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Who leads and who lags? Technology Diffusion, E-commerce and Trade Facilitation in a model of Northern hub vis-à-vis Southern spokes

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Abstract

In this paper, advanced economies are aggregated into 'North' whereas 'South' comprises the less advanced ones. Trade induced technology diffusion is source of enriched technological contents. We also consider two scenarios: (i—"hub and spokes [HAS]") the North establishes separate bilateral FTAs with each South; and (ii—"FTASS") Southern economies jointly establish a full-fledged FTA with North. Simulations confirm that: (i) North- South and South-South trade-led technology diffusion induces TFP-growth; (ii) relatively less developed South catches up; (iii) three regions experience welfare improvement; and (iv) IT-enabled E-commerce facilitate trade. Public policies play role in catalyzing international competitiveness, innovativeness and absorption.

• **JEL classification:** J24, O31, O47, F43, C68

• **Keywords:** Technology diffusion, Trade facilitation, Capture, E-commerce, CGE model, Clusters

"*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.

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I. Introduction: A Brief Review of the Issues

How are the benefits of globalization seized by countries with contrasting trade, institutional capacities and development policy, and experiencing idiosyncratic growth problems? This paper investigates this research question in the light of the pithy remarks quoted above, concerning growth and development potential of information and communications technology (IT or ICT, interchangeably) as a general-purpose technology. Globalization opens up new opportunities in terms of trade in goods and services, sharing of ideas and availability of knowledge-capital. For example, the success stories of emerging Asian and some Latin American countries show that combination of technological competence, upgrading skills via human capital to undertake complex capital, and skill- and technology-intensive activities breaks the barriers of industrial growth. Comparatively disadvantaged groups, like the Sub-Saharan Africa and other underdeveloped regions, lag behind these early leaders and are not well-prepared to take advantage of the E-economy because of inability to create enabling 'systems of learning and diffusion' encompassing human capital base, institutions, technological infrastructure (Lall 2001; Kenny, 2003).

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'.

Amongst the multitude of potential benefits associated with liberalized trade, the aspect of trade-induced knowledge spillover is discussed at length. Compared to the developed North, Lall (2001) analyses, the South has increased its exports in technology-intensive manufactures, with high technology manufactures claiming largest share. However, trade in technology-intensive products exhibit disparate regional concentration. For example, while East Asia and Latin America register growth in high- and medium-technology exports, except India's software boom South Asia does well in low-technology products, with Africa being relatively much laggard in exports of dynamic products. However, with rapid pace of economic integration via trade economic growth of a country is very much influenced by the trade partners' economic growth. Considering a panel of 101 developing and industrial economies, Arora and Vamvakidis (2004, 2005a) has shown that the United States (US) being a major 'global engine' and among the 10 most important trading partners, economic integration with the developing South has led to substantial growth spillover. In case of 'regional engine' like South Africa in the African continent, Arora and Vamvakidis (2005b) has shown that a 1 percentage point increase in South Africa's growth rate is associated with a 1/2-3/4 percentage point increase in growth rate in other African economies. It can be envisaged that South-South trade, via cross-regional growth-spillover, could foster economic growth in the least-advanced South- see for example, Barro and Sala-I-Martin (2002), Sachs and Warner (1995), Stiglitz and Charlton (2005).[1]

However, it is clear that in the new economy better information network is necessary for realizing the potential benefits of North-South and South-South trade. In this context, the role of ICT as general-purpose technology (GPT) can no way be overstated. 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).

Another important feature of ICT-diffusion that needs attention is that technological infrastructure enhances trade facilitation and efficiency of transshipments of goods (Stiglitz and Charlton, 2005; Hertel et al., 2001). Geographical distance, volumes of trade, market access, logistics infrastructure and income work in tandem for facilitating trade. Under the 'new-age' Free Trade Agreement (FTA), role of E-commerce and customs automatization are important forces reducing time lag of delivery of goods and the administrative costs. By fostering efficient supply chain management, diversification of global production processes, and logistics of trans-border movements of products, ICT enables higher volume of E-commerce. We elicit the role of technical efficiency in trade facilitation as import-

[1]The nexus between domestic growth and relative income level and the growth rate of the trading partners has been discussed at length (e.g., Panagariya (2004), Frankel and Romer (1999) Schiff and Wang (2003, 2004), Lederman et al. (2003)). With the proliferation of trade agreements, economic growth and developments in a given region becomes closely related to developments taking place abroad.

augmenting technological change in global Transport Services.

While ICT has profound impact on economic benefits, ICT- fetishism is no panacea (Grace, Kenny and Qiang 2004). According to Stiglitz (2003), "globalization can be a very powerful force for developing countries, enabling the technology gap and the knowledge gap that separates the developed from the less developed countries to be overcome." Nevertheless, he stresses the role of "fundamental reforms in the institutions and in the policies governing globalization." Accrual of benefits from trade and technology depends on a whole host of factors accounting for local conditions, like human capital, structural congruence, socio-institutional features (Das 2003; Stiglitz and Charlton 2005; Grace, Kenny and Qiang 2004). In particular, government policies could shape the region-specific investment climate by proper choice of policy instruments influencing infrastructure, property rights, governance features, scarcity of tertiary human capital, weak institutional capacity, and other pertinent socio-institutional features inhibiting spread of e-commerce in the LDCs (Kenny 2003).[2]

Developing strong local capabilities and absorption capacity (AC) for assimilation of cutting-edge research require skill formation via educational attainment. Lall (2001), gathering evidences on 'tertiary enrolments in core technical subjects' as indicator of human capital necessary for 'export dynamism', has inferred that in this respect the rapidly emerging economies outpaced others like Africa-the 'outsider' South-in skill acquisition and developing R&D capability. 'Outsiders' to the process of technological dynamism fail whereas the 'insiders', developing 'capability' base by investing in human and social capital, evolve as leaders. As argued by Stiglitz (2003), for better-designed institutions and intellectual infrastructure, "[one] needs to have a coterie of individuals who are able to absorb knowledge, translate that knowledge, and adapt the knowledge."

We develop a North-South Computable General Equilibrium Model (CGE) of technology transfer (based on a global trade model (Hertel ed. 1997)). In this paper, advanced economies are aggregated into 'North' whereas 'South' is the agglomeration of relatively less advanced ones. North', as a group, is more amorphous (homogeneous) in terms of composition and advancement. The Southern composite region is further disaggregated into two regions- a 'developed South'

[2]On the basis of Investment Climate Surveys conducted at the firm level for 26,000 firms in 53 developing nations and the World Bank's 'Doing Business Project' benchmarking different indicators for regulatory regime for 130 countries, World Development Report (2005) looks at variations in investment climates across the world and their perceived influence on growth and poverty across nations.

and the relatively laggard (but upcoming) countries of a ‘less-developed South’ based on their growth and development episodes. The performances of the newly industrialized economies, however, are as mixed across these nations in the developing South as are the heterogeneities among them.

Also, the recent proliferation of bilateral agreements has created a number of “hub-and-spokes” configurations: i.e., one economy becoming a “hub” by establishing bilateral agreements with a number of smaller nations (the “spokes”). In this paper, more specifically, we consider two scenarios: (i-the “*hub and spokes*” scenario) the North establishes separate bilateral FTAs with each economy in the Southern Hemisphere; and (ii-the “*FTA*” scenario) both Southern Hemisphere economies jointly establish a full-fledged free trade area with North.

In particular, this paper studies the impact on welfare, efficiency and produc- tivity of South via trade-induced technology spillover from the North. The paper, as it unfolds, is divided into six sections and a concluding section. Analysis of the issues intrigued further discussions on economic structure, synergy between geographical and technological clusters in section 2. Logical extension of the arguments led to a model development in sections 3 and 4. Section 5 documents the parameters. Simulation experiments are analyzed in sections 6 and 7. Section 8 concludes.

II. A North-South Perspective on Technology Diffusion: Literature, Stylized Evidences and Theory

A. Prior Work and Trade-embodiment Hypothesis

Role of technology for achieving economic growth is well discussed in the literature. Modern economic growth is led by innovations in biotechnology (foods and medicines), transportation, materials (nanotechnology), and communications infrastructure (ICT). Acquisition of state-of-the-art technologies invented in the industrialized nations (North) by the developing economies (South) is a dominant mode of fostering productivity growth. Trade-mediated technology spillover enhances knowledge propagation via sophisticated imported equipment and communication network (Coe et al., 1997; Keller, 2004; World Development Report, 2005; Hoekman and Javorcik eds, 2006; Grossman and Helpman, 1991; Schiff and Wang 2006). Regional spillover of innovative output depends on close proximity of technologically interdependent industries and regional network of innovators (Feldman, 1994; Jaffe et al. 1993; Baptista, 2001). Trade acts as a conduit for networking between regions separated geographically. This paper postulates a trade-embodiment hypothesis: trade facilitates the acquisition of know-how embedded in goods. In other words, mediated by trade-induced spillovers regional clustering of industries located in advanced and semi-advanced nations can have strong positive effects on catalyzing knowledge transfer, collective learning within geographical territory, adoption, and resultant growth in the recipient clusters in hosts.[3] Falvey, Foster, and Greenaway (2004) have found that both exports and imports act as sources of R&D-spillovers for a range of 21 countries with imports being the dominant channel.

For technological advancement of developing countries, the development of appropriate technology and its actual use in production depend on a host of issues related to social and economic structure (Sen, 1999). Regional variations in adoption of diffused technologies are explained by epidemic or learning effect, interpersonal networking between producers and adopters, spillovers or knowledge-sharing (Baptista, 2001). According to World Development Report (2005), "Recent research has emphasized that TFP can also be understood to encompass more than just differences in technology. The broader environment in which firms operate matter too, whether this is understood in terms of property rights, institutions, or the investment climate (ibid., p.29)." Recent empirical evidences show that China and India have achieved considerable progress in creating better investment climate by improving upon the institutional and infrastructural bottlenecks (World Development Report, 2005). Thus, government support in fostering a skilled workforce by investing in human capital and making education more inclusive has high development dividends.

In the technology diffusion literature, plethora of studies considers the dynamism of the broad industrial clusters and spatial dissemination of knowledge across geographical clusters. In what follows, we describe some stylized facts based on the cluster database that we construct for our model.

B. Regional and Industrial Clusters: Database and Stylizations

In the technology diffusion literature, the dynamism and technological compe-

[3]Different models of diffusion adopt different approaches in treating learning effects and information on nature of technologies. Disequilibrium approach harps on the assumption of information asymmetries whereas in equilibrium approach, perfect information about the nature and existence of new technology is assumed. Baptista (2001) adopts a combined approach for modeling choice of an optimal adoption time. Given different focus of our research, we do not discuss these micro aspects in our current research. FDI is another conduit of technology diffusion. However, primary focus being spillover capture relative merits of two channels are not discussed.

titiveness 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.[4]

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

[4]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.

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.[5] 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 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.

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[6], 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

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[5]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.

[6]The manufacturing sector is the source of innovation via R&D with spillovers to other user sectors.

[7]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.

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

Table 1. Continued

Regional Groupings	Constituents	GTAP Identifier (GSC1)
RIE	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

trade (Guerrieri and Milana, 1995; Martin et al., 1997).[7] 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

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

determine '*technological criteria*' for the industries.[8] 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).[9] 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.[10] ICT services, based on ISIC, Rev 3., are separated in 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*

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

[10]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.

[11]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.'

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.

clusters following the OECD (1996, 1997, and 2004) taxonomy.[11]

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).[12]

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 atomic scale to invent new products, it has applications in every field.[13] 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-

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

[13]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.

Table 3. Concordance of GTAP sectors with technology clusters

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

2002 as well as complete intersectoral transactions for 2002. Following is the mapping of the GTAP sectoral classification (GSC1) to the technology clusters.

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.[14] Below we present average annual growth rates[15] of global and regional trade in each of the clusters over the period 1965-2002, calculated from the GTAP database.

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.[16] However, this has also been accompanied by closer integration of OECD and non-OECD countries leading to internationalization of

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.

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

[15]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].

[16]It was 4.8% in 2000 (OECD, 2004).

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.

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).

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.[17] Concerted efforts by the government and policy reforms strengthening indigenous capabilities has led to rise in

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.

[17]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.

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.

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-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.

We consider core Information Communication Technology (ICT) cluster, and transmitted benefits to user-clusters—Bio-technology (BT), Nanotechnology (NT), Transport Equipment (TE), Fabrication (FT), Consumption Goods (CG) and International Transport Services (ITS)—all exhibiting higher growth in trade. Growth resurgence in the second part of the 1990s has largely been attributed to the capital deepening and accelerated pace of technological change, aided by diffusion of ICT as a general-purpose technology (Oliner and Sichel 2000; Jorgenson and Stiroh 2001; Basu et al., 2003). Not only that, Stiroh (2004) has found growth enhancement in ICT-using, especially IT-intensive sectors as well.[18] This has been supplemented by educational attainment and improvement in the quality of capital and labor. Globally, the projected growth rate of this sector is 6%, and with higher R&D-investment spending, there are immense prospects for sustained growth in both OECD areas and emerging non-OECD nations like China, India, Indonesia, Russia, and South Africa (OECD, 2006b). Moreover, the sector has experienced 'global restructuring' as the production and export locations have shifted to developing economies like China, India, Korea—growing more rapidly than the developed nations—who are cost-efficient, focusing on low-value process, and

[18]Accroding to Stiroh and Jorgenson (2000), a sector is said to be IT-intensive if its IT-investment in total investment is more than the threshold 50% in the ranking of IT-intensity sector. Using this criterion, both services (Financial intermediation, Business Services, Wholesale and Retail Trade) and manufacturing (Machinery and Equipment at large, Printing and publishing, Wearing apparel, dressing and dying of furs) sub-sectors are included in the IT-intensive sectors.

shifting gradually to high-value processes. Consequently, trade in ICT goods has surpassed total trade especially in OECD—compared to 3% growth in total merchandise trade total ICT goods registered an annual compound growth rate of more than 4% between 1996 and 2002 (OECD, 2004b). OECD (2006b) reports that the share of such goods in total merchandise trade is 13.2%. There has been surge in the ICT-enabled services like wholesale and retail trade, finance, and telecommunications with increase in efficiency and productivity (Stiroh 2001; Pilat and Lee 2001). For example, Rapidly Industrializing Economies (RIE) like India and China account for 6.5% of exports and 5% of imports of computer and information services and other services (OECD 2006b).

There has been widespread diffusion of ICT in ICT-producing and ICT-user firms (Cette, Mairesee, and Kocoglu 2005). In fact, ‘firm-level evidence suggests that effective diffusion and use of ICTs are key factors in broad-based growth when combined with effective human resource strategies involving education and training and organizational change’, reports OECD (2004b). It is true that ICT production has benefited from technological advancement (e.g., in manufacturing semiconductors or electronic components) and has been the main driver of growth, trade and employment in most of the countries; however, as an enabler, it has ripple effect on ICT-using sectors - namely, the services sector and non-ICT high technology manufacturing sectors, non high-technology sectors such as petroleum and coal products, oil and gas extraction, mining (OECD 2004b, p.57). The largest rises in trade are registered in ICT-related services such as communications. Substantial growth in trade in services are predominantly “business services” comprising a heterogeneous group of activities such as telecommunications, software development, database management, financial services, construction and engineering—to name a few. In this context, it is pertinent to note that due to the potentials for appropriation of the maturing ICT-cluster in other sophisticated product categories, there are several emerging ICT-based technology applications that underpin the widespread benefits of ICT as a GPT. According to OECD (2006b), via spin-off effects ICT facilitates interconnectedness and convergence of diverse technological applications including Neurotechnology and biotechnology.

Concomitant with ICT-developments, recently NT is the most rapidly growing sectors with considerably high share of R&D-funding (293 million USD in the US, 210 million USD in the EU and 190 million USD in Japan) and registering almost 11% annual growth in trade (Table 4). From Tables 4 and 5, we see that global trade in ICT manufacturing registered the highest growth rate, followed by the NT, BT, transportation and fabrication clusters. According to *World Development Report* (World Bank 2000, pp.64-65), "During 1994-97, world exports of services grew by more than 25 percent. … In addition, the rise of electronic commerce has created new possibilities for trade in services." E-business, defined by OECD (2004) as 'ICT-enabled intra- and inter-firm business processes over computer-mediated networks', underpins the presence of ICT-based network technologies and industrial globalization. Quite evidently, technological infrastructure promotes trade facilitation via, for example, market access, logistics infrastructure, port efficiency and favorable customs procedure that work in tandem to eliminate iceberg-type transaction costs (Wilson et al., 2005). For example, just as the technological change in the international transport (transoceanic and air) and distribution has spurred trade among nations in the 19th century, similarly, ICT-enabled internet has led to globalization of E-commerce in the 20th century. Following section documents such evidences and explores the lacunae in its formal treatment.

C. E-commerce and Trade Facilitation: A View through Technology Lens.

ICT-enabled integrated business processes is accompanied by changes such as streamlining of business processes via rapid use of sophisticated information technology, transformation of the value chain via outsourcing, global sourcing, networked organization, use of e-business software. In particular, many emerging economies (especially in Asia) are in the process of establishing themselves as regional B2B E-commercial hubs by linking suppliers and customers across borders. However, there is lack of agreement for harmonized definitions and concepts in measurability of e-commerce and this involves conceptual difficulties (OECD 2005). In this paper, we adopt the definition proposed by OECD (1997, 2000, 2003b) to include any commercial transactions (B2B, B2C, and C2C) taking place over networks facilitated by ICT-technologies.[19]

Economic and social implications of such e-commerce revolution are enormous. This is due to several effects such as: extending the local businesses to global marketplace, opening export markets to firms in developing nations for trade in goods and services, improving efficiency of firms via cost saving and reduction of inventory costs (Grace, Kenny and Qiang 2004). IT-use leads to cost savings in the

[19] VanHoose (2003) has distinguished between the terms, e-business and e-commerce, by referring to intranet transaction within an organization as a salient feature distinguishing the former from the latter. We do not make such distinction.

form of B2B E-commerce (Brookes and Wahhaj 2000). The sources of cost-savings are: cutting down of internal processing and paperwork costs of purchasing inputs, reduction of inventory cost via just-in-time inventory control, elimination of intermediaries, reduction of input prices. In this context, TradeNet or electronic data interchange (EDI) system, a B2B transaction mode, introduced by Singapore in 1989 for processing trade documents reduced substantially the bureaucratic trade-processing costs by almost 50% (VanHoose 2003). E-business has grown in volume in such a way that it involves transborder exchange of values between businesses via for example, Electronic Fund Transfer (EFT), and network infrastructure. Electronic-commerce-led customs automization shapes global trade logistics (Hesse and Rodrigue 2006; Hertel et al., 2001). E-business makes firms more competitive—increasing labor productivity growth, improving efficiency in procurement, and inducing operational efficiency (OECD 2004, 2003, 2006; Motohashi 2003; Clayton et al., 2003). For firms with skilled workforce, human resources, and organizational changes the E-business applications have higher dividend payoffs in terms of improved communications, productivity, reduced cycle times, online procurement, saving on procurement costs (OECD 2004).

Enabling technologies such as ICT and transportation has paved the way for new forms of global competition via ‘Global production networks’ (GPN) and ‘Global Commodity Chains’ (GCC), which shape the interrelationships between global and regional trade and production processes. In fact, plethora of evidences exist on ‘geographical and functional integration of production, distribution, and consumption’ due to factors such as, regional trade agreements, global institutions like WTO, containerization, transforming port-cities into global mega-hubs (Hesse and Rodrigue 2006). In particular, it has been argued that this aspect of transportation, logistics, and freight distribution in facilitating GPN and GCC has not been given due emphasis and also, explicitly linking them with globalization of technologies via ICT has been ignored by the economic and transport geographers, thus, understating the tremendous progress in E-business, multi-modal transportation and logistics networks facilitating global trade. Trade facilitation is part of such logistics. It is a key factor for GPN and E-commerce underpins it via automated, streamlined customs procedure and shedding of bureaucratic, administrative costs. Hence, *geography of production* and *geography of distribution* needs reconciliation linking production technology with technology-induced changes in trade logistics. Also, ‘institutional changes within the logistics industry’, for example, in case of containerization, EDI, port operations, need to be given its due focus (Olivier and Slack 2006).

The factors, which are generally responsible for sustainable economic development, are adequate institutional base favoring business climate, network and spillover effects, governance, and 'adaptation close to local usability' (Qiang and Pitt 2004). Regulatory framework, rule of law, and governance complements adequate communication infrastructure. Because these new emergent applications are complex in terms of risk and uncertainty in development, 'the interaction of technological opportunities, commercial development, social acceptance and use will ultimately determine which innovations and applications become widespread', mentions OECD (2006b). Low level of human capital and human development are formidable obstacles to uptake and diffusion of new technologies. All these factors conjointly underpin productivity growth in the developed and emerging economies alike. We now probe beyond the stylized cluster analysis to provide a theoretical structure to enunciate the principal pathways of technology acquisition and trade linkages of clusters.

III. Model of Technology Diffusion

Superior technologies of current vintages are researched in the HIE (i.e., North). RIE and LMIE have depended on HIE. Mode of access to foreign technology is imports as well as exports (Falvey et al., 2004). Traded intermediates ferry the knowledge-capital embodied in the commodities produced with new 'ideas' (Eaton and Kortum, 1996; Navaretti and Tarr, 2000; Schiff and Wang, 2004). Self-propellant inventions in IT are GPT inducing technical change via spillovers to other recipient clusters (Linstone, 2004; Meijl and Tongeren, 1998; OECD, 2000). However, as mentioned in Section 1, several factors are necessary for creating an enabling broader environment for usefulness and speed of diffusion of ICT. Liu and San (2006) has discussed the importance of economic and social factors facilitating 'social learning' of technology. In particular, based on social learning theory they identified several factors—viz., political stability and free of violence, degree of urbanization, adult literacy, ability to use English, costs of internet access, and openness to trade—conducive for penetration and perceived usefulness of ICT.

We reserve 'r'($r = HIE$) and 's'($s \in RIE, LMIE$) respectively for the source (unique) and recipients of technological change. The direct channels are diffusion through North-South interactions, namely, between HIE-RIE and HIE-LMIE. In the same vein as Schiff and Wang (2006), there are indirect channels of technology diffusion, namely, (i) the transmission of trade-related HIE-RIE to LMIE via RIE-LMIE trade, and (ii) the transmission of trade-related HIE-LMIE to RIE via LMIE-RIE trade.[20]

Also, Southern growth depends on the extent of technology propagation 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; Das, 2002). Adaptation and absorption for local use are important factors for technology diffusion. To maximize the spillover effects, solid pool of skilled workers is necessary. Also, IT, BT and NT cluster improve health facilities and contribute to a healthy population who could potentially absorb the new technologies. In particular, all these help storage and transmission of data, monitoring, publication and dissemination of research (Grace, Kenny and Qiang, 2004). All these are captured by the region '*s*' specific AC_s index ($0 \le AC_s \le 1$).

Successful economic development depends on institutional development such as regulatory framework for an ICT-firm, mentions Qiang and Pitt (2004). Not only that, ICT itself could empower a civil society and facilitate decision-makers for acquisition and management of policy information. As argued by Grace, Kenny and Qiang (2004), it enhances decision-making and provides transparency in the apparatus for appropriate public administration and its accountability. Thus, spillover adoption depends, *inter alia*, on institutional factors like political stability, good governance, and intellectual property rights (Schiff and Wang, 2004, Liu and San, 2006). Transmitted technology delivers benefits if the level of governance quality of source vis-à-vis destinations is optimal (Groot et al., 2004). Institutional quality is indicated by a binary governance parameter, (GP_{rs}, $0 \le GP_{rs} \le 1$) as:

$$GP_{rs} = \min\left[1, \frac{GP_s}{GP_r}\right] \tag{1}$$

If $GP_s > GP_r$, it enables '*s*' to utilize the technology effectively. Domestication of foreign technology depends on indigenous inventive capabilities and techn-

[20]Multiplicity of source of knowledge-creation is not considered in the present research. The primary emphasis being the technology transmission from the developed to the least-developed economies, the trade-mediated technology spillovers via direct and indirect channels capture the possibilities of diffusion from LDCs to DCs on an *ad hoc* basis. Modeling aspects of technology flow from developing to developed nations are of considerable interest and could be modeled in future research extension. However, as we do not model the mechanism of knowledge creation per se, it does not undermine our purpose.

ological infrastructure (R&D expenditure) in '*s*' (Bayoumi et al., 1999). Accordingly, a bilateral technological-proximity parameter, $0 \le TD_{rs} \le 1$, between source and '*s*', is constructed as:

$$TD_{rs} = \min\left[1, \frac{TD_s}{TD_r}\right] \tag{2}$$

Socio-cultural affinity determines trading nations' structural symmetry. Social cohesion and acceptance of 'new' technology is assumed to depend on human resource development—specified via region-specific 'social acceptance' parameter (SA_s) by:

$$SA_s = \min\left[1, \frac{SA_s}{SA_{threshold}}\right] \tag{3}$$

Cultural or structural homogeneity and technological proximity are interlinked. For two socio-culturally homologous trading nations, there is considerable scope for appropriating the potential spillover. Thus, a larger magnitude of SA than the threshold level is conducive for technology acquirement by destination '*s*' ($0 \le SA_s \le 1$).

Conjointly, 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' efficiency in appropriating trade-embedded spillovers from *unique* '*r*':

$$SS_{rs} = GP_{rs} \cdot TD_{rs} \tag{4}$$

$$\theta_s = AC_s \cdot SA_s \cdot SS_{rs} \tag{5}$$

Actual productivity level depends on $\theta_s \in [0, 1]$, $\theta_s = 1$ implies full absorption.

One of the crucial aspects of globally integrated production process is that imports, sourced from affiliated or non-affiliated firms of the exporters, are necessary for production of exportable. Typically, import content of exports are measured using input-output tables –capturing the interlinkages between producers and users of goods and services, where embodied imports comprise total direct and indirect imports (OECD, 2003a). 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,

$$E_{irjs} = \frac{F_{irjs}}{M_{ijs}} \tag{6}$$

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

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

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

where primes indicate first and second derivatives of E_{rs}. Source '*r*' reaps technological spillover via inputs embodying technology so that:

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

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:

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

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

TFP transmission equation for '*s*' is:

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

where aca_{ir} is an exogenous TFP improvement in sector '*i*' of '*r*'(*unique*) and ava_{js} is the induced endogenous TFP percentage-change in TFP $[i \neq j, r \neq s]$. We assume that invention in IT-cluster translates into induced-innovation in user-clusters (e.g., BT, NT). Such a mechanism is invoked via:

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

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

IV. Mechanism for E-commerce and Trade Facilitation

Globalization of E-commerce and customs automization is aided by investment in IT industries and spillover. E-commerce adoption improves commodity shipments, port efficiency, and streamlined customs procedure (e.g., electronic trade document exchange system, ETDS), reduced 'bureaucratic trade cost'. With E-commerce penetration, the estimated reduction in wholesale retail margin is 4.9% as compared to 19.6% in the absence of E-business.

Following the idea of gravity model, we see that the cost of distance is the delay in delivering the final and intermediate goods in time to the destinations. More specifically, if the transaction cost is high then it creates obstacles for the trading partners to interpenetrate their markets. Along with that, inadequate infrastructure and relatively underdeveloped service sector create impediments for harnessing technological benefits. If criterion of proximity is prime factor, then for neighborhood countries with similar resource-endowment the scope for integration is enhanced by lowering of transaction costs. Even with differences in terms of factor endowments, lowering transaction costs can facilitate trade flows. By forming FTAs between the Souths (*FTASS*), lower transport and associated costs via uniform reduction in the trade barriers, LMIE will not suffer as some sophisticated manufactures previously imported from HIE will now be imported from RIE; thus, generating gains to LMIE from relocation of supply. ETDS specifically speeds up efficiency in shipment by reducing waiting time (direct effect) and indirectly eliminating inventory holding costs and spoilage (Hummels 2000; Hertel et al., 2001).[21] This value of transaction cost savings is product specific with high values for intermediate goods like 0.51% per day for machinery and other equipment and 0.94% for petrochemicals whereas low value for bulky products (Hummel 2000). Thus, aided by IT, the higher the penetration rate of such technologically superior procedures of processing commercial transaction, the lower will be the non-tariff trade costs due to fall in margin (wholesale-retail) and thus, the higher will be trade facilitation resulting in technology transfer.

Depending on the technological advancement in a high-tech sector and its penetration rate there will be reduction in average effective price due to technical efficiency. To capture this effect, we consider efficiency enhancing technical change in a sector '*i*' in region '*r*' exported to region '*s*' [ams (*i*, *r*, *s*)] which induces concomitant technical efficiency in the transportation of goods using it as intermediate from source '*r*' to recipient '*s*'. In particular, we consider an import-augmenting technical progress (assumed to be exogenous) in IT-sector. This induces *endogenous* technical efficiency in '*i*' for transaction costs related to shipment from '*r*' to '*s*' [atmfsd (*m*, *j*, *r*, *s*)], depending on the extent of its penetration rate (penetration parameter) and the quantity of sales (exports) of a good to the transport sector for shipment from '*r*' to '*s*' per unit of output of that sector.

[21] Accroding to Hertel et al. (2001), ETDS led customs automization in Japan would reduce effective merchandise prices for trade partners by 0.20%. This time saving varies across products as has been studied by Hummels (2000).

In GTAP model, there is a global transportation sector assembling regional sales/ exports of trade, transport and insurance services via a Cobb-Douglas production technology to produce a composite homogeneous transport good for moving merchandise across the borders (Hertel and Tsigas, 1997). Specifically, to facilitate shipping this transport good is used in fixed proportion with the volume of shipment of a good along a specific route. Therefore, any technical efficiency [ams (*i*, *r*, *s*)] in commercial transactions along a specific commodity '*i*' or route will lead to decline in transaction cost and hence, will result in technology diffusion in the destinations '*s*' from source '*r*'. Any augmentation in ams (*i*, *r*, *s*) will lead to higher exports of goods '*i*' from region '*r*' to '*s*' [qxs (*i*, *r*, *s*)] for a given transportation service of commodity '*i*' from '*r*' to '*s*' [qts (*i*, *r*, *s*)].

ICT, *ipso facto*, does not promote trade. It depends on the extent of social acceptance (SA_s) of technology-based business modes and technological symmetry (TD_{rs}) Cultural or structural homogeneity is closely related to geographical proximity (see Linneman (1966), Rauch (2001)). E-commerce adoption depends on IT infrastructure and education for accessing such facilities (Panagariya, 2000).[22] IT-intensity in clusters (*j*) in '*s*' is:

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

where

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

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

Synchronization of customs procedures depends on the extent of E-commerce penetration between North (*r*) and South (*s*)[Ω_{ijrs}]:

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

E-commerce transmission to '*j*' in '*s*' is given by:

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

where $\omega_{rs} = SA_s \cdot TD_{rs}$, and ams_{jrs} is percentage-change in import-augmenting technical progress for '*j*'$[i \neq j]$ in '*s*'$[r \neq s]$ induced by ava_{ir}.

With technological change like containerization of international trade, given the shipping-route ITS freight charges shrink due to global trade facilitation via 'intermodalism' (Hummels and Skiba, 2002). Technological spillover from IT-

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

cluster to ITS-cluster induces commodity-cluster- and route-specific input-augmenting technical change via intensity of IT-usage in margin commodity (services). This trade facilitation causes price reduction in services '*m*' by lowering *CIF-prices* implied by a given *FOB value*.

Technical change in shipping '*i*' from '*r*' to '*s*'($atmfsd_{mjrs}$) depends on IT-cluster intensity in '*m*' and share of '*m*' in transshipment cost of '*i*' (i.e., ITS-intensity) – Ξ_{imrs}– ratio of foreign-sourced IT-intensity into '*m*'[S_{imrs}] and services '*m*' usage into '*s*'[T_{ms}]:

$$\Xi_{imrs} = \frac{S_{imrs}}{T_{ms}} \tag{15}$$

Now, the ratio of Ξ_{imrs}(*unique* '*i*') and margin m's share in cost of delivering '*j*' from '*r*' to '*s*'[V_{mjrs}] gives service-embodiment [Φ_{mjrs}]:

$$\Phi_{mjrs} = \Xi_{imrs}/V_{mjrs} \tag{16}$$

E-commerce based productive-efficiency capture [Θ_{mjrs}] is written as:

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

The transmission equation for trade-facilitation is given by:

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

V. Methodological Framework, Database and Parameters

An augmented version of Computable General Equilibrium (CGE) trade model Global-Trade-Analysis-Project (GTAP) (Hertel, 1997) is solved using General Equilibrium Modeling Package (GEMPACK) software (Harrison and Pearson, 1996).[23] The modeling framework is an extended version of the GTAP comparative-static global trade model with regional details of the global economy (Hertel 1997). It belongs to the class of comparative-static CGE models similar to the Australian ORANI model (Dixon et al., 1982). It is to be noted that particularly the issue of technological change and trade policy will affect the production decisions. Investments in technological change and incurring cost for E-commerce will depend on the aspect of profitability. This, in turn, depends on the rate of return on investment. In other words, R&D, production and growth depends

[23]Data, equations, parameters, computer coding and model TABLO are not reported for parsimony.

crucially on TFP-dynamics. Depending on the movements of rates of return, capital flows in and out of the participating regions. However, in our analysis the issue of capital mobility and investments has not been considered. Although technology transfer and its dissemination could be linked to dynamic changes in productivity, a comparative-static simulation traces adequately the technology-induced effect between control scenario and the post-shock simulated period.[24]

The model has a detailed specification of demand and production structures, inter-regional and international trade, and consumer welfare. Typically, it has a nested production and utility structure with flexible functional forms. The model is based on the microeconomic foundations, providing a detailed analysis of consumer (household) and firm behaviors within the individual regions and trade linkages between the participating regions. Perfect competition is assumed in the markets for factor inputs and outputs. The model and database are suitable for analyzing the effects of issues such as technological change, trade liberalization, and e-business.

On the demand side, each super-household (a representative regional decision-maker), at the top-most level, maximizes Cobb-Douglas utility, subject to overall regional income split between private and public households and regional saving. This derives private and government households demand for goods. Allocation of income allocation over consumer demand for commodities sourced from various regions takes place in four stages. The utility-maximization behavior fosters demand equations for private consumption, government consumption and savings. The second stage allocates government expenditure across commodities sourced domestically, abroad and from other domestic regions. Thus, the third stage allocates this demand across domestic, imported and intra-regional sources. The final stage allocates these imported goods across regions.

Producers combine intermediate inputs along with primary factors of production. The derived demand for primary factor inputs is based on profit-maximizing (or dual cost-minimizing) behavior of firms. Armington (1969) assumption differentiates commodities based on their origin of production. Aggregate regional investment in making new capital goods is given by the output of a non-traded "capital goods"

[24] In particular, incorporating technology-creation by R&D-effort in the appropriate sector would allow us to pursue rigorous analysis of technical change. Incorporating research effort into producer's decision-making process (unlike treating it as exogenous policy shifts) would impart valuable insights. Although the model has basic ingredients for consideration of such issues, it needs to be further fine-tuned for richer dynamics of technical progress. These issues are reserved for further research agenda.

sector, which involves the use of intermediate inputs only. As the model is short-run in nature, capital supply is fixed in each sector during the simulation period.

At the top level, a composite output is produced with a Leontief fixed proportion technology using intermediate inputs and a primary input composite with no scope for substitution. Each intermediate input is produced in a Constant Elasticity of Substitution (CES) production nest using ‘domestic’ and a ‘composite’ of foreign goods distinguished by region of origin (using the Armington assumption). Here each region uses domestically sourced and foreign inputs. Primary factor composite consists of land, labor, and capital, which are combined through CES production technology. However, there is scope for substitution between domestic and imported materials of the same commodity. Prices for commodities are determined via market clearing through interregional and international trade. Analogously, market-clearing conditions in the factor inputs generate factor rewards. No joint production is allowed.

The model is neither intertemporal, nor sequential to generate temporary equilibria. We are concerned with medium-run production and trade in the wake of trade policy-technology shocks. As we do not consider dynamic changes in the long run, we adopt the standard neo-classical partial long-run or medium-run global closure where no reallocation of shares in investment is considered, but inter-industry capital mobility within a region is allowed.[25] As described in Section 2, a 3-regions ×7-clusters aggregation of GTAP database (Version 6) is calibrated.

For capture-parameter, *AC* is derived from the GTAP database’s skilled-unskilled labor payment shares, which captures skill-intensity measure such that $AC_{HIE} > AC_{RIE} > AC_{LMIE}$. *GP* is computed from World Bank's data (Kauffman et al., 2003) via Equation (1) such that HIE vis-à-vis RIE has higher magnitude than HIE-LMIE pair.[26] *TD*, based on specification of Equation (2), is calculated by R&D-expenditure as percentage of GDP (Human Development Report, 2003), where HIE-RIE combination register higher values than the HIE-LMIE conjugate. For SA_s, we consider human development index (Human Development Report, 2003) with RIE

[25]Macroeconomic environment is specified by allocating the composite investible funds to ensure equality between global saving and global investment. Specification of the macro-environment by adopting a particular ‘closure’ (depending on the short, medium, and/or, long-run nature of the problem) governs the methods of distribution of investible ‘funds’. Depending on appropriate length of run for the experiment, the particular value of a binary coefficient is chosen to select the mechanisms of allocation of funds.

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

as benchmark. Taking RIE as 'threshold', via Equation (3) we derive the magnitudes of these parameters such that $SA_{HIE} > SA_{RIE} > SA_{LMIE}$, implying that HIE has higher acceptance index (1.22) than LMIE (0.92), which has lower *AC* and *TD* values. Equation (5) yields binary index SS_{rs}. Typically, as compared to binary pair HIE-LMIE, HIE-RIE has higher value.

VI. Simulation Design and Counterfactuals

We consider *two generic types* of shocks viz.: **[A]** Total Factor Productivity (TFP) augmentation in high-technology sector/s in HIE flowing to RIE as well as other developing spoke LMIE; and **[B]** with the proliferation of bilateral trade agreements, HIE establishes FTAs with the Southern economies, either sequentially or non-sequentially, to provide preferential access to each other's markets. We consider the following scenarios:

A. Technology and Trade Facilitation Scenario: Pure Productivity Shock

We simulate 4% exogenous Hicks-Neutral TFP shock in IT-cluster in HIE (**identifier**: *GtapIT*). Following equation (11), this implies that the productivity growth in IT-sector induces intermediate-input augmenting technological change in other technology clusters.[27] Nonetheless, the productivity surge in ICT sectors and induced-spillover to ITS sector and transportation equipment, simultaneously, facilitates E-commerce and trade (**identifier**: *EcomTrfac*).

We follow a comprehensive study by Keller (1999, 2001), who calculated a TFP index by industry for 8 OECD countries.[28] We match Keller's (1999) ISIC [Rev.2] sectors with the GSC1 sectors in our current implementation. From the figures, it is evident that the industries included in the hi-tech clusters experienced rapid technological change and hence, higher average annual TFP growth during 1970-91—around 3.4% is the average growth in such sectors. According to Keller (1999), the average annual growth in multifactor productivity in the composite hi-

[27]We simulated the impact of TFP shock in BT and NT sectors separately. However, the results are similar pattern with modest changes in welfare as compared to IT-scenario. For parsimony, we do not report them.

[28]Harrigan (1998) also provides such index for TFP level for only 4 manufacturing sectors but with no consideration about R&D and technology-trade nexus via inter-industry flow matrix. Basu et al. (2003) is one of the recent estimates of TFP growth in ICT-producing and ICT-using sectors for the U.S. economy.

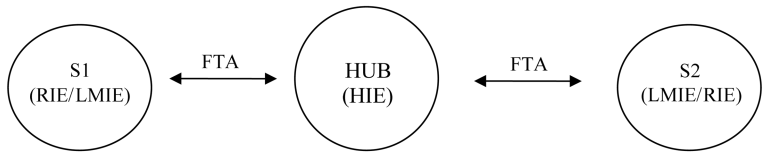
tech sector was 3.2% during 1970-1991. Since we do not have data for the base period 1997 being simulated in our experiment, we use linear extrapolation method to extrapolate growth rates over 6 years encompassing the simulated period. Thus, the extrapolated growth rate of 4 (3.86%) is used as the TFP shock in the hi-tech sector in the origin HIE.[29] This is also supported by the findings of Basu et al. (2003), who find that for U.S. and U.K. the TFP growth rates during post-1995 period in the ICT-producing sectors are 4.43% and 3.75%, respectively.

B. Scenario of Trade Policy Configuration with Technological Progress.

Hub-and-spokes (HAS): We consider a simple 3-player HAS configuration, with HIE being the hub and the RIE and LMIE being the spokes, for preferential market access to each other's markets. That is, two separate FTAs are *simultaneously* established: HIE-RIE FTA and HIE-LMIE FTA. In terms of the actual policy experiment, we assume that each arrangement consists of an *immediate* (i.e., no phasing-in), *complete* (i.e., no excluded sectors and no partial liberalization) and *preferential* (i.e., no liberalization with non-members) removal of the relevant tariffs and any quantifiable non-tariff barriers. A conceptual framework for HAS scenario is presented below:

FTASS: Following the establishment of the HAS system, we also consider a comprehensive regional agreement—FTA between two Souths (FTASS)—where we simulate implementation of an intra-spoke trade liberalization. In this stylized model, the move from HAS to the FTASS would be achieved in the form of a bilateral liberalization among the disjointed spokes. In particular, using the updated database from the previous experiment, we simulate trade liberalization between the spokes, to have full-fledged liberalization among the three players. If S1 is a larger and more developed country (RIE) than S2 (LMIE), then S2 will likely be

Figure 1. A stylized presentation of a Basic Hub and Spokes Configuration



[29]According to Keller (1999, 2001) the rate of growth of R&D stock in USA is 7.4% of which 90% is originating in manufacturing comprising hi-tech and heavy manufacturing. That is, the growth of R&D in manufactures especially in heavy manufacturing and hi-tech. is 0.90×7.4%=6.4% (approximately). Simple average of the TFP indexes in these 2 sectors is also 3.2%

much more worse off than S1 from the HAS configuration, since it is at a disadvantage relative to S1 in catering to the hub's market. In this case, intra-spoke liberalization might lead to preference dilution accumulated under HAS-configuration. To the extent that HAS affects the international flows of goods and services and that some technological spillovers are associated with international trade flows from HIE to RIE and LMIE, it is argued that the existence of HAS may affect the cross-country flows of technology between HIE and the other two regions. Because RIE trades more with the HIE, it will be more likely to benefit under HAS whereas LMIE is more likely to catch up with the RIE due to indirect spillover benefits accruing to them under FTASS. Thus, there is room for preference accumulation by LMIE.

[i-TFP shock in the presence of *joint* HAS and FTASS]: In this situation, we consider GTAPIT scenario taking place *simultaneously* under each HAS and intra-spoke liberalization (**identifier:** *JtHAS*). Then, FTASS is simulated. In this scenario, we conjecture that LMIE gains *directly* in FTA phase but *indirectly* in HAS phase via RIE—the reason being by simultaneously establishing FTA with the HIE, RIE gets a head start directly whereas LMIE does not. Thus, we run a simulation with one such *sequential* HAS configuration.

[ii-TFP shock under *sequential* HAS and FTASS]: Consider the sequence where HIE, at first, forms FTA with RIE and then with LMIE. In the next phase of trade liberalization with FTASS, LMIE will be able to reap gains out of this technology spillover from the HIE (**identifier:** *HASSeq1*).[30] The hub will remain the more efficient supplier (compared to S2) into developed spoke's market and thus, being a hub produces some kind of "first mover advantage". We also consider a reverse sequence where LMIE is the first-spoke mover (**identifier:** *HASRevSeq*).

VII. Analysis of Results

A. Macroeconomic and Sectoral Impacts: Pure Productivity Spillovers.

From Table 7, LMIE has highest region-wide trade-embodiment index (E_{irs}). Nevertheless, higher capture-parameter ($\theta_{RIE} < \theta_{LMIE}$) magnifies E_{irs}(0.21) to higher spillover-coefficient (γ_{irs})(0.25) by 20% compared to LMIE (3%). Despite having low θ_{LMIE}, with post-simulation technological benefits higher, γ_{irs} and E_{irs} result into

[30] In a *reverse sequence* where at first LMIE forms FTA with HIE and then with the RIE, the technological benefits will be harnessed by LMIE at later stage only when HIE liberalizes trade with her.

Table 7. Simulated macro impact for GtapIT

Regions	E_{irs}/E_{ir}	γ_{irs}/γ_{ir}	θ_r/θ_s	SS_{rs}	Regional TFP (% change)	Real GDP (% change)	Volume of Exports (% change)
HIE	0.1	0.55	0.82	1	2.6	2.1	1.1
RIE	0.21	0.25	0.1	0.23	1.2	1.1	1.5
LMIE	0.31	0.32	0.02	0.06	1.67	1.42	1.6

Table 8. Simulated sectoral impact for GtapIT

Regions (1)	Sectors (2)	Spillover Coefficients (3)	TFP growth (%) (4)	Regional Export (5)	Export Price Index (6)
HIE	IT	0.69	4	1.54-	2.6
	BT	0.28	1.78	1.4	-1.8
	NT	0.43	1.74	0.21	-1.6
	TE	0.54	2.39	1.82	-2.4
RIE	IT	0.42	1.65	0.81	-2.3
	BT	0.14	0.55	0.33	-1.5
	NT	0.24	0.95	2.87	-1.9
	TE	0.31	1.22	0.81	-2.2
LMIE	IT	0.4	1.64	-2.82	-2.1
	BT	0.41	1.6	2.76	-2.1
	NT	0.35	1.39	2.07	-1.8
	TE	0.28	1.09	-1.08	-1.9

higher TFP, exports 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 7). HIE, thus, reaps the maximum productivity growth by sourcing relatively high proportion of its own 'technological improvement-bearing' input. TFP-growth acts as an export supply shifter for each generic commodity so that output and global trade increases (Tables 7 and 8).[31]

Following the TFP shock all the *sectors* experience differential TFP growth depending on the values of *sectoral* embodiment indexes and spillovers. Because of higher γ_{irs}, except IT- and TE-cluster, LMIE has higher TFP-escalation than RIE

[31] The simulation results reported here do not represent forecasts or predictions; rather, these are based on the specific experiments on 'what if' basis. Typically, the results indicate the deviation of the variables from the base-case scenario in the absence of the exogenous shock. The results are endogenous variation of the concerned variables in response to external perturbations into the system. We thank the referee for raising this point.

(Table 8). Higher θ_{RIE} appropriates higher doses of 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 the changes in sector-wide relative supply prices, shapes regional composition of trade, depending on the movements in price-relativities among the generic commodities (Table 8). This is governed by the magnitude of the sectoral spillover coefficients. As expected, cost-reducing spillovers led to decline in supply prices (Column 6), causing rise in regional exports (Table 8). Having the highest magnitude of capture-parameter and largest domestic spillover and having supplied mostly the locally produced intermediate in its own market, HIE is able to capture most of the productivity gains from the domestic technology transmission. RIE, having higher θ_r as compared to LMIE, registers higher technology spillover due to higher trade-embodiment index (Column 2, Table 7). Following TFP shock, marginal produc- tivity of the primary factors improves by equal percentage changes and hence, the returns to factors also increased during the simulation period with smaller effects in case of LMIE.

B. Impacts via E-commerce and Trade Facilitation

For *EcomTrfac*-simulation, we focus primarily on the margin services (ITS-cluster) and TE-cluster. Ex-post, compared to 1.3% increase in *GtapIT*-scenario E-commerce augments global ITS-usage by 2.3% and leads to growth in regional GDP and TFP. Technology diffusion causes price of ITS-services to fall by 2.1%. Decline in aggregate export and import price indexes contributes to escalation in

Table 9. Simulated sectoral impact for EcomTrfac

Regions	Sectors	Ecom-Penetration	TFP (%)	Export	Import	Export price index
HIE	IT	-	4	2	3.7	-2.5
	ITS	0.8	2.4	2	3.5	-1.3
	TE	0.8	1.8	1.6	2.9	-1.8
RIE	IT	1	4	4.1	4.1	-4.1
	ITS	1.3	5.2	4.2	5.1	-3.2
	TE	1.61	6.53	6.5	7.5	-4.1
LMIE	IT	1	4	1.9	4.4	-3.8
	ITS	1.25	5.05	3.7	6.3	-3
	TE	1.54	6.3	4.2	4.5	-4.2

regional exports, imports, and ITS-sales (Table 9). IT-led E-commerce penetration fosters trade facilitation reflected in higher sales of margin services and technical change in ITS (Table 9). Technical efficiency in shipping led to decline in prices of inter-regional transportation of cluster-commodities contributing to rise in global trade in all sectors (Table 9).

C. Coupled Effects of Technology and Tariff Liberalization.

[i] HIE-RIE-LMIE HAS configuration: The simulation result shows that the simultaneous HAS configuration does indeed divert trade away from between non-participating spoke regions to each hub-spoke combination. As was argued earlier, the discriminatory nature of the FTA with the hub moves each spoke away from free trade with other spokes. Spoke to spoke trade would suffer as trade is diverted towards the hub. As Table 10 shows, while HIE (the hub)'s exports to the RIE and to LMIE expand by 230 percent, and 41 percent respectively, the trade between the two spokes decline slightly (16% and 24%).

HIE's imports from RIE and LMIE also increased by 299% and 394%, respectively. With only 3 regions, there is no scope for export diversion as there are no non-participating regions in the scheme. In this particular case, more trade seems to be created that diverted so that HIE's total import and total export rise by 10.18 percent and 11.24 percent respectively.

[ii] RIE-LMIE FTASS (Spoke to spoke liberalization, no sequencing): With the HAS network of FTAs present, we simulate a (hypothetical) preferential trade liberalization between HIE and LMIE.[32] In the simple comparative static version of the simulation model, the impact of such trade liberalization on the hub is likely to be negative, since the intra-spoke liberalization would necessarily lead to some dilution of the preferential market access that HIE enjoys in each of the two

Table 10. Simulated impact of JtHAS configuration on bilateral trade flows (% changes)

Source	Destination		
	1 HIE	2 RIE	3 LMIE
1 HIE	0.00	231.63	41.03
2 RIE	299.4	0.00	-15.96
3 LMIE	394.13	-23.71	0.00

Source: Author's simulation.

[32] Of course, removing the barriers between the spokes may not accurately represent a full fledged regional FTA or FTAA. This point is especially relevant in the presence of complex rules of origin.

Table 11. FTASS: Simulated impact of a RIE-LMIE liberalization (% changes)

Source	Destination		
	1 HIE	2 RIE	3 LMIE
1 HIE	0.00	5.47	-10.45
2 RIE	-8.63	0.00	42.27
3 LMIE	-11.07	111.39	0.00

Source: Simulations by the Author.

spokes. As shown in table 11, HIE's export to LMIE declined by 10 percent—export of IT, BT, and NT cluster products drop by almost 12%, 7.8%, and 28%, respectively. Interestingly, there is very little change to HIE's export to the RIE (5.5%) suggesting limited preference dilution in the RIE market.

Following the reciprocal and preferential trade liberalization between RIE and LMIE, their bilateral trade increase substantially: export from LMIE to the RIE increase by 111 percent while trade going the other way jumps up by more than 40 percent whereas there is preference dilution in HIE market as imports into HIE from RIE fall by 8.6% (Table 11).

The change in relative prices and the change in trade flows are associated with improved terms of trade (prices of export relative to prices of import-TOT, henceforth) as well as net welfare for the three participating economies. In fact, Table 12 shows that HIE's terms of trade improves by as much as 0.03% which is

Table 12. Simulated Regional Effects on Aggregate Trade Performance of the Regions (JtHAS and FTASS, *without sequencing*)

Regions	HIE		RIE		LMIE	
Type of configuration→:	Joint HAS (1)	FTASS (2)	Joint HAS (1)	FTASS (2)	Joint HAS (1)	FTASS (2)
Percentage Changes in↓:						
1. Terms-of-trade	0.03	-0.36	0.18	0.42	-1.28	0.82
2. Aggregate export price index	- 3.12	- 2.44	- 2.97	- 1.83	- 4.39	-1.39
3. Aggregate import price index	- 3.15	- 2.09	-3.14	- 2.24	-3.15	-2.19
4. *Change* in trade balance	+27473.7	- 5017.2	-18928.3	12696.9	-8545.5	-7679.7
5. Welfare (EV, $ million)	473227.5	472564.34	78047.5	96457.05	8502.17	35923.07
6. Regional Household Income	2.31	2.32	1.28	1.61	0.64	2.85
7. Per Capita Utility	2.33	2.33	1.29	1.62	0.65	2.87
8. Contribution of TFP to EV	467772.9	459680.7	70598.9	77483.2	21269.1	22045.3

Source: Authors' simulation impact of 4% TFP Shock in Hi-tech.

principally driven by preferential market access and increase demand for its goods (at the expense of other regions) in the two spoke-markets. Under HAS, Hub's welfare also improves by the equivalent of more than $473227 million, while for RIE and LMIE it increase by $78047 million and $8502 million respectively. Under FTASS scheme, both RIE and HIE managed to augment its welfare substantially while HIE's welfare diminished marginally.

In the simultaneous HAS case, the TOT movement preserves the same ranking and order of magnitude except for RIE and HIE who register relatively smaller imporovements in terms of trade due to preferential market access and resultant rise in trade. Moreover, TFP shock acts more favorably to these regions. Thus, welfare increases considerably contributed by predominantly technical change (see rows 5 and 8 in Table 12). Also, HIE is able to register positive change in trade balance (i.e., trade creation) except RIE and LMIE whose exportable become relatively dearer compared to the price of the importable. In case of FTASS, TOTs fall in HIE whereas other considered regions show improvement. This is due to the fact that in the FTASS scenario, RIE and LMIE, having higher capture of direct and indirect spillovers, are able to appropriate the benefits of market accesses in these two regions. Although, export diversion occurs between two spokes, it is not substantial and the presence of technology transfer makes the welfare to improve. LMIE is able to reap technological benefits via direct and indirect spillovers and hence, regional income and utility increases (2.85%) by highest of all three regions. During these simulations, values of world supply of all tradeables decline because of fall in prices following TFP escalation.

[iii]TFP with-HASSEQ1, HASREVSEQ and FTASS (1st and reverse Sequencing)

In this scenario, HIE moves first to form FTA with RIE and then joins LMIE. The results are not substantially different for the non-sequential trade policy scenario. But, due to first-mover advantage the effects are different in two sequences (Tables 13 and 14). For example, all the regions are experiencing welfare increase (row 5)-contributed predominantly by value-added augmenting TFP improvement (see row 8). However, in sequence 1, RIE and HIE perform better due to preference accumulation effect via market access in their respective markets. In the first phase, substantial accrual of gains to RIE is caused by reciprocal removal of trade barriers and concomitant higher doses of technology flows (see rows 5, 6 and 8). This is direct effect. However, in the second phase when RIE joins LMIE, the latter gains in terms of welfare and TOT due to indirect spillover of technological benefits via traded intermediates sourced from RIE after trade liberalization. But, LMIE being

Table 13. Simulated Regional Effects on Aggregate Regional Trade Performance (sequencing 1)

Regions	HIE			RIE			LMIE		
Type of configuration→:	HIE-RIE HAS (1)	HIE-LMIE HAS (2)	FTASS (3)	HIE-RIE HAS (1)	HIE-LMIE HAS (2)	FTASS (3)	HIE-RIE HAS (1)	HIE-LMIE HAS (2)	FTASS (3)
Percentage Changes in↓:									
1. Terms-of-trade	-0.19	0.28	-0.4	+0.69	-0.6	+0.43	-2.3	1.06	+0.82
2. Aggregate export price index	-3.05	-2.2	-2.4	-2.3	-2.9	-1.8	-5.14	-1.3	-1.4
3. Aggregate import price index	-2.86	-2.46	-2.1	-2.9	-2.35	-2.20	-2.9	-2.33	-2.17
4. Change in trade balance	+14241.3	-6381	-3572.8	-27190.8	+24233.7	+11234	+12949.6	-17852.7	-7667.2
5. Welfare (EV,$ million)	467451.3	493510.2	468314.4	92343.3	71242	96031.8	6401.8	21559.3	35787
6. Regional Household Income	2.3	2.4	2.3	1.5	1.2	1.6	0.5	1.7	2.8
7. Per Capita Utility	2.3	2.4	2.3	1.5	1.2	1.6	0.5	1.7	2.9
8. Contribution of TFP to EV	467736.7	459884.8	455671.6	71220.8	78226.3	77041.5	18346.9	20179.4	22024.7
9. Value of merchandise Exports	6.1	0.4	-1.9	10.3	-1.7	0.92	-4.5	17.3	7.5
10. Value of merchandise Imports	5.41	0.5	-1.7	12.8	-2.8	0.6	-6.8	20.3	8.3

Source: Simulated impact of 4% TFP Shock in Hi-tech sector plus sequential HAS and FTAA.

Table 14. Simulated Regional Effects on Regional Trade Performance (reverse sequencing)

Regions	HIE			RIE			LMIE		
Type of configuration→:	HIE-LMIE HAS (1)	HIE-RIE HAS (2)	FTASS (3)	HIE-LMIE HAS (1)	HIE-RIE HAS (2)	FTASS (3)	HIE-LMIE HAS (1)	HIE-RIE HAS (2)	FTASS (3)
Percentage Changes in↓:									
1. Terms-of-trade	+0.18	-0.10	-0.34	-0.58	0.73	0.43	1.60	-2.84	0.81
2. Aggregate export price index	-2.21	-2.99	-2.43	-2.98	-2.17	-1.8	-0.78	-5.73	-1.4
3. Aggregate import price index	-2.39	-2.90	-2.1	-2.4	-2.9	-2.2	-2.3	-2.96	-2.2
4. Change in trade balance	-7720.2	14367.2	-3509.6	27441.1	-27573.3	11071	-19721	13206.2	-7561.2
5. Welfare (EV,$ million)	493060.4	473294.7	468456.3	54676.3	90753.5	96024	25871.5	9865.1	35885.3
6. Regional Household Income	2.41	2.30	2.29	0.9	1.5	1.62	1.96	0.74	2.85
7. Per Capita Utility	2.42	2.31	2.30	0.90	1.53	1.63	1.97	0.75	2.87
8. Contribution of TFP to EV	467299.6	463318.3	455837.6	63097.6	68871.6	76966.8	21760.9	24720.3	22124.6
9. Value of merchandise Exports	0.69	5.74	-1.85	-1.66	+10.2	+0.92	18.95	-5.61	+7.5
10. Value of merchandise Imports	0.83	5.1	-1.7	-3.04	+12.8	+0.6	+21.6	-7.3	+8.3

Source: Simulated impact of 4% TFP Shock in Hi-tech sector plus sequential HAS and FTAA.

relatively laggard in capturing the potential spillover benefits (due to non-access and low constellation of capture-parameters) suffers from deterioration of trade balance (row 4, Table 13). Under full-fledged FTASS scenario, however, it improves its trade balance, although lower than RIE (row 4, Table 13). Comparing the respective FTASS columns with the two sequential HAS networked liberalization episodes for each of the reported regions, we can infer that FTASS has been welfare-augmenting and trade creating for most of them especially RIE and LMIE.

For HIE as hub, although it accumulates preferences under two HAS sequences, this preference gets diluted in FTASS scenarios where the welfare increase is moderate and lowered to $468314 million from $493510 million, although preferential access to larger LMIE market augments its welfare marginally higher. As conjectured, in the reverse sequencing with LMIE as the first-mover, it reaps more benefits. HIE and LMIE both experience improvements in TOT, welfare and trade balance. This is because being first to form PTA with HIE offers increasing market access and direct technology transmission at the expense of the RIE. Moreover, in the second phase indirect trade-induced benefits are transmitted via forming FTA with RIE.

Due to upsurge in trade under HAS and FTASS configuration, in the presence of technology flows vehicled via trade, there is enhancement of production efficiency resulting in income gains (row 6, Tables 13 and 14). However, this increase in income creates further gain via increase in gross investment and capital accumulation. Thus, even in a comparative static framework we see positive nexus between trade liberalization and growth—'trade-induced investment-led growth' (Baldwin 1992, 1993). In each case, compared to HAS sequences the FTASS scenario gives much augmentation of capital goods leading to further efficiency gains. Thus, even in a static CGE framework we get quasi-dynamic effects with trade policy reform owing primarily to trade-led technology spillover mechanism. Both sequences are trade-creating especially for the spokes who are leader in technology acquisition as well as forerunner in joining FTA with the HUB.

VIII. Summary of Findings

The preponderant role of international trade in economic growth and development can in no way be ignored. Of late, amongst the multitude of potential benefits associated with liberalized trade regime and regional trade integration the aspect of trade-induced spillover in facilitating knowledge transmission is emphasized. In this paper, we construct an empirical general equilibrium model (global trade (CGE) model) to highlight the role of skill for assimilating the technology ferried via traded intermediates. This is done in a model with highly aggregated regional dimension but relatively more disaggregated at the sectoral level. In this paper, advanced economies are aggregated into 'North' whereas 'South' is the agglomeration of relatively less advanced ones.

Based on evidences of industry-specific R&D in the North-South and South-South trade patterns, and input-output relations in the three composite regions, the results well accord with our *a priori* expectations: (i) in general, North- South and South-South technology diffusion embodied in traded goods have a positive impact on TFP; (ii) being superior in the league in acquisition of spillover benefits, superior South is able to transfer it to laggard South so that it catches up; and (iv) E-commerce due to ICT-enabled services facilitates greater volume of trade flows and reduce transaction cost via efficiency enhancement. These results have implications for the technology transfer, human capital formation and resultant productivity dynamics under the economic forces of globalization.

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 harnessing the potential benefits. It elicits the importance for catalyzing international competitiveness via R&D, skill accumulation, and development of logistics infrastructure. Additionally, IT-enabled E-commerce services facilitate greater embodied spillover and reduce transaction cost.

Thus, the model provides a conceptual framework to elicit the role of public support policies in the evolution of international competitiveness, technological innovativeness, development of national and international logistics infrastructure and effective adoption. We do not offer an apocalyptic pronouncement; rather provide a nuanced insight into the rapid development of the countries in the Southern cone.

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