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Abstract

Technology transfer costs have a profound influence on the firm's entry mode into a production sharing relationship. To explore this nexus, we associate technological complexity of the off-shored input with the organizational mode of international production sharing by extending the Antràs (2005) model. We modify the Antràs model by proposing that the low-tech input, as qualified within the model, cannot be produced in the low wage south without costly technology transfer. The cost of technology transfer in turn depends on three factors, which are the technological complexity of this input, the absorptive capacity of the host country and the wages of the host country. Our model refines the results obtained in Antràs (2005). We find that

1. For high-tech goods, intra-firm transfer is preferred vis-à-vis outsourcing only for intermediate range of technological complexity of the off-shored input,
2. On the other hand, for low-tech goods, where the likelihood of outsourcing is higher in Antràs, intra-firm offshore contract is still possible for low range of technological complexity.

Our model has policy suggestions for host countries which aspire to maximize their benefits from the exploding global production phenomenon. As the wage gap between the source and the host country falls, cost considerations for offshoring disappear. New sources of comparative advantage should therefore be created in the host country by subsidizing technology investment and higher education to build higher absorptive capacity.

Keywords: Outsourcing, Foreign Direct Investment, Technology Transfer, Absorptive Capacity

JEL Classification: D23, F12, F23, L22, L33

Section 1: Introduction

In the early stage of production fragmentation, every firm faces the "make or buy" choice. The importance of this decision is reflected in the recent proliferation of internalization literature relating to foreign sourcing. Current research on the theory of international sourcing has revealed that the organizational structure of the multinational firm is influenced by the degree of standardization of the good, factor intensity of the offshored input, intensity of the offshored input in final good, productivity of sourcing firms, legal framework, and market thickness in the host country. One common denominator across all these factors is that they crucially impact the cost borne by the sourcing firm. Surprisingly, the cost of technology transfer – transmission and assimilation – that has been central to the theory of multinational corporations (MNC) since the last three and half decade has been overlooked with regard to vertical production transfer. This paper fills the gap by incorporating the cost emanating from technology transfer in Antràs (2005) model and thus relating the internalization decision of a firm to the technological complexity of the offshored input and the wages and absorptive capacity of the host country.

Technology transfer costs are as crucial in a vertical relationship as in horizontal FDI or licensing. Particularly, in an outsourcing transaction with an unaffiliated supplier, assimilation costs are significant. A survey of Indian Business Process Outsourcing (BPO) vendors (The Hindu Business Line, 2005) reveals that 25.2% of total wage cost is spent on training of its employees to produce inputs of the quality standards set by its buyer. Arora et al (2000) in their extensive fieldwork on Indian software BPO industry find that a significant amount of specialized training for all employees, including the skilled employees, is undertaken after recruitment which lasts on an average for 2-3 months. In 2004, Caliber Point Business Solutions Limited, a third party BPO service provider to Hexaware Technologies, made substantial investments in technology infrastructure like fiber optic technology for the backbone of Local area Network, Dell Intel Xeon Servers and Network Security using Stonegate Firewall and IDS and Tata Honeywell CCTV.

We introduce product/firm specific technology transfer cost for the offshored fragment in the Antràs (2005) model thereby introducing heterogeneity across firms manufacturing a single product or products of a single firm. The cost of technology transfer varies with the technological sophistication of the offshored input. If a firm has *n* products whose offshored input differ in their technological complexity, then, internalization decision will vary for each of these products. Alternatively, if all firms in the market have only one product that differ in the technology it employs for producing its offshored input, then again, firms diverge in their decision to internalize. We differentiate between vertical foreign direct investment (VFDI) and international outsourcing (IO) in the usual Grossman-Hart-Moore way of contractual bargaining power. Using evidence from existing studies on horizontal relationships and current offshoring surveys, we distinguish between intra-firm and arm's length production contract with respect to the technology transfer cost borne by the sourcing firm in the two alternative modes. The technology transfer cost incurred by a sourcing firm in an internal production transfer is substantial and is a part of its relationship specific investment (RSI), while the subsidiary manager has little incentive to invest in technology assimilation. On the same note, if the offshore production is contracted to an outside supplier, then the supplier has to incur a significant proportion of the technology transfer costs while the sourcing firm has little motivation to bear the costs of technology transmission. Technology transfer costs are a function of the complexity of technology used to produce the off-shored input, the absorptive capacity of the host country and its wage rate. Since the technology transfer costs borne by the sourcing firm varies with its organizational mode, so naturally internalization decision becomes a function of technological complexity of the input, host country absorptive capacity and the wages.

Several studies have found a correspondence between the complexity of a product (whole or the fragment being offshored) and the firm's organizational structure. Based on field research conducted in the US, Singapore, UK and India, Aron and Singh (2002) find that lower end processes like data transformation or customer service which embody less complex skills are outsourced to a third party. On the other hand, complex inputs in the global value chain are offshored to an affiliated supplier. Gereffi et al (2003) describe five organizational forms of fragmented production based on case studies in the bicycles, apparel, horticulture and electronics industries. They also conclude that high complexity of a good is compatible with intra-firm transaction unless the supplier capability is high. Davidson and McFetridge (1985) studied transactions involving high-tech products of 32 US based multinational companies (MNC) between 1945 and 1975. Their logit estimates indicated that the probability of internalization is higher for transactions involving products with newer technology. Most of these studies focus on transaction cost economies to explain the linear relationship between the tendency for vertical integration and higher technological complexity of the input. These models however do not explain the rising demand for medical electronics, designs of digital devices bought from Asian manufacturers by Dell, Hewlett-Packard, Motorola, and Philips but sold under their own brand names.

In Antràs (2005) model, the decision to internalize depends on the intensity of low-tech input (the offshored input) in final product. A low intensity of the offshored input implies lesser contribution by the supplier in total surplus and property rights theory dictates that it is optimal for sourcing firm to get the residual rights of control and hence intra-firm relationship emerges. On the other hand, a high intensity of offshored input implies greater contribution by the supplier in total surplus and optimization results in an outsourcing contract. We extend Antràs (2005) model by intertwining the role of intensity of the offshored input and technological complexity of this input. Given the absorptive capacity of the host country, our model reveals that at high relative home country wages, a good with low intensity of offshored input, is more likely to get offshored through intra-firm transactions only for intermediate range of technological complexity. At low and high levels of technological complexity, the sourcing firm is better off engaging an unaffiliated supplier to produce the offshored input. The intuition for this result is as follows. When the intensity of offshored good is low, then by Antràs (2005) model there is greater probability for production transfer to occur via the VFDI mode. This makes the profitability of the sourcing firm in the VFDI mode more sensitive to technological complexity thereby choosing an affiliated supplier only for intermediate range of technological complexity. By making an intra-firm transfer, the sourcing firm faces lower host country wages and lower contractual costs but higher costs of technology transfer vis-à-vis outsourcing. At low technological complexity, the distortion in technology transfer investment by the supplier is low, while at high technological complexity the savings from technology transfer cost forces the sourcing firm to choose an unaffiliated supplier. If the intensity of the offshored input is high, then, the intra-firm production transfer is preferred to outsourcing at low technological complexity of the offshored input. In both the case, however, outsourcing is preferred to VFDI at high technological complexity of the offshored input. Our result is empirically testified in Borga and Zeile (2004) where the volume of intra-firm trade falls with increasing R&D intensity of the affiliate[1].

Our model highlights the possibility of different trends that can emerge in the organizational structure of fragmented production. We have observed offshoring relationships of the form “Build-Operate-Transfer” whereby a sourcing firm initially establishes an outsourcing relationship with an unaffiliated supplier and then at a later stage takes over the offshoring unit to make it a captive one. Our model predicts that relationship of this form will most likely transpire for the high-tech goods as in case Aviva Plc. Our model, on the other hand, also

[1] The evidence from Borga and Zeile (2004) is relevant to this paper only to the extent that the intra-firm trade they are talking about is the import of inputs from the parent firm to the affiliate for further processing.

predicts that a transformation from captive to third party as exemplified by General Electric India operations, but by and large for low-tech goods.

The model delivers implications for policy on technology and absorptive capacity in the host country. In real world, we do not observe outsourcing of inputs embodying complex technology on a wide scale. If the host country government subsidizes technology investment by the domestic vendors, then there is higher probability of an outsourcing contract for technologically complex input, given the level of absorptive capacity. Moreover, if a host country enlarges its absorptive capacity by heavy investment in education to build its comparative advantage in inputs embodying complex technology, then they stand to gain by getting more value-added work through both VFDI and outsourcing.

The paper beyond this point is organized as follows. Section 2 discusses the literature associated with this research area. In section 3 we develop the model and discuss the consequences of introducing technology transfer costs in the Antràs (2005) model. Section 4 discusses the results of the model and section 5 makes a conclusion.

Section 2: Related Literature

In this section, we intend to assimilate internalization literature with the literature on technology transfer costs and contract theory. Several studies have examined the horizontal mode of entry by a multinational in the presence technology transfer costs. For example Mattoo, Olarreagaz and Saggi (2004) build a theoretical model where establishing a subsidiary is preferred to acquisition of domestic firm if the cost of technology transfer is high. This is because a high cost of transferring technology to the acquired firm is associated with a smaller cost advantage over domestic firms and a high acquisition price. Based on the information obtained for twenty-six projects of U.S. firms in chemicals and petroleum refining and machinery, Teece (1977) finds that cost due to technology transmission can range from about 20%-80% of a project costs. In our paper, we propose that the burden of this cost can be shifted by transferring ownership share and therefore impact the internalization decision of a firm.

A major stumbling block in relating technology transfer literature to internalization decision in fragmentation is that there is little research on vertical transfer of technology and the related costs. Therefore, we have to rely on studies relating to horizontal technology transfer. Horizontal technology transfer models do not offer much evidence on the cost sharing pattern between the transferor and the transferee or the resource cost of technology absorption by recipient firms. Recently, several instances from BPOs and sourcing firms, as cited in the introduction confirm our belief that technology absorption is also a substantial proportion of costs and hence may impact internalization decision of the sourcing firm. Thus, we need to rely on a combination of horizontal technology transfer research, information based on case studies of BPOs and captive offshored production units (VFDI), reports or surveys published in popular media.

The other strand of literature which we incorporate in our model is contract theory which has been known to influence the sourcing firm's decision to internalize since Grossman and Hart (1986). Incompleteness of contracts is an inevitable feature that sets in when transaction happens between two independent entities as in case of Antràs and Helpman (2004) and Antràs (2003, 2005). With incomplete contracts, these models show that the bargaining power of the MNC is higher with VFDI mode vis-à-vis outsourcing. Besides this difference between VFDI and outsourcing, Antràs and Helpman (2004) also emphasize that the organizational fixed costs is higher for VFDI. In such an economy, more productive firms venture into VFDI. Based on evidence provided by Dunning (1993), Antràs (2003) assumes that if a good requires RSI in capital and labor, then the sourcing firm always contributes to capital investment. This implies that for a capital-intensive good, the sourcing firm contributes more to aggregate surplus and optimality requires integration with the supplier. Antràs (2005) is also based on the same principle as Antràs (2003) where the two inputs are labeled as high-tech and low-tech instead of capital and labor. The sourcing firm makes RSI in high-tech input and therefore we expect intra-firm production transfers for high-tech good. However, with time, as the intensity of high-tech input falls, it can be outsourced. This highlights that the degree of standardization is also higher for a product that is outsourced relative to a product that is produced by a MNC subsidiary.

To understand these two strands of research together in one framework, we split technology transfer costs into transmission and assimilation costs. Transmission cost is the cost to shift codified knowledge like blueprint, formulas, management techniques customer list, or tacit knowledge like know-how, information gained from experience which is usually borne by the transferor. Assimilation cost is the expenditure on R&D by the supplier, cost of training workers to adapt to new technology, or acquiring new technology from technology market. These costs are typically borne by the recipient firms unless the host government makes it mandatory for the investing foreign firm to make investment on technology absorption or acquisition.

For the VFDI mode, we would expect high technology transmission costs in proportion to technology assimilation cost. This is justified by the high bargaining power of the parent firm in an intra-firm transaction which induces it to invest in costly technology transmission but at the same time reduces the incentive of the subsidiary manager to invest in assimilation of the technology. Our insight is spelled out in the survey by Chuang and Chang (1993) on foreign affiliates and domestic licensee firms (and joint ventures) in Taiwanese pharmaceutical industry. They find that foreign subsidiaries in the host country do not give much importance to the cost of technology transfer in their profitability analysis. At the same time, licensee firms are very careful about the cost of technology. Their results are explained by emphasizing that domestic firms rely on external market to channel the ingestion of technology and thus have to bear pecuniary expenditure and adaptation costs. On the other hand, a subsidiary obtains technology from its parent firm which precludes any transaction in the technology market, and therefore has little incentive to assimilate technology or its costs.

Teece (1977) survey found that technologies closer to the frontier are transferred to a subsidiary vis-à-vis an arm's length agent. Since the cost of transferring technology is positively related to its age, a parent firm spends more resources for transmitting technology to a subsidiary vis-à-vis an arm's length unit. UNCTC (1987) also finds empirical evidence in the cases of US and German firms where intra-firm technology transfer is far more significant than that taking place between independent parties. This is a reflection of the MNC preference towards fully controlling the assets transferred to overseas establishments. Since full control of technology transferred is not granted in case of an arm's length contract, the MNCs may not prefer to bear the costs of technology transferred to an arm's length agent.

In the current context, technology transfer by a sourcing firm to an outside supplier may also be limited by the fact that a third party vendor (TPV) usually has more than one client. Therefore, if a client transfers its technology to the supplier, it undertakes a risk that its technology maybe used by the supplier to serve other clients as well. Therefore, any rational sourcing firm will not transfer its technology to its TPV to the extent possible. Hence, the TPV has to invest on its own training and technology acquisition contrary to a captive (subsidiary) unit which can depend on its parent firm for technology. Examples can be found in the Indian third party BPO companies like VisualSoft Technologies Ltd, Zensar Technologies, iGate Global Solutions etc. who have to spend a considerable proportion of their revenues on technology acquisition and absorption.

Since a sourcing firm has little incentive to invest in technology transmission in an arm's length relationship, it is therefore the technology assimilation and acquisition costs which gain more importance. This is also supported by the Grossman and Hart theory relating to the bargaining power of the unaffiliated supplier vis-à-vis the affiliated one. Chudnovsky (1991) report on north-south technology transfer finds that technical assistance to local suppliers is crucial for meeting their performance metric, however, this is precisely the area where assistance from technology providers are missing. Egan and Mody (1992) find that in a subcontracting relationship the buyer is willing to transmit only the minimum information required to get the product out of the production cycle. If the product must adhere to stringent quality specifications before being accepted, then it is entirely left to the supplier's discretion to take up the contract, get involved in the manufacturing process and produce the good of requisite quality at lowest possible cost. Thus, the supplier incurs most of the technology transfer or adaptation expenditure. Our assumption is implicit in a theoretical model by Bartel et al (2005). An increase in the rate of technological change, in their model, increases outsourcing because it allows the sourcing firms to use the services of the supplier based on leading edge technologies without incurring the sunk costs of adopting these new technologies. The assumption implicit in their analysis is that it is always the supplier of the input who subsumes the cost of technology in an outsourcing relationship.

Assumption 1**:** *In case of VFDI, the parent firm incurs a significant share technology transfer costs, while in case of outsourcing, it is the unaffiliated input supplier who bears a large proportion of this cost.*

Section 3: The Model:

Consider a world with two countries – the developed north and the low wage south and a good *y* produced with labor only. We borrow demand function and production function from Antràs (2005) model, given by (1) and (2) respectively. Consumer preferences are such that a unique producer, *i*[2], of good *y* faces the following isoelastic demand function:

$$y(i) = \lambda \, p(i)^{-1/1-\alpha} \qquad (1)$$

Where *p(i)* is the price of good *y(i)* and λ is a given parameter known to the producer.

The final good *y* is produced using two inputs, high-tech, x_h , and low-tech, x_l , with intensity (*1-z*) and *z* respectively.

$$y = \left(\frac{x_h}{1-z}\right)^{1-z}\left(\frac{x_l}{z}\right)^{z} \qquad (2)$$

By assumption, the South lacks the capability to produce the high-tech input like R&D. Thus, it is only the low-tech input that can be offshored. Unlike Antràs[3] (2005), the production of the low-

[2] Firms in Antràs (2005) model are homogeneous and hence the subscript *i* is not present in his model.
[3] In his model, there is a one to one relationship between labor and output of low tech input.

tech input depends not only on the employment of labor, $L^{S}_{x_l}$, but also on the labor productivity, $T^{S}(A(i))$, where *A(i)* is the firm specific or product specific technological complexity of the low tech input.

$$x_l = x_l\left[L^{S}_{x_l}, T^{S}(A(i))\right]$$

$$\frac{\partial T^{S}(A(i))}{\partial A(i)} > 0\ ,\ \frac{\partial^2 T^{S}(A(i))}{\partial A(i)^2} < 0 \qquad (3)$$

$$0 < A(i) < 1, \quad T^{S}(0) = 0, \quad T^{S}(1) = 1$$

A high level of *A(i)* implies a more advanced technology within the class of technologies available in the technology market[4]. In Acemoglu, Antràs and Helpman (2006), more advanced technology is implicitly more productive. Aron and Singh (2002) explain the concept of revenue distance, where a higher revenue distance of a production stage implies lower contribution to revenue and value-addition, and hence lower productivity. In their model, inputs using less complex skills have large revenue distances and hence lower productivity.

To ease interpretation of *A(i)* and how it is different from *z*,, we can consider an example from a consulting firm. A consulting project can be treated as a final good *y*, produced using two inputs - x_h and x_l . A consultant's strategic analysis of the client's problem is a high-tech input, an input available in the north only, while data analysis of the client is a low tech input which can be offshored. If the consulting project requires relatively less amount of data analysis vis-à-vis a consultant's strategic analysis, then the project is intensive in high-tech input and the parameter *z* is low for such a project. Data analysis for the project can be done using two techniques, varying in their technological complexity - SAS or excel. Technological complexity, *A(i)*, for SAS is higher than *A(i)* for Excel and accordingly, efficiency for data analysis is higher in SAS.

In the above example, *i* refer to the different kinds of consulting projects handled by a firm, one that requires sophisticated data analysis and the other that doesn't. Our model shows that variation in technological complexity of the low-tech input across projects induces difference in their organizational modes.

Assumption 2: *The production of low -tech input is linear in productivity and labor.*

$$x_l = T^{S}(A(i))\, L^{S}_{x_l} \qquad (3')$$

$$x_l = x_l\left(L^{S}_{x_l}, 0\right) = 0, \quad x_l = x_l\left(L^{S}_{x_l}, 1\right) = x_l\left(L^{S}_{x_l}\right) = L^{S}_{x_l}$$

[4] The technology that we refer to in case of offshoring is typically a standardized one, available in the technology market.

A(i) = 0 means that the technological complexity of the offshored input is too low to justify production in the South, and *A(i)* = 1, implies that high technological complexity makes productivity of southern labor high enough to match the productivity of the northern labor.

If technological sophistication adds to productivity, it cannot come without cost. A higher level of technological complexity has to be matched by a corresponding rise in efforts to transmit and assimilate the technology. In the example of the consulting project discussed above, there are costs of running data analysis in SAS – license costs and training costs. Excel, which has a lower technological complexity, has a lower technological transfer cost vis-à-vis SAS. This is straightforward and follows directly from Teece (1977) observation that more recent technology embodying more complex mechanisms require more resources to be transferred – whether they are transmitted by the sourcing firm or have to be acquired, technology transfer cost is a positive function of technological complexity. Teece (1977) study supports our view that technologies closer to the frontier embody more complex mechanisms and hence require more resources to be transferred.

In addition to this cost, Chuan and Chang (1993) model suggests that technology transfer cost may also depend on many factors and most interestingly on the mode of technology transfer, absorptive capacity of host country and the level of technological development of the host country. To endogenize the technology transfer cost with respect to the mode of organizing production fragmentation, we use assumption 1. The buyer (supplier) understands that there is little incentive for the supplier (buyer) to invest in technology assimilation (transmission) in an intra-firm (external) production contract and hence she decides to take a small fixed payment, TT^S $\left(TT^N\right)$ from the supplier (buyer) in lieu of its unverifiable and insignificant investment in technology transfer. In case of an intra-firm (external) production transfer, the technology transfer cost incurred by the buyer (supplier) is given by C, defined below in equation (4), while in an outsourcing contract (VFDI), the buyer (supplier) incurs a small fixed cost, $TT^N \left(TT^S\right)$. To simplify algebra, and without loss of generality, we assume that these fixed payments are insignificant and close to 0.

Assumption 3: $TT^N \approx 0, \quad TT^S \approx 0$.

Absorptive capacity of the host country has been cited as crucial to technology transfer costs by Baranson (1970), Mattoo et al (2005), Teece (1977), Pack and Saggi (1997). Eicher and Kalaitzidakis (1997), model the host country absorptive capacity and emphasize the importance of local human capital necessary to absorb FDI technology. Long (2005) deals with the issue of training cost in fragmented production. However, our model differs from his in two aspects. We endogenize the technology transfer cost and then relate it to the issue of internalization. Per contra, Long (2005) focuses on explaining incomplete offshoring to a low wage nation in the presence of exogenous training costs. In our model, we propose that to produce low tech input in the south, there is an additional cost of equipping each southern labor employed to produce the low-tech input with the firm or product specific technology. The technology transfer cost whether transmission or assimilation depends on the host country wages, its absorptive capacity and the technological complexity of producing the low-tech input.

Assumption 4: *The functional form for technology transfer cost is the same irrespective of the mode of organization of fragmented production*.

$$C = C\left[q\left(w^S, \xi\right), A(i)\right]$$

$$\frac{\partial C}{\partial q} < 0, \quad \frac{\partial C}{\partial A(i)} > 0, \quad \frac{\partial^2 C}{\partial A(i)^2} > 0$$

Where *q(.)*, the efficiency of technology transfer, is a function of wages in the south, w^S, and the absorptive capacity of the host country, ξ. Higher wages imply higher productivity of labor[5] and hence efficiency in absorbing the transferred technology. At the same time, the inherent capability of the population measured by, say, the educational standard is also a crucial factor in determining the efficiency of transfer. This hypothesis has been supported by Teece (1977) study which found a negative relationship between cost of transferring technology and host country's absorptive capacity. Usually, all countries maintain some statistics on the human capital figures like R&D, literacy rate, skilled labor to unskilled labor ratio or investment on human capital formation. Thus, a sourcing firm can form a perception of the absorptive capacity of the country hosting its production.

By assuming a linear production function for x_l, we get a linear cost function.

$$C = \Omega(A(i))\ \hat{C}\left[q\left(w^s, \xi\right)\right] \qquad (4)$$

As in Antràs (2005), we consider three possible organizational forms: (1) Vertical integration in the North/ Domestic outsourcing (DO) (2) Unaffiliated Supplier in the South: Outsourcing and (3) Affiliated Supplier in the South: VFDI.

[5] This can also be rationalized by using the efficiency wage theory; however, we choose not to use this terminology as wages in our model are exogenous.

Vertical Integration or outsourcing in the North

Antràs (2005) assumes that vertical integration and domestic outsourcing in the north are equivalent because of complete contract enforcement. To maintain this supposition in our model we need to additionally assume that all firms in the north have identical absorptive capacity and hence require no technology transfer to produce the low-tech input. Demand and production function is given by (1) and (2) respectively. Assuming that one unit of labor produces one unit of the input, the profit of the northern firm is given by:

$\Pi^N = \lambda^{1-\alpha}\,\zeta_z^{\alpha}\,x_h^{(1-z)\alpha}\,x_l^{z\alpha} - w^N x_h - w^N x_l$ Where $\zeta_z^{\alpha} = (1-z)^{-(1-z)}(z)^{-z}$

This case is exactly the same as in Antràs (2005). Profit maximizing price and equilibrium profit is given by:

$$p^N(z) = \frac{w^N}{\alpha} \qquad \text{(5a)}$$

$$\Pi^N = \lambda(1-\alpha)\left(\frac{w^N}{\alpha}\right)^{-\frac{\alpha}{1-\alpha}} \qquad \text{(5b)}$$

International Outsourcing- Unaffiliated supplier in south

Assumption 1 and 3 together imply that the technology transfer cost in an outsourcing relationship is borne by the supplier. The RSI for the sourcing firm comprises of its commitment to producing the high tech input only.

Assumption 5: *As in Antràs (2005), competition among southern suppliers of low-tech input drives their profit to zero.*

A transfer payment, T, from the supplier to the sourcing firm has to be allowed for such that the profit of the outsourcing partner is driven to zero. The profit function for the sourcing firm outsourcing to a TPV in the south is:

$$\begin{aligned}\Pi_o^N &= \phi R - w^N x_h + T \\ &= \phi\left(\lambda^{1-\alpha}\,\zeta_z^{\alpha}\,x_h^{(1-z)\alpha}\,x_l^{z\alpha}\right) - w^N x_h + T\end{aligned}$$

Where R denotes the total revenue from the relationship and ϕ is the share of the sourcing firm in the total value of the relationship. It is also a measure of the bargaining power of the sourcing firm.

In Antràs (2003) model, RSI by the supplier (sourcing firm) is in labor (capital) investment while in Antràs (2005) it is the resources committed to produce the low tech (high-tech) input. Besides the RSI in low-tech or high-tech input production, our model has an additional component of RSI which is incurred by the supplier or the sourcing firm contingent on the organizational mode. The supplier (sourcing firm) has to make RSI in technology transfer costs in case of outsourcing (VFDI).

The unaffiliated supplier maximizes:

$$\Pi_o^S = (1-\phi)R - w^S x_l - C\, L_{x_l}^S - T$$

$$= (1-\phi)\left(\lambda^{1-\alpha}\, \zeta_z^{\alpha}\, x_h^{(1-z)\alpha}\, x_l^{z\alpha}\right) - w^S L_{x_l}^S - \Omega(A(i))\; \hat{C}\left[q\left(w^S, \xi\right)\right] L_{x_l}^S - T$$

Using $(3')$ and (4) we get:

$$\Pi_o^S = (1-\phi)\left(\lambda^{1-\alpha}\, \zeta_z^{\alpha}\, x_h^{(1-z)\alpha}\, x_l^{z\alpha}\right) - \left(\frac{w^S + \Omega(A(i))\; \hat{C}\left[q\left(w^S, \xi\right)\right]}{T^S\left(A(i)\right)}\right) x_l - T$$

The term $\left(\frac{w^S + \Omega(A(i))\; \hat{C}\left[q\left(w^S, \xi\right)\right]}{T^S\left(A(i)\right)}\right)$ is the Average Efficiency cost (AEC), adjusted for productivity for producing x_l the low tech input.

Profit maximization of the two agents and setting T so as to make the supplier break even leads to the following expression for the sourcing firm's ex ante profits and profit maximizing price in IO equilibrium:

$$\Pi_o^N = \lambda\ \left[(1-z\alpha) + \varphi\alpha(2z-1)\right]\left[\frac{\left(w^N\right)^{1-z}(AEC)^z}{\phi^{1-z}(1-\phi)^z\,\alpha}\right]^{-\frac{\alpha}{1-\alpha}} \tag{6a}$$

$$P_o = \left[\frac{\left(w^N\right)^{1-z}(AEC)^z}{\phi^{1-z}(1-\phi)^z\,\alpha}\right] \tag{6b}$$

The profit maximizing price in Antràs (2005) when outsourcing is chosen is given by:

$$p = \frac{\left(w^N\right)^{1-z}\left(w^S\right)^z}{\alpha\,\phi^{1-z}(1-\phi)^z} \tag{6c}$$

Our price equation, (6b), is analogous to the above equation except that the southern production cost is augmented to include the technology transfer costs, adjusted for productivity enhancement due the sophistication of technology.

Let $\Theta_1 = \frac{\Pi^N}{\Pi_O^N}$

International outsourcing is preferred to domestic outsourcing in north if $\Theta_1 < 1$,that is,

$$\frac{w^N}{AEC} > \left(\frac{\varphi}{1-\varphi}\right)\left[\frac{1-\alpha}{(1-z\alpha)+\varphi\alpha(2z-1)}\right]^{\frac{1-\alpha}{z\alpha}} \frac{1}{\varphi^{\frac{1}{z}}}$$

$$> L_1(\varphi, z, \alpha) = \left(\frac{\varphi}{1-\varphi}\right)\left[\frac{1-\alpha}{(1-z\alpha)+\varphi\alpha(2z-1)}\right]^{\frac{1-\alpha}{z\alpha}} \frac{1}{\varphi^{\frac{1}{z}}}$$

Assumption 6: *To further simplify algebra, we assume that* $\hat{C}[q(w^s,\xi)]$ *is linearly separable in* w^S *and* ξ.

That is, $\hat{C}[q(w^s,\xi)] = w^s . \tilde{C}(\xi)$

Using the above assumption, $\Theta_1 < 1$ if,

$$\frac{w^N}{w^S} = \omega > L_1(\phi, z, \alpha). \frac{AEC}{w^S} \qquad (7)$$

Where, $\frac{AEC}{w^S} = \left(\frac{1+\Omega(A(i))\ \tilde{C}(\xi)}{T^S(A(i))}\right)$,

ω and $L_1(\phi, z, \alpha)$ are given for given *A(i)*, so we examine the behavior of AEC/w^S.

$\frac{\partial\left(AEC/w^S\right)}{\partial A(i)} = 0$ if:

$$\frac{\partial\Omega(A(i))}{\partial A(i)}\frac{A(i)}{\Omega(A(i))} = \frac{\partial T^S(A(i))}{\partial A(i)}\frac{A(i)}{T^S(A(i))}\left[1+\frac{1}{\Omega(A(i))\tilde{C}(\xi)}\right] \qquad (8)$$

$$\Rightarrow \eta_\Omega = \eta_{T^S}\left[1+\frac{1}{\Omega(A(i))\tilde{C}(\xi)}\right]$$

That is, the elasticity of the cost of technology transfer with respect to technological sophistication, *A(i)*, is equal to the weighted elasticity of productivity of southern labor with respect to the technological complexity weighted by $\left[1+\frac{1}{\Omega(A(i))\tilde{C}(\xi)}\right]$. Lets define the technological complexity at which (8) holds to be $A^*_{i,o}$.

Proposition 1: The function reaches minima at $A^*_{i,o}$ when $\frac{\partial\left(AEC/w^S\right)}{\partial A(i)} = 0$.

Mathematically, the cost function is convex with respect to the technological complexity and the productivity function is concave, then second order conditions confirm our assertion that $\left(AEC/w^s\right)$ is a convex function.

I*ntuitively*, the proposition implies that at lower levels of technological complexity, the increment to productivity is higher than the increment to technology transfer costs. At higher level of technological complexity, the increment to technology transfer costs is much larger than its contribution to increasing southern productivity. One can justify this because had the technology transfer cost not be prohibitively high, one would have observed the offshoring of advanced stages of production as well.

Hence, $\left(\frac{1+\Omega(A(i))\ \widetilde{C}(\xi)}{T^S(A(i))}\right)$ falls for low levels of technological complexity, *A(i)* < $A^*_{i,o}$. For $A(i) > A^*_{i,o}$ it rises. Equation (7) can be depicted by figure 1[6].

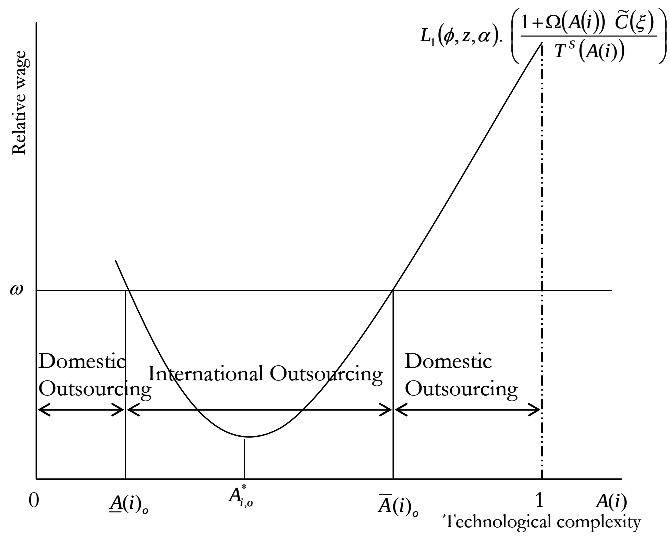

Figure 1: Tradeoff between northern production and International Outsourcing

The sourcing firm stands to gain from IO vis-à-vis DO due to lower host country wages while it stands to lose due to costs from contractual distortions and suboptimal RSI in technology transfer. Any technological complexity below $\underline{A}(i)_o$ implies a greater distortion due to incomplete contracts than it saves costs due to cheap southern labor. Similarly, any *A(i)* above $\overline{A}(i)_o$ increases technology adaptation cost more than it adds to productivity and also increases distortions due to incomplete contracts.

Proposition 2: *Only at intermediate levels of technological complexity is international outsourcing preferred to domestic outsourcing. At low and high levels of technological sophistication, domestic outsourcing dominates international outsourcing.*

Proposition 3*: To host outsourcing contracts with the full range of technological complexity, the host country should possess a minimum level of absorptive capacity. Analogously, the range of*

[6] The curvature and slope of the curve depends on parameters like z, α, ϕ *and* ξ

technological complexity available for outsourcing can be increased if the absorptive capacity is raised.

If we look at equation (7), we can derive that $\frac{\partial A(i)}{\partial \xi} > 0$ for $A(i) > A^*_{i,o}$ and $\frac{\partial A(i)}{\partial \xi} < 0$ for $A(i) < A^*_{i,o}$. Thus outsourcing expands at both ends with a rise in absorptive capacity.

Vertical Integrated supplier in the South or VFDI

We retain Hart-Moore (1990) premise that the sourcing firm has a right to higher share in surplus (bargaining power) in an intra-firm transaction vis-à-vis a market transaction. This assumption is given mathematically in Antràs (2005) as:

$$\bar{\phi} = \delta^{\alpha} + \phi\left(1 - \delta^{\alpha}\right) > \phi \qquad (9)$$

Where δ is the proportion of output expropriated by the sourcing firm if the manager of the subsidiary is fired. In Antràs (2005), the expression for the profit maximizing price in case of VFDI is analogous to equation (6c) with ϕ replaced by $\bar{\phi}$.

In our model, the multinational firm assumes the technology transfer costs to train the labor in a VFDI contract. As in outsourcing, T' is set such that competition among suppliers drive their profit down to zero. The profit function of a multinational is given by:

$$\Pi_f^N = \bar{\phi}\,\mathrm{R} - w^N x_h - \Omega(A(i))\ \hat{C}\left[q\left(w^S, \xi\right)\right] L^S_{x_l} + T'$$

$$= \bar{\phi}\left(\lambda^{1-\alpha}\ \zeta_z^{\alpha}\ x_h^{(1-z)\alpha}\ x_l^{z\alpha}\right) - w^N x_h - \Omega(A(i))\ \hat{C}\left[q\left(w^S, \xi\right)\right] \frac{x_l}{T^S\left(A(i)\right)} + T'$$

RSI on the part of the integrated supplier comprises of its resources committed to produce the low-tech input only with insignificant expenditure on technology absorption. The subsidiary manager maximizes:

$$\Pi_f^S = \left(1 - \bar{\phi}\right)\mathrm{R} - w^S x_l - T'$$

First order conditions for maximization of the MNC profits under VFDI yields price:

$$P_f = \left[\frac{\left(w^N\right)^{1-z}\left(\frac{w^S}{T^S\left(A(i)\right)}\right)^{z}}{\bar{\phi}^{\,1-z}\left(1-\bar{\phi}\right)^{z}\alpha}\right]$$

In case of VFDI, the presence of technology transfer cost does not distort prices since they are incurred by the multinationals while the amount of southern labor employed is determined by the subsidiary. Thus, technology transfer cost is like a fixed cost to the multinational. Equilibrium profit of the MNC is given by:

$$\Pi_f^N = \lambda \left[(1 - z\alpha) + \bar{\phi}\alpha(2z - 1) - (1 - \bar{\phi}) z\alpha \frac{\Omega(A(i))\ \hat{C}[q(w^s, \xi)]}{w^S} \right] \left[\frac{(w^N)^{1-z} \left(\frac{w^s}{T^S(A(i))} \right)^z}{\bar{\phi}^{1-z} (1 - \bar{\phi})^z \alpha} \right]^{-\frac{\alpha}{1-\alpha}} \quad (10)$$

***Assumption 7**: Let ϕ = ½ as in Antràs (2005)*

Using assumption 6 and 7, we get that for VFDI to yield a positive profit is[7]:

$$A(i) < \Omega^{-1} \left[\frac{2 - \alpha(1 + \delta^\alpha) + 2z\alpha\delta^\alpha}{\alpha z (1 - \delta^\alpha) \tilde{C}(\xi)} \right] = b \quad (11)$$

Per contra, Π_o^N>0 for all range of *A(i)*. This result comes by because in case of outsourcing it is the unaffiliated supplier that makes RSI in technology transfer, while the resulting gain in productivity is also enjoyed by the sourcing firm. In case of VFDI, the MNC makes RSI in technology transfer, while both parties enjoy the productivity gain.

***Proposition 4**: The sourcing firm stands to lose from VFDI (in absolute terms) if the technological complexity of the low-tech input is higher than a critical level, b defined in (11).*

To evaluate the relative prevalence of VFDI vis-à-vis DO we compare (10) with (5b), the respective profit functions of the sourcing firm in the two alternative modes of organization.

Let $\Theta_2 = \frac{\Pi^N}{\Pi_f^N}$

Then, VFDI is preferred to production in north if $\Theta_2 < 1$,that is,

$$\Rightarrow \omega > L_2(\bar{\phi}, z, \alpha, A(i), \xi). \frac{1}{T^S(A(i))} \quad (12)$$

$$L_2(\bar{\phi}, z, \alpha, A(i), \xi) = \left(\frac{\bar{\phi}}{1 - \bar{\phi}} \right) \left[\frac{1 - \alpha}{\left[(1 - z\alpha) + \bar{\phi}\alpha(2z - 1) - (1 - \bar{\phi}) z\alpha \frac{\Omega(A(i))\ \hat{C}[q(w^S, \xi)]}{w^S} \right]} \right]^{\frac{1-\alpha}{z\alpha}} \frac{1}{\bar{\phi}^{\frac{1}{z}}}$$

[7] For z>½ or z<½,the numerator is always positive.

Let $\Psi = L_2\left(\bar{\phi}, z, \alpha, A(i), \xi\right).\frac{1}{\mathrm{T}^S\left(A(i)\right)}$

$$\frac{\partial \Psi}{\partial\left(A(i)\right)} = \underbrace{\frac{\partial L_2\left(A(i)\right)}{\partial\left(A(i)\right)}}_{+}.\frac{1}{\mathrm{T}^S\left(A(i)\right)} - \frac{L_2\left(A(i)\right)}{\left[\mathrm{T}^S\left(A(i)\right)\right]^2}.\underbrace{\frac{\partial \mathrm{T}^S\left(A(i)\right)}{\partial\left(A(i)\right)}}_{+}$$

Let the level of technological complexity at which $\frac{\partial \Psi}{\partial\left(A(i)\right)} = 0$ be $A^*_{i,f}$.

The first term in the above total derivative denotes the effect of increase in technological complexity on technology transfer costs, which is positive and the second term gives its effect on labor productivity due to a small increase in *A(i).* As in assumption 6, we suppose that at lower levels of technological complexity the second effect dominates, that is for A(i) < $A^*_{i,f}$, an increase in technological complexity increases the profitability of the sourcing firm by increasing productivity of the low tech input produced in the south than can be offset by an increase in technology transfer cost.

Proposition 5: *For reasons corresponding to proposition 1, for A(i) <* $A^*_{i,f}$, $\frac{\partial \Psi}{\partial\left(A(i)\right)} < 0$.

It reaches minimum at say $A^*_{i,f}$ and then it rises. With this proposition, equation (12) has been depicted graphically in figure 2[8].

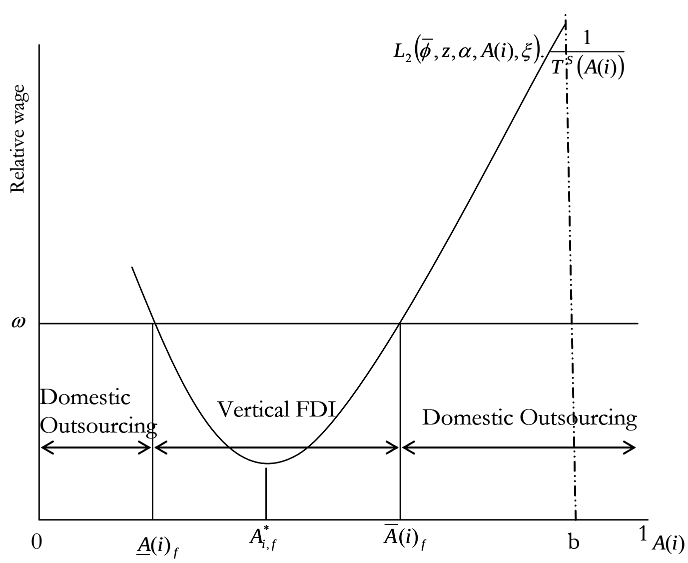

Figure 2: Tradeoff between northern production and Vertical FDI

[8] The curvature and slope of the curve depends on parameters like z, α, ϕ, ξ *and* δ

The prevalence of DO below $\underline{A}(i)_f$ and above $\overline{A}(i)_f$ can be explained as in case of international outsourcing.

Proposition 6: *Only at intermediate levels of technological complexity is vertical FDI preferred to domestic outsourcing. At low and high levels of technological sophistication, domestic outsourcing dominates vertical FDI.*

Proposition 7*: To host VFDI contracts with the full range of technological complexity, the host country should possess a minimum level of absorptive capacity. Analogously, the range of technological complexity available for intra-firm contracts can be increased if the absorptive capacity is raised.*

If we look at equation (12), we can derive that $\frac{\partial A(i)}{\partial \xi} > 0$ for $A(i) > A^*_{i,f}$ and $\frac{\partial A(i)}{\partial \xi} < 0$ for $A(i) < A^*_{i,f}$. Thus VFDI expands at both ends with a rise in absorptive capacity.

Comparing International Outsourcing with VFDI

To compare the profit functions of the sourcing firm in the two alternative regimes of organization of fragmented production, we look at equation (6a) and (10).

Let $\Theta = \frac{\Pi_o^N}{\Pi_f^N}$

$$\Theta = \left[\frac{(1 - z\alpha) + \phi\alpha(2z - 1)}{\left[(1 - z\alpha) + \phi\alpha(2z - 1) + (1 - \phi)\alpha\left(\delta^\alpha(2z - 1) - (1 - \delta^\alpha)\, z\left(\Omega(A(i))\,\widetilde{C}(\xi)\right)\right)\right]}\right]^{\frac{1-\alpha}{z\alpha}}$$
$$\left[1 + \frac{\delta^\alpha}{\phi(1 - \delta^\alpha)}\right]\left[\frac{\phi}{\delta^\alpha + \phi(1 - \delta^\alpha)}\right]^{\frac{1}{z}}\left[\frac{1}{\left(1 + \Omega(A(i))\,\widetilde{C}(\xi)\right)}\right]$$

Using equation (9) and ϕ = ½, we can simplify the above equation to:

$$\Theta = \left[\frac{\left(1 - \frac{1}{2}\alpha\right)}{\left[\left(1 - \frac{1}{2}\alpha\left(1 + \delta^\alpha(1 - 2z)\right)\right) - \frac{1}{2}\alpha\, z(1 - \delta^\alpha)\left(\Omega(A(i))\,\widetilde{C}(\xi)\right)\right]}\right]^{\frac{1-\alpha}{\alpha z}}\left[\frac{1}{(1 + \delta^\alpha)^{\frac{1-z}{z}}(1 - \delta^\alpha)}\right]\left[\frac{1}{\left(1 + \Omega(A(i))\,\widetilde{C}(\xi)\right)}\right]$$

To have meaningful comparison between VFDI and international outsourcing, we need to hold $A(i) < \Omega^{-1}\left[\frac{2 - \alpha(1 + \delta^\alpha) + 2z\alpha\delta^\alpha}{\alpha z(1 - \delta^\alpha)\widetilde{C}(\xi)}\right] = b$, and for $A(i) > b$, either IO or DO exists, but not VFDI.

Let us now look at the partial derivative of Θ with respect to $A(i)$.

$$\frac{\partial \Theta}{\partial A(i)} = \Theta \underbrace{\frac{\partial \Omega(A(i))}{\partial A(i)} \widetilde{C}(\xi)}_{+} \left[\frac{(1-\alpha)(1-\delta^{\alpha})}{2\left(\underbrace{\left(1 - \frac{1}{2}\alpha\left(1+\delta^{\alpha}(1-2z)\right)\right)}_{+} - \underbrace{\frac{1}{2}\alpha z(1-\delta^{\alpha})\Omega(A(i))\widetilde{C}(\xi)}_{+} \right)} - \underbrace{\frac{1}{1+\Omega(A(i))\widetilde{C}(\xi)}}_{+} \right]$$

$\frac{\partial \Theta}{\partial A(i)} < 0$, that is, as technological complexity increases, the profitability from VFDI increases if:

$$A(i) < \Omega^{-1}\left[\frac{2-(1-\delta^{\alpha}) - 2\alpha\delta^{\alpha}(1-z)}{((1-\alpha)+\alpha z)(1-\delta^{\alpha})\widetilde{C}(\xi)} \right] = a \qquad (13)$$

Clearly, a<b, else production will never be offshored via intra-firm contract.

$\frac{\partial \Theta}{\partial A(i)} > 0$, that is, as technological complexity increases, the profitability from outsourcing increases if

if $\Omega^{-1}\left[\frac{2-(1-\delta^{\alpha}) - 2\alpha\delta^{\alpha}(1-z)}{((1-\alpha)+\alpha z)(1-\delta^{\alpha})\widetilde{C}(\xi)} \right] < A(i) < \Omega^{-1}\left[\frac{2-\alpha(1+\delta^{\alpha}) + 2z\alpha\delta^{\alpha}}{\alpha z(1-\delta^{\alpha})\widetilde{C}(\xi)} \right]$ (14)

Hence, $a < A(i) < b$ then, $\frac{\partial \Theta}{\partial A(i)} > 0$

Proposition 8*: If in equilibrium, international outsourcing occurs for technological complexity below 'a', then a small increase in technological complexity, still less than 'a', will induce a regime switch from international outsourcing to VFDI.*

Proposition 9*: If in equilibrium, VFDI occurs in the range $a < A(i) < b$, then an increase in technological complexity in this range will switch the organizational form to international outsourcing. Thus, at higher level of technological complexity, the organizational form of fragmented production is likely to be an external one.*

We can consider two relevant and interesting cases that come up with this model. For *z* < ½, $(1-\delta^{\alpha})^{z}(1+\delta^{\alpha})^{1-z} < 1$ and technological complexity $A(i) > \Omega^{-1}\left[\frac{1+\frac{1}{2}\alpha}{1-\frac{1}{2}\alpha}\right]\frac{1}{\widetilde{C}(\xi)}$ the function Ψ representing a MNC's profitability with VFDI is more sensitive to *A(i)* than the similar function,

$[L_1(\phi, z, \alpha).\ AEC]$for outsourcing[9]. It is intuitive because at low *z*[10], there is higher probability for the sourcing firm to consider a VFDI contract vis-à-vis outsourcing (Antràs, 2005). Then, if we introduce technology transfer costs, the sourcing firm has to take into account these costs to offshore the input. Transfer costs are a convex function of technological complexity and hence raise the sensitivity of the MNC in an intra-firm transfer vis-à-vis external contract at low *z*.

In figure 3, we consider the case of low *z* and therefore we have drawn the VFDI curve steeper than the IO curve. At high relative northern wages, ω, if international outsourcing equilibrium occurs below technological complexity *a*, then there is a tendency to switch to VFDI (equation 13, proposition 8). The figure shows that, low levels of technological complexity, below $\underline{A}(i)_o$ goes with DO only. For the range of technological complexity between $\underline{A}(i)_o$ and P, we may have IO and between P and *a*, we have VFDI. Again, between *a* and $\overline{A}(i)_o$ we have IO because $\frac{\partial \Theta}{\partial A(i)} > 0$ for $A(i) > a$.

It is observed that the rate of growth of wages in countries which host offshoring contracts is very high, at about 20% per annum. What do we expect of the relative prevalence of the two organizational forms of international production sharing? In figure 3, we show the impact of fall in northern relative wages from ω to ω'. The bold lines define the new range of technological complexity for international production sharing. We observe a fall in off-shoring at the two ends of technological complexity. If the fall in wages is not large, the region for VFDI may not be impacted at all, while, on the other hand, if the fall in relative wages is very large, international outsourcing may be completely wiped out. Therefore, with a fall in north-south wage differential, one moves from multiple regime switch situation, where, the regime switches twice as the technological complexity increases, to a unique regime switch situation where the regime switches from VFDI to IO and finally if the wage differential is low enough, we have a situation of all pervasive VFDI. The result is intuitive because a fall in relative northern wages represents a loss in comparative advantage of the low wage south. As we have observed rising wages in offshoring destinations like India, our model suggests to build a new source of comparative advantage or else witness its growth and employment emanating from the off-shoring industry fall. One such source of comparative advantage has been discussed in Acemoglu, Antràs and Helpman (2006), where better contracting institutions can influence the level of production sharing by impacting relative productivity of the final good sector. There can

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9 Assuming that this critical *A(i)* is lower than $\underline{A}(i)_f$, we draw the VFDI function steeper than the IO function at all levels of technological complexity.

10 We assume that for z>½, the good to be high-tech and for z<½, the good is low-tech.

be yet another source of comparative advantage, which is the host country's absorptive capacity and technology expertise. A high level of absorptive capacity and proficiency in technology can sustain a higher technologically sophisticated good by lowering the cost of technology transmission and hence widen the range of off-shoring. Proposition 3 and 7 advocates this point.

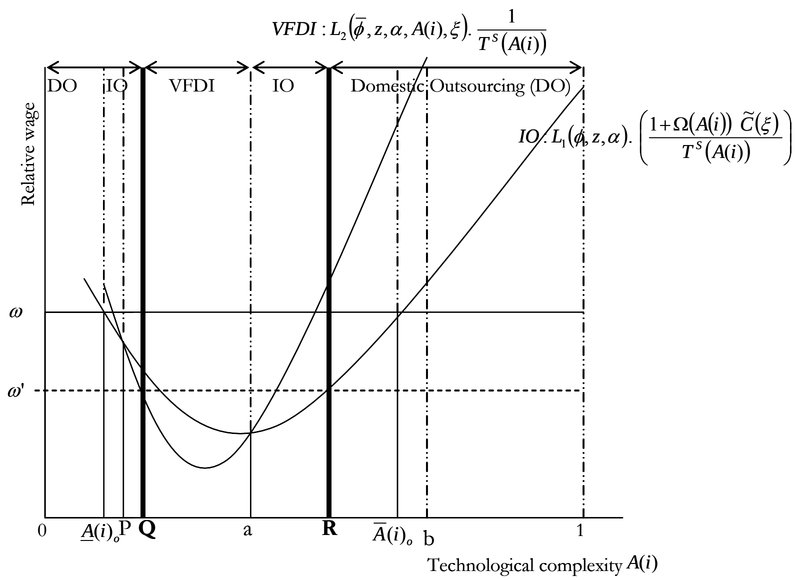

Figure 3: Possibility of multiple switches for high-tech good

For *z* > ½ along with other parametric restrictions on δ and α, the VFDI profitability function is less sensitive to technological complexity of the offshored input than the sourcing firm's profit function in IO. The intuition is again derived from Antràs (2005). The probability for outsourcing is higher for high *z* and hence the cost of the supplier assumes greater importance and making it more sensitive to technological complexity. Again, for *A(i)>a*, (from equation 14) the profit from IO is expected to be higher vis-à-vis VFDI. This implies that we would expect a low-tech input to be contracted internally for lower range of technological complexity but externally for higher *A(i)*. In this case, if relative northern wages fall to a level say, ω', then it is VFDI which is completely wiped out and we observe only international outsourcing regime.

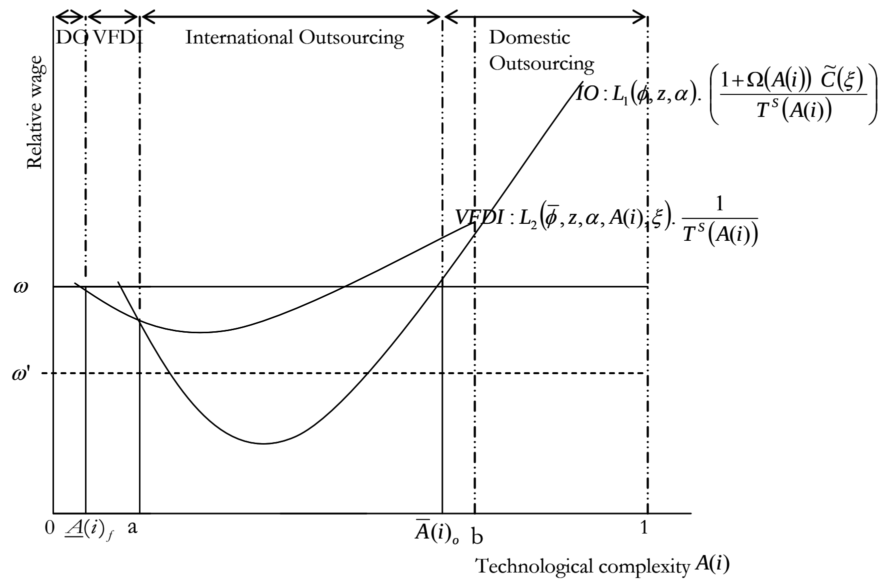

Figure 4: Possible Regimes with low-tech good

Section 4: Discussion

A point worth noting is that, in both the cases above, it is always outsourcing which is preferred at higher levels of technological complexity of the offshored input irrespective of the value of *z*. This is because at higher levels of *A(i),* the high cost of technology transfer is a strong disincentive for the sourcing firm to undertake an intra-firm production transfer. In case of VFDI the MNC makes RSI in technology transfer while the ensuing productivity gain is shared by the supplier as well. As the technological complexity crosses a threshold, the MNC is no longer willing to bear the cost of technology transfer and is better off sharing a larger part of the surplus in return for the unaffiliated party's RSI in technology transfer. Our result shares a similarity with Bartel et al (2005). An increase in the speed of technology, in their model, encourages domestic outsourcing vis-à-vis intra-firm production transfer. Our model proposes that a firm with higher complexity of technology will always choose to outsource it provided the host country has a threshold level of absorptive capacity. The forces driving similar results in the two models are however different. In the closed economy model of Bartel et al (2005), acceleration in the pace of technological change raises the technology adoption costs of the final good firm and hence increases the per-period unit cost of producing in-house. This shifts the demand for outsourcing outwards irrespective of its service price because it allows firms to use services based on leading edge technologies without incurring the large and recurrent fixed costs of adopting these new technologies.

Perhaps a widely held notion is that firms do not outsource the production of technologically complex inputs. The trend to buy technologically complex inputs from unaffiliated suppliers is not completely absent though. For instance, Dell contracts out the design for notebooks, Personal Computers, digital televisions. Hewlett-Packard seeks external assistance to develop servers and printers. Motorola purchases designs for its cheapest phones from unaffiliated suppliers. These firms acquire complete designs of digital devices from Asian developers, and modify them to suit their own specifications, and finally stamp their own brand name. The trend is fast spreading from electronics sector to navigation systems, pharmaceutical and even consumer goods. For example, Boeing is working with HCL Technologies, an Indian third party service provider, to co-develop software ranging from navigation systems and landing gear to the cockpit controls. Similarly, 20% of Procter & Gamble's new product ideas come from external source. The reason for outsourcing complex technological products within the basic stage of production can also be rationalized by the fact that these products require specialized skills and knowledge which can be offered by only a broad network of specialists. That is perhaps the reason why many pharmaceutical companies have begun to outsource basic research[11]. To ensure that the possibility of outsourcing at higher technological complexity does not remain a theoretical opportunity only, we need a dynamic involvement by the host country in globalization. The model thus delivers implications for the need of an active technology policy in the host country. Since the sourcing firm is not likely to make an intra-firm production contract at high levels of technological complexity, the host country government should subsidize the domestic vendors' technology investment so as to enhance its overall participation in the global production.

Some leading companies have simultaneously adopted a mix of captive and outsourced services wherein some of the more complex and core processes are being handled by the captive unit. Credit card companies, for instance, have complex technologies in place to analyze customer behavior. If a country has low absorptive capacity, its third party outsourcing service providers may get trapped in low value-add work as is depicted in figure 3. Given the possibility of multiple switches, it is possible for a TPV to jump to high value add and technologically complex work if the country enhances its absorptive capacity through investment in human

[11] In contrast to Antràs (2005), Acemoglu, Aghion and Zilibotti (2005) show that firms closer to technology frontier (intensive in high tech input) are more likely to outsource to focus on R&D. It is likely that the inputs of a high-tech good are more technologically complex than the inputs of a low tech good. Thus, their model is also capable of generating a result similar to ours that more technologically complex inputs are outsourced.

capital and the TPV makes conscious effort to acquire and invest in technology. An increase in absorptive capacity decreases the cost of technology transfer and hence raises profitability of the sourcing firm. When z is low, VFDI is more sensitive to technological complexity and it is likely VFDI increases as a result of a rise in absorptive capacity vis-à-vis IO. However, as z, rises with time due to standardization, it is outsourcing which benefits as a result of rising absorptive capacity. When offshoring began in India, it was limited to low end jobs like call centers. TPV Companies like Progeon and Wipro Spectramind[12] have proved that the ability to handle complex processes can be acquired overtime.

A dynamic interpretation of our result is also possible. Consider figure 3. A recent trend in the offshoring business is the method of "Build-Operate-Transfer" (BOT) whereby a TPV uses its knowledge and skills of the local market to create an offshore production unit on behalf of a multinational firm. When this unit reaches a critical mass, a certain level of maturity, the multinational takes over and is transferred by the TPV. The offshore unit is then called a captive unit or a subsidiary of the MNC. For example, Aviva Plc, a United Kingdom-headquartered insurer, testing the waters in the Indian market, decided to opt for the BOT model. This model can explain the movement from IO to VFDI typically in a high-tech final good. Now consider figure 3 and 4. A switch from VFDI to outsourcing mode is likely with time as the captive supplier's maturity evolves. This is exemplified by GECIS to GENPACT[13] transition in December 2004. GECIS was a subsidiary of GE in India and in the year 2004, it transformed to a TPV after eight years of operations in India. Such a transition is predicted in our model for both the low-tech and high-tech final goods.

Empirical evidence relating to our model is found in Borga and Zeile (2004). They regress the volume of intra-firm trade on a number of parent firm related factors, host country characteristics and affiliate related variables. Affiliate R&D intensity is found to be negatively related to the volume of intra-firm trade. We can interpret R&D intensity of affiliate to be some measure of technological complexity the fragmented good's input. The result is thus supposed to mean that as the technological complexity of the input rises, the probability of VFDI falls. The second important result of Borga and Zeile (2004) that is crucial for our paper relates to the education standards of the host country and its income. Their results confirm that the volume of intra-firm trade falls if the host country has higher levels of education or income. This matches

[12] Progeon, a subsidiary of Infosys, has concrete plans to enter into more complex BPO activities as part of its expansion strategy. Moving in the direction, Progeon has formed a partnership with Aceva Technologies Inc to offer finance and accounting solutions. Wipro Spectramind is the second largest third-party offshore BPO providing services in insurance processing, telemarketing, mortgage processing, and technical support services apart from customer services.

[13] More and more captive spin-offs like that of British Airways-WNS, SwissAir-TCS, Conseco-EXL and GECIS-Genpact are expected to take place in the Indian scenario as the absorptive capacity in India rises.

with our model's intuition. As the absorptive capacity increases, the host country can be a ground for more technologically complex products. Since higher technological complexity is more compatible with outsourcing, our model predicts a fall in intra-firm trade with rise in absorptive capacity especially so for low-tech products.

Section 5: Conclusion

This paper builds on the framework provided by Antràs (2005). We emphasize the importance of contractual differences between the VFDI and outsourcing and propose that in case of an intra-firm production transfer, a significant proportion of the technology transmission cost is borne by the sourcing firm. Per contra, in a relationship with an outside contractor, the cost of technology acquisition or assimilation assumes more importance which is undertaken by the supplier. This assumption adds to the results in Antràs (2005) model and shows the possibility of multiple regime switches. Specifically, in Antràs (2005), VFDI is preferred to outsourcing if the intensity of high-tech input is high. However, in our model, we have an additional factor, the technological complexity of the offshored input which is also a critical variable in internalization decision of the firm. Only if the high-tech input is matched with intermediate range of technological complexity of the offshored input, is the VFDI mode preferred. This is because high technological complexity increases the cost of technology transfer for the MNC. The sourcing firm's profitability from VFDI mode is more sensitive to technological complexity if the final good is high-tech. Hence, the MNC prefers to have intra-firm contracts only for intermediate range of technological complexity. On the other hand, even if z is high, the sourcing firm may still want to transfer production internally if the complexity of offshored input is low. This is again explained by the sensitivity of the profit functions in the two alternative modes and the incidence of technology transfer costs.

A dynamic interpretation of our model may be used to explain a BOT relationship as well as recent transitions from captive units like GE Capital to GENPACT or British Airways to WNS. In future, it may be valuable to broaden this paper by looking at the relative growth and welfare effects of VFDI and outsourcing on the host country. Another useful extension can make the current model dynamic, where technology becomes more complex with each instant and improves productivity along with evolution of absorptive capacity. This brings in a new meaning of comparative advantage for the host country. In such a model we would certainly expect absorptive capacity to form an important basis for increasing greater participation in global production.

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