Hub-and-Spokes FTAs in the Presence of Technology Spillovers:

An application to the Western Hemisphere[†]

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Abstract

The recent proliferation of bilateral agreements has created a number of "hub-and-spokes" types of trade relationship: i.e., one economy becomes a "hub" by establishing bilateral agreements with a number of nations (the "spokes"). This paper compares and contrast the economic implications of hub-and-spokes (HAS) configuration vis-à-vis FTA of the Americas (FTAA) from the viewpoints of both the hub (Chile) and the spokes (US and Mercosur) in the Western Hemisphere using an augmented version of a nine-region, seven-traded-commodity comparative-static GTAP model. To the extent that HAS affects the international flows of goods and services and that some technological spillovers are associated with international trade flows, it is shown that the existence of HAS affects trans-border technology flows from developed spoke to developing hub and/or, spoke regions either directly or indirectly through open regional trade. 4% Hicks-Neutral technical progress in high-technology products in developed spoke (USA) has differential impacts on productivity elsewhere. Destination regions' ability to utilize new technology hinges on their extent of technology capture contingent on their *absorptive capacity*, *proximity and institutional-structural congruence*. Together with trade flows, these factors determine the recipient's success in assimilating foreign technology. Differential rates of technology transmission via intermediates are also ascribed to trade policy under sequential comparative static trade liberalization scenarios. With sequencing, the benefits accrue more to Chile as first mover and relatively less to Mercosur. But, with technology flows under full-fledged FTAA the gains are more pronounced compared to bilateral FTA between Chile and Mercosur under HAS. Without sequencing, the gain to Chile is not so prominent. Diminution of welfare under FTAA scheme is attributed to preference dilution impact. Also, sectors intensive in high tech products register higher productivity growth.

Key Words: Hub and Spokes, Free Trade Areas, Technology transfer, Absorption, Geography, Governance, Welfare, Preference Dilution, Growth.

***JEL classification*:** D58, F16, O4

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1. Introduction

The recent proliferation of bilateral agreements has created a number of "hub-and-spokes" type of trade relationship: i.e., one economy becomes a "hub" by establishing bilateral agreements with a number of other nations (the "spokes"). This has been especially noticeable in the Western Hemisphere. Mexico and Chile, in particular, have adopted very ambitious and aggressive bilateral liberalization agendas, forming Free Trade Areas (FTAs) with virtually every region in the hemisphere, and effectively becoming the hubs in the region.[1]

This paper investigates the economic implications of a hub-and-spokes (HAS) configuration from the viewpoints of both the hub and the spokes and quantifies those implications using a augmented version of a widely used general equilibrium modelling framework. To the extent that HAS affects the international flows of goods and services and that some technological spillovers are associated with international trade flows, it is argued that the existence of HAS may affect the cross country flows of technology.

In its simplest form, a HAS shares many of the characteristics of simple free trade agreement with respect to their effects on non-member as well as member countries. However, it is different from a more comprehensive regional agreement (say the FTAA) in that trade barriers remain between spokes. Among other effects, this may lead to a disproportionately larger share of the hub in the trade flows among the different partners. In Section 2 of this paper, we present as simple conceptual framework that is useful in understanding the different economic effects of a HAS.

To account for possible dynamic impact of HAS, a mechanism for trade-induced technology transfer is presented in Section 3. In this paper, trade is the primary conduit for technology flows and fosters productivity escalation via spillover effects, as the more open recipient regions benefit from transfer of knowledge capital. Thus, sectors with high import contents of relatively technologically sophisticated goods may harness the benefits of technologically superior inputs used in the production process (see Navaretti and Tarr (2000), Coe, et al. (1997), Coe and Helpman (1995)). In the spillover mechanism presented in this section, traded intermediates ferry the current state-of-the-art embedded in the foreign intermediate imported into the developing country hubs.

Section 4 presents the simulation designs, database and methodology used to quantify the issues discussed in the previous sections in the context of the trade liberalization process in the Western Hemisphere. Using a version of the GTAP database (version 5.4), we perform two kinds of trade liberalization experiments. First, we consider a HAS with Mexico being the hub and the other Western Hemisphere economies being the spokes. Second, we simulate the implementation of a comprehensive regional trade liberalization in which trade is liberalized between all western hemisphere economies. Also, we simulate technology shocks in the hi-tech sector/s and trace the ensuing changes in productivity in the client sectors and regions via traded intermediates embodying technological advancement. Section 5 reports the results of the policy simulations in terms of the effects of different types of trade liberalization on trade and production patterns, welfare and economic growth induced by trade-mediated technology flows. Section 6 concludes with some policy implications.

2. Hub and Spoke: Conceptual Considerations

Figure 1 illustrates the concept of hub-and-spokes arrangement that we are interested in: the central hub establishes two different bilateral FTAs with the two spokes (S1 and S2) while those spokes retain their MFN barriers on each other's goods.

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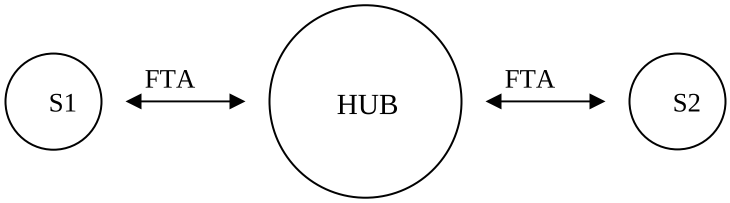
[1] Mexico has, for instance, established FTAs with the United States, Canada, Colombia, Venezuela, Bolivia, Chile, Costa Rica, Nicaragua, Honduras, Guatemala, El Salvador, and Uruguay. Talks are also underway for an FTA with Mercosur. Chile has preferential trade relationship with Colombia, Ecuador, Mercosur, CACM, Canada, Mexico, and United States.

Figure 1: Basic Hub and Spokes Structure: A Stylized Model



The HAS configuration has numerous economic implications, many of which are similar to those found in the standard literature on preferential or discriminatory trade policy (e.g., trade diversion and trade creation). From the viewpoint of the hub, the system is beneficial since it provides preferential access to the market of each spoke. The hub also provides free access to each spoke so that effectively it moves closer to a unilateral free trade regime, which means that the potential adverse terms of trade impact of trade diversion is limited. At the same time, the degree of competition will also be more intense in the hub's market which may hurt domestic firms but benefit consumers. In a more dynamic dimension, the hub can become a more attractive location for foreign investment given its better market access (and potentially higher income), which may lead to an agglomeration of economic activities.

While each spoke has free trade with the hub, the discriminatory nature of the FTA moves it away from free trade with other spokes. Spoke to spoke trade would suffer as trade is diverted towards the hub: it is relatively more advantageous to import from the hub, as it is to export to the hub's market. Each spoke loses from being discriminated against in all the different FTAs from which it is excluded. Even the market access gains from the FTA with the hub would be diluted since the hub is giving the same (if not more favourable) preference to all the other spokes. After all, preference to everybody may be equivalent to no preference at all.

The net impact on the different countries depends on the magnitude of each of the effects just discussed.[2] Those different effects are summarized in Table 1. The table suggests that hub producers and consumers tend to be better off than their respective spoke counterpart.

Table 1. Effects of Hub and Spokes configuration on producer and consumers in different market

		Markets		
		Hub	**S1**	**S2**
	Hub	More competition from S1 and S2	Improved preferential access to S1	Improved preferential access to S2
Producers	**S1**	Dilluted preferential access to Hub	More competition from Hub	Discriminated against in S2
	S1	Dilluted preferential access to Hub	Discriminated against in S1	More competition from Hub
Consumers		Better availability of goods from S1 and S2	Better availability of goods from Hub (potential trade diversion)	Better availability of goods from Hub (potential trade diversion)

One could also tentatively extrapolate from the table that if S1 is a larger and more developed country (say the United States) than S2 (say Mercosur), then S2 will likely be much more worse off than S1 from the HAS configuration, since it is at a disadvantage relative to the hub (say Mexico) in catering to the large S1 market. From this type of analysis, it can be

[2] Of course, this discussion abstracts away from the important issue of "rules of origin". Incorporating that issue in the analysis would likely exacerbate the adverse impact of the configuration on the spokes.

conjectured that, from the point of view of developing countries in the Western Hemisphere, trade liberalization under FTAA is more attractive than being a spoke in a Mexico (or Chile)-centered hub and spoke scenarios.

This analysis can be used to address an interesting general question: *having achieved the status of being an hemispheric hub, would Mexico or Chile have any incentive to pursue a full fledged regional trade liberalization*? In this stylized model, the move from HAS to the FTAA would be achieved in the form of a bilateral liberalization among the disjointed spokes. Of course, removing the barriers between S1 and S2 may not necessarily be an accurate representation of a full fledged regional FTA.[3]

In a simple comparative static simulation, the possible impact of such trade liberalization under HAS configuration is likely to be negative, since the intra-spoke liberalization would lead to some dilution of the preferences that the hub enjoys in each of the spokes. In fact, following up with the logic presented above, moving from a HAS to a regional FTA ends up hurting the hub since it might be the case that almost all the benefits of being a hub are dissipated. Therefore, the optimism about the accumulation of preferences gathered under PTAs might be shadowed by the preference dilution effect.

However, incorporating a mechanism of hysteresis or persistence via technology spillovers could leave room for altering such conclusion. Because it trade more with the developed spoke (S1), the hub will be more likely to benefit from the trade induced productivity gains. And if that causes a persistent technological advantage, the adverse effects of moving to a more comprehensive FTA will be limited since the hub will remain the more efficient supplier (compared to S2) into developed spoke's market. In that sense, being a hub produces some kind of "first mover advantage" in a purely dynamic framework. So the hub may still want to pursue the regional FTA, especially if that leads to increased income and thus larger export markets in the spokes for its products. In the paper, we do not model R&D and technology creation aspects and hence, we abstract away from the dynamics involved.[4] However, even in a comparative static framework Baldwin (1992, 1993) type capital accumulation enables us to trace the dynamic and static gains due to technology spillovers, capital accumulation and associated movements of rates of return to capital following trade liberalization[5]. Next section documents a mechanism for trade-induced technology flows and rationale for induced productivity enhancement.

3. A Mechanism for Trade-induced Technology Transfer

Advanced technologies of recent vintages are researched and invented in the developed countries. Developing countries have depended for their growth and development on foreign technologies originating in their more developed counterparts. Their growth and development depend not only on the extent and nature of the technology that is available to them, but also on their competence, or capabilities, for effectively absorbing and adopting the diffused technology.[6] This is the "embodiment hypothesis": technical knowledge transmits via traded goods. The technology generated at the sources of inventions spillover to the destinations through bilateral trade linkages.

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[3] This point is especially relevant in the presence of complex rules of origin: product from S1 using input from S2 may not be allowed duty free in the hub market.

[4] This does not undermine our purpose since our primary interest is to trace the technology driven growth in the context of FTA and possible configurations of such agreements.

[5] See Itakura (2003) on this Comparative static version of GTAP CGE model

[6] Thus, international trade in commodities facilitates propagation of superior 'technologies' embodied in those traded goods and services [see for example, Coe, et al. (1995, 1997), Dietzenbacher (2001), Eaton and Kortum (1996), Connolly (1997), Keller (1999, 2001), World Development Report (World Bank 1999) for empirical evidences].

In this paper, we consider trade-mediated technology transfer via intermediates.[7] In particular, we model the impact of total factor productivity augmenting technical change (assumed to occur exogenously) in the United States.[8] Such a technological innovation, via traded intermediates, induces productivity enhancements in other user sectors especially heavy manufactures intensive in its usage in other regions. We, then, trace the ensuing changes in the recipients via trade and sectoral feedback under the two different types of liberalization scenarios namely, HAS vis-à-vis FTAA.

Different factors affect the capacity of a given economy to capture the benefits of technological innovation. Investment in human capital or skill acquisition, for instance, can help develop technological or social capability to harness or to absorb innovation.[9] The effective assimilation depends, *inter alia*, on the skill intensity of the labor force which helps unlocking the potential of technology to induce productivity growth. We refer to this factor as education-related absorption capacity (**AC**).

Not only AC, but also distance (geographical or socio-cultural) limits the extent of knowledge diffusion and widening of the technology frontier.[10] Hall and Jones (1999), Frankel and Romer (1999), Deardorff (2001), Keller (2001) have also shown that other 'unobserved' factors do affect trade, international transaction and economic development. For example, cultural familiarity or affinity determines the degree of social cohesion and acceptance of 'new' technology. It is through the familiarity with another country's institutional factors like legal side, habits and languages that one geographically closer country becomes culturally similar leading to social cohesion. The high level of economic integration via trade observed over last few years is expected to reduce the degree of localization (agglomeration) of knowledge flows. We incorporate such effect via the exogenously specified 'adjacency parameter (**AP**).' It is a composite measure of cross-sectional variation in relative distance, and hence in cultural affinity of countries, to their trade partners.

In the same vein, Schiff and Wang (2002, 2004) discuss, in the context of Latin American and Caribbean countries, the role of *governance and institutional quality* along with education in appropriating the latest state-of-the-art diffused through traded intermediates for achieving virtuous growth cycles. We incorporate the institutional factors via a parameter reflecting the index of governance (**GP**). Typically, it is argued that technology transmitted via intermediates from the source of technology creation will deliver the potential benefits to the recipients if the level of governance quality of origin vis-à-vis client is (nearly) similar, if not identical. The more the trading regions/economies are institutionally, structurally homogeneous the more is the mutual compatibility of them becoming bilateral trade partners as opposed to the case of incongruence or heterogeneity in socio-cultural factors between them. Cultural or structural homogeneity is closely related to geographical proximity (see Linneman (1966), Rauch (2001, Frankel (1997). Even with differences in terms of factor endowments, lowering transaction costs can enhance integration and facilitate trade flows between '*non-naturals*'. Consider the case of quite small (compared to the US and Rest-of-the-world); quite open economies like Mexico (A) and Chile (B)—having *comparative disadvantage in terms of low endowment of human capital or*

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[7] The nexus between domestic growth and relative income level and the growth rate of the trading partners has been discussed at length (e.g., Baldwin (2003), Panagariya (2004), Schiff and Wang (2003, 2004), Lederman et al. (2003), De Ferranti et al. (2003)). With the proliferation of trade agreements, economic growth in a given country becomes closely related to developments taking place abroad. Arora and Vamvakidis (2002, 2004), Vamvakidis (1998, 2002) has found a strong positive relationship between long-run growth in the U.S. and in the rest of the world via spillover effects.

[8] Role of FDI in technology transfer is also emphasized in the literature. However, the primary emphasis being on the trade flows via regional economic integration, we focus solely on trade as a vehicle of advanced technology from source to the client regions and sectors.

[9] See, for example, Abramovitz (1997), Cohen and Levinthal (1986), Coe et al. (1995, 1997), Keller (1997), Das (2000, 2002), Pack and Westphal (1984), Leahy and Neary (2004).

[10] According to Keller (2001), the estimated *geographic half-life* of spillovers is only 1200 kilometers i.e., the distance at which half of the diffused technology spillovers have tendency to disappear.

skill and governance compared to the US and Canada. Suppose A has *relatively less* disadvantage than B. Then, by forming FTAs between them (naturals with presumably lower transport and associated costs (TAC)) via uniform reduction in the trade barriers, B will suffer as some sophisticated manufactures previously imported from US, Canada and ROW will now be imported from A; thus, only generating gains to A from relocation of supply to B's market protected from competition from others (non-naturals). In that case, lowering TAC between the distant partners will probably enable more welfare gains via wider scope of market penetration. Thus, we specify a *binary* governance parameter as comparative measure of institutional quality indicator between two potential trade partners[11].

Conjointly, binary source and destination-specific AP and GP determine the institutional-structural congruence index (**SC**) which together with the absorption capacity (AC) determine the technology capture parameter (**CAP**) which encapsulates the role of structural congruence, adjacency and skill-intensity to appropriate the potential benefits of trade-induced technology transfer.

3.1 Conceptual Framework for Trade-induced Technology Transmission: Theoretical Premise.

In a multi-sectoral, multi-regional framework such technological spillovers can be conveniently traced. Recent studies such as, van Meijl and van Tongeren (1997, 1998) [henceforth, MT], Dietzenbacher (2001), Sjoholm (1996, 1999), and Das (2000) have modeled the issues of technology transfer. Productivity growth rates of countries are related through international trade linkages and associated "embodied" knowledge-spillovers. However, MT's model incorporates the essential elements of 'AC' and 'structural similarity (SS)' factors (proxied by land-labor ratios) in determining the local usability of foreign technologies. 'AC' is constructed as a binary (source- and destination-specific) index of human-capital-induced absorption capacity of the participating trade partners. Analogously, SS is also a binary index. Together with trade volume, these two indexes determine the 'productive efficiency' parameter.[12]

Such features as cultural similarity, governance and geographical (adjacency) parameters are ignored in the previous modeling efforts. It is argued that domestic usability of the transmitted foreign technology depends mainly on the *recipient's* capability to utilize the diffused technology. Quite reasonably, we assume that if a laggard region 'C' is good at absorbing technology from developed region 'A', it will (to a first approximation) be equally good at absorbing technology from another region 'B' which (from C's point of view) is structurally similar to 'A'. Also, another region 'D' who is institutional structure-wise similar to 'C', will also be able to reap the technological benefits (*indirectly*) from not only 'A' and 'B' but also *directly* from 'C' if they integrate via trade. Thus, the AC factor is made destination-specific only.

In the present paper, *firstly*, we modify the technology spillover equations by incorporating the nexus between AC and institutional and structural characteristics. *Second*, we make the 'AC' factor destination-specific only. The 'SC' factor retains its 'binary' affix, though. The trade-induced technology transmission mechanism implemented here is based on Das

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[11] Also, especially in the context of geographical barrier (i.e., distance variable) for technology transmission one could model the role of technical efficiency in trade facilitation via its effects on reduction in transaction costs (for example, owing to customs automization, e-commerce type commerical innovations). For any discussion on FTA, this is pertinent [see Hertel et al. (2001), Hummels (2000), Keller (2001)]. This can be implemented via GTAP as '*import-augmenting*' technical change where such cost-cutting entails higher volume of imports shipped from one region to another. Elimination of iceberg-type trade costs via import-augmenting technical change in a high technology sector captures the role of technology in reducing trade transaction cost and providing stimulus for the trade flows across the border (i.e., trade facilitation). However, for parsimony, this issue is not discussed in the paper.

[12] Although AC depends not only on Human Capital alone, but also on constellation of factors such as Infrastructural Facilities, Learning Effects, and R&D creation, however, while defining AC in our model we have not considered these factors.

(2000)—the model developed and implemented within the static GTAP framework. *Third*, most importantly, unlike MT (1998) and Das (2000) we have incorporated the role of adjacency variable in the line of gravity models and also, governance variable representing the degree of social cohesion and acceptance for effective absorption of transferred technology. Also, *fourthly*, as will be evident from Section 4, we consider the role of trade and capital accumulation effect under HAS vis-à-vis FTAA scenario. The basic spillover equations and necessary modifications made are described in the next section.

3.2 Spillover Equations: Modifications to Theory

Technology embodied in traded and domestic intermediate inputs spills over to *all* other sectors and affects their total factor productivities. That is, following an exogenous technological improvement in one sector of one region, all other sectors in the source region, and all sectors in other regions experience *endogenous* Hicks-Neutral total factor productivity [henceforth, TFP] improvement. The embodiment index is defined in terms of input-specific trade intensity. For the current implementation, we adopt two different specifications for the technology transmission equation: the first one applies for the *trade-induced spillover* between destination regions and the source of technological change, while in the second one, we consider endogenous *domestic spillover* to the sectors in the source itself from the sector experiencing *exogenous* technological change there.

3.3 Definition of Embodiment Index

The amount of trade-induced knowledge spillover from a source sector in the donor region to a particular sector in the client regions via traded intermediates depends on the input-specific trade intensity of production of that sector. Hence the embodiment index is defined in terms of trade intensities for different specific material inputs; i.e., source and using sector-specific trade-embodiment index. We define this index [E_{ijrs}] as the flow of imported intermediate produced in sector 'i' in source region 'r' that is exported to firms in sector 'j' in recipient region 's' [F_{irjs}] per unit of composite intermediate input of 'i' used by sector 'j' in destination 's' [M_{ijs}]. The latter—M_{ijs}—is a simple aggregate of nominal values and is the total (i.e., domestically sourced as well as composite imported inputs) usage of intermediate input 'i' by sector 'j' in region 's'. Thus, it is expressed as

$$E_{irjs} = F_{irjs}/M_{ijs} \qquad (1)$$

where F_{irjs} is the imports of 'i' from source 'r' used by sector 'j' in recipient 's'. In GTAP notation, M_{ijs} is the value of purchases of tradeable intermediate i by firms in industry j of region r.

For governance parameter (GP), it is measured by the following rule

$$GP_{rs} = \mathit{min}\ [1, GP_s/GP_r] \qquad (2)$$

According to (2), if destination's' has higher GP_s than that of source 'r' i.e., GP_r, then it is conducive structure for's' to effectively utilize the transferred technology. Otherwise, if the client region lags in institutional quality behind the advanced source [i.e., $GP_s<GP_r$], then it poses hindrance in's' for absorbing the technology even if AC is high there. Here, $0\leq GP_{rs}\leq 1$.

It is to be noted that the definition for the spillover coefficient bears an additional subscript for source sector 'i' so that we write it as

$$\gamma_{ijrs}\left(E_{ijrs},\theta_s\right) = E_{ijrs}^{1-\theta_s} \qquad (3)$$

where γ_{ijrs} is the spillover coefficient between 'i' in source 'r' and 'j' in destination 's' and θ_s is "capture parameter". θ_s is the product of the recipient-specific AC-index AC_s (where $0\leq AC_s\leq 1$) and the *binary institutional-structural congruence* index SC_{rs} (where $0\leq SC_{rs}\leq 1$); it measures the efficiency with which the knowledge embodied in bilateral trade flows from source 'r' is *captured* by the recipients 's' so that:

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

Now, SC_{rs} depends on binary governance parameter (GP_{rs}) and binary adjacency parameter (AP_{rs}). Thus, we can write

$$SC_{rs} = GP_{rs} \,.\, AP_{rs}. \qquad (4a)$$

Therefore, with 'r' being unique source it follows that:

$$\theta_s = AC_s.\, GP_{rs}.\, AP_{rs} \qquad (4b)$$

The actual productivity level from the potential streams of 'latest technology' depends on $\theta_s \in [0,1]$ with $\theta_s=1$ implying full appropriation of the foreign technology. For the destination region 's', θ_s and E_{rs} jointly determine the value of the '*Spillover Coefficient*' $\gamma_s(E_{rs}, \theta_s)$.
$\gamma_s(.)$ has the properties that

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

where primes indicate the first (′) and the second (′′) derivatives with respect to E_{rs}.
More specifically,

$$\gamma_s(E_{rs}, \theta_s) = E_{rs}^{1-\theta_s}\ ,\ 0 \le \theta_s \le 1 \qquad (5)$$

It is to be noted that trade intensity is treated as a *binary* variable indexed both for the recipient sector 'j' in a given region 's' and for the source sector 'i' and region 'r' of the intermediate products that it uses as inputs. In the GTAP database, however, there is no information to accommodate this degree of disaggregation excepting the information on the aggregate imports of the composite intermediate good used by any given sector in any given region (i.e. $F_{ij\bullet s}$). Thus, the regional composition of imports for individual using sectors in s is not known. Therefore, we circumvent this data limitations by making a pro-rata *assumption* based on import proportionality—i.e., it is assumed that an imported input is proportionally distributed across all user sectors.[13] Thus, if F_{irjs} indicates usage in region 's' by industry j of imported intermediate i from source r, we assume that the share of imported input 'i' from source 'r' in receiving region 's' holds for all industries 'j' in 's' using imported input 'i'

$$F_{irjs}/F_{ij\bullet s} = F_{ir\bullet s}/F_{i\bullet\bullet s} \qquad (6)$$

where $F_{i\bullet\bullet s}$ is the aggregate imports of tradeable commodity 'i' in region 's' from all source regions. In equation (3), the left-hand ratio is the quantity share of source r in the imports of i by sector j in its total imports of 'i' whereas the right-hand ratio is the market share of source 'r' in the aggregate imports of tradeable 'i' in region 's' evaluated at market prices. Following GTAP notation, the coefficients $F_{ij\bullet s}$ is VIFM (i,j,s)—the value of purchases of imported intermediates i by sector j in any region s evaluated at market prices, $F_{ir\bullet s}$ is VIMS (i,r,s)—the value of imports of tradeable good i from r to client s, $F_{i\bullet\bullet s}$ is VIM (i,s)—the value of aggregate imports of tradeable commodity i in region r evaluated at importer's market prices and the *right-hand ratio* is the coefficient SM_IRS (i,r,s). As said before, SM_IRS (i,r,s) is *assumed* to hold for all industries 'j' in 's' using imported 'i' from origin of innovation 'r'. In the GEMPACK implementation, we define a new coefficient VIFM_RS (i, j, r, s) to match F_{irjs} for the definition of the embodiment index [E_{irjs}].

In the source region, the benefits of a technological change (exogenous) in a particular sector is reaped *directly* by the other sectors via the usage of locally produced intermediate inputs embodying advanced technology and *indirectly* via the *changes in price relativities* of imported intermediates. Thus, the latest technology embodied in the intermediate inputs experiencing technological progress diffuses to other sectors using that material input/s sourced *domestically*. Hence, the exogenous TFP improvement in the source sector in the region of origin endogenises

[13] This particular assumption is driven by limitations of data availability. However, in the literature on embodied international technology diffusion, this is a common assumption. See OECD (2000), *Science and Technology Indicators Scoreboard*.

the TFP improvement in the receiving sectors via a *domestic* spillover effect. Therefore, the relevant sectoral embodiment index [E_{ijr}] for the sectors in the source region is given by

$$E_{ijr} = D_{ijr}/M_{jr} \qquad (i \neq j) \qquad (7)$$

where D_{ijr} is the quantity of domestic tradeable commodity 'i' used by firms in sector 'j' of source region 'r' and M_{jr} is the domestic production of 'j' in 'r'. However, for the source country the relevant capture parameter is defined in terms of the human capital-induced absorption capacity (AC_r) and *own* institutional governance factor (GP_r) with geographical adjacency parameter set to unity i.e., $AP_r = 1$ because within its own market trans-national distance is unimportant. Thus, we assume that the higher is AC and GP in 'r', the higher will be the domestic sectoral spillover such that the spillover coefficient for source region is written as

$$\gamma_{ijr}(E_{ijr}, \theta_r) = E_{ijr}^{1-\alpha_r} \qquad (8)$$

where $\alpha_r \in [0, 1]$ is the human capital induced capture-parameter for source 'r'. θ_r has one-to-one correspondence with α_r (where r is the source region).

3.4 Spillover Equation and Productivity Shock

Following our discussion above, the productivity transmission equation for the recipient regions can be written as

$$ava(j, s) = E_{ijrs}^{1-\theta_s} .ava\ (i, r) \qquad (9)$$

where ava (i,r) and ava(j,s) are respectively the percentage changes in TFP levels (HNTP parameters) in source and destinations [$i \neq j$, $r \neq s$]. For the source region 'r', the transmission equation [where i and j ($i \neq j$) are the innovating sector and the receiving sectors respectively] is given by

$$ava(j, r) = E_{ijr}^{1-\alpha_r} .ava\ (i, r) \qquad (10)$$

For own source region 'r', the measure of *governance parameter (GP_r)* (unlike in equation 2 for binary measure between 'r' and 's') is assumed to be unity (as often is the case with USA) and $GPr \in [0, 1]$. Hence, it implies minimum 100% governance factor or full realization.

4. Database, Model and Simulation Design

4.1 Database: Sectoral and Regional Aggregation

We use a version of the comparative static GTAP model (database version 5.4) tailored to suit our purpose. Version 5.4 of the GTAP database (i.e., GTAP Sectoral Classification, revision 1 (GSC1)) distinguishes 78 regions and 57 sectors and provides us with the splits of labor payments between the skill and unskilled categories [see McDougall et al. (2002)]. It represents the state of the world economy in 1997. A reduced dimension 9×7 aggregation of the Version 5.4 of the GTAP database is used to calibrate the model. Choice of regional dimension is motivated by our primary emphasis on the trade-growth nexus under HAS vis-à-vis FTAA structure in the Western Hemisphere. In terms of the sectoral aggregation, we consider seven composite clusters of commodity types—agriculture, natural resources, food and beverages manufacturing, heavy manufactures, light manufactures, high-technology products, and services. Table 2 presents the regional and sectoral aggregations. Sectoral composition is documented in Table 3 below. This aggregation allows us to trace the productivity spill-overs that could result from trade liberalization. In fact, it has often been emphasized that trade liberalization facilitates trade-mediated technology transfer via imported intermediates and capital goods. High-technology products are supposedly intensive in sophisticated technology and trade in such products is a primary conduit for technological spill-over across borders.

Table 2: Sectoral and Regional Aggregations used for the implementation

Version 5.4 Sectors with Identifier	Version 5.4 Regions with Identifier
1. AGR [agriculture]	1.USA [United States]
2. NRE [natural resources]	2. CAN [Canada]
3. FOOD [food and food products]	3. MEX [MEXICO]
4. LMNFCS [Light manufacturing]	4. CAmCar [Central American and Caribbean]
5. HMNFCS [Heavy manufacturing]	5. Andean [Andean Pact]
6. HITECH [High Technology Products]	6. Chile [Chile]
7. SVC [Services and activities, NES]	7. MERCOSUR [Argentina, Brazil, Uruguay, Paraguay]
	8. RestLA [Rest of Latin America]
	9. Rest of the World [ROW]

Source: GTAP database.

Table 3. Sectoral Composition

Sectoral Aggregation	GTAP Sectors
Agriculture	Paddy rice, Wheat, Cereal grains nec, Vegetables, fruit, nuts, Oil seeds, Sugar cane, sugar beet, Plant-based fibers, Crops nec, Bovine cattle, sheep and goats, horses, Animal products, Raw milk Wool silk-worm cocoons, Bovine cattle, sheep and goat, horse meat prods
Natural Resources	Forestry, Fishing, Coal, Oil, Gas, Minerals nec, Petroleum, coal products
Food manufacturing	Meat products nec, Vegetable oils and fats, Dairy products, Processed rice, Sugar, Food products nec, Beverages and tobacco products
Light manufactures	Textiles, Wearing apparel, Leather products, Wood products Metal products, Motor vehicles and parts, Transport equipment nec,
High-tech manufactures	Electronic equipment, Machinery and equipment nec, Manufactures nec
Heavy manufactures	Paper products, publishing, Chemical, rubber, plastic products, Mineral products nec, Ferrous metals, Metals nec
Services	Electricity, Gas manufacture, distribution, Water, Construction Trade, transport, Financial, business, recreational services, Public admin and defence, education, health, Dwellings & Svces

Source: GTAP database and aggregations by Authors

4.2 GTAP Implementation: Methodology and Parameters

4.2.1 Methodology

Because of our enhancement of theory via technology spillover mechanism in the presence of HAS, a modified comparative static GTAP model is used to achieve this task. It is a multi-regional, multi-sectoral computable general equilibrium global trade model [see Hertel (1997)] with several equations appended in line with our theory. The economic model includes additional equations as documented in sections 3.3 and 3.4 above and also, the modified equation for TFP appended to the standard GTAP model, some additional coefficients and additional parameters for AC, GP and SC.[14] In our model, technological change in the high technology sector at the source USA is treated exogenously. Thus, technological change in the origin of development is *exogenous* and intermediate input is the primary vehicle for technology transfer from source to destinations. Such a technological innovation entails induced productivity enhancements when the output of the sector is used as an intermediate in other sectors especially manufactures. In other words, we specify a total factor productivity improvement in the hi-tech sector in USA and trace the ensuing changes in the recipients via trade and sectoral feedback. In the current experiment, we assume one unique source sector of innovation 'i' identified by the set named 'SRCSEC'. SRCSEC is a subset of the set of traded commodities i.e., TRAD_COMM.

A complementary subset—NSRCSEC—comprises the traded sectors other than the sector in 'SRCSEC'. The source region 'r' (i.e., USA) is also unique. Following our notations and specification of sets, $i \in$SRCSEC, $j \in$NSRCSEC, $r \in$SRC and $s \in$REG_NOT_SRC, with SRCSEC and SRC being single-element sets. However, in our experiment the source of TFP improvement is *uniquely* in sector 'i' in the single donor region 'r'. In GTAP, for enforcing economy wide TFP shock the variable 'ava (j, r)' has been made normally endogenous with "avadiff [j]" and "avarega[r]" being exogenous. But, for shocking individual "ava [j,r]" pairs (i.e., for sector and region specific average rate of value added augmenting tech change), some components of the variable *avaall (j, r)* has been made endogenous and the relevant equation has been changed. Hence, by shocking *exogenously* specific pairs of avaall[j, r] by a given magnitude whilst keeping both avadiff [j] and avareg [r] *unshocked*, one can make ava [j,r] to move together with avaall [j, r] (*exogenous*).

4.2.2 Parameter Settings:

In our augmented theoretical model, we have three sets of parameters in addition to the standard GTAP model parameters. These are skill-induced **AC** index, governance parameter **GP** and proximity parameter **AP**. As regards the destination-specific absorption capacity parameter, we calculate the skill-unskilled labor payment shares for all the regions as of 1997 and use those skill-intensity ratios as proxying AC of the regions. As per our calculation, α_r proxying AC_{USA} is highest of all the regions. Calculated AC-values are such that $AC_{USA} > AC_{MERCOSUR} > AC_{CHILE} > AC_{MEX} > AC_{RESTLA} > AC_{CAMCAR}$. However, for highly composite regions the figures are surprisingly high. For example, Canada trails little behind Mercosur whereas within the same group the differences are small and show similar intensity implying that they have *more or less similar pattern* of skill-intensity. Thus, from the AC-index it is obvious that the developing Americas in Western Hemisphere have low skill-intensity compared to the US but *amongst themselves* they exhibit broadly similar intensity.

For **GP**, we proceed in several steps: (i) we use the World Bank's (2003) most recent and comprehensive data on six dimensional governance indicator made available by Kauffman et al. (2003, 2004).[15] These values at much disaggregated level are bounded between -2.5 and + 2.5; (ii) on the basis of these disaggregated observations at regional level for each category, we construct a simple average, *composite governance indicator* for each GTAP region as representative for *overall* institutional-structural feature. Typically, as the six aspects are '*by virtue of inherent commonality*' interrelated, the indicators are interrelated as well. Thus, composite indicator as simple arithmetic average of the estimates of score on each separate ones is a reasonable proxy for *overall attribute* of governance. For *composite regions*, we calculate such aggregate values by mapping the component GTAP regions with regions in Kauffman et al. (2003) dataset. Having constructed such individual country/region-wise indexes, we transform via Equation (2) to find

[14] Structural equations, coefficients and parameters of the model encoded in TABLO language are not reported here for space limitations. TABLO code has been modified to make necessary adjustments for incorporating the theory and equations. Accordingly, parameters file and set declaration have been changed to operationalize the augmented model. Those will be mentioned in places with parsimony.

[15] These indicators for perceived institutional quality are: Voice and accountability, Political Stability, Government effectiveness, Regulatory Quality, Rule of Law, and Control of corruption. The values of such parameters for AC, AP and GP are not reported here for want of space.

binary indexes of one with different unique source like USA. The values are bounded between '0' (extremely low degree of governance) and *unity* (i.e., like the value between USA and Canada with almost perfect governance). For indexes we consider the absolute magnitude of indexes as we make *relative* '*scaling*' for binary comparison with respect to USA as the benchmark. Based on these findings, we infer that USA and Canada are more institutionally (structurally) homogeneous as opposed to other Latin American countries. From our calculation, as expected, we see that *excepting* Chile, Andean and Central Americas, for other developing spokes the values are low with Mexico having the lowest binary GP index of all (0.1).

However, region-specific *endowment ratios* (i.e, proxied by value of *capital* endowment to *composite labor payment ratios from GTAP database*) show some pattern: ratios for the countries USA and Canada are of the same order of magnitude, that is, in the range of 0.61-0.67 whereas those for LACs the range is higher, viz., 0.96-2.02. On the basis of these relative endowment comparisons, we can also infer that USA and Canada are structurally more congruent whereas compared to developed US and Canada the LACs (the developing regions as a group) are structurally similar among themselves and hence, they show same range of values.

Regarding binary adjacency parameter (**AP**), we do not have measures of geographical barriers for the composite regions especially for the group of countries lumped in ROW. In the literature, the most widely used comprehensive proxy measuring such variable is the *ad valorem* transportation and insurance costs—ratio of *c.i.f* trade to *f.o.b* values or the *c.i.f* margin (see Frankel (1997)). Therefore, we assign some 'reasonable' values based on stylized evidences on transport margins present in the GTAP dataset. In particular, we consider as *fob vis-à-vis cif margin* the value of transportation services associated with the shipment of a tradable commodity (margin services) 'i' from 'r' to recipient 's' in the GTAP Database. We find ratios of such bilateral values *aggregated* across all commodities relative to total value of international transportation services across all goods as well as all routes. This ratio enables us to capture the relative importance of physical distance between two trading nations. The calculated share of transport cost summed across all traded goods in imports of margin commodity is relatively low for Canada whereas for the Latin American countries this value is higher and of the same order within group; however, the inter-regional differences are not significantly large. *Assuming* that the *lower* is such value; the *higher* is the degree of adjacency (i.e., proximity) and the *higher* is the extent or scope of integration and homogeneity facilitating knowledge capture, we assign higher values for Canada whereas for the rest seven we choose relatively lower or same magnitude within the same group of regions. Accordingly, the default parameter file in GTAP has been modified by including specific values for these parameters. The model is solved using customized windows program Gempack.[16] In what follows, we describe the policy experiments.

4.3 Policy Experiment: Simulation Design

We consider *two generic types* of shocks viz., **[A]** trade policy shocks related to trade liberalization episode under HAS vis-à-vis FTAA and **[B]** technology shocks related to Total Facto Productivity (TFP) augmentation in high-technology sector in the developed spoke USA flowing to Chile as Hub as well as other developing spoke regions[17].

[A] Trade liberalization Scenarios:

Two kinds of potential trade liberalization experiments can be investigated to trace their economic effects on trade patterns, welfare and economic growth.

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[16] This is developed by Ken R. Pearson and colleagues at the Centre of Policy Studies/IMPACT, Monash University, Australia based on GEMPACK software suite. See Harrison and Pearson (1996) for GEMPACK simulation software.

[17]In this paper, for parsimony Mexico is not considered as an alternative hub. Although Mexico is in NAFTA and Chile has already formed FTA with Mercosur (and with USA) Mexico has not negotiated as yet. Moreover, from stylized evidences for the technology capture parameters, Mexico stands in the lower end of the spectrum in the list of Americas with lowest value for GP, AC, and SC and hence, for resultant capture parameter. However, it would be worthwhile to explore impact of technological innovation originating (*potentially*) in any Hub like Chile. Given our focus, this does not undermine our purpose.

[A.1-Hub-and-spokes] We consider a simple 3-player HAS configuration, with Chile being the hub and the United States and Mercosur being the spokes. That is, two separate FTAs are *simultaneously* established: Chile-U.S. FTA and Chile-Mercosur 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[18].

[A.2-FTAA] Following the establishment of the HAS system, we simulate the implementation of the regional trade liberalization in FTAA in which trade is liberalized between all the considered spokes economies. In particular, using the updated database from the previous experiment, we simulate trade liberalization between the spokes—US and Mercosur—to have full-fledged liberalization among the three players.

[B] Technology Shocks and scenarios:

Under a mechanism of trade-induced technology spillover between regions, we want to investigate whether hub (like Chile) is going to deliver the potential spillover benefits and resultant productivity growth to the other relatively laggard developing spoke/s when it gets spillover from USA—the advanced spoke and source of technological progress. To offer comparative enumeration of the potential impact for trade-induced productivity under HAS-type and FTAA with no-TFP shock scenario [as in A above], we consider the following experiments:

[B.1- Pure Productivity Shock] Only productivity shock in the US spilling over to other regions *without* any HAS or FTAA.

[B.2- TFP shock in the presence of *both* HAS and FTAA] In this situation, we combine A-1 and A-2 scenarios above with B-1 taking place *simultaneously* under each HAS and intra-spoke liberalization. In this scenario, we conjecture that Mercosur gains *directly* in FTAA phase but *indirectly* in HAS phase via Chile—the reason being by simultaneously establishing FTA with the US, Chile gets a head start directly whereas Mercosur does not. Thus, we run a simulation with one such sequential HAS configuration.

[B.3- TFP shock under *sequential* HAS and FTAA with Chile-US as first HAS-FTA] Consider the sequence where Chile at first, forms FTA with USA and then with Mercosur. In the next phase of trade liberalization with FTAA, Mercosur will be able to reap gains later out of this technology spillover from the US.[19]

4.4 Policy Shocks and Closure:

The particular policy experiment is a TFP improvement in hi-tech sector in USA. Among several empirical studies estimating TFP indexes across regions, very few provide industry specific TFP indexes. To the best of our knowledge, amongst the recent studies only Keller (1997, 1999) calculated a TFP index by industry for 8 OECD countries.[20] Keller (1999, 2001) also modeled the role of growth of R&D stock and geographical variables in extending the knowledge frontier. 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 and heavy manufacturing 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 (1997, 1999), the average annual growth in multifactor productivity in the composite hi-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

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[18] As a basis for comparison, one could also consider a scenario of WTO-style non-discriminatory global trade liberalization. However, this is not simulated in the present paper.

[19] On the contrary, in a *reverse sequence* where at first Chile forms FTA with Mercosur and then with the US, the technological benefits will be harnessed by Mercosur at later stage only when USA liberalizes trade with her.

[20] 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.

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 experiment[21]. In particular, assuming USA as the origin of technology creation we shock the Hicks-Neutral technological coefficient in USA in hi-tech sector by 4% in 1997 and simulate the technology Spillovers from USA to other sectors and regions. Since the hi-tech sector includes the goods with the relatively most rapid rates of technological improvement, we consider that as the source of innovation. In what follows, we document selectively the major simulation results. The closure is the standard GTAP GE closure (see Hertel (1997) and McDougall (2003) for augmented GTAP version 6.2) with added exogenous variable '*avaall*' added in both the cases to suit our purpose—the components *avaall (SRCSEC, SRC)*, *avaall ("CGDS", REG)* are treated as exogenous in the closure file.

5. Analysis of Selective Simulation Results:

5.1 Impact of Trade Policy Shock

[A.1] Chile-United States-Mercosur HAS configuration

The simulation results shows that the HAS configuration does indeed divert trade away from non-participating regions to the participating ones. As was argued earlier, the discriminatory nature of the FTA with the hub also moves each spoke away from free trade with other spokes. Spoke to spoke trade would suffer as trade is diverted towards the hub: it is relatively more advantageous to import from the hub, as it is to export to the hub's market.

As Table 4 shows, while Chile (the hub)'s exports to the United States and to Mercosur expand by 15 percent, and 68 percent respectively, the trade between the two spokes decline slightly. Chile's export to other non participating regions would also drop due to export diversion. At the same time, Chile's imports from those two economies increase by 43 percent and 45 percent respectively. Chile's imports from other regions experience double digit drops in all cases. In this particular case, more trade seems to be created that diverted so that Chile's total import and total export rise by 8 percent and 7 percent respectively. 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) as well as net welfare for the three participating economies.

Table 4. Simulated impact of a hub-and-spokes configuration on bilateral trade flows among modeled economies (percent changes)

	Destination								
Source	1 US	2 Canada	3 Mexico	4 CAmCar	5 Andean	6 Chile	7 Mercosur	8 RestLA	9 ROW
1 US	0.00	-0.08	-0.11	-0.13	-0.15	43.47	-0.21	-0.08	-0.15
2 Canada	0.00	0.00	0.00	0.00	0.00	-13.13	0.00	0.00	-0.01
3 Mexico	0.12	0.16	0.00	0.04	0.05	-17.17	-0.11	0.00	0.07
4 CAmCar	-0.01	0.09	0.00	0.02	0.00	-11.24	0.00	0.46	0.03
5 Andean	0.12	0.19	0.11	0.06	0.15	-14.18	0.21	0.00	0.14
6 Chile	14.96	-3.18	-1.73	-2.22	-1.77	0.00	68.55	-1.47	-1.77
7 Mercosur	-0.70	-0.63	-0.58	-0.74	-0.57	45.07	-1.01	-0.41	-0.62
8 RestLA	0.25	0.00	0.00	0.00	0.00	-11.11	0.00	0.00	0.09
9 ROW	0.05	0.06	0.03	0.02	-0.02	-13.77	-0.01	0.16	-0.01

Source: Simulated effects of reciprocal, bilateral FTA between Chile and USA, Mercosur.

In fact, Table 5 shows that Chile's terms of trade improves by as much as 0.62 which is principally driven by preferential market access and increase demand for Chilean goods (at the

[21] 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%

expense of other regions) in the two large spoke-markets. Chilean welfare also improves by the equivalent of more than $100 million, while US and Mercosur increase by $322 million and $258 million respectively. The ROW aggregate, which is the most “discriminated against” region, loses the equivalent of $570 million.

Table 5. Simulated impact of a hub-and-spokes configuration

Region	Terms of Trade (percent)	Equivalent variation ($ million)	Trade balance ($ million)	Real value of exports (percent)	Real value of imports (percent)
1 US	0.03	322	-43.32	0.08	0.1
2 Canada	-0.02	-45	22.77	0	-0.03
3 Mexico	-0.04	-46	23.48	-0.01	-0.08
4 CAmCar	-0.02	-15	14.75	0	-0.04
5 Andean	-0.07	-51	17.03	-0.03	-0.13
6 Chile	0.62	108	-343.1	5.87	7.7
7 Mercosur	0.14	258	-224.79	0.66	0.81

Source: Simulations by the Authors.

[A.2] United States-Mercosur FTA (Spoke to spoke liberalization)

With the HAS network of FTAs present, we simulate a (admittedly hypothetical) preferential trade liberalization between the two spokes (United States and Mercosur).[22] 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 Chile enjoys in each of the two large spokes. As shown in table 6, Chile’s export to Mercosur declined by 8 percent—export of high tech goods drops by almost 20 percent. Interestingly, there is very little change to Chile’s export to the US suggesting limited preference dilution in the US market. Following the reciprocal and preferential trade liberalization between the United States and Mercosur, their bilateral trade increase substantially: Export from Mercosur’s to the United States increase by 35 percent while trade going the other way jumps up by more than 60 percent.

Table 6. Simulated impact of a hypothetical US-Mercosur (spoke-to-spoke) liberalization following the HAS experiment on bilateral trade flows among modeled economies (percent changes)

	Destination								
Source	1 US	2 Canada	3 Mexico	4 CAmCar	5 Andean	6 Chile	7 Mercosur	8 RestLA	9 ROW
1 US	0.00	-0.49	-0.53	-0.97	-1.27	-1.97	60.28	-2.27	-1.11
2 Canada	0.09	0.00	0.32	-0.12	-0.21	-0.64	-8.45	0.00	-0.04
3 Mexico	0.19	0.70	0.00	0.04	-0.22	-0.95	-11.70	0.00	-0.01
4 CAmCar	-0.32	0.46	0.46	0.22	0.00	-0.63	-5.38	-1.37	0.21
5 Andean	-0.09	0.29	0.65	0.16	0.04	-0.69	-4.44	-1.69	0.19
6 Chile	0.03	0.94	1.26	1.52	0.85	0.00	-8.09	0.00	0.85
7 Mercosur	34.76	2.39	3.64	3.24	2.95	1.94	-8.76	1.76	1.48
8 RestLA	0.24	0.93	0.00	0.00	0.00	0.00	-1.87	0.00	0.36
9 ROW	0.43	0.53	0.60	0.10	-0.09	-0.72	-10.56	-0.91	0.01

Source: Simulations by the Authors.

[22] Of course, removing the barriers between the spokes may not necessarily be an accurate representation of a full fledged regional FTA or FTAA. This point is especially relevant in the presence of complex rules of origin: product from one spoke using input from a second spoke may not be allowed duty free in the hub market.

Following up with the logic presented earlier, spoke to spoke trade liberalization can hurt the hub in a static framework since it might dissipate some of the benefits of being a hub are dissipated. Table 7 shows that Chile's terms of trade decline by 0.24 percent following a US-Mercosur liberalization due to the decrease in the degree of preference that Chile enjoys in those market. This lead to a decline of $65 million in Chile's welfare. Not all the welfare gains from the previous HAS liberalization are dissipated because Chile still enjoys advantageous access to Mercosur and the United States relative to the other regions in the model. While the United States seems to gain from an FTA with Mercosur, in terms of trade (0.28 percent) and welfare ($3 billion), this later end up being hurt by its own liberalization—largely driven by the preferential removal of relatively high barrier on manufacturing goods.

Table 7. Simulated impact of a hypothetical US-Mercosur (spoke-to-spoke) liberalization following the HAS experiment

Region	Terms of Trade (percent)	Equivalent variation ($ million)	Trade balance ($ million)	Real value of exports (percent)	Real value of imports (percent)
1 US	0.28	3026	-889.11	0.62	0.87
2 Canada	-0.14	-308	170.38	0.02	-0.19
3 Mexico	-0.15	-127	95.12	0.02	-0.23
4 CAmCar	-0.12	-79	67.03	0.06	-0.15
5 Andean	-0.08	-55	36.53	-0.01	-0.16
6 Chile	-0.24	-65	19.9	-0.15	-0.44
7 Mercosur	-0.49	-285	-2274.33	5.04	5.4

Source: Simulations by the Authors.

5.2 Impact of Technology Shock and Trade Policy:

5.2.1 Macro Aspects

In this section we consider the macroeconomic repercussions following the TFP escalation and its induced flows. This enables us comparative enumeration of pure technology spillover effects per se vis-à-vis its combined effect with trade liberalization episodes.

[B.1] Pure TFP Shock

We confine our discussion mainly for three sectors viz., Hi-Tech, Heavy Manufacturing and Light Manufacturing and the regions USA, CAN, Chile, Mexico and Mercosur.[23] This is because technological change is more predominant in the manufacturing sectors with hi-tech sector's contribution to productivity of heavy manufacturing using it intensively being high.

Table 8 summarizes the impact of such a shock on some selected macroeconomic variables in the selected regions. After the TFP improvement in hi-tech in the USA and the associated endogenous TFP changes in all other sectors (both domestically and abroad), the economy-wide index of TFP registers an improvement in almost all the regions. However, the magnitude of the index differs markedly across the regions (see row 1, Table 8). USA, being the source of innovation, experiences the highest overall technological progress whereas other regions experience a TFP improvement of lower magnitude than USA; more importantly, amongst the recipients, Canada receives higher doses of technology transmission than the developing spokes and Chile as hub. Being neutral in nature, the TFP change translates into an equivalent increase in real GDP at factor cost in the regions. As all primary factors become equally productive following the Hicks-neutral shock and its transmission, regional index of real value-added (in effective units) register an equivalent TFP

[23] Inundated with heaps of simulation results, due to limitations of space, we report only selected important ones. Those are available upon request.

improvement; however, the differences in the performances being driven by the differentials in technology transfer and its capture.

Table 8. Simulated regional effects of 4% TFP shock in the Hi-tech sector in the USA on Selected Macroeconomic Variables (% changes of level variables from their control values).

Percentage change in:	USA	Canada	Chile	Mercosur	Mexico
1. Region-wide index of TFP growth	3.8	2.1	1	0.2	1.5
2. Real GDP at Factor Cost	3.8	2.1	1	0.2	1.5
3. Region-wide Price index of Value-added	1.9	1.2	1.2	1	1.1
4. Region-wide index of Real Value-added	3.8	2.1	1	0.2	1.5
5. Real Return to Skilled Labor [CPI adjusted]	3.64	2.20	1.05	0.30	1.80
6. Real Return to Unskilled Labor [CPI adjusted]	3.63	2.14	1.00	0.22	1.62
7. Real Rental price of Capital	3.61	2.12	1.03	0.23	1.70
8. Welfare [EV]	286816.2	13495.7	750.1	2590.9	6248.5

As will be evident from Table 9, the capture of transmitted technology depends on the magnitudes of the economy-wide and sectoral embodiment indexes and spillover coefficients vis-à-vis source and the destinations. Since the policy shock is injected in the first period (i.e., the base period 1997) we quote the base-period values of such indexes.
The aggregate spillover index gives us an average *overall* magnitude of technology appropriated by all user sectors in the source (i.e., USA) as well as client regions from the hi-tech sector in the USA via traded and/or domestic intermediates.

Table 9: Values of economy-wide embodiment-indexes, spillover coefficients, parameters for governance, adjacency, capture and congruence [(a)]

GTAP Regions (1)	Embodiment Index (E_{irs}/E_{ir}) (2)	Spillover Coefficient (γ_{irs}/γ_{ir}) (3)	Capture-Parameter (θ_r) (4)	AC (5)	GP_{rs} (6)	AP_{rs} (7)	$SC_{rs} = AP_{rs} \times GP_{rs}$ (8)
1. USA	0.70	0.84	0.71	0.71	1.00	1.00	1.00
2. CAN	0.33	0.48	0.38	0.40	1.00	0.95	0.95
3. Chile	0.14	0.21	0.25	0.41	0.70	0.85	0.60
4. Mexico	0.35	0.37	0.04	0.38	0.10	0.90	0.09
5. Mercosur	0.03	0.04	0.08	0.43	0.22	0.80	0.18
6. CamCari	0.16	0.24	0.24	0.38	0.80	0.80	0.64
7. Rest of LA	0.21	0.26	0.16	0.38	0.50	0.85	0.43
8. Andean	0.23	0.34	0.28	0.43	0.80	0.80	0.64

(a) Values shown relate to the base period pre-shock levels.

From Table 9, it is evident that the aggregate embodiment index in USA $[E_{ir}]$ is higher than those in the destinations $[E_{irs}(s \neq r)]$ - compare figures in column 3. Since the capture-parameter (θ_r) in USA is higher than θ_s in all the regions (see column 4, Table 3), from Equations (6) and (7) it is clear that USA reaps the maximum spillover (γ_{ir}) (see column 3 of the same Table). For Canada and Mexico, although the values of E_{irs} are of the same order of magnitude, the aggregate spillover coefficient (γ_{irs}) is of much higher magnitude in former than in other regions including Chile. This is because the higher value of the capture parameter $[\theta_r]$ magnifies value of the embodiment index and hence enables Canada, Mexico and Chile to record a much higher rate of TFP improvement than Mercosur. The higher values of GP, AP, SC and hence, of θ_r translates into pronounced productivity and welfare gains in Canada with Chile and Mexico having moderately higher gains. Despite having higher θ_r in Chile than Mexico, higher embodiment index and spillover coefficient in Mexico translate into relatively higher TFP and welfare gains there. Thus, increased trade along with 'right' combination of GP, AP and AC factors impact on technology transmission. However, the higher θ_r magnifies the extent of spillover in Chile Hub. Note that the ordering of the spillover coefficient in column 3 of Table 9 matches the ordering of the real GDP in row 2 of Table 8. For Chile and Mexico it does not show much change compared to Canada but for Mercosur**,** the effect is minimal due to low values of SC, GP and hence, of θ_{rs}. Also, following the TFP improvement in the hi-tech sector the region-wide index of TFP registers improvement in most of the regions with Canada, USA, Mexico and (too some extent, Andean bloc) as the leading regions.

From Table 9, it is evident that the aggregate embodiment indexes in Canada and Mexico are high among the client regions due to higher volume of trade flows from USA and also we see Canada has the highest magnitude of spillover coefficient as compared to other destinations (see columns 2 and 3). Having the highest magnitude of capture-parameter and largest domestic spillover and having supplied mostly the locally produced intermediate inputs in its own market, USA is able to capture most of the productivity gains from the domestic technology transmission. Canada, having higher θ_r as compared to Chile and Mexico, registers higher technology spillover due to higher values of trade-embodiment index (see Column 2, Table 9). Similar considerations explain the cases for other destination region Andean. We observe that TFP shock makes all the factors more productive so that the marginal productivity of the primary factors improves by equal percentage changes and hence, the returns to factors also increased during the simulation period with negligible effects in case of Chile and Mercosur (this is due to much less productivity gains and lower enhancement of composite value-added). However, following the TFP shock all the *sectors* experience differential TFP growth depending on the values of *sectoral* embodiment indexes and spillovers as discussed below.

The changes in price relativities coupled with the Armington (1969) specification of commodity substitution lead to inter-regional competition via international trade. For the global economy as a whole, we see that there has been an increase in the quantity index of world trade by 1 percent. This is the increase in global real exports (or equivalently, in global real imports). Also, world supply of hi-tech, heavy manufactures and light manufactures register more than 1 percent increase with service sector having 1.4% increase due to higher intensively usage of hi-tech components. Following the shock, the *aggregate* volume of exports increases in the principal beneficiaries of TFP changes namely, Canada, Chile and Mexico whilst for Mercosur, it declines by small. By contrast, the *aggregate* volume of imports increases in *all* the regions; although not so strongly as the rises in exports in USA, Canada and Mexico--see Table 10.

Table 10. Simulated regional effects on aggregate trade performance and welfare of the regions

Percentage change in:	USA	Canada	Chile	Mercosur	Mexico
1. Terms-of-trade	-0.81	0.22	0.03	0.26	0.33
2. Aggregate export price index	-1.93	-1.38	-1.23	-0.99	-1.33
3. Aggregate import price index	-1.13	-1.60	-1.26	-1.24	-1.65
4. Real value of exports	4.32	2.69	0.92	-0.31	2.20
5. Real value of imports	1.52	2.55	0.93	0.73	2.22
6. Change in trade balance	16298.71	1013.66	12.08	-570.59	429.03
7. Welfare (EV)	286816.2	13495.7	750.1	2590.9	6248.5
8. Regional Household Income	3.97	2.38	1.07	0.30	1.82
9. Per Capita Utility	3.97	2.37	1.07	0.30	1.82

Source: Simulated impact of 4% TFP Shock in Hi-tech sector.

The preceding discussion shows that the TFP shock erodes competitiveness of Chile and Mercosur (due to lower capture) whereas USA, Canada and Mexico, reaping almost the maximum potential benefits, become more competitive. A much larger rise in the volume of exports from USA, Mexico and Canada and relatively smaller order of magnitude of fall in the volume of exports from Mercousr and others translate into a rise in the volume of global trade in hi-tech and manufactured products. Because the changes in price relativities across regions (after the TFP shock) induce changes in regional terms-of-trade (TOT), the pattern of inter-regional competition is disturbed.

As the TFP improvements act as an export supply shifter for each generic commodity so that for each commodity the volume of global merchandise exports, as well as imports, increase. A relatively much larger fall in export prices in USA as compared to the falls in these prices in other regions in the hemisphere translate into a much larger decline in the regional price index of merchandise exports in the USA than in other regions- see rows 2 and 3 in Table 10. However, the values of the changes in the regional price indexes for exports preserve the same ranking and order of magnitude as the regional quantity indexes of exports. The magnitude and directions of the changes in commodity-specific export price indexes are driven by the changes in regional aggregate export price indexes. These export price indexes for the commodities are share-weighted averages across regions of the aggregate exports price index of each commodity from exporting region - the weights being the shares of regional exports in global exports for that commodity. As expected, we see that this has been governed by the magnitude of the sectoral embodiment indexes and spillover coefficients (depending on AC, AP and GP parameters). In effect, following the TFP shock the supply prices for all the produced commodities fall in all the regions whereas for Mercosur they fall by little (as it experiences lesser benefits from transmitted technological spillover). Thus, the productivity shock has been trade creating for the global economy as a whole. Next couple of sections gives comparative enumeration of combined simulated effects of trade cum liberalization scenarios.

[B.2]TFP with-HAS and FTAA, no sequencing

Table 11. Simulated Regional Effects on Aggregate Trade Performance of the Regions

Regions	USA		Chile		Mercosur		Mexico		Canada	
Type of configuration→:	Joint HAS (1)	FTAA (2)	Joint HAS (1)	FTAA (2)	Joint HAS (1)	FTAA (2)	Joint HAS (1)	FTAA (2)	Joint HAS (1)	FTAA (2)
Percentage Changes in↓:										
1. Terms-of-trade	-0.78	-0.55	0.25	-0.2	0.36	-0.72	0.29	0.2	0.21	0.11
2. Aggregate export price index	-1.92	-1.75	-1.02	-1.73	-0.89	-2.18	-1.36	-1.38	-1.39	-1.42
3. Aggregate import price index	-1.15	-1.21	-1.27	-1.54	-1.24	-1.47	-1.65	-1.58	-1.6	-1.52
4. Change in trade balance	16303.95	16318.99	160.19	36.65	-563.8	204.74	414.53	392.28	1003.1	959.34
5. Welfare (EV)	287121.3	294994.5	846.66	913.64	2768.6	2058.26	6206.47	6239.38	13454.5	13457.23
6. Regional Household Income	3.98	4	1.21	1.3	0.27	0.21	1.81	1.81	2.37	2.34
7. Per Capita Utility	3.97	4	1.2	1.3	0.27	0.21	1.81	1.8	2.37	2.34
8. Contribution of TFP to EV	294897.2	300239.8	750.27	874.55	2015.34	2686.23	5252.98	5335.39	11249.7	11433.1
9. Contribution of Allocative Efficiency to EV	-41.48	129.5	51.41	78.65	321.71	433.49	652.46	694.14	1743.61	1779.53

Source: Simulated impact of 4% TFP Shock in Hi-tech plus joint HAS and FTAA *without sequencing.*

Compared to B.2 scenario, in the simultaneous HAS case the TOT movement preserves the same ranking and order of magnitude except for Chile and Mercosur who register relatively higher improvement 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, 8 and 9 in Table 11). Also, these countries are able to register positive trade balance (i.e., trade creation) except Mercosur whose exportable become relatively dearer compared to the price of the importable. In case of FTAA, TOTs fall in these two regions whereas other considered regions maintain the same sign. This is due to the fact that in the FTAA scenario, USA and Canada, the biggest benefactors of trade-induced technology flows and having higher parameters of such capture, 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.

[B.3]TFP with-HAS and FTAA, sequencing

In this scenario, Chile moves first to form FTA with US and then joins Mercosur. The results are not substantially different for the only Trade policy scenario. But, due to trade-induced technology spillover the effects are magnified. For example, all the regions are experiencing welfare increase (see row 5, Table 12)—contributed predominantly by value-added augmenting TFP improvement (see row 8, Table 12). However, in sequence 1, Chile and US perform better due to preference accumulation effect via market access in their respective markets. In the first phase, substantial accrual of gains to Chile 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 Chile joins Mercosur, the latter gains in terms of welfare and TOT due to indirect spillover of technological benefits via traded intermediates sourced from Chile after trade liberalization under HAS network. But, Mercosur having 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 12). Under full-fledged FTAA scenario, however, it improves its trade balance, even higher than Chile (row 5, Table 12). Comparing the respective FTAA columns with the two sequential HAS networked liberalization episodes for each of the reported regions, we can infer that FTAA has been welfare-augmenting and trade creating for most of them especially USA and Mercosur.

Table 12. Simulated Regional Effects on Aggregate Trade Performance of the Regions

Regions	USA			Chile			Mercosur		
Type of configuration→:	Chile-US HAS (1)	Chile-Mercosur HAS (2)	FTAA (3)	Chile-US HAS	Chile-Mercosur HAS	FTAA	Chile-US HAS	Chile-Mercosur HAS	FTAA
Percentage Changes in↓:									
1. Terms-of-trade	-0.77	-0.81	-0.54	-0.2	0.46	-0.2	0.21	0.41	-0.76
2. Aggregate export price index	-1.91	-1.96	-1.77	-1.51	-0.88	-1.77	-1.05	-0.85	-2.26
3. Aggregate import price index	-1.15	-1.17	-1.24	-1.3	-1.33	-1.57	-1.26	-1.25	-1.5
4. Change in trade balance	16300.68	16344.06	16383.35	105.65	111.07	36.99	-565.51	-572.54	233.87
5. Welfare (EV)	287205.3	292110.7	300366	715.26	1123.27	932.67	2513.15	2906.44	2077.91
6. Regional Household Income	3.98	3.97	4	1.02	1.61	1.33	0.25	0.29	0.21
7. Per Capita Utility	3.98	3.96	3.98	1.02	1.61	1.32	0.25	0.29	0.21
8. Contribution of TFP to EV	294897.6	300279.8	305584.6	759.39	885.9	892.42	2014.91	2072.01	2756.25
9. Contribution of Allocative Efficiency to EV	-37.15	-53.77	132.33	10.06	131.97	80.48	229.31	353.43	446.59
10. EXPAND (Capital, r)	**0.53**	0.54	**0.57**	**0.77**	0.79	**0.82**	**0.49**	0.51	**0.53**

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

For Chile as hub, although it accumulates preferences under two HAS sequences, this preference gets diluted in FTAA scenario where the welfare increase is moderate and lowered to $933 million from $1123million. Moreover, due to upsurge in trade under HAS and FTAA configuration, in the presence of technology flows vehicled via trade, there is enhancement of production efficiency resulting in income gains (row 6, Tables 11 and 12). 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))—see row 10, Table 12. In each case, compared to HAS sequences the FTAA scenario gives much augmentation of capital goods leading to further efficiency gains. Under only HAS type scenarios, such changes in investment levels is almost negligible. Thus, even in a static CGE framework we get quasi-dynamic effects with trade policy reform owing primarily to trade-led technology spillover mechanism.

5.2.2) Sectoral Aspects

Since technology transmission effect can be better traced at the sectoral level, to elicit the underlying mechanism behind macro impacts, we consider sectoral issues following *only* TFP Shock with *no* trade liberalization. With technology transfer via traded intermediates it is worthwhile to focus on TFP impacts per se. The values of *sectoral* embodiment indexes and spillovers reported in Table 13.

Table 13: Simulated impact on sectoral TFP, output and spillover coefficient by sectors*

Regions (1)	**Sectors** (2)	**Spillover Coefficients (Base period)** (3)	**Sectoral TFP Growth** (4)	**Percentage changes in Sectoral Output** (5)
USA	LMnfcs	0.94	3.78	4.09
	HMnfcs	0.94	3.74	3.95
	HiTech	0.91	4	4.06
	Svces	0.92	3.68	3.7
CAN	LMnfcs	0.57	2.26	2.4
	HMnfcs	0.54	2.17	2.27
	HiTech	0.67	2.67	2.88
	Svces	0.49	1.95	1.96
Chile	LMnfcs	0.3	1.18	1.23
	HMnfcs	0.27	1.08	1.02
	HiTech	0.34	1.36	0.91
	Svces	0.24	0.97	1.03
Mercosur	LMnfcs	0.03	0.1	0.16
	HMnfcs	0.03	0.11	0.12
	HiTech	0.1	0.39	0.08
	Svces	0.05	0.21	0.27
Mexico	LMnfcs	0.2	0.81	0.49
	HMnfcs	0.52	2.09	1.86
	HiTech	0.58	2.32	2.47
	Svces	0.34	1.36	1.56

*Figures are in percentage changes of the respective variables following 4% TFP shock.

From Tables 11 and 13, it is clear that USA, having reaped most of the benefits from domestic spillover via the hi-tech sector (source of TFP growth), the sectoral TFP growth is highest in all four sectors as compared to other regions (column 4, Table 11). The highest value of capture parameter magnifies the values of spillovers there and hence resulted in higher TFP growth. Similar considerations apply for Canada, Chile and Mexico with the magnitudes differing. However, for the relatively laggard regions with lower magnitude of θ_r viz., Mercosur, the resultant sectoral TFP growth is [ava (j, r)] of very low magnitude in Mercosur and Mexico (as compared to the USA and Canada). The sectoral TFP improvement resulted in higher percentage increases in output in all the regions (see column 5, Table 11). Thus, ava [j, r], being low, does not dominate the percentage changes in sectoral output in Mercosur. Hence, the effect of endogenous TFP improvement has been modest with reallocation of factors across sectors, to some extent, influencing the changes in output in Canada and other regions. Regarding supply price changes, the cost-savings is reflected in lower prices [ps (i, r)] in all sectors. The falling cost is largely attributed to a decline in price of composite value-added and its constituents in a sector 'j' in region 'r' [pva (j, r)] (in conventional units). However, compared to HAS sequences, in FTAA scenario Mercosur registers much larger fall in prices compared to Chile, due to transmitted productivity gains from US directly and indirectly from others, thereby grabbing market access at the expense of Chile as Hub.

From Table 14, we infer that as changes in relative price in all three sectors in Canada, Mercosur and Chile vis-à-vis USA is much higher, the regional aggregate exports [qxw (i,r)] in all three sectors from USA to all the destination regions increase following the shock. For the major beneficiaries of TFP improvements, viz., USA, and Canada, the percentage increase in the quantity index of exports [qxw (i,r)] is governed by the relative changes in the market prices of the tradeables imported from one source to another [i.e., pms (i,r,s)-pms (i, t, s) where $r \neq t$]. For Chile, after FTAA formation it loses market access not only to other spoke but also to other markets due to preference dilution and hence registers fall in exports of hi-tech products; also, compared to Mercosur, we see very little percentage rise in exports of others (rows 1,2 and 3, Table 14). In the simulation, as expected we find that for USA the percentage increases [qxw (i, r)] for Hi-tech and heavy manufactures.

Table 14: Simulated effect on aggregate regional exports of commodities under FTAA[(a)]

GTAP Sectors	Regions				
	USA (1)	Chile (2)	Canada (3)	Mexico (4)	Mecosur (5)
1. Hitech	6.81	-9.9	3.57	3.39	4.56
2. Heavy Mnfcs	3.96	1.63	2.72	2.28	6.33
3. Light Mnfcs	6.17	1.86	2.57	0.88	21.79

(a) Simulation results of 4% TFP shock.

6. Concluding Remarks

In this paper, we investigate the economic implications of hub-and-spokes configuration and compare it with a broader type of regional liberalization in which free trade is established among spokes. We argue that such configuration is likely to alter trade pattern disproportionately in favour of the hub, since from the point of view of each spoke, it becomes more advantageous to import from the hub, as it is to export to the hub's market. We confirm this result in a simulation exercise scenario in which Chile becomes the hub, and the United States and Mercosur are the spokes. This type of results would be even stronger if the spokes are small developing countries. Even the preferential market access that a given spoke gains from the FTA with the hub would likely be diluted by the fact that the hub is also giving the same (if not more favourable) preference to all the other spokes. After all, preference to everybody may be equivalent to no preference at all.

This argument relates to the debate of whether a Free Trade Area of the Americas would be superior to a series of criss-crossing bilateral FTA among the potential FTAA members. In fact, having achieved the status of being an hemispheric hub, countries Mexico or Chile may no longer have any incentive to pursue strenuous full fledged FTAA-type regional trade negotiations. In our simulations, we show that the move from HAS to the FTAA (proxied by a bilateral liberalization among the disjointed spokes) is likely to hurt the hub, due to the dilution of the preference that it enjoys in each of the spokes.

Given that the HAS configuration definitely affect the pattern of trade among all concerned economies, we argue that it could also affect the flow of technological innovation (embodied in trade in intermediates). We augment the standard modelling framework to capture this possibility. Following the technology shock, we calibrate: (i) regional disparities in capturing transmitted productivity gains; (ii) the impact on global trade; (iii) welfare impact. The model results show that technological innovations in the hi-tech sector result in a significant increase in manufacturing production. Also, results show that sectors that use hi-tech products intensively register higher output growth especially in USA experiencing much higher benefits of TFP change. It is quite likely to consider multiplicity of sources of technology creation. In this context, modelling skill formation, appropriateness of technology and indigenous R&D capabilities will impart valuable insights for enunciating policy insights so as to foster absorptive capacity. All these will help in formulating more refined specification of technology capture and adoption. However, given the limited scope, we do not explore these issues in the current analysis.

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