DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 03-17

Productivity Spillovers and Economic Growth

Productivity Spillovers and Economic Growth

-Was East Asia Unique?-

Kazuhiko Yokota[†]

November 2003

Abstract

Recent empirical studies on international R&D spillovers have shown that technology diffusion across countries raises productivity and, hence, boosts economic growth. However, these studies do not explain how technological knowledge accumulated in the tradable sector can be transferred to the rest of the economy. This paper answers this question by focusing on the aspect of externalities between the tradable and non-tradable sectors. The second purpose of this paper is to test for the statistical similarity of East Asian countries. In so doing, we modify the multi-sector framework and estimate the reduced forms using pooled data comprised of 51 countries over 24 years. Empirical results clearly show that some Asian countries can be regarded as one group in terms of the magnitude of the productivity spillover effect. We find statistical differences in the estimated parameters between East Asian countries, developed countries, and developing countries, with the East Asian countries showing the highest spillover effects.

Keywords: Multi-sector model; Spillover; Growth; East Asia; Externality

JEL Classification: F43, O41, O53, O57

---

[*]This is a revised version of chapter 3 of my Ph.D. dissertation titled "Essays on Multinational Enterprize, International Trade, and Technology Spillover". I would like to thank the members of my thesis committee, James Markusen (advisor), Keith Maskus (second advisor), Yongmin Chen and Ruqu Wang for their helpful comments, especially thank Keith Maskus for his careful reading, suggestions and encouragements. I also thank David Kritzberg for helpful suggestions and discussions. All remaining errors are, of course, my own responsibility.

1 Introduction

International transactions across borders affect economic growth mainly through three channels of technology transfer: productivity increase by capital or intermediate goods imports, learning by exporting, and foreign direct investment activities. These three channels are important especially for technology diffusion. This technology diffusion increases productivity and boosts economic growth.

Coe and Helpman (1995) initiated the argument on international R&D spillovers. They confirmed that there exist international R&D spillovers between developed countries. Although their estimation framework was based on the theories by Grossman and Helpman (1991), their estimated equation assumed that total imports play a crucial role of transmitting R&D spillovers. Coe, Helpman and Hoffmeister (1997), Xu and Wang (1999) and Eaton and Kotum (2001), instead, considered capital imports as carriers of knowledge capital. Coe, Helpman and Hoffmeister (1997) estimated North-South knowledge spillovers controlling for the effects of capital imports. Xu and Wang (1999) discussed the effects of capital imports on North-North international knowledge spillovers more directly.

On the other hand, Keller (2000, 2002a, 2002b) focused on the role of intermediate goods imports as carriers of knowledge capital. Keller's estimations were based on the theory of "love of variety" of intermediate goods and he used industry level data. He captures more precisely the mechanism of knowledge spillovers than previous "nation-wide" estimations.

However, these papers focused on the spillover mechanism between countries but not between industries. Only Keller (2002) implicitly controlled for the effects of knowledge spillovers between industries. In every economy, there are tradable and non-tradable sectors. Especially for developing countries, the share of non-tradable sectors is relatively high. In the process of economic growth, positive effects from

cludes the paper.

2 Multi-sector Frameworks

Feder's (1982) pioneering work first introduced the paradigm of a two sector framework with productivity spillovers between tradable and non-tradable sectors. Feder's framework makes it possible to estimate parameters of sectoral productivity differentials as well as productivity spillovers.[1]

productivity of both capital and labor in the tradable sector exceeds those in the non-tradable sector by δ^a. Superscript "*a*" stands for the capital goods import framework. Further we assume that in the tradable sector the productivity of imported capital obtained,

$$\dot{Y} = F_K I + F_L \dot{L} + \left(\frac{\delta_a}{1+\delta^a} + F_x \right) \dot{X} + (1+\eta^a) F_K M_k. \tag{4}$$

The following is the last assumption about the production function,

$$N = F(K_n, L_n, X) = X^{\theta^a} \varphi(K_n, L_n), \qquad \theta^a \in [0,1].$$

φ represents a linear homogenous function. θ^a represents the degree of externality effect of productivity spillover from tradable to non-tradable sectors which is a main concern in this paper. The marginal productivity of tradable sector's outputs X in the non-tradable sector is then,

$$F_X = \theta^a \left(\frac{N}{X} \right) = \theta^a \frac{(N/Y)}{(X/Y)} = \theta^a \frac{1-(X/Y)}{(X/Y)} = \frac{\theta^a}{X/Y} - \theta^a.$$

Following Feder (1983), in the second term in the right hand side of equation (4) we assume a linear relationship between the marginal productivity of labor and the average productivity of labor, that is $F_L = \lambda^a (Y/L)$. Putting these together with equation (4) and transforming it into the growth rate term, the following equation of GDP growth rate is obtain,

$$\frac{\dot{Y}}{Y} = F_K \left(\frac{I}{Y} + \frac{M_k}{Y} \right) + \lambda^a \frac{\dot{L}}{L} + \frac{\delta^a}{1+\delta^a} \frac{X}{Y} \frac{\dot{X}}{X} + \theta^a \frac{N}{Y} \frac{\dot{X}}{X} + \eta^a F_K \frac{M_k}{Y}. \tag{5}$$

Equation (5) will be used for estimating the parameters in the later sections.[4] The interpretation of the equation (5) is as follows: the rate of GDP growth is composed of the contribution of factor accumulation (capital and labor), and the efficiency gains from shifting factors from the non-tradable sector to the tradable sector. The efficiency gains have two different sources: one comes from the resource reallocation between low (non-tradable) productivity and the high productivity (tradable) sectors, and the other

[4] Alternative specification for equation (5) is; $\frac{\dot{Y}}{Y} = F_K \frac{I}{Y} + \lambda^a \frac{\dot{L}}{L} + \frac{\delta^a}{1+\delta^a} \frac{X}{Y} \frac{\dot{X}}{X} + \theta^a \frac{N}{Y} \frac{\dot{X}}{X} + (1+\eta^a) F_K \frac{M_k}{Y}$. Estimation results of this specification do not affect the other coefficients estimated much, but worsen the overall results. So we don't report the results of this alternative specification.

comes from the productivity spillover effect of tradable sector to non-tradable sector. The former effect is captured by δ^a and η^a and the latter is by θ^a. Unlike the existing literature, our main purpose is to observe θ, not δ.

However, equation (5) has a problem for estimation. As Alexander et al. (1996) point out, equation (5) is non-linear in δ. Hence, even if the estimated coefficient, $\delta/(1+\delta)-\theta$, is an unbiased estimate, the derived δ is biased although consistent since the expected value of a non-linear function is not the non-linear function of the expected value. The problem of non-linearity is discussed and solved in the next section.

2.2 Intermediate Goods Import

The other carrier of technology across borders through international trade is intermediate goods imports. Since it is difficult to combine capital import framework together with intermediate framework, we instead argue each framework separately. In this subsection we analyze technology spillover effects between sectors formulating intermediate goods import framework.

In the intermediate goods framework, the exportable sector can import intermediate goods instead of capital goods.

$$N(t) = F(K_n(t), L_n(t), V_n(t), X(t)) \tag{6}$$

$$X(t) = G(K_x(t), L_x(t), V_x(t), V_m(t)), \tag{7}$$

where V_n, V_x are intermediate goods produced domestically and used for non-tradable and tradable sectors respectively. V_m is imported intermediate goods used for tradable sector. It should be noted that $N(t)$ and $X(t)$ represent *outputs*, not *value added*, of non-tradable and tradable sectors, respectively. Other variables are the same as in the capital import case. The superscript "b" indicates the parameters of intermediate goods import framework. The productivity differential assumptions are the same as

Taking derivative with respect to time, t

difference between domestic and imported intermediate goods, i.e., $\eta^b > 0$, the size of coefficient depends on the relative size of p_v and p_m. However, if domestic marginal productivity is less than foreign marginal productivity, that is, $\eta^b > 0$, and if both markets are perfectly competitive and there are no trade barriers, the price of imported intermediate p_m must be less than the price of domestic intermediate p_v. In this case, the size of coefficient of the last term becomes large. However, whether the coefficient is also small or large crucially depends on policy induced distortion that affect both domestic and import prices of intermediate goods. Even if the productivity differential (η^b) is large, for example, industrial policy that subsidizes domestic intermediate sectors reduces the price of domestic intermediate goods, p_v. In this case, the estimated coefficient may be small. Hence if estimated coefficient is large, we interpret this term as the effect of intermediate goods import on the growth rate. On the other hand, if coefficient is small, we have two different interpretations; One is that the effect of intermediate imports on the economic growth is small. The other one is that a strong industrial policy may distort the price system.

3 Data

The data used for estimation were collected for 51 countries over 24 years (1968 to 1992). 51 countries include 19 OECD member countries and 32 developing countries. The classifications of high and low income countries by region follow the World Bank, *World Tables*. Country classification is shown in Appendix Table 1.

The data on GDP, investment, population, price indices of capital good were obtained fro369(g)1.e(fro38e)-1(d)-387forts oears22.914ars5.611.foarsb326(the)arsSummershelon effecc

XT International Trade Data Search System provided by the Institute of Developing Economies, Tokyo. Capital imports goods consist of SITC 7 (machinery and transportation equipment), and intermediate imports consist of SITC 5 (chemical products and SITC 6 (products classified by materials).

To transform international trade data from nominal term into real term, we used export and import price indices which were obtained from the International Monetary Fund (IMF), *International Financial Statistics*, various issues.

Since international trade data fluctuate greatly every year especially in developing countries, we took three-year moving average on all variables for getting meaningful results.

4 Parametarization and Estimation

By adding constant term, c, and well-behaved error term, , on the equation (5), we get following equation:

$$y = c + \alpha_1 (s_I + s_{Mk}) + \alpha_2 l + \alpha_3 s_X x + \alpha_4 s_N x + \alpha_5 s_{Mk} + \qquad (13)$$

where $y = \dot{Y}/Y$, $s_I = I/Y$, $s_{Mk} = M_k/Y$, $l = \dot{L}/L$, $s_X = X/Y$, $s_N = N/Y$, $x = \dot{X}/X$, and the parameters to be estimated are $\alpha_1 = F_K$, α_2 [illegible]

The effect of capital import η^a can be estimated from dividing α_5 by α_1. η^a is also tested from the above Wald statistics. Productivity spillover effects (θ^a) is directly obtained from the estimate of α_4.

In the same manner we obtain the following estimated equation from equation (12),

$$y = c + \beta_1 s_I^n + \beta_2 l + \beta_3 s_X^n x + \beta_4 s_N^n x + \beta_5 s_{Vm} v_m + \quad , \tag{14}$$

where $s_I^n = pI/p_yY$, $s_X^n = pX/p_yY$, $s_N^n = pN/p_yY$, $s_{Vm} = V_m/Y$, $v_m = \dot{V}_m/V_m$, $\beta_1 = F_K$, $\beta_2 = \lambda^b p/p_y$, $\beta_3 = \delta^b/(1 + \delta^b)$, $\beta_4 = \theta^b$, and $\beta_5 = \eta_p^b$. The term P/Y in equation (12) is now included in the constant term in equation (14).[7]

The productivity differences between tradable and non-tradable sectors δ^b and η^b are estimated and tested in the same way in equation (13). Productivity spillover parameter θ^b is directly estimated from β_4.

5 Results

Table 1 reports the results of the regressions using Equations (13) and (14). All regressions use groupwise heteroscedastic model with fixed effect (Greene, 2000, p598).

Foe all 51 country sample, developing 31 country sample, and Latin American 15 country sample, all estimated coefficients except for α_5 are positive and highly statistically significant. This is consistent with the hypotheses that each factor of input affects the economic growth positively. On the other hand, OECD 19 and Asian 7 group do not have positive α_1 either α_5.

Productivity differentials (δ) between trade and non-trade sectors have positive effects on the economic growth in capital import framework for all samples with highly statistically significant level. On the other hand in intermediate import model, only the OECD sample has statistically significant positive effect of productivity differentials.

[7] As we will see in the estimation results section, P/Y term is interpreted as a difference in fixed effects.

If we focus on the size of productivity spillover θ^a, which is equal to α_4, we find that all sample have positive and statistically significant e□ects and that OECD19 sample has very high θ^a but developing samples do not.

Results of intermediate import model in Table 1 show that for all 51, developing 32 and OECD19 samples have all positive estimated coe□cients which are consistent with the hypotheses. Furthermore, almost all estimates are statistically highly significant. Calculated δ^b says that OECD19 sample has higher δ than Developing 32 sample but the latter is not significant. θ^b is higher in the OECD sample than in developing sample but again estimated θ^b

6 Test of Poolability - Was East Asia different from others?

In the previous section, we estimated both capital and intermediate goods imports equations using pooled data and found that the intermediate goods imports model fit the data very well while the capital import model does not. In this section we describe the methodology to analyze the structural similarities of East Asia countries and discuss the results. We have two questions. First, when we say "East Asia countries," can those countries actually be regarded as one group? Second, if some Asian countries may form a group, which countries belong and does that group have a distinct economic structure?. The poolability test is applied for these purposes. This test is essentially a Chow test, extended to the case of N linear regressions. To test the poolability of the data, we estimate unrestricted and restricted regression equations and test the corresponding F value. For our purposes, we use these F test procedures for every combination among East Asia 7 countries, ie, 120 regressions for each model. Appendix C explain the detailed procedures.

The results of the stepwise poolability test, classified by the parameter θ, show the following (See Appendix Table 2 for details): In capital import framework, the test concludes that Hong Kong, South Korea, Taiwan, Singapore and Thailand have statistically (25% of F test) same estimated parameter θ while in the intermediate import framework, Hong Kong, South Korea, Taiwan and Thailand form one group in terms of the statistical similarity of parameter θ.

Table 3 shows the results of regressions conducted on East Asian groups. While the results of the capital import model have estimated coefficients which have opposite expected signs (α_1, α_2, and α_5), the intermediate import model has all expected signs of parameters and 4 parameters out of 5 are highly significant. Calculated δ^b for East Asia is 0.574, which is much higher than the developing country sample estimate of 0.094

of intermediate goods increase economic growth in all samples.

(3) The parameter estimate for the productivity spillover effect (θ) between the tradable and non-tradable sectors is positive and highly significant for all samples in the capital import model. The all-countries sample and the developed sample have positive and highly significant effects on economic growth in the intermediate imports framework.

(4) The productivity spillover effect in developed countries is much greater than that in developing countries in both the capital and intermediate imports frameworks.

(5) The effect of intermediate goods imports (η) in developing countries is greater than that in developed countries. This implies that there may be a large quality gap between imported and domestic intermediate goods in developing countries.

(6) According to the poolability test for East Asia 7 countries, only Hong Kong, Korea, Taiwan, and Thailand can be regarded as one group with respect to the productivity spillover effect θ in the intermediate goods framework, i.e., they have statistically identical estimates of the structural parameter θ.

(7) In the intermediate goods framework, the group of East Asia 4 has greater productivity differentials and spillover effects, and a lower intermediate goods effect compared to the developing and developed groups. A high productivity differential (δ) implies the existence of the allocative distortions in the market.

(8) East Asia 4 has statistically different parameter estimates of θ than the parameter estimates of θ for the group of all other countries, and the group of developing countries. This suggests that East Asia 4 experienced larger productivity spillovers in the 1970s and 1980s.

Although, as we have seen, productivity differentials of tradable and non-tradable sectors (δ) and between imported and domestic capital or intermediate goods (η) are sources of economic growth, these differentials come from the misallocations of the factors. In other words, as a source of economic growth, productivity differentials are unsustainable engines of growth. Thus, in the long run, the effects of productivity differentials may diminish as an economy grows. On the other hand, the benefits of productivity spillover effects can continue after the misallocations are resolved. In this sense, policies that enhance this spillover are crucially important for economic growth in any country. Spillover effects occur though both forward and backward linkages of industries. However, theoretical and empirical investigations of this linkage mechanism would serve as a valuable extension to the present study.

Appendix

where $Z' = (Z_1', Z_2', ..., Z_N')$ and $u_i' = (u_1', u_2', ..., u_N')$.

Under the null hypothesis $H_0 : \gamma_i = \gamma$ for all i, we can test using the following F ratio;

$$F = \frac{(S_2 - S_1)/(2N - 1)}{S_1/(}$$

References

[1] Alexander, W. Robert J., Paul Hansen, and P. Dorian Owen (1996), "Inference on Productivity Differentials in Multi-sector Models of Economic Growth," *Journal of Development Economics*, 51, 315-325.

[2] Baltagi, Badi H. (1995), Econometric Analysis of Panel Data, John Wiley and

[17] Robinson, Sherman (1971), "Sources of Growth in Less Developed Countries: A Cross-Section Study," *Quarterly Journal of Economics*, 85(2), 391-408.

[18] Maddala, G. S. (1977), Econometrics, McGrowhill.

[19] Syrquin, Moshe (1987), "Growth Accounting with Intermediate Inputs and the Transmission of Technical Change," *Journal of Development Economics*, 26, pp. 17-23.

[20] Young, Alwyn (1991), "Learning by Doing and the Dynamic Effects of International Trade," *Quarterly Journal of Economics*, 106, 369-405.

Parameter (Variable)					
$\hat{\ }_1 (S_I^n)$	0.044	0.071	0.003	0.09	-0.05
	(5.659) ***	(6.864) ***	(0.216)	(7.194) ***	(-2.404) **
$\hat{\ }_2 (l)$	1.026	1.757	0.451	2.06	0.44
	(6.530) ***	(7.388) ***			

$\hat{}_1 (S_I \quad S_{Mk})$	-0.007	$\hat{}_1 (S_I^n)$	0.019
	(-0.249)		(0.681)
$\hat{}_2 (l)$	-0.371	$\hat{}_2 (l)$	1.302
	(-1.708)		