Technology Diffusion, E-commerce and Trade Facilitation in a model of Northern hub vis-à-vis Southern spokes -A Tale of Two Souths.*

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Abstract

The study develops a North-South model of trade-mediated technology diffusion that proves that (i) higher constellation of absorptive capacity, governance, and structural congruity facilitates South's effective assimilation of Northern technology; (ii) lower capture-parameter hinders adoption in South; (iii) technology-induced E-commerce fosters trade and international commerce via E-business. The study has policy implications for human resource development, technology transfer and international business.

Keywords: Spillovers; Capture; Trade facilitation; E-commerce; Information Technology, International Trade.

JEL classification: **C68; F43; O33; O30; O40.**

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Technology Diffusion, E-commerce and Trade Facilitation in a model of Northern hub vis-à-vis Southern spokes -A Tale of Two Souths.

"*Well-designed globalization can promote technology and development*."— Joseph Stiglitz, Asian Development Review, 20 (2), 2003.

"*Information and communication technologies (ICT) are crucial in spurring 'development, dignity and peace*. *Let us turn the digital divide into digital opportunity*." –Ban Ki-moon, UN Secretary-General, February 27, 2007.

1. Introduction and synoptic literature review:

Acquisition of state-of-the-art technologies invented in the industrialized nations (North) by the rapidly-developing economies (South) is a dominant mode of fostering productivity growth (Hoekman and Javorcik, 2006). Trade-mediated technology spillover enhances knowledge-propagation (Coe et al., 1997; Keller, 2004). [1] The study considers core Information Technology (IT) cluster, and transmitted benefits to user-clusters—Bio-technology (BT), Nanotechnology (NT), Transport Equipment (TE), Consumption Goods (CG) and International Transport Services (ITS). Literatures abound with ICT's role as a GPT for knowledge-sharing, enhancing productivity, facilitating trade, and access to global supply chains (Linstone 2004; Grace, Kenny, and Qiang 2004; Qiang and Pitt, 2004). 'Informatization'—ICT-driven economic and social transformation—is a complex process for achieving 'critical development goals' via investment in social and economic infrastructure (Qiang, 2007). Apart from ICT, bio-technological innovations (BT) and nanotechnology (NT) are two major innovations driving economic growth (Evenson and Santaniello, 2006). Additionally, technological infrastructure promotes trade facilitation via market access, logistics infrastructure, port efficiency and favorable customs procedure that work in tandem to eliminate iceberg-type transaction costs (Wilson et al., 2005). Electronic-

[1] FDI is another conduit of technology diffusion. However, primary focus being spillover capture relative merits of two channels are not discussed.

commerce-led customs automization shapes global trade logistics. The study models the role of technical efficiency in trade facilitation as an import-augmenting technical change in ITS-cluster. The adoption of trade-induced spillover enables South to catch-up. And structural heterogeneity in the South, however, translates into mixed performances. The disparate growth-dynamics of the newly-industrialized economies, influences the disaggregation of the composite South into high-performing 'Rapidly-industrializing economies (RIE)' and relatively laggard, 'Low-and-Middle-income economies (LMIE)'. 'North (Highly-industrialized economies-HIE)', as a group, is structurally and economically more homogeneous. Concurrently, the rise in trade between these developing nations has led to the emergence of "a new geography of global trade" between the Souths (see for example, United Nations, Press Release, November 22, 2006). Share of such trade has gone up from 25% in 1980s to 40% of total trade in 2003 (UNCTAD, 2004). In fact, Fugazza and Robert-Nicoud (2006) has discussed about the prospects of benefits from South-South trade liberalization via 'economic complementarities' and its indirect contribution to the promotion of North-South trade via improvements in 'supply capacity'.

Sections 2 and 3 develop models—the core model delineating the principal mechanism for trade-mediated technology diffusion from source to destination regions and sectors, and a conjugate model of E-business penetration facilitating trade via spread of ICT. Section 4 documents data and parameters used for the model implementation. Section 5 implements the model by constructing simulation scenarios for technological progress occurring in the ICT technology-cluster. Section 6 concludes that the intensive usage of ICT and ICT-enabled systems coupled with adequate development of socio-institutional infrastructure induces productivity growth and expansion of e-business activities across industries. Thus, the model illustrates a mechanism to emphasize the role of public policy in inducing concerted effort on R&D and promoting adequate human resource development for facilitating international business.

2. Core Model

Superior technologies of recent vintages are researched in the HIE. RIE and LMIE harness such Northern technologies and the mode of access to foreign technology is primarily imports (Falvey et al., 2004). Knowledge-capital embodied in the commodities produced with new 'ideas' diffuses to the destinations through traded intermediates (Eaton and Kortum, 1996; Navaretti and Tarr, 2000; Schiff and Wang, 2004). Self-propellant inventions in IT induce technological spillovers to recipient clusters (Linstone, 2004; Meijl and Tongeren, 1998; OECD, 2004).

The study reserves $'r'(r = HIE)$ and $'s'(s \in RIE, LMIE)$ respectively for source (unique) and recipients of technological diffusion. Southern growth depends on the extent of diffusion as well as on their capabilities, for effectively assimilating the diffused technology i.e., absorptive capacity (AC) proxied by human-capital intensity (Cohen and Levinthal, 1989). Investment in skill helps unlock the potential of technological capability (Caselli and Coleman, 2006). AC_s index is region $'s'$ specific $(0 \leq AC_s \leq 1)$.

Spillover adoption depends, *inter alia*, on institutional factors like political stability, good governance, and property rights (Liu and San, 2006). Thus, transmitted technology delivers benefits if the level of governance quality of source vis-à-vis destinations is optimal and helps social learning of latest state-of-the-art (Groot et al., 2004).[2] We capture this factor via a binary governance parameter, $(GP_{rs}, 0 \leq GP_{rs} \leq 1)$, indicating institutional quality as:

$$GP_{rs} = \min[1, \frac{GP_s}{GP_r}] \qquad (1)$$

If $GP_s > GP_r$, it enables $'s'$ to utilize the technology effectively. Otherwise, for $GP_s < GP_r$, it hinders absorption.

Domestication of foreign technology depends on indigenous inventive capabilities (R&D) in $'s'$ (Bayoumi et al., 1999). Accordingly, a bilateral technological-congruence parameter, $0 \leq TD_{rs} \leq 1$, between $'r'$ and $'s'$ is constructed as:

$$TD_{rs} = \min[1, \frac{TD_s}{TD_r}] \qquad (2)$$

Social acceptance of 'new' technology is assumed to depend on human resource development-led structural symmetry—specified via region-specific 'social acceptance' parameter (SA_s) by:

$$SA_s = \min[1, \frac{SA_s}{SA_{threshold}}] \qquad (3)$$

A larger magnitude of SA than the threshold level facilitates absorption by $'s'$ $(0 \leq SA_s \leq 1)$.

TD_{rs} and GP_{rs} determine a binary structural-symmetry index (SS_{rs}) that in conjunction with AC_s and SA_s gives 'capture-parameter' (θ_s) —recipients' productive-efficiency in appropriating spillovers from *unique* $'r'$:

[2] Social learning theory advocates that several factors like English proficiency, political stability, degree of corruption and violence, adult literacy, etc. are crucial for effective 'learning' and assimilation. In the context of e-learning via ICT, these are pertinent.

$$\theta_s = AC_s.SA_s.SS_{rs} \qquad (4)$$

$$SS_{rs} = GP_{rs}.TD_{rs} \qquad (5)$$

$\theta_s \in [0,1],\ \theta_s = 1$ implies full appropriation.

Trade-mediated spillover from source $'i'$ $(unique'i')$ in $'r'$ to a sector $'j'$ in client $'s'$ depends on input-specific trade-intensity encapsulated in a trade-embodiment index $[E_{ijrs}]$—imported intermediate $'i'(i =$ IT-cluster$)$ in source $'r'$ that is exported to firms in sector $'j'$ in $'s'[F_{irjs}]$ per unit of composite intermediate $'i'$ used by client-sector $'j'$ in $'s'[M_{ijs}]$. Thus,

$$E_{irjs} = \frac{F_{irjs}}{M_{ijs}} \qquad (6)$$

Spillover coefficient for $'j'$ in $'s'$ (γ_{ijrs}) is:

$$\gamma_{ijrs}(E_{ijrs}, \theta_s) = E_{ijrs}^{1-\theta_s} \qquad (7)$$

$\gamma_s(0) = 0,\ \gamma_s(1) = 1,\ \gamma_s' = (1-\theta_s).E_{rs}^{-\theta_s} > 0,\ \gamma_s'' = [-\theta_s(1-\theta_s)/E_{rs}^{1+\theta_s}] < 0.$

Primes indicate first and second derivatives of E_{rs}.

Source $'r'$ reaps technological spillover via inputs embodying technology so that:

$$E_{ijr} = \frac{D_{ijr}}{M_{jr}}, i \neq j \qquad (8)$$

where D_{ijr} is the quantity of domestic tradeable $'i'$ used by j^{th} sector of $'r'$. M_{jr} represents domestic production of $'j'$ in $'r'$. Capture-parameter depends on $AC_r(\alpha_r)$. Given constellation of SA, TD and GP, higher AC induces knowledge-spillover via:

$$\gamma_{ijr}(E_{ijr}, \alpha_r) = E_{ijr}^{1-\alpha_r} \qquad (9)$$

θ_r has one-to-one correspondence with $\alpha_r, 0 \le \alpha_r \le 1$.

TFP transmission equation for $'s'$ is:

$$ava_{js} = E_{ijrs}^{1-\theta_s}.ava_{ir} \qquad (10)$$

where ava_{ir} is exogenous TFP-improvement in sector $'i'$ of $'r'$ (*unique*) and ava_{js} is induced endogenous TFP (percentage-change) $[i \neq j, r \neq s]$.

Invention in IT-cluster translates into induced-innovation in recipient user-clusters (OECD, 2004). Such a mechanism is invoked via:

$$af_{ijs} = E_{ijrs}^{1-\theta_s}\ af_{ijr} \qquad (11)$$

where af_{ijr} is i^{th} $(unique\ 'i')$ input-augmenting technical change in j^{th} sector in $'r'$.

3. Modeling E-business Penetration and Trade-Facilitation

Improvements in customs procedure and E-commerce usage reduce transaction cost and time-lag of merchandise delivery. Streamlined customs procedure (e.g. electronic data interchange system, ETDS in Singapore) reduces 'bureaucratic trade cost' by 50%, spoilage and inventory-holding cost thereby, increasing trade (Hertel, Walmsley, and Itakura, 2001; Vanhoose, 2003). Globalization of E-commerce and customs automization is aided by investment in IT-cluster and consequential spillover.

However, ICT-induced trade facilitation depends on the extent of social acceptance (SA_s) of technology-based business modes and technological symmetry (TD_{rs}) (Johnston and Wright, 2004). E-commerce adoption depends on infrastructure and education (for example, E-learning or informatization via access to network) for accessing such facilities

(Panagariya, 2000).[3] Such an IT-induced penetration reflects IT-intensity in clusters (j) in $'s'$, as given below:

$$\psi_{ijrs} = \frac{V_{irs}}{W_{jrs}} \tag{12}$$

where

V_{irs} : Intermediate-imports $'i'$ (IT-cluster) from $'r'$ to $'s'$.

W_{jrs} : Total imports of $'j'$ from $'r'$ to $'s'$.

Extent of E-commerce penetration between North (r) vis-à-vis Souths (s) $[\Omega_{ijrs}]$ is expressed as:

$$\Omega_{ijrs} = [\psi_{ijrs}]^{(1-SA_s.TD_{rs})} \tag{13}$$

Customs procedures are synchronized via E-commerce transmission in $'s'$ as follows:

$$ams_{jrs} = [\psi_{ijrs}]^{(1-\omega_{rs})}.ava_{ir} \tag{14}$$

where $\omega_{rs} = SA_s.TD_{rs}$, ams_{jrs} is ava_{ir} – led percentage-change in import-augmenting technical progress $[i \neq j]$ $[r \neq s]$.

However, enhanced imports require access to ITS–ports, air transport, and distribution in destinations. Given the shipping-route, global trade facilitation and intermodalism causes reduction in ITS-freight charges (Hummels and Skiba, 2002). This is aided by technological change like containerization of international trade. In fact, improvement in port efficiency from 25th to 75th percentile reduces shipping costs by 12% and raises trade by 25% (Clark et al., 2004). IT-usage intensity in margin commodity (services) causes technological spillover to ITS-cluster. This induces commodity-cluster- and

[3] Information Technology Agreement is signed for opening trade in IT-related equipment and facilitating access to communication networks for E-commerce.

route-specific input-augmenting technical change and results in price reduction in services $'m'$ by lowering *CIF-prices* implied by a given *FOB value*. Inadequate adaptation and infrastructural bottlenecks hinder such diffusion.

Technical change in shipping $'i'$ from $'r'$ to $'s'$ $(atmfsd_{mjrs})$ depends on IT-intensity in $'m'$ and the share of $'m'$ in $i's$ transshipment cost. These two determine the extent of impact of ICT in ITS-shipping, Ξ_{imrs}. We define it as the ratio of foreign-sourced IT-intensity into $'m'$ $[S_{imrs}]$ and services $'m'$ usage into $'s'$ $[T_{ms}]$:

$$\Xi_{imrs} = \frac{S_{imrs}}{T_{ms}} \qquad (15)$$

Ratio of Ξ_{imrs} $(unique'i')$ and margin $m's$ share in delivery cost of $'j'$ from $'r'$ to $'s'$ $[V_{mjrs}]$ gives service-embodiment$[\Phi_{mjrs}]$ and spillover assimilation $[\Theta_{mjrs}]$as:

$$\Phi_{mjrs} = \Xi_{imrs} / V_{mjrs} \qquad (16)$$

$$\Theta_{mjrs} = [\Phi_{mjrs}]^{(1-\omega_{rs})} \qquad (17)$$

Consequently, trade-facilitation is captured by transmission equation as:

$$atmfsd_{mjrs} = \Theta_{mjrs}(\Phi_{mjrs}, \omega_{rs}).ava_{ir} \qquad (18)$$

4. Methodology and Data

An augmented version of comparative-static Computable General Equilibrium (CGE) Global-Trade-Analysis-Project (GTAP) trade model (Hertel, 1997) is solved using General Equilibrium Modeling Package (GEMPACK) software.[4] A 3-regions ×7-clusters aggregation of GTAP database (Version 6) is calibrated.

2.2 Regional and Industrial Clusters: Database and Stylizations

[4] Data-sources, software, equations, and parameters are not reported for parsimony. An appendix defining them is available from author.

In the technology diffusion literature, the dynamism and technological competitiveness across industrial clusters are quite common. Based on spatial variation of diffusion and adoption of new technologies, there has been considerable evidence on differences in technology transfer between large country groups such as the North and the South. Role of geographical proximity and contiguity in facilitating trade flows between regions is important. Krugman (1991, 1995) has emphasized the role of geography and locational choices in formation of 'natural' trade blocs by consideration of 'proximity.' 'Global production networks' (GPN) and 'Global Commodity Chains' (GCC), representing functionally integrated production network in a supply chain, have emerged as a major area of focus in economic geography. Role of adjacency in promoting trade between neighbouring countries is explored. Various versions of the gravity model have been widely used to study such effects [Deardorff and Stern (1994), Frankel (1997), Wei and Parsely (1995), Groot et al. (2004)]. They find strong linkages between bilateral trade and explanatory factors like geographical proximity, language, common history reflecting cultural similarity. In this context, the importance of distribution via logistics and transportation industries has been emphasized (Hesse and Rodrigue 2006).

According to Baptista (2001), 'the diffusion of the new technological processes may occur faster in geographical areas where the density of sources of knowledge is higher'. In other words, geographical clustering facilitates and stimulates networking between producers and adopters of new technologies, thus, enabling spillovers, and imitation. Technology propagates much faster in the clusters with higher density of early technologically progressive adopters (users), presence of innovative firms and larger accumulated technological base. Therefore, in this paper we consider broadly aggregated regional clusters, namely, one advanced industrialized North (*the source* or producer of knowledge), relatively superior South (*the early adopters* of current technology), and a relatively laggard South (*the slow follower* of innovation diffusion). Constellation of factors like indigenous inventive capabilities, own R&D effort, skill-intensity and socio-institutional parameters act as facilitator of North-South knowledge transmission.[5]

However, these tripartite grouping is *not* based on physical geography of constituent regions/countries. Rather, geographical distribution of spillovers based on region-specific growth and developmental features forms the basis of our regional clustering. Although we consider the World Bank's (2007) classification of countries based on GNP per capita, we, however, do not strictly follow this classification. Since scientific development, industrialization and technological innovation is also contingent on the non-pecuniary aspects of growth and development, instead, we focus on complementary aspects like educational and institutional features which supplement the income-based criterion.[6] Thus, we divide the world economy into three amorphous geographic clusters: the North (i.e., highly industrialized economies-HIE); the advanced South (the rapidly industrializing economies-RIE-comprising the first-tier and second-tier dynamic Asian and Latin American economies); and the Less-developed South (the low-and-middle income economies-LMIE-including the impoverished Africa and Middle East). To decipher the temporal and spatial dispersion of technology and trade, we take the Global Trade Analysis Project's (GTAP) database (Version 6). The GTAP database (base period 2002) divides the world economy into 87

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[5] According to OECD (2006), compared to 7% in 1995 China, Israel, Russia, and South Africa contribute combined 17% of R&D expenditure of OECD nations in 2004.

[6] Sen (1999, 2005) mentions that concept of development solely 'parasitic' on the criterion of GNP per capita fails to capture aspects of proper developmental features. As this paper focuses on the roles of human capital, knowledge accumulation, innovation process and its diffusion as major force behind industrial growth and development, grouping countries based on GNP *only* is not suitable and hence, we broaden it by considering the factors underlying recent episodic growth performances and hysteresis of development of some rapidly developing nations like Brazil, Russian Federation, India, and China.

regions, 57 sectors and 2 classes of labor. Table 1 presents the regional concordance and geographical matching of constituent regions/nations. Typically, HIE includes the European Union (EU 15), OECD nations, plus the non-OECD members of the European Free Trade Area (EFTA). RIE and LMIE are agglomerations of regions with intra-group homogeneity. RIE includes the rapidly advancing economies. LMIE consists of the rest of the world that has not experienced as fast growth as comparable to the RIE-constituents. The underlying assumption is that strong regional clustering of high-technology industries occur in HIE followed by RIE whereas LMIE is the late adopter in the diffusion-assimilation race.

[See Appendix Table 1]

In the literature for trade-embodiment of technology, role of high-technology products incorporating, either directly or indirectly, R&D-intensive products via intermediates and capital goods are emphasized. According to the 1997 OECD study[7], technology is defined as the direct and indirect R&D embodied in different types of intermediate inputs and capital equipment. Diversification towards knowledge-intensive products has led to rising share of science-based goods in trade (Guerrieri and Milana, 1995; Martin et al, 1997).[8] We follow OECD (2003a, 2005) classification of manufacturing activities according to technological intensity using ISIC Rev.3 breakdown of activity. Based on Hatzichronoglou (1997), OECD (2003a, 2005) 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

[7] The manufacturing sector is the source of innovation via R&D with spillovers to other user sectors.
[8] According to the World Bank (1999) classification, high-technology exports comprises manufactures at the 4-digit level of disaggregation in the SITC, Revision 1, Sections 5-9 excluding division 68.

determine '*technological criteria*' for the industries.[9] This methodology led to classification of manufacturing industries into high-technology, medium-high-technology, medium-low and low technology groups. According to this classification, 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. However, capturing knowledge-intensivity of service sector poses challenge because of lack of consensus on definition and dearth of data. By adopting a narrow definition (ISIC Rev 3.) and based on idea of embodied technology flows estimated from input-output tables, market service activities are considered knowledge-intensive. Most of these services are intensive users of IT.

As far as the nomenclature is concerned, we adopt the OECD (1997, 2003a, and 2005) definition of industrial clusters. For explorations of the underlying causes for innovation and dynamic efficiencies, nature and quantum of 'knowledge flows' and their determinants in a particular cluster have drawn much attention (Basant 2002; OECD 2005; Wixted, Yamano, and Webb 2006). OECD (1996, 1997) divides industries into five broadly defined *technology clusters*—'industries sharing a number of common characteristics', which are also called 'Categories of Embodied Investment' (OECD, 1996).[10] Based on SITC, Revision 3, and Commodity Product Classification and Harmonised System (HS, Rev 2.), OECD (2003a) and OECD Outlook (2004b) have developed a classification of five broad categories of ICT goods separately from ICT-services.[11] ICT services, based on ISIC, Rev 3., are separated in

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[9] See OECD (2003), pg. 141 and Annex I, pg. 155.

[10] OECD (1996), *Science, Technology and Industry Outlook*.

[11] Working Party on Indicators for the Information Society (OECD 2003a), A proposed classification of ICT goods, DSTI/ICCP/IIS, OECD. As the development of a 'detailed classification' of services was not easy because of lack of consensus on including activities into industry-based sector definition, the ICT-services are distinguished from ICT-goods and ICT-production based on ISIC, Rev 3.

the 'services' cluster comprising telecommunications, IT-enabled and related services facilitating trade. This separation is suitable for our purpose of trade-related technology diffusion from IT-production to IT-user sectors. Table 2 presents the OECD classification of industries into broadly defined *technology clusters* following the OECD (1996, 1997, and 2004) taxonomy.[12]

[See Appendix Table 2]

From table 2, we see that consumer goods and materials technology cluster include some of the core BT and NT sectors. Recently, both of these technologies have grown markedly due to scientific advances in areas such as genomics, proteomics, genetic engineering, and materials science. Due to lack of methodological consensus and differences in definitions of biotechnology firms, there is difficulty of comparable statistics. Based on OECD (2006) definition of BT applications, for our purpose, we classify the BT cluster to focus on agricultural or plant biotechnologies based on application fields in agro-food, forestry, and food processing whereas others are grouped into consumer goods cluster (see Table 3). [13]

Similarly, for nanotechnology there is 'lack of agreed definition'. However, it refers to a range of new technologies specifically aimed to manipulate matters at the nanometric scale and it encompasses many broader research activities (OECD 2003a). Accroding to Darby and Zucker (2003), nanoscience represents a Grilichesian breakthrough (i.e., invention of a method of inventing) with a potential to drive metamorphic technological progress to wide range of products. Because it essentially involves manipulation of materials at the

[12] OECD (1997), *Science, Technology and Industry Scoreboard of Indicators*, pp- 40-41.According to Thomas Hatzichronoglou (1997), in the proposed new classification by industrial sector, 'the concept of technology intensity has been expanded to take into account both the level of technology specific to the sector (measured by the ratio of R&D expenditure to value added) and the technology embodied in purchases of intermediate and capital goods.'

[13] Three major fields of such applications with comparable country coverage are: health, agro-food and industry-environmental fields (p. 26, OECD 2006).

atomic scale to invent new products, it has applications in every field. [14] Hence, we classify the NT cluster by considering the products having potential to undergo such technological breakthroughs.

The GTAP Version 6 database provides us with time-series trade data for 1965-2002 as well as complete intersectoral transactions for 2002. Following is the mapping of the GTAP sectoral classification (GSC1) to the technology clusters.

[See Appendix Table 3]

According to *World Development Report* (World Bank 1999, p.27), the share of high-technology industries in total manufacturing value-added and exports has grown in almost all the emerging economies. According to OECD (2005), over 1999-2003, high technology products had the highest exports-production ratio and import-penetration rates. High-technology industries accounted for over 30% of all manufacturing exports in case of the USA, South Korea, the UK and the major EU nations. High-technology industries like electronic equipment and computers represents about 25% of total OECD trade and registered highest growth rates in manufacturing trade (OECD 2003a). Together with medium high-technology (transportation cluster, chemicals, machinery and equipment), the share is 65% of manufactures trade.[15] Below we present average annual growth rates[16] of global and regional trade in each of the clusters over the period 1965-2002, calculated from the GTAP database.

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[14] Nanobiotechnology is an emerging key technology of the 21st century and is a field of research which lies at the cross-roads of biotechnology and nanoscience (Niemeyer and Mirkin, 2004). It combines advances in science and engineering concerned with biological systems and nanostructured materials.

[15] OECD (2003), pg. 147.

[16] Average annual growth rates are calculated by Ordinary Least Square regression as follows: Suppose $X_t = X_0 (1+r)^t$ where X_t is the value of trade in any technology cluster X at the end of year t and t=1965-95, r is the geometric growth rate of X and X_0 is the value of X at the beginning of the period. Logarithmic transformation of the expression yields $\ln X_t = \ln X_0 + bt$ where $b = \ln(1+r)$. By regressing $\ln X_t$ on t, we obtain the least-square estimates b^* of b. Thus, average annual growth rate (r) is [*antilog* b^* -1].

[See Appendix Table 4]

Rise in volume of exports of technology-intensive industries is attributed to rise in investment in knowledge (i.e., R&D expenditures, software investment, human resources via higher education), especially in ICT sector, accounting for 5.2% of GDP in the OECD economies in 2002.[17] However, this has also been accompanied by closer integration of OECD and non-OECD countries leading to internationalization of R&D activities. Considering the trade in manufacturing exports, it is evident that the share of high-technology exports in total manufactured exports is higher for some RIE members than for many HIE members and for all LMIE members (Table 5).

[See Appendix Table 5]

According to OECD (2003a), in 2001 17% of global R&D expenditure is accounted for by the major non-OECD economies whereas in 2003 it grew up to 20%. For example, in case of China and India it is about USD 60 billion and 20 billion respectively in 2000-2001. OECD (2003a, 2005) documents that technology-intensive manufacturing and service exports have grown at rapid pace in OECD and major Asian non-OECD countries as well.[18] Concerted efforts by the government and policy reforms strengthening indigenous capabilities has led to rise in R&D-intensity in countries like China, Israel, Singapore, Taipei, etc. (OECD, 2006). From Table 6, we observe that both RIE and LMIE have registered relatively higher annual average growth in trade in technology clusters.

[See Appendix Table 6]

Not only that, it is pertinent to note that trade among the regional clusters of developing economies, RIE and LMIE, has also increased. This reflects considerable scope for South-

[17] It was 4.8% in 2000 (OECD, 2004).
[18] It has been documented that the growth in high-technology exports in the non-OECD rapidly developing economies has outstripped that in Europe and Japan.

South trade liberalization, via for example, proliferation of (preferential) regional trade integration, causing further enhancement in trade in technology-intensive products especially between upstream and downstream firms in the Southern trade partners. In this context, as argued by Fugazza and Robert-Nicoud (2006), this intra-South trade liberalization would promote ‘economic complementarities’ between complementary segments of production chain, and augment ‘supply capacity’ of the South to serve the Northern markets at lower prices. Schiff and Wang (2006) has explored such trade-related direct and indirect ripple effect of North-South and South-South technology diffusion.

For capture-parameter, AC is measured by skill-intensity such that $AC_{HIE} > AC_{RIE} > AC_{LMIE}$. We compute GP_{rs} from World Bank's data (Kauffman, Kraay, and Mastruzzi, 2003)[19] and TD_{rs} from R&D-expenditure as percentage of GDP (Human Development Report, 2003). For SA_s, we consider human development index (Human Development Report, 2003) with RIE as benchmark. Equations $(1)-(5)$ yield binary index SS_{rs}.

5. Results

We simulate 4% (exogenous) Hicks-Neutral TFP shock in IT-cluster in HIE (**identifier**: *GtapIT*). Such TFP-growth concomitantly catalyzes induced-productivity in recipients. Simultaneously, induced-spillover facilitates E-commerce and trade (**identifier**: *E-business*).

[19] These institutional quality indicators are: Voice and accountability, Political stability, Government effectiveness, Regulatory quality, Rule of law, and Control of corruption.

From Table 1, LMIE has highest region-wide trade-embodiment index (E_{irs}). Nevertheless, higher capture-parameter ($\theta_{RIE} > \theta_{LMIE}$) magnifies E_{irs} (0.21) in RIE to higher spillover-coefficient (γ_{irs}) (0.25) by 20% compared to LMIE (3%). Despite low θ_{LMIE}, with post-simulation technological benefits higher, γ_{irs} and E_{irs} translate into higher TFP and GDP growth in LMIE. In HIE, principal beneficiary of technological change, highest value of θ_{HIE} amplifies spillover γ_{ir} reflected in highest GDP and TFP-growth (Table 1). HIE reaps maximum productivity growth by sourcing relatively high proportion of its own ‘technological improvement-bearing’ input.

Table 1 here.

TFP-growth acts as an export supply shifter for each generic commodity. Regional output and global trade increase (Tables 1 and 2). This productivity growth and increased trade also translate into higher welfare changes in the regions experiencing higher spillover effects, namely, RIE and LMIE (Table 1). From Table 1, we infer that in all three regions the IT-induced technological progress and its effective assimilation has contributed significantly to welfare changes. HIE, the originator of technological breakthrough, has the highest total factor productivity growth, followed by RIE and LMIE. RIE, although capturing trade-induced spillover, cannot outperform LMIE as the latter has higher trade-embodiment indexes and resultant spillover effects.

Because of higher γ_{irs}, except IT- and TE-clusters, LMIE has higher TFP-escalation than RIE (Table 2). Higher θ_{RIE} appropriates higher embodied-spillover via IT into TE-clusters. However, higher E_{irs} with appropriate constellation of θ_{LMIE} enables LMIE to catch-up with HIE, illustrating growth-enhancing roles of both θ_s and E_{irs}. Following TFP-shock, inter-generic commodity competition, dominated by changes in relative supply prices and movements in price-relativities among the commodities, shapes regional composition of trade (Table 2). This is governed by the magnitude of the sectoral spillover coefficients. As expected, cost-reducing spillovers led to decline in supply prices (Column 9), causing rise in regional exports in product clusters (Tables 1, 2).

Table 2 here.

In Table 2, we observe that HIE and RILE has the higher revealed comparative advantage (RCA) in IT, followed by BT and NT clusters. On the contrary, in case of LMIE the clusters having higher RCA are NT and BT. However, following trade-induced technological spillover, as compared to RIE, LMIE has registered higher productivity growth in BT and NT clusters. Consequently, regional exports and imports have swelled in the clusters benefiting from the spillover effects via IT-intensity. This is confirmed by the major contribution of TFP changes in IT sector in HIE and LMIE, with relatively less pronounced effect in LMIE, the comparatively disadvantaged region in terms of productivity capture and its absorption.

For *E-business*-simulation, we focus primarily on the services (ITS-cluster) and TE-cluster. Ex-post, compared to 1.3% increase in *GtapIT*-scenario E-commerce (interchangeably, e-business) augments global ITS-usage by 2.3%. IT-led technology diffusion causes growth in regional GDP and TFP and fall in price of ITS-services (2.1%). Decline in aggregate export and import price indexes escalates regional exports, imports, ITS-sales, and welfare (Table 3). It is evident from Table 3 that E-commerce via IT-usage has contributed lion's share of regional welfare changes in the recipient regions, namely, RIE and LMIE.

Table 3 here

E-commerce penetration induces efficiency-enhancement in ITS-cluster and facilitates trade with higher sales of ITS-services to international transport and shipping (Tables 3, 4). Following the technology transmission, volume of exports, imports and sales of international transport services to global transport sector registered increase. It is to be noted that such IT-led penetration in logistics infrastructure led to augmentation of technical change in ITS-shipping by 4.5% and 14% in RIE and LMIE, respectively. Synchronization of customs procedure via E-commerce transmission, given by equation (14), translates into higher TFP indices in International Transport Services (ITS) and transport equipment (TE) sectors (see Table 4, below). Technical efficiency in shipping led to decline in inter-regional transportation prices for cluster-commodities, thus, contributing to rise in global merchandise trade (Tables 3 and 4). Thus, ICT-induced spillover, aided by adequate human resource development and institutional development, led to growth in international business. From last two columns of Table 4, we observe that RIE and LMIE have both been able to register an improvement in sectoral trade balances in the IT, Transport services and Equipment sectors except a negligibly small decline in case of LMIE in ITS-cluster. However, intensity of IT-usage and resultant E-business activities has led all these regions to register higher trade volumes (Column 7, Table 4) owing to fall in market prices of the composite imports and exports (Columns 8 and 9, Table 4). Technological spillover enables the regions to have cost-reduction reflected in decline in prices and changes in relative prices escalate global trade and international commerce in these technology-intensive products. This finding supports our hypothesis that information technology diffusion and development of other technology clusters facilitate E-commerce penetration, reduces transaction costs, and promote global e-business. Moreover, the results in Tables 1, 2 and 4 show that the technology transmission and absorption mechanism contributes substantially to welfare improvement of almost all the regions, with much pronounced effect being visible for the advanced Southern regions. Contribution of TFP escalation to welfare enhancement, as reported in the results, shows that trade-induced technology transmission and E-commerce improves global welfare. However, this is facilitated by endowments of human capital, good governance, social capital, and human resource development.

Table 4 here

6. Conclusion

Effective assimilation of trade-embodied North-South technology transfer induces TFP-growth. Additionally, IT-enabled E-commerce services facilitate greater embodied spillover and reduce transaction cost. Spillover capture, aided by human capital based adoptive capability, better governance and institution, causes increase in income and welfare. This accrual of benefits—contingent on constellation of absorptive capacity, education, socio-institutional features like governance, technological symmetry and social acceptance—could lead to sustained productivity growth and promote international business. The socio-institutional and structural parameters enable technology absorption, higher productivity growth, and hence facilitate global integration. Thus, the paper has policy insights for promoting better institutional framework, social structure, adequate human capital formation, and technology policy in conjunction with trade policy to foster economic growth. Proper constellation of skill-intensity, governance and structural-institutional factors aid technology capture and thus, enables South to catch-up. Fostering human capital formation, better governance and institutions is crucial for a successful international business strategy and for harnessing the potential benefits under globalization. The paper elicits the importance for catalyzing international competitiveness via R&D, human resource development, and development of logistics infrastructure-the sine qua non for a fruitful global business.

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Tables to be inserted into the Text

Table1: Simulated macro impact for GtapIT

Regions	E_{irs} / E_{ir}	$\gamma_{irs} / \gamma_{ir}$	θ_r / θ_s	SS_{rs}	**Regional TFP (% change)**	**Real GDP (% change)**	**Volume of Exports (% change)**	**Welfare (in million dollars)**	**Contribution of TFP in welfare Change**	**Export price Index**
HIE	0.1	0.55	0.82	1	2.6	2.1	1.1	472480.6	443041	-2
RIE	0.21	0.25	0.1	0.23	1.2	1.1	1.5	70962.8	64254	-2.1
LMIE	0.31	0.32	0.02	0.06	1.67	1.42	1.6	21430.9	18825	-1.9

Source: Author's simulation results

Table 2: Simulated sectoral impact for GtapIT

Regions	Sectors	Spillover Coefficients	Revealed Comparative Advantage	TFP growth (%)	Output supply	Regional Export	Regional Import	Export Price Index	Contribution of TFP changes to Welfare (changes)
HIE	IT	0.69	1.03	4	1.27	1.54	0.65	-2.6	50510
	BT	0.28	0.94	1.78	1.22	1.4	0.95	-1.8	2697
	NT	0.43	0.84	1.74	1.18	0.21	1.93	-1.6	17558
	TE	0.54	1.4	2.39	2.03	1.82	1.99	-2.4	10953
RIE	IT	0.42	1.06	1.65	0.44	0.81	0.28	-2.3	6652
	BT	0.14	1.02	0.55	0.88	0.33	1.54	-1.5	1881
	NT	0.24	1.04	0.95	1.74	2.87	0.78	-1.9	6001
	TE	0.31	0.6	1.22	0.47	0.81	0.5	-2.2	1415
LMIE	IT	0.4	0.4	1.64	1.25	-2.82	0.98	-2.1	710
	BT	0.41	1.45	1.6	1.48	2.76	0.7	-2.1	1656
	NT	0.35	2.25	1.39	1.82	2.07	1.43	-1.8	2389
	TE	0.28	0.22	1.09	-0.25	-1.08	0.91	-1.9	111

Source: Author's simulation results

Table 3: Simulated macro impact for E-business

Change in:	HIE	RIE	LMIE
Aggregate export price index	-1.7	-3.6	-3.5
Aggregate import price index	-2.5	-2.6	-2.7
Volume of exports	2.9	3.8	3.4
Volume of imports	3.8	2.4	2.9
Real GDP	1.9	2.3	2.9
Regional TFP	2.6	1.2	1.7
Technical change in ITS-Shipping	-	4.5	14.6
ITS-sales to International Transport	1.4	3.4	3.2
IT-embodiment in ITS	0.8	1.3	5.05
IT-capture in ITS	1	1.1	3.3
Contribution of Technical change via E-commerce (IT)	-	76073	19077
Welfare level changes (in million US $)	478116	128114	38218.8

Note: All rows except last four are in %-changes.

Table 4: Simulated sectoral impact for E-business

Regions	Sectors	Ecom-Penetration	Spillover Coefficient	TFP (%)	Revealed Comparative Advantage	Export	Export price index	Price of Composite Imports	Change in Trade Balance ($US million)	Contributio n to Welfare of Sectoral TFP (change)
HIE	IT	-	0.69	4	1.03	2	-2.5	-3.2	-11273.2	50477
	ITS	0.8	0.67	1.8	1.06	2	-1.3	-2	-4664	298395
	TE	0.8	0.54	2.4	1.36	1.6	-1.8	-2.3	-4405	10938
RIE	IT	1	0.42	4	1.06	4.1	-4.1	-5.5	10761	6954
	ITS	1.3	0.3	5.2	0.93	4.2	-3.2	-5	5106	40063
	TE	1.61	0.31	6.53	0.56	6.5	-4.1	-7.1	3121	1471
LMIE	IT	1	0.41	4	0.36	1.9	-3.8	-5.8	830	741
	ITS	1.25	0.36	5.05	0.91	3.7	-3	-5.1	-215	12008
	TE	1.54	0.3	6.3	0.22	4.2	-4.2	-7	1491	115

Source: Author's simulation results

APPENDIX

Sectoral and Regional Clusters

Appendix Table 1: Matching between GTAP regions and regional clustering

Regional Groupings	Constituents	GTAP Identifier (GSC1)
HIE	Australia	AUS
	New Zealand	NZL
	Japan	JPN
	Canada	CAN
	United States of America	USA
	United Kingdom	GBR
	Austria	AUT
	Germany	DEU
	Denmark	DNK
	Sweden	SWE
	Finland	FIN
	France	FRA
	Italy	ITA
	Netherlands	NLD
	Spain	ESP
	Switzerland	CHE
RIE	China	CHN
	India	IND
	Hong Kong	HKG
	Republic of Korea	KOR
	Argentina	ARG
	Brazil	BRA
	Indonesia	IDN
	Malaysia	MYS
	Mexico	MEX
	Turkey	TUR
	Philippines	PHL
	Singapore	SGP
	Thailand	THA
	Hong Kong	HKG
	Chile	CHL
	Taiwan	TWN
	Viet Nam	VNM
	Sri Lanka	LKA
	Rest of North America	XNA
	Colombia	COL
	Peru	PER
	Venezuela	VEN
	Uruguay	URY
	Rest of Andean Pact	XAP
	Rest of South America	XSM
	Rest of FTAA	XFA
	Belgium	BEL
	Greece	GRC
	Ireland	IRL
	Luxembourg	LUX
	Portugal	PRT
	Rest of EFTA	XEF

	Bulgaria	BGR
	Croatia	HRV
	Cyprus	CYP
	Czech Republic	CZE
	Hungary	HUN
	Poland	POL
	Romania	ROM
	Russian Federation	RUS
	Rest of Former Soviet Union	XSU
	Morocco	MAR
	South Africa	ZAF
	Rest of South African Customs Union	XSC
	Zimbabwe	ZWE
	Rest of SADC	XSD
LMIE	Rest of Oceania	XOC
	Rest of East Asia	XEA
	Rest of Southeast Asia	XSE
	Bangladesh	BGD
	Rest of South Asia	XSA
	Central America	XCA
	Rest of the Caribbean	XCB
	Rest of Europe	XER
	Albania	ALB
	Malta	MLT
	Slovakia	SVK
	Slovenia	SVN
	Estonia	EST
	Latvia	LVA
	Lithuania	LTU
	Rest of Middle East	XME
	Tunisia	TUN
	Rest of North Africa	XNF
	Botswana	BWA
	Malawi	MWI
	Mozambique	MOZ
	Tanzania	TZA
	Zambia	ZMB
	Madagascar	MDG
	Uganda	UGA
	Rest of Sub-Saharan Africa	XSS

Appendix Table 2: Technology clusters and 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 (1997), Science, Technology and Industry–Scoreboard of Indicators. pp.40-41.

Appendix Table 3: Concordance of GTAP sectors with technology clusters

Technology clusters	**Elements**	**GSC1 Identifier**
ICT Cluster	Electronic equipment Machinery and equipment nec Manufactures, NEC	ELE OME OMF
Consumer Goods	Sugar cane, sugar beet Plant-based fibers Crops nec Bovine cattle, sheep and goats, horses Animal products nec Raw milk Wool, silk-worm cocoons Fishing Bovine meat products Meat products nec Vegetable oils and fats Dairy products Processed rice Sugar Food products nec Beverages and tobacco products Wearing apparel Leather products Wood products Paper products, publishing Petroleum, coal products	C_B PFB OCR CTL OAP RMK WOL FSH CMT OMT VOL MIL PCR SGR OFD B_T WAP LEA LUM PPP P_C
Biotechnology Cluster (BT)	Paddy rice Wheat Cereal grains nec Vegetables, fruit, nuts Oil seeds Forestry	PDR WHT GRO V_F OSD FRS
Nanotechnology Clsuter (NT)	Coal Oil Gas Minerals nec Textiles Chemical, rubber, plastic products Mineral products nec	COA OIL GAS OMN TEX CRP NMM
Transport Equipment	Motor vehicles and parts Transport equipment nec	MVH OTN
Fabrication	Ferrous metals Metals nec Metal products	I_S NFM FMP

Services	Electricity	ELY
	Gas manufacture, distribution	GDT
	Water	WTR
	Construction	CNS
	Trade	TRD
	Transport nec	OTP
	Water transport	WTP
	Air transport	ATP
	Communication	CMN
	Financial services nec	OFI
	Insurance	ISR
	Business services nec	OBS
	Recreational and other services	ROS
	Public Administration, Defense, Education, Health	OSG
	Dwellings	DWE

Appendix Table 4: Annual growth rates for global trade in technology clusters, 1965-2002

Technology Clusters	Average Annual Growth Rates (%)
Information and communication technology	12
Consumer goods	9.1
Biotechnology Cluster	6.1
Nanotechnology Cluster	10.4
Transport Equipment	11.2
Fabrication	9.1

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

Appendix Table 5: Average annual growth rates for trade in technology clusters, 1965-2002

Technology Clusters	Average annual growth (%) in trade from		
	HIE	RIE	LMIE
ICT	10.24	21.2	18.3
Consumer goods	8.3	10.1	7.91
Biotechnology Cluster	5.6	6.9	6.2
Nanotechnology Cluster	9.98	14.3	8.87
Transport Equipment	10.67	23.2	17.33
Fabrication	7.61	12.4	10.04

Source: Calculated from the time-series trade data for the aggregated GTAP Database. Similar methodology (as in previous Table) is involved.

Appendix Table 6: Average annual growth rates for each region's bilateral trade in technology clusters, 1965-2002

Technology Clusters	**Average annual growth (%) in trade from**					
Source Region:	**HIE**		**RIE**		**LMIE**	
To Destination Regions:	**RIE**	**LMIE**	**HIE**	**LMIE**	**HIE**	**RIE**
ICT	12.4	9.03	21	17.8	18	23
Consumer goods	10.1	8.1	9.4	11.7	7.6	9.1
Biotechnology Cluster	6.7	7.5	5.7	10.3	5.02	9.9
Nanotechnology Cluster	11.7	8.9	12.9	17.5	8	13.3
Transport Equipment	11.3	8.4	27.1	22.4	16.7	16.9
Fabrication	9.8	6.7	11.2	15.03	8.2	16.6

Source: Calculated from the time-series trade data for the aggregated GTAP Database. Similar methodology (as in previous Table) is involved.