5. What Role for 'Learning'? A North-South Tale of Enrichment Effect*

Gouranga G. DAS[1]

Abstract

Drawing on the asymmetric growth experiences of the advanced, emerging, and the underdeveloped economies, this paper explores the scope of learning effects via North-South trade by offering quantitative measures of coefficient of differences in trade. Constructing technology appropriation parameters and indigenous and foreign-sourced R&D via trade-mediated spillover to the recipients, it shows that North-South trade flows could lead to product sophistication of exports via enhancement of technology frontier. This is enrichment effect. Aided by the right adoption of parameters such as absorptive capacity, innovation capability and technological upgrading, knowledge flow transmits enrichment benefits in a multi-speed world, facilitates productivity improvements, alters level of product sophistication, and enables narrowing the North-South technology gap.

Keywords: technology diffusion, trade, enrichment, learning, specialization

JEL Classification: J24, O31, O47, F43, C68

"Where is the largest long-run impact of the technology surrounding the internet likely to occur? Once you note that time and distance and related costs are compressed, and that remoteness loses some of its significance, the answer seems obvious: the big impact is likely to be in international markets, global supply chains, in access to information and services in places that have been remote from them - in short, the global economy, and especially in the developing countries."- Michael Spence (p. xiii, 2011) in 'The Next Convergence: The Future of Economic Growth in a Multispeed World'.

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* *I acknowledge the valuable comments from conference participants at the Chinese University of Hong Kong. Comments from two anonymous referees and interactions with Professors Ron Davies (University College, Dublin) and Bruce Blonigen (University of Oregon, USA) were truly valuable.*

[1] Department of Economics, Hanyang University, Erica Campus, South Korea. Email: dasgouranga@gmail.com.

I. Introduction and Scope of Research

Under globalization, 'idea' flows enrich the knowledge-base to widen the technological frontier and broaden the product spectrum. Growing to maturity of the infant economies often depends on the forerunners as source of enriched spillovers, especially via world trade. According to Spence (p.xv, 2011), "[T]he huge asymmetries between advanced and developing countries have not disappeared, but they are declining, and the pattern for the first time in 250 years is convergence rather than divergence." In particular, it has been emphasized that the success stories of East Asia and the other newly industrializing nations owe much to the concerted efforts by the government directed towards 'closing the technology gap'. Enrichment via learning and absorption of frontier technology enable a recipient to experience productivity growth, promote richness, and achieve economic prosperity. Thus, less developed or developing countries (LDCs) have often adopted trade and technology policies, and have depended for their growth and development on technologies originating in the developed countries (DCs). Thus, enrichment occurs through trade and technology transmission and depends on a whole host of factors, such as skill, human capital, indigenous inventive capability, and structural congruence of trade partners (Das, 2010). In this paper, by North we refer to the G7 or developed countries, while South refers to the developing economies including the emerging engines of growth. Thus, the North-South distinction refers to the world where economies are classified according to growth-development status.

Offering a theoretical framework for idea flows and its '*social and reciprocal*' character, Lucas (2009a, p.1) says: "a study of economic growth in the world as a whole must be a study of the *diffusion* of the industrial revolution across economies, a study of the *cross-country flows of production-related knowledge* from the successful economies to the unsuccessful ones." Jones and Romer (2009) offer vistas of research exploring the interactions between increased market integration (via trade) and variables such as: ideas, human capital, population and institutions. Expanded gains from trade via trade-led technology transmission could be realized in terms of enrichment via sophisticated exports and imports embodying current vintage technology. Ng (2002) analyzed the effects of enrichment of growing trade partners on Malaysia on the basis of some ad hoc coefficients of differences in export-imports and computed, a priori, average values of such measures. This paper adds value by offering analytical argument behind such technology upgrading of exports, and imparts an operational insight by refining the concept of Ng (2002). In this context, studies by Hausmann, Hwang and Rodrik (2007) and recently, Brambilla *et al*., 2012), have emphasized the importance of specialization pattern and exports on productivity and economic growth. In particular, they show that '*income level of a country's exports*' matter for growth dividends to occur. In particular, by establishing a hierarchical product space structure they infer that, *ceteris paribus*, '*countries become what they produce*' by showing that countries that produce what rich countries export tend to have higher growth than the countries that specialize in 'poor-country goods' (pg. 2). For this to occur, 'cost discovery' by entrepreneurs is central. Herein arise the opportunities of enrichment whereby trade-effects *induce* specialization along the line of their trade partners - rich or poor. As this kind of trade-mediated productivity enhancements could be better handled in a framework incorporating multi-sectoral, multi-regional linkages, the computable general equilibrium (CGE) approach is suitable. We unravel the interlinkages between imports and productivity in the world economy where ideas flow via *intersectoral and inter-regional linkages* embedded in input-output relationships. This paper uses database from Global Trade Analysis Project's (GTAP) CGE model (Hertel ed. 1997) and teases out some factors for enrichment via trade-mediated technology flows. More specifically, we consider technology ferried via traded intermediates and R&D-intensity in production as primary source of *enriched* technological contents. Drawing on the insights of the work, this paper builds upon some quantitative measures to show how 'export matters' for induced productivity, that accrues as 'bonus', and causes enrichment benefits. The paper develops as follows: Section 2 reviews existing framework and Section 3 offers conceptual refinements. Section 4 describes data. Section 5 presents some stylized facts for reconciliation with Hausmann *et al*., 2007), operationalizes such refinements, while Section 6 concludes.

II. A View on Enrichment: General Idea and Scope

Although the discussion of 'enrichment effect' is not new in economics literature, Ng and Ng (2000) argue that, in general, 'proportionate enrichment[2]' of a country/region benefits the others and the world as a whole provided the demand pattern is homothetic and under the assumption of 'strong non-inferiority' of demand structure. Ng (2002) argues along the similar vein and presents empirical evidences for the scope of enrichment effect for Malaysia with its selected trading partners. By measuring the *extent of differences* in the export/import categories for each of Malaysia's trading partner at the aggregative level, it has been argued that *the larger is its differences in export/import structures with any or more of its trading partners, the larger is the accrual of benefits from 'enrichment effect.'* Thus, although not made explicit and not taken into consideration the aspects of direct investment, quality-ladder, product development, and knowledge transfer, this simplistic view of 'enrichment' is couched in terms of benefits to a destination from a source or origin via export-import and the differences in the measures of such trade exhibit the scope or extent of beneficial enrichment. In order to elicit the role of enrichment effect, we construct *a la* Ng (2002), the coefficients of differences in imports and exports for each product categories.

Let $S_{k,i}$ = i-th commodity group's export/import share in total exports/imports, for country $k \in \{N, S\}$, where N and S are generic source of enriched technology (say, North) and destination (other developing/less developed partners), respectively. *Coefficient of differences in exports* for sector 'i' is:

$$CX_{NS,i} = |SX_{N,i} - SX_{S,i}| \qquad (1)$$

Aggregating over all 'i' for each $k \in \{N, S\}$ we get a 'scalar' *regional index* of differences and scope of potential enrichment,

[2] *Ng (2002) defines 'proportionate enrichment effect' as "an increase in the ability to produce all goods proportionately" [p. 311].*

$$CX\_NS = \sum_i CXNS,i = \sum_i | SXN,i - SXS,i | \tag{2}$$

Similarly, *for imports*: $CXNS,i = | SMN,i - SMS,i |$ (1')

And, aggregating over 'i', $CM\_NS = \sum_i CMNS,i = \sum_i | SMN,i - SMS,i |$ (2')

As Ng (2002) mentions, ignoring the mechanism of technological transfer via trade and FDI is a drawback of their analysis. OECD (2010) documents that intermediate inputs' share in goods trade is 56% and 73% of services trade owing to international fragmentation, thanks to technology facilitating development of production networks. Although via intermediate usage the technology spills over, the invention takes place in some relatively advanced sectors like ICT, biotechnology, nanotechnology favoring some sectors. Thus, consideration of either 'biased' or '*disproportional*' enrichment is more realistic than the neutral type. Using Equations (1), (2), (1') and (2'), alike Ng (2002) we compute the coefficients for both exports and imports between one North (here, G7 group) vis-à-vis other destinations and find simple average values. However, we identify *some lacunae*. The result, however, is *not perfectly general,* because as Ng and Ng (2000) argues, it depends on the *patterns* of exports and imports of the country concerned and its trading partners. To be more specific, according to them it *depends on the similarity or dissimilarity* of sets of goods traded. *Firstly*, it does not specify the mechanism of such enrichment and, hence, such discussion is done on an *ad hoc* basis. *Second*, unlike Hausmann *et al*., 2007), it does not consider the product level effect and, hence, fails to consider the effect of product heterogeneity or increased *scope of trade in different product* categories, terms-of-trade effects in a post-enrichment world inundated with more traded goods. *Third*, it ignores the crucial role played by factors such as learning via education or skill and social acceptance contingent on institutional parameters. As Ng (2002, p. 317) recognizes that ignoring the technology capability aspect makes their measure narrower in scope and also admits that 'the mutual benefits from the enrichment effect will be greater', we refine their measure. Trade is a conduit for technology diffusion, whereby technology upgrading causes product sophistication or enrichment effects. Here the formal interpretation of 'enrichment' is refined in terms of *assimilation* of state-of-the-art technologies from cutting-edge research in ICT, bio-technology or nanotechnology. By constructing sectoral coefficients of differences across the technology clusters, we identify the *dividing line of congruence and incongruence for each cluster* between North (G7) and the Southern destinations (S). Aggregating the sector-wise coefficients, we derive *a 'scalar' singular index which measures the extent of possible enrichment spillover between* North and the South. Specifically, we multiply each bi-lateral regional coefficient by innovation capability index constructed in the section below.

III. Does Trade Matter for Enrichment? Refinements and Operational Definition

The role of international trade in economic growth and development can in no way be ignored (Das 2012b, OECD 2010a&b). Arora and Vamvakidis (2005) has shown for a panel of 101 developing and industrial economies, economic integration with the developing South has led to substantial growth spillover from the United States (US) and 10 most important trading partners. Das (2010) has shown that reaping the technological benefits needs prerequisites such as skill-intensity, structural symmetry, and openness apart from domestic environment. Structural similarity is often captured by institutional indicators such as governance (Kaufmann *et al*. 2009). Despite the multitude of sources of 'enrichment', the confluence of science, technology and human capital have been the most influential one. For example, the role of human capital development, better institutions, and other enabling factors such as innovative capabilities, absorptive capacity, sound macroeconomic policies are discussed (Caselli and Coleman, 2006; Coe, Helpman and Hoffmaister (CHH), 2008; Lucas 2009a&b). Empirical evidences on technology diffusion proliferated (*World Bank,* 2008*),* Hoekman and Javorcik (2006), Spence (2011). Schiff and Wang (2006) document direct and indirect North-South R&D spillovers between 15 OECD and 24 developing nations across 16 manufacturing industries. Bitzer and Geishecker (2006) present decomposition analysis of evidences of substantial trade-generated positive knowledge spillovers for the 17 OECD countries, especially via imported intermediates. Broadly speaking, two strands of analysis in the technology-diffusion literature can be distinguished -'aggregate-level analyses' and cross-country 'industry-level' analyses -both confirming the importance of goods embodying foreign technological know-how as the source of technology acquisition via benefits of North-South and South-South triangular exchange (Das 2012a&b).

Because all goods *do not* have similar consequences for economic performance, '[Specialization] in some will bring higher growth than specializing in others (Hausmann *et al*., p. 1, 2007))'. Therefore, having high differences in exports and imports vis-à-vis its trade partner/s is not an obstacle *per se* for a country as such; rather, this switches on advantage for aligning its productivity level *along* the partners' export basket/s. Exploiting the benefits of trade-differences enables it to move up the *hierarchy in goods space* and, consequently, enriches it via growth effects. Following previous discussion, larger magnitudes of *CX_N*S and *CM_NS* imply larger scope of enrichment via trade - both regionally as well as sector-wise - in a sector 'i' via technology embedded in imported intermediates. In this paper, 'enrichment' is specifically defined in the context of technological superiority or latest state-of-the-art. Thus, the ability to produce more goods (either proportionately or on a *non-neutral* basis) originates from invention or innovation. Recent development in the induced-productivity growth theory emphasizes the roles played by domestic *R&D* efforts and exposure to foreign technology (Keller 2003, Eaton and Kortum 2002). In particular, CHH (2008), Kosempel (2007) have confirmed for a connection of complementarities for a cross-section of OECD and non-OECD countries. According to Coe *et al*., 2008), average *R&D*-intensity is almost 11% for high technology cluster group of industries as opposed to the low cluster ones (where it is 1.3%). Also, 96% of world's *R&D* expenditure flows take place in the developed North. Technological progress enriches the productive spectrum, so that *different varieties* of goods are produced. *R&D* gives scope for cross-border learning and subsequent innovations via cumulative *R&*D experience; also, human capital feeds on this to augment skill and, hence, the quality of labor force. This is the learning effect (indirect enrichment) via absorption.

As domestication of foreign technology depends on building technology infrastructure and technological achievement (*TA*), we need to consider a broader aggregative multi-dimensional 'Innovation Capability Index ($0<ICC_r<1$)' based on the World Investment Report (2005). Kosempel (2007) has shown that elasticity of human capital acquisition in response to technology, a measure of *learning propensity*, determines TFP. Thus, productivity of human capital-induced skill depends on availability of learning scope or latest technology to a region ($0<TA_r<7$) related to R&D; and we get scores of such measure from the Global Competitiveness Report (2009-2010). The extent of enrichment is, therefore, dependent on the index of innovation-sharing, which depends on skill-intensity proxying absorptive capacity (*AC*). Conjointly, *TA, ICC* and *AC* determine regional 'Technology Absorption Parameter (TAP_r)', prime mover for enrichment benefits. Thus,

$$TAPr = ACr.\ TAr.\ ICCr \tag{3}$$

$$TAP_{ns} = \min\,[1,\ TAP_s/TAP_n], \qquad \text{where: } r=n,\ s=k,\ u \tag{4}$$

Here, also $TAP_{ns} \in [0, 1]$ with zero implying least absorption capacity.

However, unlike Ng (2000, 2002), based on embodied technology transmission and assimilation of state-of-the-art here we present enrichment indexes *adjusted for domestic binary absorptive capability measure* as proxied by Technology Appropriation Parameter between 'n' and 's' (TAP_{ns}) - composed of technological achievement (*TA*), innovation capability index and own *R&D* ($R\&D_s$). As a preliminary research effort, we here consider domestic R&D expenditure data (as % of GDP) as flow variable measure. For own *R&D* ($R\&D_r^d$), we combine data - domestic R&D expenditure as percentage of *GDP (GERD)* from UNESCO (2008) for the base year (i.e., 2004) - to match the single region and derive a simple average for composite regions. As Global Trade Analysis Project (*GTAP*, Hertel ed., 1997 and Narayan and Walmsley, 2008) database has regional imports and exports of each sector, we take these bi-lateral intermediate import shares to generate foreign *R&D* flows ($R\ \&\ D_r^f$) via:

$$R\&D_s^f = R\&D_n^d.TFP_n.\Psi_{ns} \quad \text{, where } r=n \text{ and } s=k,\ u \tag{5}$$

where: n = source and 's' is destination. Ψ_{ns} = bilateral intermediate import shares in value-added. Adopting the same formula for different bi-lateral pairs to derive intra-regional flows, we get total - own plus foreign-trade induced -R&D for a region 'r':

$$R\ \&\ D_r = R\ \&\ D_r^d + R\ \&\ D_r^f \qquad \forall r = n,\ k,\ u \tag{6}$$

Based on Chinese panel data for 2002-2006, Feng *et al*., 2012) show that imports from OECD and 'product upgrading facilitated by technology or quality' enabled Chinese firms for greater participation in export market on larger scale. Hanson (2012) has also shown the importance of North-South and South-South trade behind the rise in global production chain, and documented evidence of China's 'export specialization' and 'hyper-specialization' in exports. Wang and Wei (2008) have shown that Chinese exports have become increasingly sophisticated thanks to human capital and favorable government policies like tax benefits for high-tech zones.

IV. Database: Sectoral and Regional Dimensions

We consider broadly aggregated regional clusters, namely advanced industrialized North (the source of knowledge), Southern engines of growth and emerging economies (the early adopters), and a relatively laggard South (the slow follower of innovation diffusion). The OECD nations account for largest of total world *R*&D. UNESCO (2009) has shown that the number of researchers in developing countries has increased by 45% as compared to 9% in the DCs. Based on *R&D* intensity, the Americas accounted for 37.6% of world R&D expenditure followed by Europe and Asia. Rapid globalization of science and technological invention has been accompanied by concentration of such activities in OECD regions as well as in non-OECD economies. ‘Southern engines of global growth’, the BRIC countries have immense potential to provide resources for investment and technologies and will become important destinations and sources of competition provided they remove their ‘internal snags’ like rule of law, education, infrastructure, to mention a few. For China, it registered an increase from 1.1% in 2002 to 1.5% in 2007, thus, accounting for 39% of *R&D* expenditure and 53% of researchers in the LDCs; whereas for India, it is about 0.8%. The intensity is much less, about 0.3%, in Sub-Saharan Africa (SSA) as compared to South Africa (1% of GDP for *R&D*).

In this context, studies showcase the role of information and communication technology (ICT) as general-purpose technology, and other kinds of technological break-through like nanotechnology and biotechnology. As our primary motivation is to explore the scope of enrichment via embodied technology spillover, we categorize the whole range of 57 product categories in the GTAP Version 7 database into 7 broad R&D-intensive technology clusters - namely, ICT, transport equipment, materials, consumption goods, fabrication and services. Of all the manufacturing technology clusters, three have high R&D-intensities - viz., ICT, transportation equipment and materials whereas consumption goods and fabrication have low R&D-intensity. We follow OECD (2003, 2005) classification of manufacturing activities according to technological intensity using ISIC Rev.3 breakdown of activity. This methodology considers both ‘technology-producer’ and ‘technology-user’ aspects and harps on three technological intensity indicators, namely R&D expenditures as proportion to value-added, production and R&D plus technology embodied in capital goods and intermediates as proportion of production, to determine ‘technological criteria’ for the industries. The IT cluster belongs to the hi-tech cluster whereas BT, NT, and transport equipment fall into medium-high and medium technology groups. Consumer goods and fabrication are in the medium-low and low technology categories, respectively. Based on the OECD (2000), we consider five broadly defined *technology clusters* which are also called ‘categories of embodied investment’. To decipher the temporal and spatial dispersion of technology and trade, we take the Global Trade Analysis Project’s (GTAP) database (Version 7) dividing the world economy into 113 regions, 57 sectors and 2 classes of labor (see Table 2) for concordance. As per OECD (2003), high-technology industries like electronic equipment and computers represents about 25% of total OECD trade and registered highest growth rates in manufacturing trade. Together with medium high-technology (transportation cluster, chemicals, machinery and equipment), the share is 65% of manufactures trade. Trade in high-technology goods increased to 25% in 2000-2001 (from 20% in 1990s) leading to the rise in volume of exports of technology-intensive industries (OECD 2004).

Table 1

Technology Clusters and Taxonomy of Industries

Technology clusters	Industries
Information and communications technology	Computers and related equipment, telecommunication and semiconductor equipment, electrical machinery, audio and video equipment, instruments
Transport technology	Shipbuilding, aircraft, motor vehicles, other transportation
Consumer goods technology	Food, beverages and tobacco, textiles, apparel and footwear
Materials technology	Agriculture, construction, mining, paper and printing, wood
Fabrication technology	Fabricated metal products, other non-electrical machinery, other manufacturing

Source: OECD (2000), Science, Technology and Industry–Scoreboard of Indicators.

Table 2

Sectoral and Regional Aggregations Adopted from Database

	Regions and Elements		Sectors	Description
1	G7	G7-North Developed	ConsumerGood	Consumer Goods Technology
2	OtherEU	EU minus G7 4 members	AgBioTech	Agriculture, Biotechnology
3	Brazil	Brazil	ElectronicIT	Electronics, ICT, Semiconductor
4	Russia	Russian Federation	Nano_Matrls	Materials, Nanotechnology
5	India	India	TransportTec	Transportation Technology
6	China	China	Metal_MedTec	Metal and Medium Technology
7	Hkg_Twn	Hong Kong Taiwan	Svces	Service Sector
8	SouthKorea	South Korea		
9	SouthEAsia	Developing Asia		
10	RSA	Rest of South Asia		
11	ECA	Europe and Central Asia		
12	SouthAfrica	South Africa		
13	LAC	LatinAmerica&Caribbean		
14	Mexico	Mexico		
15	OthrOECD	OECD minus G7 minus EU		
16	MENA	MiddleEastNorthAfrica		
17	SSA	Sub-Saharan Africa		
18	ROW	All other regions		

Source: Derived by author based on GTAP Data and concordance with OECD (2000).

V. Data Analysis and a Synthetic Operational Framework

V.1. Stylized Facts with Adjusted Enrichment Coefficients

Considering time-series trend over 1965-2002, we present average annual growth rates of global and regional trade in each of the clusters over the period 1965-2002 (Table 3).

Table 3

Regional Growth Rates for Global Trade in Technology Clusters, 1992-2006

Technology Clusters	Average annual growth (%) in trade from		
Source Region:	G7	Other EU	Other OECD
Information and communication technology	5.3	6.9	4.9
Consumer goods	3.8	3.8	4.0
Biotechnology Cluster	2.4	4.1	4.9
Nanotechnology Cluster	8.3	10.2	8.9
Transport equipment	6.4	6.8	7.7
Fabrication	5.8	5.9	7.2

Source: Calculated from the time-series trade data for the aggregated GTAP V7 Database.

This gives the dynamic perspectives of gradual evolution of scope of enrichment during passage of time between developed North and relatively laggard South. Here, ‘r’ represent regions where $r\in\{n, k, u\}$ where ‘n’ is the source, ‘k’ and ‘u’ are other Northern and Southern recipients, respectively. $s\in [k, u]$ represents generic ‘destinations’. Also, $s \subset r$ and $n\neq k$, $u \neq k$. We use UNESCO (2008). See Tables 4 and 5 below.

Table 4

Bi-lateral Domestic (Own) R&D (GERD as % of GDP) (Derived from Equations 5 and 6)

GTAP Regions	OWN R&D$_r$	Bilateral R&D$_{ns}$	
G7-North Developed	2.235	1	
EU minus G7 4 members	1.923	0.860	
Brazil	0.969	0.430	
Russian Federation	1.067	0.478	
India	0.804	0.360	
China	1.440	0.644	
HongKong Taiwan	0.695	0.311	
South Korea	2.600	1.000	
Developing Asia	0.395	0.177	
Rest of South Asia	0.367	0.164	
Europe and Central Asia	0.576	0.258	
South Africa	0.919	0.411	

GTAP Regions	OWN $R\&D_r$	Bilateral $R\&D_{ns}$
Latin America &Caribbean	0.270	0.121
Mexico	0.504	0.226
OECD minus G7 minus EU	1.874	0.838
Middle East North Africa	0.541	0.242
Sub-Saharan Africa	0.243	0.109

Source: Author's calculations.

Table 6 shows the *Technology appropriation parameters* based on equations (3), (4), (5), and (6). From the Table, for the BRIC group, the higher TAP parameter values are attributed to higher skill-induced absorption capacity (AC_r), innovation capability (ICC_r), and technological achievement. From the table, we observe that although the developing countries like Brazil, India, SSA, MENA, LAC have higher values of such indices (*implying higher enrichment scope*), the lower bilateral technology achievement indexes, *relative to G7* composite region, *reduce* the *adjusted enrichment indexes*; thus, *in terms of these adjustment* we see that generally the regions with higher coefficient of differences and higher bilateral TAP_{ns} and $R\&D_{ns}$ factors have better scope of enrichment (like Hong Kong Taiwan, South Korea, BRIC, OECD) in contrast with the regions with higher CX_NS and CM_NS, *but lower* TAP_{ns} and $R\&D_{ns}$ (e.g., SSA, MENA, RSA, East Asia, South Asia).

Table 5

R&D Flows Comprising Own R&D and Trade-mediated Flows

	Intra-Regional flows in 3 Composite North					
	n1= G7	n2=OthEU	n3=OthOECD			
	$TRDF_{n1s}$	$TRDF_{n2s}$	$TRDF_{n3s}$	Aggr $R\&D_f$	$R\&D_d$	Total $R\&D_r$
1 G7	0.818	0.248	0.040	1.107	2.235	3.342
2 OtherEU	1.013	0.341	0.036	1.391	1.923	3.314
3 Brazil	0.918	0.183	0.030	1.131	0.969	2.100
4 Russia	0.816	0.244	0.020	1.080	1.067	2.148
5 India	0.500	0.150	0.080	0.730	0.804	1.533
6 China	0.762	0.077	0.027	0.865	1.440	2.305
7 Hkg_Twn	0.907	0.069	0.040	1.016	0.695	1.711
8 SKorea	0.925	0.060	0.046	1.032	2.600	3.632
9 SEAsia	0.732	0.099	0.034	0.865	0.395	1.260
10 RSA	0.529	0.106	0.036	0.671	0.367	1.038
11 ECA	0.831	0.252	0.023	1.106	0.576	1.682
12 SAfrica	0.882	0.167	0.036	1.085	0.919	2.004
13 LAC	0.871	0.141	0.019	1.031	0.270	1.301
14 Mexico	1.527	0.078	0.012	1.617	0.504	2.121
15 OthOECD	1.010	0.301	0.043	1.354	1.874	3.227
16 MENA	0.866	0.201	0.037	1.104	0.541	1.646
17 SSA	0.692	0.218	0.020	0.930	0.243	1.173

Source: Author's calculations based on R&D data and Trade shares of GTAP V7.

It depicts the measure of structural and technological congruence between the north (G7 here) and other destinations, showing that relatively advanced nations and dynamic adopters (Hong Kong, South Korea, BRIC) have higher values as compared to the followers or laggards, for example, MENA, RSA or SSA. Preceding discussion shows that global integration has led to technology flows- *indirectly via embodied* traded intermediate inputs and/or, *directly via disembodied* through IT-enabled services and their increasing penetration- and disproportional rise in productivity in the recipients, where some regions do perform better than the others in terms of effective capture. Thus, *effectiveness* of trans-border technology diffusion are contingent on several factors that, amongst a tall order, we identify as: *recipient's (any region 'r' specific)* own domestic R&D ($R\&D^d$), foreign-trade induced R&D flows via imported intermediates ($R\&D^f$), connectivity with advanced world via superior network, human development (HDI), human-capital induced skill-intensity proxying learning or absorption capacity (AC), availability of latest technology (TAP), and socio-institutional parameter.

Table 6

Coefficient of Differences in Exports and Imports between G7 and other Destinations, and the Parameters

REGIONS	CX_G7-S	TAPns	R&Drs	CM_G7-S
Brazil	0.6385	0.41	0.43	0.3387
Russia	1.0713	0.39	0.4775	0.2848
India	0.4368	0.13	0.3597	0.5197
China	0.6665	0.11	0.6444	0.4181
Hkg_Twn	0.4432	0.8	0.3110	0.3265
SouthKorea	0.3308	0.57	1.0000	0.3490
SouthEAsia	0.4553	0.16	0.1766	0.2788
RSA	1.1478	0.06	0.1642	0.2668
ECA	0.3071	0.3	0.2579	0.1515
SouthAfrica	0.7234	0.44	0.4113	0.1206
LAC	0.7575	0.17	0.1210	0.1321
Mexico	0.3041	0.35	0.2256	0.2418
OtherOECD	0.5120	1	0.8384	0.1145
MENA	0.9648	0.23	0.2423	0.1644
SSA	1.0869	0.04	0.1089	0.1860
OtherEU	0.3585	0.94	0.86	0.148164

Source: Author's calculations based on GTAP7 Data.

In what follows, we offer an operational angle to our indicators and also develop a stylized framework for eliciting a theoretical argument behind operationalizing enrichment via trade.

V.2 Coefficient of Differences and Enrichment: Foundation for Operationalization

We reconcile the idea of product sophistication a la Hausmann *et al*., 2007) with the concept of trade-led enrichment. In the first stage, we calculate productivity level associated with a particular product 'i' ($PRODY_i$) by calculating in steps: (i) value-share of 'i' in overall regional aggregate export basket to all destinations 's' (s≠r) of particular region 'r' (X_{ir}/X_r) and aggregating such shares across all regions 'r' in our database (r = 1,2,…,17) to derive total global value-shares for each 'i' [$\sum_r(X_{ir}/X_r)$]; (ii) then, finding shares of regional product-wise value-shares in global product-wise value-shares via dividing regional shares by aggregative global total (RCA_{ir}); (iii) multiplying RCA_{ir} in the next stage with per capita regional GDP (Y_r) - so as to assign weights to the income level according to export value shares - yields productivity level (reflecting income level also) associated with a product 'i' in a region 'r'($PRODY_{ir}$); (iv) summing $PRODY_{ir}$ across all r's gives $PRODY_i$, so that we write:

$$\mathrm{PRODY_i} = \sum_r PRODYir = \sum_r \frac{X_{ir}/X_r}{\sum_r X_{ir}/X_r}.PCGDP_r = \sum_r RCA_{ir}.PCGDP_r \quad (7)$$

This gives ranking of export basket goods irrespective of size of the economies, but being weighted by export share (RCA_{ir}), relative importance is attached to regional per capita income. Using (A), in the next stage, we derive, as weighted average of $PRODY_i$, the 'productivity level associated with region/country r's export basket ($EXPY_r$)' by multiplying '$PRODY_i$' with weights, the shares - X_{ir}/X_r (see step (i) above) - and summing over all product categories 'i' as below:-

$$EXPY_r = \sum_i \frac{X_{ir}}{X_r}.PRODY_i = \sum_i EXPY_{ir} \quad (8)$$

From the formulae, it can be inferred that high value-share in export basket of 'low-quality' exports from a technologically poor country is reflected in $PRODY_i$, by giving low income level more weight and low income levels associated with a product. Converse is true for rich country - low value-share of low quality goods implies lower weights given to high income level and, hence, rich countries will have lower rank in relatively inferior technology-based goods. From (8), it is clear that higher $PRODY_i$ inflates $EXPY_r$ when the value-share of export of a particular product is high. That means, by implications, that when production of 'superior' product with better technology leads to product sophistication, then if a country could increase the value-share of that sophisticated exports in the export basket, by aligning comparative advantage, it becomes more productive reflected in higher income level. Looking at Table 7, we observe that G7 and other developed economies have higher $EXPY_r$ and $PRODY_r$ values as compared to Sub-Saharan Africa or Rest of South Asia excluding India, MENA, among few others. In case of dynamic rapidly industrializing East Asia, South Korea along with Hong Kong and Taiwan register high values, confirming our conjecture about dynamic comparative advantage in these economies. As export destinations and product quality are related to income level and skill, the enrichment sophistication reflects some kind of technology adjustment (Brambilla *et al*. 2012). Also, Bustos (2011) showed the impact of regional free trade agreement (FTA) on productivity and technology upgrading for Argentinean firms thanks to resource allocation and technology adoption and new technology. Thus, adjusting the enrichment coefficients with R&D-flows and *TAP* parameter would offer better operational concept. Tables 7 and 8 offer such adjusted figures (*CMAdj* and *CXAdj*). From Table 7, we see that country with hi *CX* and *CM* has low *EXPY* and *PRODy* and vice versa. At the product level, from Table 8, consider the case of hi-tech clusters like electronic-IT, transport-technology, and services (IT-based) with higher income levels as opposed to agri-biotech or consumer goods clusters. This is because hi-tech clusters constitute a relatively important part of the exports of high income countries such as Korea, Hong Kong, Taiwan, and G7 and also emerging economies like India and China as opposed to the products with low values, which are important in the export basket for less developed economies with low income per capita. Considering variation of *EXPY* across regions, from Table 7 we see that *EXPY*, *PRODY* and per capita GDP are highly correlated as rich (poor) country tends to export more human capital (unskilled), technology (low tech), physical capital (labor)-intensive goods that tend to be exported by others with similar income levels. In case of China and India, these values are higher even with low per capita income because of recent growth, export diversification leading to varieties of exports with high *PRODY* such as ICT-based, and services.

Table 7

Values for EXPY, PRODY ('000 US $), Coefficient of Enrichment Adjusted for Technology, R&D

Regions	EXPY (r)	lnEXPY (r)	PRODY (r)	CX_G7S	CX_{AdjRD}	CM_G7S	$Tech_{Adjusted}$	$R\&D_{adjust}$
1 G7	10269.81	9.24	15126.93	0.240	0.370	0.120	0.120	0.110
2 OtherEU	9722.68	9.18	11471.52	0.359	0.308	0.148	0.139	0.127
3 Brazil	8761.27	9.08	1832.44	0.639	0.275	0.339	0.139	0.146
4 Russia	8869.88	9.09	1443.01	1.071	0.512	0.285	0.111	0.136
5 India	9081.63	9.11	226.91	0.437	0.157	0.520	0.068	0.187
6 China	9625.17	9.17	428.20	0.667	0.429	0.418	0.046	0.269
7 Hkg_Twn	10197.67	9.23	5079.55	0.443	0.138	0.326	0.261	0.102
8 SouthKorea	10548.85	9.26	5448.29	0.331	0.331	0.349	0.199	0.349
9 SouthEAsia	9669.08	9.18	491.77	0.455	0.080	0.279	0.045	0.049
10 RSA	7758.18	8.96	176.70	1.148	0.188	0.267	0.016	0.044
11 ECA	9596.28	9.17	1546.89	0.307	0.079	0.151	0.045	0.039
12 SouthAfrica	9213.68	9.13	2059.43	0.723	0.298	0.121	0.053	0.050
13 LAC	8500.16	9.05	1516.76	0.758	0.092	0.132	0.022	0.016
14 Mexico	10168.44	9.23	2664.26	0.304	0.069	0.242	0.085	0.055
15 OthrOECD	9342.66	9.14	13234.47	0.512	0.429	0.114	0.114	0.096
16 MENA	8876.66	9.09	961.72	0.965	0.234	0.164	0.038	0.040
17 SSA	8396.54	9.04	172.66	1.087	0.118	0.186	0.007	0.020

Source: Author's calculations.

Table 8

PRODYi Values ('000 US$) and Correlation Coefficients of EXPY and PRODY with Adjusted Enrichment Indicators

	PRODY(i) Values	Correlation Coefficients	Values
1 ConsumerGood	6654.23	CXAdjT with EXPY	0.202
2 AgBioTech	5251.54	CXAdjRD with EXPY	0.032
3 ElectronicIT	11177.94	CXAdjRD with PRODY	0.376
4 Nano_Matrls	8364.48	CXAdjT with PRODY	0.094
5 TransportTec	13029.62	CMAdjT with EXPY	0.64
6 Metal_MedTec	9062.19	CMAdjRD with EXPY	0.484
7 Svces	10963.86		

Source: Author's calculations.

We see that South Korea and Hong Kong have highest *EXPY*s and, also, China has narrowed the gap with them, whereas for India the *EXPY* value is lower than for China and other countries like South Africa and South East Asia as we do not explicitly include software exports driving economic growth and India’s export sophistication. In case of Latin America and Caribbean, with the exception of Mexico the values are lower as export products are more concentrated on natural resources and primary products. Sub-Saharan Africa shows lowest values of all the regions along with MENA because primarily heavy dependence of their exports on natural resources and primary products. Europe and Central Asia register higher value for *EXPY* and *PRODY* because of recent experience of economic growth. On the whole, it is pertinent to note that our analysis matches with key findings of Hausmann *et al*., 2007), and additionally offers explanation for factors, such as, skill, technology, R&D, institutional quality as fundamentals underlying such evidences.

From the correlation coefficients in Table 8, we see that *adjusted with TAP* and R&D, the coefficient of differences (*CXAdj* and *CMAdj*) have strong positive relations with *EXPY* and *PRODY*. This is because with the adjustments for technology aspects, the high *CX* and *CM* values are lowered, thus, meaning improvement in enrichment scope. Hence, low coefficients of differences (*CX* and *CM*), attained via better *TAP* and R&D constellation for advanced and maturing countries, transforms *EXPy* and *PRODy* values into higher magnitude as in case of BRIC, South Korea (registering high values for both PRODY and EXPY). As these *CX* and *CM* bilateral values are calculated with respect to G7, also they could be calculated with respect to other regions advanced technologically. However, it supports our conjecture that: for countries with high CX and CM, they have low *EXPY (PRODY*); but for countries with low *CX* and *CM*, they have already exploited 'enrichment benefits' and, hence, registered higher *EXPY (PRODY)* - like BRIC and South Korea, etc. Further, with adjustment for technology related factors, the countries with high *CX* and *CM*, could get better and, hence, could enrich themselves via aligning production pattern and specialization. Binary comparison with G7, advanced league of countries, offers us valuable insights, which could be useful for comparison with other trade partners without undermining our purpose. Of course, with G7 having highest *EXPY* and *PRODY*, the destinations have scope of more enrichment benefits as technology and associated factors are conducive for a given *CX, CM*; but, the countries with low *CX*, *CM* could harness more enrichment benefits as their *TAP*, R&D factors are much superior than the laggards RSA, SSA, etc. This is in line with Bustos (2011) and Brambilla *et al*., 2012), for quality of exports for Argentinean manufacturing firms' exports to high-income recipients.

Also, R&D - own plus foreign-sourced - contribute to higher technological benefits and innovation capability. Brambilla *et al*., 2012) have studied the links between skill-intensive activities, skill utilization, and country characteristics, such as income, quality-preference, and even language. Thus, the higher is a country's level of development (proxied by per capita GDP, *PCGDP*), the more is the scope of being enriched via growth spillover. Choi *et al*., 2009) has shown that income distribution affects consumption patterns and trade in quality-differentiated product varieties. Thus, for checking the relationship between *PRODY(r), EXPY(r*), and technology appropriation parameter (*TAP*)-adjusted *CM (CMAdj(r))* we run OLS regressions under long-linear specification to estimate the following relationships separately for a sample of 17 regions (single and composite) as below:

$$\ln PRODY(r) = \alpha+\beta 1 \ln TAP(r)+\gamma 1 \ln PCGDP(r)+\delta 1 \ln R\&D(r)+\mu(r) \quad (r = 1 \ldots 17) \tag{8a}$$

$$\ln EXPY(r) = \alpha 2+\beta 2 \ln TAP(r)+\gamma 2 \ln PCGDP(r)+\delta 2 \ln R\&D(r) + \mu(r) \quad (r = 1 \ldots 17) \tag{8b}$$

$$\ln CMAdj(r) = \alpha 3+ \beta 3 \ln PCGDP(r) + \gamma 3 \ln R\&D(r) + \mu(r) \quad (r = 1 \ldots 17) \tag{8c}$$

The estimated equations, respectively, are given below (with Student's t values for the estimated slope coefficients for each i^{th} category in the parentheses):

$$\ln PRODY(r) = \underset{(-0.31)}{-0.25}+\underset{(0.91)}{0.13} \ln TAP(r)+\underset{(8.93)}{0.91} \ln PCGDP(r)+\underset{(0.22)}{0.04} \ln R\&D(r), \quad \mathbf{R^2=0.98, S.E.=0.16}$$

$$\ln EXPY(r)=\underset{(27.93)}{9.03}+\underset{(0.37)}{0.02} \ln TAP(r)+\underset{(0.14)}{0.01}\ln PCGDP(r)+\underset{(1.12)}{0.08} \ln R\&D(r), \quad \mathbf{R^2 = 0.50, S.E. = 0.06}$$

$$\ln CMAdj(r) = \underset{(-1.55)}{-0.164} + \underset{(1.78)}{0.038} \ln PCGDP(r) + \underset{(0.30)}{0.028} \ln R\&D(r), \quad \mathbf{R^2 = 0.47, S.E. = 0.05}$$

There are statistically significant relationship between PRODY, EXPY, CMAdj and TAP, PCGDP, R&D. The slope coefficients measure the elasticity of respective variables with respect to TAP, R&D, and per capita GDP. The point estimates signify that an increase in a region's R&D, technology acquisition, foreign trade, and income level contributes to product upgrading and enhancement. It also highlights the fact that even by trading with rapidly emerging economies, the least developed countries will benefit by specializing in commodities which they import; it is growth-promoting and by changing production, it gives them chance for export diversification, to 'become what they produce'.

V.3. Enrichment and Learning: Stylized Mechanism

Although Hausmann *et al*., 2007) present a model to derive those indexes (see EXPY and PRODY indexes), they do not provide any *quantitative connection* for the plausible determinants of them. From operational point of view, here we offer a conceptual framework for deciphering the mechanism. Knowledge-capital produced with new 'ideas' diffuses to the destinations through traded intermediates (Hoekman and Javorcik, eds, 2006). We harp on *major* progenitor of technological change or *sui generis* 'North', destinations comprising the amalgam of heterogeneous nations - the dynamic adopters, as well as the relatively laggards 'South'. With preponderant role being ascribed to ICT-cluster as guiding the 'law of motion' of technology clusters, there has been shifts in policy priorities for deepening the achievement via focus on R&D, skill formation, and socio-institutional factors. They are encapsulated into a *learning effect and adoption parameter* (*LeAP*) that conjointly offer substantial scope for extension of spillover-induced technology frontier (notional) and underpin actual frontier realizations. All told, destinations' growth depends on the extent of technology propagation, as well as on fostering absorptive capacity (AC) proxied by skill intensity (Caselli and Coleman, 2006, Das 2010). AC_r index is region 'r' specific.

The ability to produce more goods (either proportionately or on a non-neutral basis) originates from the R&D-led invention or innovation *per se*. With opening up of international trade, increased cross-border overhauling of goods via exports and imports leads to trans-border flow of enrichment benefits via traded intermediates. Not only hindrance in acquisition in *AC*, but also socio-economic distance (either due to institutional or socio-cultural barriers) limits the extent of knowledge diffusion. World Bank (2008) has emphasized the role of community-driven development for harnessing creativity and social capital. Acceptance of 'foreign technology' in a socio-economic system depends also on social capital, social cohesion and cultural affinity based on network and trust. Such measure is gauged in terms of the UN's human development index (*HDI*) because it embraces multi-faceted nature of social acceptance via factors such as, health, education, literacy as well as income characteristics. Familiarity with another country's institutional factors like legal side protecting intellectual property rights (*IPRs*), habits and even languages enables regions to become culturally congruent and trustworthy via self-enforcing and self-confirming nature of engagement of parties.

Regarding corruption or transparency, we take Transparency International's (2008/9) Global Corruption Barometer data on Corruption perception Index ($0<T_r<10$). Also, a composite indicator of national competitiveness ($1<C_r<7$) which encapsulates different aspects of a nation's technological readiness in terms of socio-economic variables is taken from *Global Competitiveness Report* (World Economic forum 2008/09). For the advanced North (here G7 composite), the major source of knowledge or current vintage technology, we define a function representing its invention capability. Same we do for other regions as well. We call it '*Indigenous, Disembodied and Embodied R&D, and Schooling* parameter ($IDEAS_r$) which depends *functionally* on *R&D, HDI*. Typically, we find that $IDEAS_r > IDEAS_u$, $\forall$ *r=n, k and s=u.* The crucial parameters for technology capture and assimilation is *Learning-enabled Absorption Parameter* (*LeAP*)—for North ($LeAP_n$) and north vis-à-vis recipients 's' ($LeAP_{ns}$) as follows:

$$LeAP_n = AC_n.ICC_n.HD_n.TA_n.IDEAS_n \tag{9}$$

AC and trade-induced *R&D*-intensity in each sector conjointly determine the sector's technology appropriation parameter and *LeAP*. Although there is distance of ideas (learning gap), trade and other factors boosting entrepreneurial productivity could overcome physical barrier. This lays the operational foundation for our enrichment indicators adjusted with technological factors. As is evident from OLS regressions and the stylized facts in the foregoing section, since *TAP* and *R&D* form the conduit of enrichment via coefficient of differences (*CXAdj* and *CMAdj*), equation (9) forms the operational building block for the concept of enrichment. From Table 5, comparing TAP_{ns}, we see that they are not equal; also, the ranking is preserved more or less. In case of structural symmetry, we see that G7 is more congruent to EU and other OECD, as compared to, for example, SSA, India, China, RSA, LAC or MENA. Typically, rapidly industrializing economies have higher socio-institutional parameter due to higher indices for governance, transparency, and lower corruption perception index. Comparing India among the BRIC and LACs, with regard to embodied and disembodies spillover the values are less. Even, the HDI values are low. Thus, it registers *low* parametric values *for 'IDEAS'*. But, if we compare India with developing South East Asia and Latin America, HDI values are lower, too. Even with the scope of higher embodied spillover, IDEAS for India are lower than these groups of emerging economies. We infer that '*IDEAS*' differ from '*LeAP*' in terms of geographical distance and other factors related to absorption of trade-mediated technology flows. Using this stylization, we see that countries such as EU and OECD, being already integrated in trade with the G7, have lower coefficient of differences (CX and CM) and, hence, lower further enrichment scope. However, they have higher *LeAP* or capture-parameter values. Therefore, higher *LeAP* means higher innate enrichment capture and, hence, lower coefficient of differences in exports/imports. On the contrary, for the LDCs having higher CX, CM values with the G7, have enough scope of enrichment provided their *LeAP* or capture-parameter values are just right or higher. But with lower *LeAP* values, their intrinsic enrichment scope is less although there are rooms for shifting up the value chain by upgrading technologies. For them, a high CX-CM value with lower LeAP parameters implies negative correlation as well. As Brambilla *et al.*, p. 3407, 2012) has spelt out, "if goods are differentiated by export destinations, then 'what you export' and 'where you export' are interrelated." OECD (2010) has mentioned that '*upgrading trade'* is inevitable for a country shifting up the value chain. The report documents that the index of technological sophistication has risen for countries like Brazil Mexico, China, Korea, South Africa, and India, whose exports fall into high-tech categories.

VI. Concluding Remarks

In this paper, we highlight the role of skill and technology for assimilating the trade-led technology via intermediates. Based on evidences of industry-specific R&D in the North-South and South-South trade patterns, and input-output relations, it is true that trade and associated enabling factors are crucial for enrichment of recipients and export sophistication. Stylized facts on 'scope of enrichment' and income levels of exports show that enrichment depends not only on trade potential, but also importantly on other factors like human capital, research capability or inventive capacity, institutions, mentioning a few. Countries such as EU, OECD have low *CX_NS*, *CM_NS* values and being already integrated via trade with G7, have lower scope of enrichment via trade; however, they have higher *LEAP* or capture parameter which entails innate enrichment already. LDCs, having higher *CX_NS, CM_NS* have enough scope for enrichment provided their *LEAP* values are higher. But, with lower *LEA*P parameter, the intrinsic enrichment scope is less although trade-led enrichment has rooms for delivering benefits. A comprehensive policy response beyond trade policy should focus on research and extension services, better governance, technology assisted by governments as well as private investors, human and social capital through learning, appropriate institution, and global cooperation. This paper offers a nuanced insight on the aspect of product sophistication and enrichment effect via trade, technology diffusion and enabling factors for upgrading product quality.

References

Arora, V., and Vamvakidis, A., 2005. "How Much Do Trading Partners Matter for Economic Growth?" *IMF Staff Papers*, 52 (April), pp. 24-40.

Bitzer, J and Geishecker, I., 2006. What drives trade-related R&D spillovers? Decomposing knowledge-diffusing trade flows. *Economic Letters*, pp. 52-57.

Brambilla, I., Lederman, D. and Porto, G., 2012. Exports, Export Destinations, and Skills. *American Economic Review*, 102 (7), pp. 3406-3438.

Bustos, P., 2011. Trade Liberalization, Exports, and Technology Upgrading: Evidence on the impact of MERCOSUR on Argentinian Firms. *American Economic Review*, pp. 304-340.

Caselli, F., Coleman II, W., 2006. The World Technology Frontier. *American Economic Review* 96, pp. 499-522.

Coe, D.T., Helpman, E. and Hoffmaister, A., 2008. International R&D Spillovers and Institutions. *IMF Working Paper WP/08/104*, pp. 1-35.

Choi, Y.C., Hummels, D., and Xiang, C., 2009. Explaining import quality: The role of the income distribution. *Journal of International Economics*, 78, pp.293-303.

Das, G.G., 2010. How to reap the induced technological bonus? A Mechanism and Illustrative Implementation. *Modern Economy*, August 2010, Vol. 1, pp. 80-88.

Das, G.G., 2012a. Fragmentation in production, vertical integration and wage inequality: A theoretical note. *Modern Economy*, December 2012, Vol. 3, pp. 958-964.

Das, G.G., 2012b. Globalization, Socio-institutional factors, and North-South Knowledge diffusion: Role of India and China as Southern growth progenitors. *Technological Forecasting and Social Change*, 79, pp. 620-637.

Eaton, J. and Kortum, S., 2002. Technology, Geography, and Trade. *Econometrica*.70 (5), pp. 1741-1779.

Feng, L., Li, Z., and Swenson, D., 2012. The connection between imported intermediate inputs and exports: evidence from Chinese Firms. *NBER Working Paper* 18260. NBER, Cambridge, MA, USA, pp. 1-46.

Hanson, G.H., 2012. The Rise of Middle Kingdoms: Emerging Economies in Global Trade. *NBER Working Paper 17961*. pp. 1-48.

Hausmann, R., Hwang, J., and Rodrik, D., 2007. What you export matters. *Journal of Economic Growth*, 12, pp.1-25.

Hertel, T.W., ed. 1997. *Global Trade Analysis: Modeling and Applications*. Cambridge, MA, Cambridge University Press.

Hoekman , B., Smarzynska Javorcik, B., 2006. *Global Integration and Technology Transfer*. Palgrave Macmillan and the World Bank.

Jones, C. J., and Romer, P., June 2009. The New Kaldor Facts: Ideas, Institutions, Population, and Human Capital. *NBER Working Paper 15094*. pp. 1-30.

Kaufmann , D., Kraay, A., and Mastruzzi, M., 2009. "Governance Matters VIII: Aggregate and Individual Governance Indicators for 1996-2008". *World Bank Policy Research Working Paper WPS 4978* June 2009, pp. 1-97.

Keller, W., 2004. .International Technology Diffusion. *Journal of Economic Literature* Vol. XLII: pp. 752-782.

Kosempel, S., 2007. Interaction between knowledge and technology: a contribution to the theory of development. *Canadian Journal of Economics,* 40 (4). pp. 1237-1260.

Lucas, R. E. Jr., 2009a. Trade and the diffusion of the Industrial Revolution. *American Economic Journal: Macroeconomics.* Vol 1(1). pp.1-25.

Lucas, R.E. Jr., 2009b. Ideas and Growth. *Economica*. Vol 76 (1). pp.1-19.

Narayanan G.B., and Walmsley, T.L., (eds.). 2008. *Global Trade, Assistance and Protection: The GTAP 7 Database*. Centre for Global Trade Analysis, Purdue University.

Ng, S., and Ng, Y-K., 2000. The enrichment of a sector (individual/region/country) benefits others: a generalization. *Pacific Economic Review*, 5, pp. 299-302.

Ng, S., 2002. The Effects of Growth of its Trading Partners on Malaysia. In Alan D. Woodland (ed.) *Economic Theory and International Trade. Essays in Honor of M. C. Kemp.* Edward Elgar.

OECD, 2000. Science, Technology and Industry Scoreboard of Indicators, Paris.

OECD, 2003. OECD Science, Technology and Industry Scoreboard. Paris.

OECD, 2004. The Economic Impact of ICT: Measurement, Evidence and Implications.

OECD, 2010. 'Trade in Intermediate Goods and Services." Working Party of the Trade Committee. *OECD Trade Policy working Paper* No. 93. Paris.

Schiff, M., and Wang, Y., 2006. "North-South and South-South trade-related technology diffusion: An industry-level analysis of direct and indirect effects." *Canadian Journal of Economics*, Vol. 39, No. 3, pp. 831-844.

Spence, M., 2011. The Next Convergence: The future of economic growth in a multispeed world. Farrar, Straus and Giroux/New York.

UNESCO, 2009. *A Global Perspective on Research and Development*. UNESCO Institute for Statistics. *UN Fact Sheet*, October 2009, No. 2.

Wang, Z., and Wei, S-J., 2008. What Accounts for the Rising Sophistication of China's Exports? *NBER 13771*. pp. 1-40. Cambridge, MA, USA.

World Bank, 2008. Global Economic Prospects: Technology Diffusion in the Developing World. Washington D.C.