-of-variety effect from the business service sector as $\alpha_i=0, \forall i$, we return to the Eaton and Kortum's (2001) model in which research intensity does *NOT* depend on a country's prosperous in the business service sector. However, to the contrary, equation (9) shows that a country that is more prosperous in the business service (larger α_i) tends to have greater research intensity. [9] Here, we presume that the shape parameter θ is sufficiently large such that $\rho-g_L>\frac{g_L}{\theta}$ since $\theta\gg 1$ in literature. We argue that, the

[8] When workers are freely movable across sectors, implied in (5) and (6), the total demand for research workers are $(1-r_i)L_i$ and that for service workers are $\widehat{\alpha}_i L_i$. Thus, the remaining workers are manufacturing workers as $(1-r_i-\widehat{\alpha}_i)L_i$, where $\widehat{\alpha}_i=\left(\frac{\theta}{1+\theta}\right)\alpha_i$.

composite business services serve to increase the probability of an idea becoming a successful idea, thus inducing more research activities. As a result, a country that is more specialized in the business services sector, which encourages the country to generate more ideas, tends to have the higher research intensity there.

The intuition is simple: a country is able to provide more varieties of the business service bundle, such that more gains arise in the presence of positive production externalities to the manufacturing sector. The positive production externalities increase the probability of an idea becoming successful in the final-good markets, in turn encouraging research activities. As a result, a country that has a higher degree of business service specialization tends to carry out research activities more intensively, leading to higher research intensity for the country. This is the main implication in this model.

6. Gravity Model

In the steady state, the relative technology level of two random countries n and i is:

$$\frac{T_n}{T_i}=\frac{L_n}{L_i}\frac{\phi_n r_n}{\phi_i r_i},$$

which, depending on the relative sizes of their labor forces, is weighted by not only their research productivity (i.e., ϕ), but also their research intensity. This model has variations in research intensity across countries due to differences in business services, so that a country's accumulated technology is also determined by its business services sector.

The condition for the labor market equilibrium in the non-research sectors in country i is: $w_i(1-r_i)L_i=\sum_{n=1}^{N}\pi_{ni}w_n(1-r_n)L_n$. With (4) and (5), we can rewrite the equilibrium as:

$$w_iL_i(1-r_i)=\frac{\sum_{n=1}^{N}T_i(\tilde{w}_id_{in})^{-\theta}w_nL_n(1-r_n)}{\sum_{k=1}^{N}T_k(\tilde{w}_kd_{kn})^{-\theta}}. \tag{10}$$

In a case of free trade ($d_{ij}=1,\forall j$), from (6), (9), and (10), we obtain an approximation:

$$\frac{w_i}{w_n}=\left(\frac{T_i/L_i}{T_n/L_n}\right)^{1/(1+\theta)}\left(\frac{1-r_n}{1-r_i}\right)^{1/(1+\theta)}\left(\frac{L_i\hat{\alpha}_i}{L_n\hat{\alpha}_n}\right)^{\frac{\alpha\theta}{(\eta-1)(1+\theta)}}, \tag{11}$$

where $L_i\hat{\alpha}_i$ denotes country i's total labor supply in the business service sector and $L_{nS}\hat{\alpha}_n$ fro country n. In addition to Eaton and Kortum's (2001, 2002) models, this current model shows that the relative wage of a pair of countries is not only determined by their per capita technology, but also is increasing in their relative research intensity and in their relative size in the business service sector. This is the second implication in this model.

[9] To ensure $\frac{\partial r_i}{\partial \alpha_i}=\left(\frac{g_L}{\theta\rho}\right)\frac{\frac{1}{1+\theta}-\frac{g_L}{\theta\rho}}{[1-\alpha_i(1-g_L/\theta\rho)]^2}>0$, we must have $\rho-g_L>\frac{g_L}{\theta}$. Given that the discount rate ρ is usually substantially larger than the population growth rate and $1\gg g_L$, it is feasible to presume $\rho-g_L>\frac{g_L}{\theta}$ when θ is sufficiently large as $\theta\gg 1$. Note that in literature, for example, Eaton and Kortum (2002) use retail prices in 19 OECD countries for 50 manufactured products to obtain a mean estimate of trade elasticity $\theta=8.28$, while Costinot, Donaldson and Komunjer (2012) obtain an estimate of the trade elasticity $\theta=6.6$.

III. *Data and Empirical Specification*

To test the predictions of our model, we need country-level data to implement the empirical estimation. As both business service intensity and research intensity are the main variables in the empirical test, the sample herein is constrained to the availability of information about R&D expenditure, researchers, and employment of individual business service industries. Most advanced countries have statistics regarding the above information, while it is lack of most developing countries. To obtain a largest dataset, we collect information from 25 members of Organization for Economic Cooperation and Development (OECD, accession before 1996) and 13 non-OECD countries from various date sources, yielding an unbalanced panel dataset of 38 countries for the period 1996-2015. Appendix Table 1 lists these countries.

The business services are defined as follows: based on the International Standard Industrial Classification Revision 3 (ISIC, Rev. 3), we exclude Wholesale and retail trade (G), Hotels and restaurants (H), Other community activities (O), Private household with employed persons (P), and Extra territorial organizations (Q) from the service sector, using the ratio of the remaining industries (I, J, K, L, M, and N) as the measure of specialization in the business services sector.[10]

Our theoretical model proposes two main predictions: first, research intensity increases with the intensity of specialization of a country's business services intensity (higher $\widehat{\alpha}_i$ in equation 9). Second, the relative wage is increasing with research intensity and with the prosperity of the business service sector, as implied in equation (11). Empirical models are thus specified to test these two hypotheses as follows:

For the hypothesis 1, as equation (9) is non-linear, we log-linearly approximate (9) by using a first-order Taylor-series approximation to test the above two predictions:

$$\ln r_{it}=\beta_0+\beta_1\ln \widehat{\alpha}_{it}+X\beta+u_i+v_t+\varepsilon_{it} \quad (12)$$

Correspondingly, the second hypothesis implied in (11) the relative wage is increasing with research intensity and with the prosperity of the business service sector is specified as follows:

$$\ln w_{it}=\lambda_0+\lambda_1\ln \widehat{\alpha}_{it}+\lambda_2\ln r_{it}+X\beta+u_i+v_t+\varepsilon_{it} \quad (13)$$

In equation (12), the dependent variable r_{it} is a country's research intensity. Two widely used measures are researchers per million people and the ratio of R&D expenditure to GDP. In equation (13), the dependent variable should be workers' average wage theoretically. As there is no detailed information regarding the average wage of workers in individual countries, we use GDP per worker employed as the proxy variable. Term $\widehat{\alpha}_i$ is the key variable, representing a country's business intensity which is measured by the ratio of business services sector employees to total labor force (millions of workers). A vector of other covariates X are also

[10] Correspondingly, the excluded service sectors in ISIC Rev. 4 contain Wholesale and retail trade, Repair of motor vehicles and motorcycles (G), Accommodation and food service activities (I), Arts, entertainment and recreation (R), Other service activities (S), Activities of households as employers undifferentiated goods- and services-producing activities of households for own use (T), and Activities of extraterritorial organizations and bodies (U).

included. The subscripts i and t denote country and time period, respectively. The terms u and ε are respectively unobserved country heterogeneity and a normally distributed error term.

To include other potential influences of R&D intensity, we refer to studies examining the determinants of R&D activity across countries, e.g., Masino (2015), Sameti et al. (2010), and Wang (2010). They conclude the importance of trade, openness, and institution. Moreover, as discussed in Eaton and Kortum (2002), we assume that the comparative advantage parameter (θ) is the same among OECD countries, and therefore it will be summed up into a constant term.[11] However, Chor (2010) unpacks sources of comparative advantage and emphasizes the importance of institutions. Considering the influences of trade and institution, we specify the empirical model as follows:

$$\ln r_{it}=\beta_0+\beta_1\ln\hat{\alpha}_{it}+\beta_2\ln HTEXP_{it}+\beta_3\ln FINDEV_{it}+\beta_4\ln GOV_{it}+u_i+v_t+\varepsilon_{it} \qquad (14)$$

The definitions of covariates are as follows. The intensity of business services is measured by the employee ratio of business services to labor force. The estimated coefficient β_1 in the regression, as implied in (9), should be positive. The term *HTEXP* is high-tech product exports and captures a country's international linkages through its high-tech industries. It is expected to have a positive influence on R&D activity as indicated by Sameti et al. (2010). Referring to Chor (2010), we include two institutional variables to differentiate a country's comparative advantages. The first one is the degree of financial development (*FINDEV*), measured by the ratio of domestic credit to private sector to GDP. The other is the degree of government integrity (GOV), which is surveyed by the Heritage Foundation. The value of *GOV* ranges between 0 and 100; a higher index value denotes better government integrity. A stable financial sector and transparent government can establish an environment favoring R&D activity (Masino, 2015).

Based on the hypothesis 2, the empirical model is specified as follows:

$$\ln w_{it}=\lambda_0+\lambda_{11}\ln L_{it}+\lambda_{12}\ln\hat{\alpha}_{it}+\lambda_2\ln r_{it}+\lambda_3\ln TL_{it}+u_i+v_t+\varepsilon_{it} \qquad (15)$$

It is easy to show that the wage inequality w_i/w_n in (11) increases with the relative measure of prosperous in the business services sector (i.e., $L_i\hat{\alpha}_i/L_n\hat{\alpha}_n$). Hence, a country tends to have a higher wage when it exhibits more prosperous in the business services sector. To precisely capture the influence of business services, labor force (ln$L$) is also controlled, because the size of labor force varies across countries substantially. As with our theoretical predictions, R&D intensity (r_{it}) should positively related to GDP per worker. The term lnTL denotes per capita technology measured by the number of U.S. patents per million populations.

Information of an individual service industry's employees is drawn from the Organisation for Economic Co-operation and Development (OECD) databank. Institutional variables (*FINDEV* and *GOV*) are surveyed by the Heritage Foundation, while data on other variables are drawn from World Bank's World Development Indicators (WDI). Table 1 summarizes the definitions, basic statistics, and data sources of variables.[12]

[11] Data on the comparative advantage parameter for non-OECD countries are available only for India (Donaldson, 2018). As the comparative advantage parameter is constant for all countries, its impact on research intensity can be captured by the individual effect in the panel data model.

[12] The correlation matrix among explanatory variables is displayed in Appendix Table 2.

Table 1 Variable Definitions and Basic Statistics

Variable	Definition	Mean (S.D.)
r	Research intensity: measured by researchers per million people.	3,215.565 (1,855.684)
RDINT	R&D intensity: measured by the ratio of R&D expenditure to GDP (%)	1.687 (0.969)
$\hat{\alpha}$	Intensity of business services specialization, proxied by the ratio of business service employees to total labor (%)	37.988 (10.098)
L	Labor force (millions of workers)	20.087 (30.472)
HTEXP	High-tech product exports (US$ billion)	25.620 (41.623)
FINDEV	Financial development: measured by domestic credit to private sector (% of GDP). Surveyed by Heritage Foundation	92.275 (49.467)
GOV	Government integrity: ranges from 0-100, and a higher value denotes stronger integrity. Surveyed by Heritage Foundation	65.888 (21.548)
TL	Per capita technology: measured by patent applications per million people	288.992 (545.353)
w	Wage: proxied by gross domestic product (GDP) divided by total employment (constant 1990 PPP)	61,89501 (41,956.89)

Note: The means and standard errors are calculated by pooling data for the period 1996-2015.

As is common in the specification of the panel data model, we allow for the existence of the individual country effect that is potentially correlated with the right-hand side regressors. Using a within country panel estimator, particularly the fixed effect (FE) model, to eliminate the individual effect is a standard estimation method. Thus, this study adopts the FE model to perform the empirical estimation.

IV. *Estimation Results*

1. Preliminary Analysis

Before starting our econometric analysis to test the theoretical predictions, we provide preliminary evidence and descriptive statistics regarding the evolution of the business services intensity and R&D intensity this sample countries, in terms of income levels and time periods.

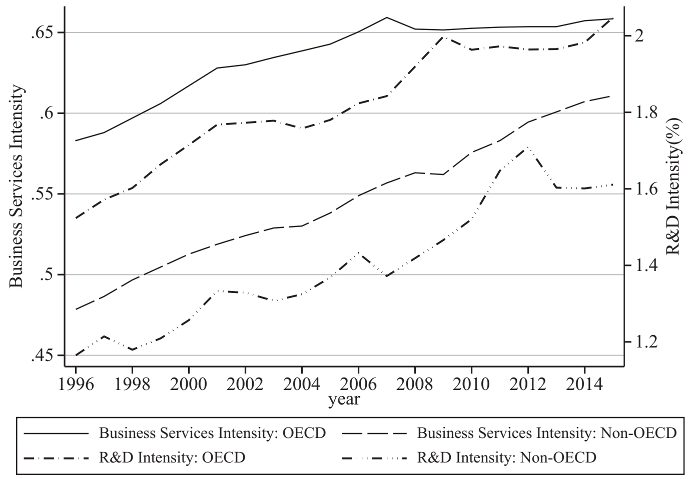
Figure 3 depicts the time trends of business services intensity and R&D intensity for all 38 sampling countries (Figure 3a) and two sub-sample countries (Figure 3b). As depicted in Figure 3a, the average R&D intensity of all countries exhibited an increasing trend from 1.411 in 1996 to 1.906 in 2015. Correspondingly, the business services intensity also climbed from 0.553 in 1996 to 0.642 in 2015 stably. Crucially, the evolutions of the business services and R&D intensity show a similar increasing trend, suggesting that the development of business services sector may positively relate to national R&D activity. One point worth noting is that the time effect probably matters to the predicted positive relationship between business services and research intensity and it should be controlled.

Given that the average R&D intensity of all countries reveals an increasing trend, Figure 3b depicts that the corresponding numbers for OECD and non-OECD countries are also increasing. As shown in the solid and long-dash lines, OECD countries devote a larger R&D intensity than when their non-OECD counterparts, but the gap tended to be reduced since 2009

Figure 3. Trends of Business Services Intensity and R&D Intensity

Figure 3a All Countries

Figure 3b OECD vs. Non-OECD



Source: calculated by the authors

and onward. Similarly, the average intensity of business services is larger for OECD countries than that of non-OECD countries and remains a similar gap across time. This suggests the existence of heterogeneity in R&D and business services across countries of various income levels.

Table 2 Business Service and Research Intensity

Dep. var.		(1) FE	(2) Researchers per million FE	(3) GMM	(4) GMM	(5) R&D/GDP FE	(6) R&D/GDP X(-1)	(7) R&D/GDP GMM
$\ln\widehat{\alpha}$	business service intensity	1.176*** (0.104)	0.895*** (0.111)	0.154*** (0.004)	0.112*** (0.017)	0.548*** (0.110)	0.523*** (0.106)	0.060** (0.025)
lnHTEXP	high-tech product exports		0.053*** (0.017)		0.005* (0.003)	0.032** (0.015)	0.032** (0.015)	0.016*** (0.005)
lnFINDEV	financial development		0.079*** (0.030)		0.048*** (0.005)	0.108*** (0.026)	0.109*** (0.026)	0.096** (0.003)
lnGOV	government integrity		0.168*** (0.054)		0.013* (0.007)	0.207*** (0.044)	0.207*** (0.044)	0.086*** (0.006)
	one-year lagged dep. var.			0.865*** (0.002)	0.845*** (0.006)			0.759 (0.018)***
Year dummy		Yes	Yes			Yes	Yes	
R-square		0.552	0.599			0.544	0.544	
Arellano-Bond test (p-value)				0.570	0.582			0.789
Hansen (p-value)				0.999	0.999			0.999
No. of obs.		704	606	631	548	606	572	534

Note: The numbers in parentheses are clustered standard errors. *** p<0.01, ** p<0.05, * p<0.1. In column (6), explanatory variables are in one-year lag form.

2. Tests on the Research Intensity Equation

Table 2 illustrates the estimated results of the research intensity equation obtained by using the fixed effect of the panel data model. The estimates in column (1) are the baseline models that estimate equation (14) with year dummies, column (2) reports the results by including all explanatory variables.

As shown in the baseline model (column 1), the estimated coefficient for $\widehat{\alpha}_i$ is statistically significant with the expected sign, thus supporting prediction 1 of our theoretical model that business services specialization is positively related to a country's research intensity. The estimated elasticity is 1.176, implying that a 1% increase in the measure of business services specialization leads to a 1.176% increase in research intensity in terms of researchers per million people. When we control for other variables, as displayed in column (2), the variable α_i continues to have a significantly positive coefficient, but their estimated magnitudes decrease slightly. Crucially, the intensive international linkages through the high-tech industries (*HTEXPR*) do influence the research intensity significantly as previously expected, highlighting the importance of trade on facilitating innovation, as found in Sameti et al. (2010). Moreover, financial development (*FINDEV*) and government integrity (*GOV*) provide a supporting role by facilitating more research activities. This finding echoes the argument in Chor (2010) that institutional factors are one of the main sources of a country's comparative advantages.

As a country's income level and the role of business sector could affect its research intensity, implying an endogenous causality. Furthermore, R&D activity is generally persistent (Cefis and Orsenigo, 2001). To address these potential econometric issues, we use the technique of generalized method of moment (GMM) for the linear dynamic panel data that was developed in Arellano and Bond (1991) to conduct the robustness check. Their approach adopts the one-year lagged explanatory variables as instruments, and requires that there be no autocorrelation in the idiosyncratic errors. Thus, Arellano-Bond test and Sargan tests are reported to judge the

TABLE 3 BUSINESS SERVICES, NATIONAL SIZE, AND PER CAPITA LABOR INCOME

Dep. var: per capita labor income		(1)	(2)	(3) X(-1)	(4) GMM
ln$L$	labor force	0.468***	0.497***	0.335**	0.413**
		(0.137)	(0.136)	(0.143)	(0.050)
ln$\widehat{\alpha}$	business service intensity	0.954***	0.949***	0.878***	0.254***
		(0.127)	(0.129)	(0.139)	(0.048)
ln$r$	researchers per million	0.102**		0.097*	0.100***
		(0.047)		(0.057)	(0.004)
ln$r$	R&D expenditure/GDP		0.120**		
			(0.058)		
lnTL	technology per capita	0.151***	0.145***	0.138***	-0.049***
		(0.023)	(0.025)	(0.024)	(0.007)
					0.781***
					(0.006)
Year dummy		Yes	Yes	Yes	
R-square		0.753	0.753	0.771	
Arellano-Bond test (p-value)					0.001
Hansen Sargan (p-value)					0.999
No. of Obs.		697	697	661	622

Note: The numbers in parentheses are clustered standard errors. *** p<0.01, ** p<0.05, and * p<0.1. In column (3), explanatory variables are in one-year lag form.

adequateness of this approach.[13] Estimates in columns (3) and (4) show that business services intensity remains to positively relate to research intensity.

To further consolidate our theoretical predictions through empirical tests, we implement robustness checks in columns (5) – (7). In column (5), we use the ratio of R&D expenditure to GDP (RD/GDP) as the measure of research intensity, becuase it is widely adopted in the innovation literature. In column (6), all explanatory variables enter the equation in the one-year lag form, in order to mitigate the causality problem between research intensity and explanatory variables. Results obtained by using the GMM are reported in column (7).

We find that results are quite similar. When the research intensity is measured by R&D intensity, the estimated elasticity of business services specialization becomes smaller. We cannot compare the elasticities with those in columns (1) – (4), because the explained variable is different. Crucially, various estimations consolidate the prediction 1 that there is a positive relation between the business services sector and research intensity.

3. Test on the Wage Equation

Table 3 presents the estimation results for testing the proposition implied in equation (15) that the relative wage increases with business services and research intensity. Columns (1) and (2) are the estimated results of the wage equation, whereas columns (3) and (4) report robustness checks by adopting the same strategies in Table 2.

The estimates are quite similar, in terms of coefficient sign and significance, in various

[13] We use the module "*xtabond*" of Stata 15 to implement the GMM estimation. Data and code are available from the authors upon request.

specifications, ensuring the robustness of empirical estimations. As illustrated in Table 3, we also find a positive and significant elasticity of country size (ln$L$) with respect to wage, ranging between 0.335 and 0.497 in columns (1) – (4). The coefficients of business services prosperous ($\ln\widehat{\alpha}_i$) are also significantly positive with a larger elasticity, ranging between 0.254 and 0.954. This highlights the importance of the wage enhancing effect brought about by the development of business service sectors. The empirical tests support the second predictions implied in equation (11).

We overall find positive and statistically significant elasticity for research intensity (ln$r$) and per capita technology (lnTL), as displayed in various estimations, while the coefficient lnTL is significantly negative in column (4). This finding is economically intuitive, because innovative activity and technological capability are also drivers of sustaining economic growth, thereby promoting a country's per worker income.

V. *Conclusion*

The services sector now plays an important emerging role in all economies, especially in developed countries. However, the existing literature neglects the critical role of the services sector in facilitating research and thus subsequently contributing to a country's relative income. By extending Eaton and Kortum's (2001) model, we incorporate business services into production to show that the country-specific business services sector is an influential factor stimulating research activities. It also provides a generalized framework to analyze the relationship between services and R&D activity that is modeled in recent theories, e.g., Alvarez and Lucas (2007) and Pienknagura (2010). Our theoretical model predicts that a country that has a higher degree of business service specialization tends to carry out research activities more intensively, leading to higher research intensity and thus higher income there.

Motivated by the theoretical predictions, we adopt an unbalanced panel dataset, containing 25 OECD and 13 non-OECD countries over the period 1996-2015, to conduct the empirical tests. Results obtained from fixed effect of panel data model find that the love of variety in business services matters, as predicted in the theoretical model, in a country's research intensity. Moreover, empirical evidence also demonstrates a positive relationship between business services (research intensity) and the labor wage, supporting the second prediction of our model. Various robustness checks to deal with the endogeneity and simultaneous problems obtain similar results, consolidating our theoretical predictions.

Some policy implications are inspired. First, after industrialization, a government should create an environment favorable to the expansion of business services. It not only provides supportive service to the manufacturing sector, but also facilitates more R&D activities. Second, given that research intensity positively relate to per capita income per worker, implying that R&D can raise the welfare of the country. Therefore, policy measures that facilitate R&D, such as R&D tax credit, should be effectively implemented. Creating a technological environment favoring innovation through protecting intellectual property rights and generating an effective national innovation system is also required.

Appendix

A.

Eaton Kortum (2001) presume that an invented idea in a country is associated with a quality q, and which is drawn from a Pareto distribution:

$$H_i(q,N_{iS})=1-\underline{\varepsilon}q^{-\theta}, \tag{A1}$$

where $\underline{\varepsilon}$ is a sufficiently small parameter in order to ensure $q\geq\underline{\varepsilon}^{1/\theta}$. As a result, firms' productivity z presents a Fréchet distribution with parameters T and θ as $Pr(Z\leq z)=e^{-Tz^{-\theta}}$.[14]

A firm in country i employs an idea, together with the composite business services, to produce a specific final-good. The chance that the idea is the best idea, which leads to the lowest production cost of a particular intermediate-good, with (4), and that the idea will command a markup of at least $m>1$ in country n is:

$$b_{in}(m)=\int_{\underline{\varepsilon}^{1/\theta}}^{\infty}1-G_n(mc_id_{in}/z)dH_i(z)=\frac{1}{\Phi_n(c_id_{in}m)^{\theta}}(1-e^{-\Phi_n(c_id_{in})^{\theta}/\underline{\varepsilon}}) \tag{A2}$$

$$\cong\frac{\underline{\varepsilon}}{\Phi_n(c_id_{in}m)^{\theta}}.^{15}$$

Note that, in (4), we have $\pi_{in}=\frac{T_i(c_{in}d_{in})^{-\theta}}{\Phi_n}$. We can then rewrite the equation (A2) as $b_{in}(m)\cong\underline{\varepsilon}\frac{\pi_{in}}{T_im^{\theta}}$.

The probability of a markup of at least m given that the idea is a successful idea in a market is:

$$\frac{b_{in}(m)}{b_{in}(1)}=m^{-\theta},$$

[14] Suppose that the number of ideas for a specific good that have arrived by time t is a distributed Poisson and the rate is positively related to the technology stock as with $\mu T(t)$, where $\mu>0$ is a parameter to represent the rate of new ideas that have arrived and is applied to all countries. As mentioned above, we have $T(t)=\int_0^t\phi rL(s)ds$. At any point of time, we have Pr $(I=k)=\frac{e^{-\mu T}(\mu T)^k}{k!}$, where I denotes the number of ideas and $k=0$, 1, 2.... While only the best idea is successful at time t in a market, the Poisson distribution is $Pr(Z\leq z)=\sum_{k=0}^{\infty}\left(\frac{e^{-\mu T}(\mu T)^k}{k!}\right)H(z,N_{iS}^z)^k=e^{-\mu T}\sum_{k=0}^{\infty}\left(\frac{(\mu TH(z))^k}{k!}\right)$. Given that $\sum_{k=0}^{\infty}\frac{x^k}{k!}=e^x$, we can rewrite the above equation as $Pr(Z\leq z)=e^{-\mu T(1-H(z))}=e^{-\mu\underline{\varepsilon}Tz^{-\theta}}$. Here, we normalize $\mu\underline{\varepsilon}=1$, such that z presents a Fréchet distribution with parameters T and θ as $Pr(Z\leq z)=e^{-Tz^{-\theta}}$.

[15] Given the price distribution in country n as $G_n(p)=1-e^{-\Phi_np^{\theta}}$, where $\Phi_n\equiv\sum_{i=1}^{N}T_i(c_id_{in})^{-\theta}$, we obtain $1-G_n(mc_id_{in}/z)=e^{-\Phi_n(mc_id_{in}/z)^{\theta}}$. Given equation (A1), we have $dH_i(z)=\underline{\varepsilon}\theta z^{-\theta-1}dz$. Putting them together, we get $b_{in}(m)=\int_{\underline{\varepsilon}}^{\infty}e^{-\Phi_n(mc_id_{in}/z)^{\theta}}\underline{\varepsilon}\theta z^{-\theta-1}dz$. Letting $x=mc_id_{in}/z$, we get $dz=-mc_id_{in}x^{-2}dx$. We finally obtain $b_{in}(m)=\frac{\underline{\varepsilon}}{\Phi_n(c_id_{in}m)^{\theta}}(1-e^{-\Phi_n(c_id_{in})^{\theta}/\underline{\varepsilon}})$. Given $T(t)=\int_0^t\phi rL(s)ds$, where T_i is positively related to a country's population L_i. Furthermore, when the number of countries N is substantially large, we should observe a large $\Phi_n(c_id_{in}m)^{\theta}\equiv(c_id_{in}m)^{\theta}\sum_{i=1}^{N}T_i(c_id_{in})^{-\theta}$, leading to an approximation $e^{-\Phi_n(c_id_{in})^{\theta}}\rightarrow 0$. As a result, we obtain $b_{in}(m)\approx\frac{\underline{\varepsilon}}{\Phi_n(c_id_{in}m)^{\theta}}$.

Appendix Table 1 Sample Countries

OECD (accession before 1996)	Non-OECD
Australia	Brazil
Austria	Chile
Belgium	Colombia
Canada	Estonia
Czech Republic	Hungary
Denmark	Israel
Finland	
France	Korea, South
Germany	Latvia
Greece	Poland
Iceland	Russia
Ireland	Slovak
Italy	Slovenia
Japan	Switzerland
Luxembourg	
Mexico	
Netherlands	
New Zealand	
Norway	
Portugal	
Spain	
Sweden	
Turkey	
United Kingdom	
United States	

Appendix Table 2 Business Service, Research Intensity, and Per Capita Labor Income – SUR Estimation

Dep. var:	(1) R&D/GDP		(2) Per Capita Labor Income
Covariates		Covariates	
$\ln\hat{\alpha}$	0.752*** (0.100)	$\ln L$	-0.019 (0.014)
lnHTEXP	0.101*** (0.010)	$\ln\hat{\alpha}$	1.082*** (0.102)
lnFINDEV	0.284** (0.046)	$\ln r$ (researchers per million)	0.311*** (0.045)
lnGOV	0.368*** (0.084)	$\ln TL$	0.049** (0.023)
Year dummies	Yes	Year dummies	Yes
R-square	0.566		0.677
No. of Obs.	565		565

Note: The numbers in parentheses are robust standard errors. *** p$<$0.01, ** p$<$0.05.

which implies that the markup that is conditional on the idea being the best idea follows a Pareto distribution with a parameter θ as $M(\theta)=1-m^{-\theta}$.

B.

In (8), the expected present discounted value of an idea that succeeds at time t could be rearranged as:

$$v_i(t)=\sum_{n=1}^{N}\phi_i\mu b_{in}(1,t)\int_t^{\infty}e^{-\rho(s-t)}\frac{P_i(t)}{P_i(s)}\,\frac{b_{in}(1,s)}{b_{in}(1,t)}\,\frac{1}{1+\theta}Y_i(s)ds \tag{B1}$$
$$=\left(\frac{1}{1+\theta}\right)\phi_i\frac{Y_i(t)}{T_i(t)}\int_t^{\infty}e^{-(\rho-g_L/\theta)(s-t)}ds,$$

where ρ is a discount rate, and $\frac{P_i(s)}{P_i(t)}$ is inflation, $\forall i$. Fully differentiating (3) with respect to t, we obtain $\frac{\dot{P}}{P}=\frac{-1}{\theta}\sum_{k=1}^{N}\pi_k\frac{\dot{T}}{T}=\frac{-1}{\theta}g_L$, implying that $P(t)=e^{-\frac{g_L}{\theta}t}$. The term $\frac{b_i(1,s)}{b_i(1,t)}$ denotes the probability that the idea will still be the best idea by time s given that it was the best one at time t. From the result of equation (A2), we obtain $\frac{b_i(1,s)}{b_i(1,t)}=\frac{T_i(t)}{T_i(s)}=e^{-g_L(s-t)}$, $\forall i$. Assuming further that both the research intensity and measure of the business services are static, $\frac{Y_i(s)}{Y_i(t)}=\frac{L_i(s)}{L_i(t)}$, $\forall i$. When trade is balanced for all countries, we get $\frac{Y_i(s)}{Y_i(t)}=e^{g_L(s-t)}$, $\forall i$. In (A1), $\int_t^{\infty}e^{-\rho(s-t)}\frac{P_i(t)}{P_i(s)}\frac{b_{in}(1,s)}{b_{in}(1,t)}\frac{1}{1+\theta}Y_n(s)ds$ represents the expected discount present values of an idea at time t from country i in market n. Whether the idea is a successful idea for a specific good in the market n is justified by the multiply term $\mu\phi_i b_{in}(1,t)$, which represents the instantaneous probability of having at least one successful idea at time t from country i in market n.

Putting them together, we can rewrite the present value of a successful idea in (B1) as:

$$v_i(t)=\left(\frac{1}{1+\theta}\right)\phi_i\frac{Y_i(t)}{T_i(t)}\int_t^{\infty}e^{-(\rho-g_L/\theta)(s-t)}ds \qquad \text{(B2)}$$
$$=\left(\frac{1}{1+\theta}\right)\phi_i\frac{Y_i(t)}{T_i(t)}\frac{1}{\rho-g_L/\theta}.$$

Recall that $T_i(t)\equiv\phi_i\int_0^t r_iL_i(s)ds$. In (4), the probability of the fraction of goods that country n buys from country i is time-invariant in equilibrium, implying that $L_n(t)$ and $T_n(t)$ grow at the same rate in the steady state, $\forall n$. Thus, we obtain $\dot{T}(t)/T(t)=g_L$. Differentiating $T(t)\equiv\int_0^t\phi rL(s)ds$ with respect to t leads to $g_L/\phi r=L(t)/T(t)$, implying $\phi_i=\frac{g_L}{r_i}\left(\frac{T_i}{L_i}\right)$. Thus, we have $\frac{Y_i(t)}{T_i(t)}=\frac{Y_i(t)}{L_i(t)}\frac{g_L}{\phi r}$.

In equation (7), we get $\frac{Y_{it}}{L_{it}}=w_{it}\left(\frac{1-r_i-\frac{\theta}{1+\theta}\alpha_i}{1-\alpha_i}\right)\left(\frac{1+\theta}{\theta}\right)$. Combining the above equations together, we get $\frac{Y_i(t)}{T_i(t)}=\frac{g_L}{\phi r}w_{it}\left(\frac{1-r_i-\frac{\theta}{1+\theta}\alpha_i}{1-\alpha_i}\right)\left(\frac{1+\theta}{\theta}\right)$. Then, we rewrite (B2) as:

$$v_i(t)=w_{it}\left(\frac{1}{\theta\rho-g_L}\right)\frac{g_L}{r}\left(\frac{1-r_i-\frac{\theta}{1+\theta}\alpha_i}{1-\alpha_i}\right). \qquad \text{(B3)}$$

Arbitrage by workers leads to $v(t)=w(t)$ in equilibrium when workers are freely movable across sectors. After some algebra, we rearrange (B3) to obtain the country-specific research intensity as:

$$r_i=\left(\frac{g_L}{\theta\rho}\right)\left(\frac{1-\frac{\theta}{1+\theta}\alpha_i}{1-\alpha_i(1-g_L/\theta\rho)}\right). \qquad \text{(B4)}$$

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