行政院國家科學委員會專題研究計畫期末報告

跨界研發與區域創新體系：
資訊業台商在美國矽谷與中國上海
、北京研發活動的比較

Cross-border R&D and Regional Innovation Systems: A Comparative Study of Taiwanese Informatics Firms' R&D Activities in Silicon Valley and Shanghai, Beijing, China

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基本上，這次兩年的研究計畫將建立在之前執行的國科會專題計畫「矽谷─新竹─上海的連結：全球化高科技生產網絡中的介面區域（NSC 91-2415-H-002-029-）」的基礎,以及過去 5 年來有關台灣資訊高科技產業發展，特別是有關新竹與矽谷關連的影響的研究基礎上。研究的目的在於審視台灣資訊產業廠商在面臨知識技術競爭過程中，藉由對外投資過程中，如何進行研發創新的活動，以及在這過程中不同區域的創新體系對於台商的技術學習的作用。

無疑的，從 1980 年代開始逐步發展的台灣資訊產業相當程度獲益於與矽谷之間綿密的技術與人才接軌，這其中回流創業帶動竹科的

發展，超過70%的竹科廠商多有矽谷回流人才的創業或是主要參與經營管理者，這在本人的既有研究成果中已加以展現（見著作目錄）。然而在1990年代中期之後，兩個新現象出現：一方面，竹科以及相關的資訊業的廠商，諸如聯電、宏碁、華邦、旺宏、廣達等企業開始在矽谷設立分公司（或者是擴大已有的公司，或併購既有的公司），分公司的目的主要著眼於建立前哨站(listening post)，一來方便與客戶的互動，但更重要的，吸收核心區域的技術發展也成為主要的任務；另一方面，也在接近2000年的同時，資訊業開始大舉投資於大陸（雖然在1990年代初期已有投資，但中期之後，尤其中國WTO資格確立後，出現更清楚的高科技台商跨界投資），從一開始利用當地便宜勞力、土地開始，逐步轉移到開發市場，甚至開發新產品變成新的發展，例如明碁、揚智、鴻海、威盛等企業，在包括深圳、上海與北京等地設立研發部門，發展大陸本地市場，甚至回銷台灣。這兩個趨勢的發展，意味著台灣的資訊廠商做為後進者，企圖藉由跨界接軌的形式，進行技術與產品的升級，值得進行比較與深入分析。

這樣的分析另一個研究的背景要放在有關全球化的脈絡中加以理解。晚近有關全球化的的研究，在不同的學域，包括社會學、政治學、商業管理以及地理學，都有許多作品討論，頗有方興未艾之勢，這包括探討國家的角色(Weiss 1998, Ohmae 1990)，城市的管理(Sassen

1991)，網路社會結構(Castells 1996)，現代性的反思(Giddens 1990)，以及全球生產鍊(Dicken 1998)。「全球化」作為一個概念的出現，大約是在 1960 年代，伴隨著由於運輸與通訊技術的改良帶來的「時空壓縮」(time-space compression)，將原本完整的地理尺度組織（包括國家、區域乃至地方）的社會與經濟發展過程進行轉變，而在一過程中，外在的全球性社會經濟組織將成為支配性的力量，而壓縮了既存的社會地理單元(Harvey 1989)。而在這一趨勢下，包括國家角色的空洞化、城市經營的企業統理方式(entrepreneurial governance)，網路社會的流動空間(space of flow)以及全球商品鍊的時空競爭結構都指出這一全球化的支配性角色，而將研究的議題與組織範疇擴大，社會經濟的動力不再僅止於組織所在的社會空間中的互動，而是有一更強勢的、非地方性的組織空間在影響著在地的社會過程。總的說來，全球化經常被視為包括資金、貨物、資訊以及人們廣泛的進行跨越邊界的活動。

事實上，除了在貿易、外資投資以及金融流動的廣化（涵蓋的地理範圍的擴張）與深化（新的跨國活動現象）之外，更重要的，技術的發展也越來越加以全球化的擴散與轉移。雖然已有許多研究指出了隨著全球政治經濟的整合，而變得普遍被認知到的現象，經常被用來指涉越來越多的技術跨國生產、傳遞與擴散的現象(Freeman &

Hagedoon 1992)。而事實上，技術全球化的現象包含了不同形式的全球與在地技術能力與資源的接軌與整合方式，如果僅是含混的將不同接軌方式放在一個過於一般性的「全球化」類型中（例如只是技術的國際貿易量增加），將無法進一步探討這一技術全球化現象對於輸出國與地主國的社會經濟將造成何種影響，以及無法精確評估技術全球化中，跨國技術轉移的意義與可能型態。我們可以透過三種全球治理型態——市場、階層與網絡，來區分不同的技術全球化類型，藉此釐清對技術學習理論的影響，並允許深化跨國技術轉移的研究。

如果我們從技術發展與擴散的治理型態出發，那麼有關技術全球化的部份，至少是指三種意義：第一，技術的全球性利用，廠商將其研發的技術在全球的市場上販售利用，也就是出口技術，是日增的國際貿易的結果。這並非是新的現象，只是有急速增加的趨勢。根據 Guerrieri & Milana (1991)的研究發現，高科技的產品佔製造業的出口比值從 1970 年的 12.2%攀升到 1989 年的 20.5%。而他們的研究也發現，一個國家出口的能力與其創新能力密切相關。要衡量廠商創新能力在國際利用的程度，可以藉由檢視廠商如何在他國保護其專利的多寡而得知，在 1990 年時，美國的專利申請中有 45%來自其它國家廠商，至於像法國與德國這種技術活動規模相對較低的國家，非本國廠商申請專利則分別佔有該國的 84%與 67%。在先進工業化國家中，

只有日本是例外，國內廠商佔專利申請的 88%。

技術全球化的第二種意義則是全球性技術合作，透過來自兩個以上國家的伙伴進行對創新或是 know-how 的開發，包括了政府研究機構與學術社群，以及在商業部門在技術上的合資。根據 Hagedoorn & Schakenraad (1990)的研究指出，在生物科技、新材料科學與資訊技術等新興科技產業，跨國廠商合作研發的合約在 1970 年代後增加迅速，究其原因主要是兩個：首先，這些新的高科技部門經常是知識密集，因此成功的創新有賴於能獲取有關當前該領域正在發展的知識，而其次，在這些產業的開始階段，取得資訊並與他人分享特別需要，因為經常個別廠商或機構並無法全面的接收所必備資訊與知識。主要的合作對象多是美國廠商，有 63%的合約是包含至少一家的美國廠商。這經常包含在廠商之間的「策略聯盟(strategic alliance)」，往往是不同地區與國家的廠商，為了特定時機、市場、產品或製程，而進行合作，並同時有彼此競爭的關係存在。有時透過不同地區廠商的互補——市場可及性與技術能力的互補，進行結盟；有時則是在政府或制度機構的主導下，廠商共同合作研發，例如在歐盟，廠商如果與多國廠商進行合作，將得到特別的研發補貼。這間接促成了包括荷蘭 Philips，德國的 Siemens 以及 Thomson-SGS 公司共組 JESSI 微電子計畫 (Castells 1996)。

技術全球化的第三個意義則是指一個國家的廠商到其它國家設立研發技術的組織，並經常與地主國的廠商形成一個研發的網絡，換言之，這種形式的技術全球化相當於技術上的外資直接投資(Foreign Direct Investment, FDI)。當前面兩種意義牽扯到廠商、企業與研究機構或其它部門，在這裡，主角只有一個：跨國公司。政府與其它公部門機構，包括大學，有可能參與國際性的研發計畫，但很難在全球的尺度上設立分支從事研發創新。在這意義上，地主國(host country)對跨國廠商研發的貢獻在於蒐集市場資訊與取得所需的技術人力，但主要仍由廠商在母國總部控制研發方向，乃至節奏。當然，這個過程也會因為地主國市場重要性而有所分散化，會進一步讓跨國公司的研發部門在地化。

上述的三種統理型態只是為了討論上方便，而將以區分的概念，在具體的發展中，經常是穿插而交錯，很難加以簡單的歸類。例如，跨國公司一方面設立分廠以建立在地的研發機制，但也同時與不同地區的當地廠商進行策略聯盟，藉以快速取得技術研發的成果。關鍵的問題就在於廠商基於何種策略性因素，必須在不同的社會與歷史脈絡的經濟空間中，採取特定的組織方式，以進行知識的擴散(diffusion)與吸納(absorption)？在這個過程中，核心的議題是技術的學習，也就是後進廠商如何與先進的廠商之間的跨界組織互動，如何影響作用於

其中的知識轉移？而其中，後進國家廠商如何藉由對外投資的方式，連結(tap into)上核心國家（或區域）的技術，並加以傳遞轉化成為母國的廠商的產品或製程的創新來源？再者，正快速崛起的中國大陸市場對於諸如台灣這種新興工業化國家卻又缺乏市場開發能力的廠商，如何有效吸納在地的創新能力，開發產品，也就越形重要。而針對台商在核心國家區域（例如加州矽谷）以及新興市場（例如大陸的核心技術區域）投資設廠，進行研發創新的過程，採取的策略、與母廠之間的分工關係、研發的在地化程度以及面臨的挑戰等議題有何差異加以比較，應該會對全球化的研發理論有所對話與發展。同時，在經驗上，也會對於台灣高科技廠商在知識競爭中的研發策略提供參考。

另一方面，這個研究還會回應有關地理組織和研發活動之間的互動相關的理論。因為儘管知識的流動在全球化的體系中似乎快速的以及多種型態的進行著，但事實上有效率的技術的轉移與學習並非容易(Henry & Pinch 2000)。因為越來越多的研究（例如 Maskell & Malmberg 1999）顯示關鍵技術與知識的移動與吸納經常鑲嵌在特定的社會脈絡與制度建構中，而 Gertler (2001)的研究則更進一步指出即使那些能將技術或是管理知識系統有效進行跨界移植的，往往是在知識輸出空間與接受的空間之間存在著組織與制度系統性的鄰近性，而

要將知識在不同創新制度體系之間轉移，或是要學習移植不同企業經營體系(business system)，經常並不是藉由體系之間競爭與學習就會產生一種單一的、支配性的「最佳方案(best practice)」的跨界收斂(convergence)的結果，而這過程空間的鄰近性(geographical proximity)往往有力於技術的學習，特別是「非明文化的(tacit)」知識的傳遞，也因此，往往在核心國家高科技區域（例如加州矽谷）也就成為許多企圖學習轉移技術的後進廠商企圖進駐接軌的領域。但這過程並非可以自發性的發生，需要進一步加以考察。尤其有關全球化中，地理聚集對創新的影響，以及對於內向投資(inward investment)在產品與製程研發的影響，都將是當前與可見未來經濟地理學跨國投資的研究的核心，本研究也將對此有所回應。

本研究因此將在理論發展上，可以一方面與有關跨國公司和全球商品鍊的研究進行比較，另一方面則可以和經濟地理學有關地方創新體系以及學習能力等文獻對話，並在最後回應有關研發的全球化研究。經驗上，則是藉由討論比較資訊業台商在矽谷與大陸的研發活動比較，可以進一步釐清有關台灣高科技發展的挑戰與機會，並且也可以就台商西進（大陸）與北進（北美核心國家）接軌的相關爭議，有所釐清。

相關研究與理論分析架構

有關後進廠商升級的研究，主要有全球商品鍊的報告，強調國際買家(global buyer)對於接受委託代工者(OEM)在技術提昇上的貢獻(Schmitz & Knorringa 2000)，研究的重點多在於產品鍊在國際尺度上的延伸，而核心廠商在這個過程中扮演著調控的角色，因為委託製造的需要，將進而轉移技術給製造者，使得製造者有機會從純粹的代工者，提升到參與設計層次的代工者（ODM），這尤其是發生在電子業與成衣業的研究（Hobday 2001 有關電子業，Gereffi 1999 有關成衣業，鄭陸霖 2001 有關鞋業，以及 Humphrey & Schmitz 2003 有關於一般性全球價值鍊中開發中國家的升級討論），儘管在這些研究中，有部分仔細的對於在全球分工過程中，後進廠商面臨的技術學習機會與限制多有著墨；但對於他們能在技術的攫取上扮演較積極角色的看法，卻少有提及，特別是後進廠商透過跨界投資的形式，滲透到技術密集的區域，藉以吸納新知（包括產品與製程），或者運用這些技術區域的有技能勞動力與工程師，進而從事研發工作，並影響產品開發或製程改良等面向的探討，尤其不足。而這種由後進廠商扮演積極主動的藉由國際化活動進行技術吸收者的角色，無疑的，將是對於往後後進者升級討論的重點。

另外，有關後進廠商的技術提昇的討論，是放在核心國家的跨國

公司到開發中國家設廠所形成的技術擴散的研究，尤其是透過發包體系，形成在地的生產體系，衍生零組件廠，或者是員工累積經驗後自行創業的形態，這在經濟地理學中討論有關外資與地方鑲嵌的研究中，已有許多的文獻探討，例如 Dicken 1998, Dicken & Malmberg 2001, 另外在有關技術管理方面的研究，例如 Cantwell 1998， Amsden & Hikino 1993, Chuang & Lin 1999 有關核心國家跨國公司的海外研發活動對於母國或區域的影響,另外包括 Florida & Kenney 1993, Shan & Song 1997 以及 Phelps 2000 也都針對核心國家之間（特別是美日之間）進行投資設廠所帶來技術研發的機會進行研究；但這些文獻都少有處理後進國家（尤其是 1980 年代之後）在開始對外投資的活動中，如何選擇進入模式(entry mode)，策略的制訂、研發的定位，以及在地理區位上的考量，以及對於這些後進國的技術提昇的作用。

其實，以目前既有的文獻可以發現，一些有名的高科技區域逐漸成為不同國家覬覦進駐的重要前哨節點，例如 Teece 1992 與 Feldman 2000 的研究就發現，包括矽谷以及波士頓地區是外國高科技廠商在美國設廠最為集中的地點。後進廠商在跨界投資的活動中，有關研發活動的區位考量，值得進一步觀察。

對於後進廠商的研發活動，不僅要注意到在進駐前的策略性考量，同時更重要的，在進駐到地主區域之後，到底這一投資行為對於

母廠以及母國的影響為何，也就是這些跨界投資的子公司所扮演的研發績效與定位，也將因應著當地在地化的條件面臨調整或深化。

在這些考量下，本研究企圖建立一個分析的架構，藉以討論後進廠商的跨國研發活動的動力、型態、策略、進入模式、區位選擇、角色定位、與母廠的互動、全球化的策略以及區域的鑲嵌，乃至面臨的問題與治理的形式等。這樣的架構，基本上需要兩個大方向的理論方向，分別是廠商全球化與發展理論，以及有關技術學習與創新的地理學。

（一）廠商的研發全球化發展：這部分的理論主要是討論有關海外技術積累對於廠商所有權優勢(ownership advantage)與資源的影響。傳統上，在後進國家中來自核心國家的外資投資對於這些地區的影響，以及後進國廠商如何藉此汲取技術養分，Vernon 1966 的產品週期理論處理這類的議題。隨著時間發展，這些外資會逐步的轉移技術給他們在後進國的子公司，因此，形成了這些核心廠商的內部知識轉移。而後進國的廠商則必須藉由和這些核心廠商的子公司進行交易或共享勞動力市場，換言之技術外部性，得到新的技術知識(Van Hoesel 1999)。但是這種型式的技術轉移也遭到批評，認為多只能轉移一些成熟或標準化的技術（Lall 1980, Poon & Thompson 1998）.

晚近有關全球化的理論則提出當廠商面臨技術的落後，有時會藉

由跨界的投資來修正此一缺陷（Dunning 1994），在這方面技術與知識被看做是建構廠商生存策略的核心能力，這種將以擁有資源為分析基礎的廠商理論認為由於技術可以增進廠商的效率與效能，因此一該被視為策略性競爭的要素（Barney 1991），當這種創造廠商價值的競爭策略不容易被其他廠商所模仿時，廠商的優勢就得以存在。這樣的觀點也就把廠商的技術能力的議題由關注在母國的部分，轉移到關注所在地主國（或區域）的條件，強調由後進國家到核心國家投資所增加的技術優勢的重要性。

技術開發的國際化是一個複雜的多維過程，它包括：(1) 國外 R＆D 實驗室；(2) 國際技術夥伴；(3) 與國外公司的合併；(4) 向國外公司的少量投資；(5) 參與大學與其他研究機構；(6) 相關製造設備的技術發展。同時還包括各種各樣的非正式資訊獲取等。這種與傳統強調核心國廠商對外投資所帶來在後進地區的技術外溢的看法相反，反而強調由後進廠商到核心地區「偷」或「學」技術的模式，也應該被視為對於創新來源越來越重視外在的資源，而非僅是廠商本身所具備的研發資源(Henderson 1999)。這樣的觀點也展示了存在於技術能力發展的階段以及對外投資的性質與方向的緊密關係：在後進國家的技術與經濟發展較低階的階段，對外投資匯集中於利用地主國的廉價勞力與自然資源的區位優勢；而在比較高階的時候，就會轉向到

技術開發的國家或地區，例如美國矽谷，而關注到技術的學習與知識的吸收。因此，廠商在較高階的經濟發展階段會更依賴在外取得的資產(Dunning 1998)；我們可以說技術後進廠商會逐步從藉由「做中學」以得到 know-how 的方式,轉移到藉由國際化的方式以學習 know-why 的階段。這至少對於包括台灣在內的後進國家廠商進駐矽谷設廠或併購已有的廠商有所解釋。

這個初步結論也呼應了暨有關於跨國公司的子公司進行研發的效益，經由研究顯示，外資的全球化於研發與科技應用上具有不同影響，由 Vickery（1996）的經驗研究可歸納出 1.在許多國家，以外國子公司實行分攤研發成本的情形是增加的。2.相較於全球性的生產與就業的擴散，研發依然趨向集中於發源國家（母國）中 3.跨國公司的子公司具有快速地應用與擴散新的技術的趨勢 4.擁有外國子公司的集團或企業，通常具有較高的勞動生產力、高等技術、或較好的組織協調性。

但是，另一個新的現象，或許也是獨特的現象，就是越來越多的包括台商或韓商在內的後進廠商，甚至核心國家的廠商(Microsoft、Intel 等)，進駐中國大陸的北京、上海乃至深圳設立包括研發活動在內的子公司，這個現象如何能在理論上得到解釋，需要進一步對於研發活動的全球化發展以及特定地域的制度鑲嵌與技術體制

(technology paradigm)有所瞭解，才能加以回應。

在這樣的觀察下，這個研究將會檢視台商在矽谷以及中國的高科技地區的投資中，創新研發活動的角色與本質，並審視在不同投資階段中的轉變形式，加以比較。

（二）學習與創新的地理學：這是本研究對話的另一大理論，我們認為跨國資本的研發活動有其重要的地理面向，而非均質的發展。在創新活動中，存在著區位的聚集與整合的經濟利益，如同 Gertler (1995, 2001)所說的，在新產品或製程的開發過程中，生產者與使用者的緊密互動是必須的。如果有許多的廠商參與到研發創新的活動，那麼地理的鄰近性將有助於更大的技術外溢。

既有的經濟地理學文獻也強調在於未明文化(tacit)知識的轉移以及地理鄰近性之間存在著緊密關係，這是因為不像一般技術轉移文獻所討論的知識多半是已經符碼化(coded)，附著在材料、機械或手冊中，因此容易跨越地理界線，未明文化的知識則是附身於人的認知和技能之中，因此，需要藉由人的展現、互動與諮詢來取得，所以未明文化知識是高度社會脈絡化，而技術越是複雜，未明文化的知識含量與面向就越多。

由於未明文化的知識是很難藉由市場貿易方式轉移，而往往包含在社會過程之中(Storper 1997, Lawson & Lorenz 1999)，因此對於後進

廠商對外投資中最具策略性的問題就在於如何掛勾(tap into)到這種在核心地區具有區位特性以及附身的技術？既有相關文獻包括以網絡為基礎的創新理論（Oinas & Malecki 1999）以及演化制度論者(Kogut 1997)，都提出鑲嵌在社會組織是未明文化知識傳遞的重要管道，而知識越是未明文化，因為知識的傳遞變得越是複雜與昂貴，需要更多的溝通，創新就越需要廠商群集。另外，在知識管理學者也指出，以科學知識為競爭基礎的技術月需要空間上聚集，這是因為在這些領域中未明文化的知識向度越複雜(Cantwell 1999)。因此，後進廠商如果要汲取到技術核心區域的知識外溢，就必須設法將在這些地區的投資鑲嵌到在地的創新環境中，因為創新越來越是由廠商與外在行動者之間累積而成的互動所決定。鑲嵌將鼓勵知識成長的過程，並允許這些廠商的子公司可以在技術或組織的方法上累積經驗，這回過頭來又可增進新的技術應用，或者發展或改良一些新的產品或製程。

無論是網絡論者或是制度演化學派也都對於傳統認為技術轉移大多發生在由母廠轉移到子公司，或者由母國轉到在地國的看法提出挑戰，由於產品週期的縮短（資訊產品尤其如此），需要由全球的尺度搜尋新的技術的要求增加，因此，讓國外的子公司獲得更自主的角色藉以取得新技術的技術轉移型態正逐漸在湧現。成功的新產品或製程的開發不僅是要在技術上有優勢，同時更重要的，要能被市場接

受，由於在產品的品質、可靠性以及技術的特殊性上存在著高度不確定性，這需要與顧客有緊密的互動。增進創新的活動因此包含著相當大程度來自於和下游顧客與上游供應商之間的豐富資訊與知識交流。另外，Porter 的「鑽石理論」分析地方生產結構的競爭性指出，對區域而言，優勢是來自於相關技術、科技與基礎設施等的高度專業化聚集，特別是當此很難加以複製的時候。產業群聚是被 Porter 定義為相關產業的多樣連結，包含垂直與水平連結兩部份。OECD 則將群聚定義為廠商間強烈互依的網絡、此網絡包含了知識生產的機構、橋樑機構或組織、顧客、制度…等創造出附加價值的生產鏈之連結。因此，如何以不同的進駐方式(entry mode)，包括新設廠或者併購既有廠商，以吸納在地的技術知識，特別是未明文化的知識，越來越是新的研發全球化活動的課題。

進駐到創新含量高的廠商聚集的區域，除了與顧客或上游供應商的垂直關係帶來創新機會外，還會帶來另外水平關係的優勢，就是由於這些地區吸引來自不同國家地區的廠商進駐，因此，技術外溢的機會還會經由工程師或有技能勞動力的流動，擴散到其他廠商，進而使得技術的來源多元化，避免封閉在特定的技術軌跡上。這些高科技區域（例如矽谷）往往吸引了不同跨國公司的進駐，成為技術發展交流的平台。

藉由創新地理學的回顧，本研究可以深入發問：什麼因素可以解釋後進廠商（如台商）在決定設立尋求創新研發的子公司上的考量？是否存在部門的專業性與活動區位之間的關連性？什麼是後進廠商開發新產品或改良製程的主要來源？如何將各個區域高度脈絡化的知識轉移到子公司，並傳遞到母廠，藉以提昇技術？同時也可以進一步問，研發活動的全球化是否就無地理上的區別？如果有怎麼將這種全球在地化(glocalization)的研發活動以及型態的演化發展如何進行？

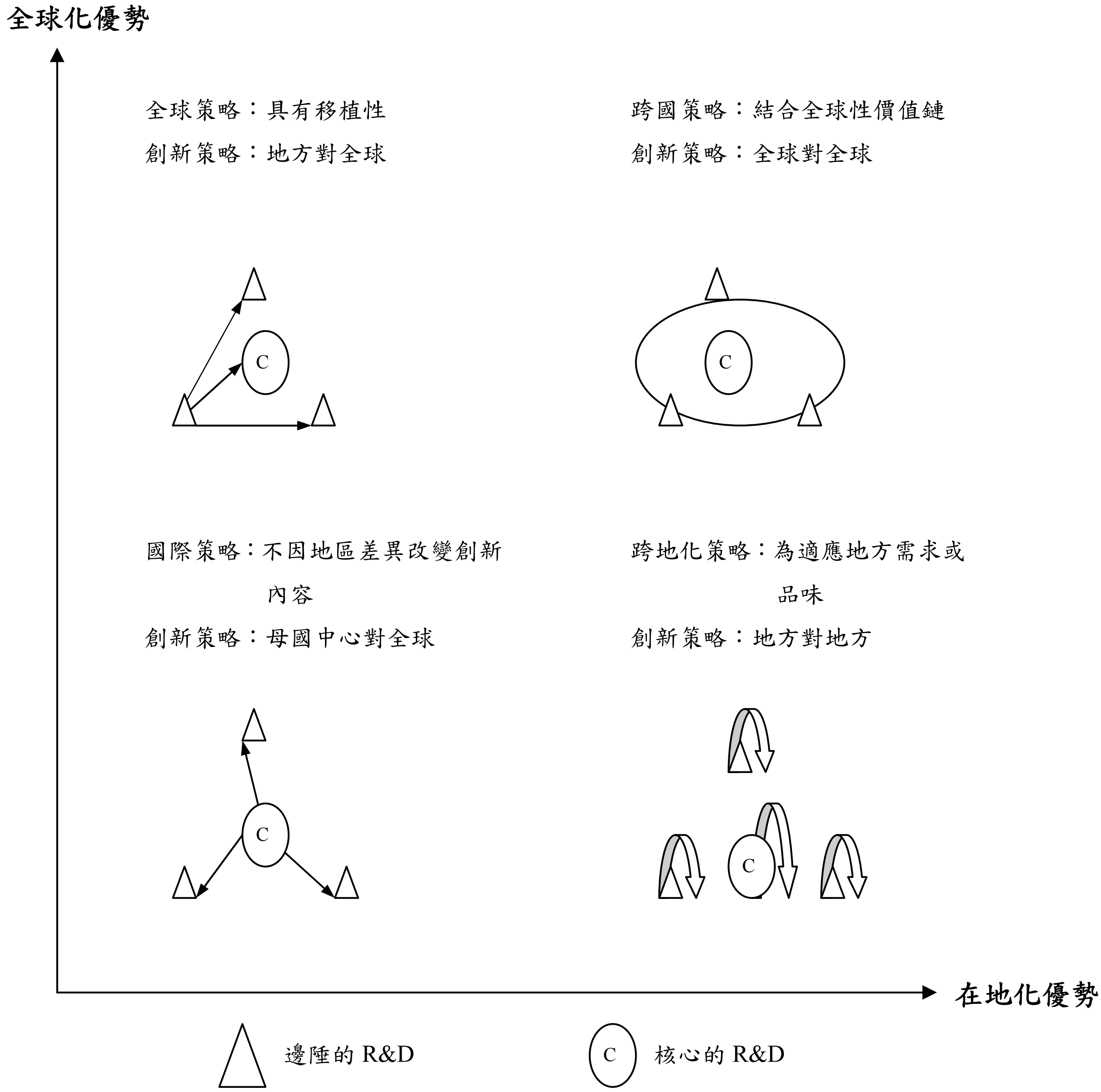
關於研發活動的全球在地化的討論，Hotz-Hart （2001）有初步的分析，他認為跨國企業應用多種策略去利用全球的技術優勢，企業策略全球化的程度與本質是根據其規模大小、商業文化、技術領域而有所差異，但可藉由部門、市場、企業結構、全球化優勢與在地化優勢...被識別的。因此，企業選擇可分成四種主要策略，可以單一選擇或多重應用：

1. 國際策略（個別國家或區域為中心結構）：企業是以國家認同、出口是來自於發源基地國，沒有特定全球化或在地化的優勢。
2. 多地區策略（多中心結構）：具有適應特定地方特徵的壓力，少有全球化的優勢，主要功能為輔助地方市場與改善其表現
3. 全球策略：產品具有性質相似的目標市場，可透過規模經濟，於

許多地區標準化的其生產設施（具有移植性者）。

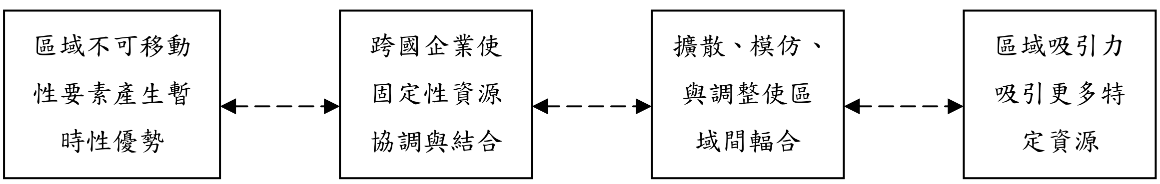
4. 跨國策略：具有特定地方特徵，同時可實行規模經濟。

（如下圖所示）



本研究最後要借用這一形態區分，來審視台商在矽谷與京滬地區研發活動的性質、角色以及與當地區域創新體系的互動，更重要的，這種型態的區分要放在動態的策略與時間面向來看，也就是說，這些區域與台商的互動型態會改變，會因為競爭的結構、技術的發展、制度的要求以及廠商發展的策略在不同歷史階段中演化。通過這樣的分析，我們可以更清楚資訊業台商在不同區域的研發活動的機會與限制。

結合前述的兩大理論的回顧，我們可以提出一個初步的分析架構，這個架構一方面要處理全球化的研發活動，另一方面則是要關照到區域的聚集與創新的體系。儘管有越來越多研發活動在不同區域進行，也是在這意義上被認為研發的全球化趨勢，但不同地區的研發活動經常反映了廠商的策略以及地區的創新環境的特色，也因此，所得到的研發成果與角色，也會因攫取不同區域的資源而有不同的發展型態，包括在創新的產品或製程的程度以及對應的市場，多有所不同。然後，又疊加在區域的研發環境之上，又吸引新的一輪的外資。如下圖所示：



回饋

這樣的理解下，我們可以比較台灣的資訊電子業廠商到矽谷與大陸的上海、北京地區進行研發活動時的目的、角色、策略、與進駐方式、在地化接軌的型態（是否以當地市場為導向，或者回傳到母廠進而以更廣大市場為導向）將有所不同，乃至於和母廠之間的關係，以及研發活動與當地市場的關係，將有清楚的比較，尤其放在廠商的國際化策略以及區域的研發創新環境的雙重角度切入，可以更具體看出廠商與區域之間的互動的多重型態。在經驗上，也比較清楚西進與北進不同策略下的廠商策略，彼此之間不盡然是競爭關係，也可能是互補的形式。

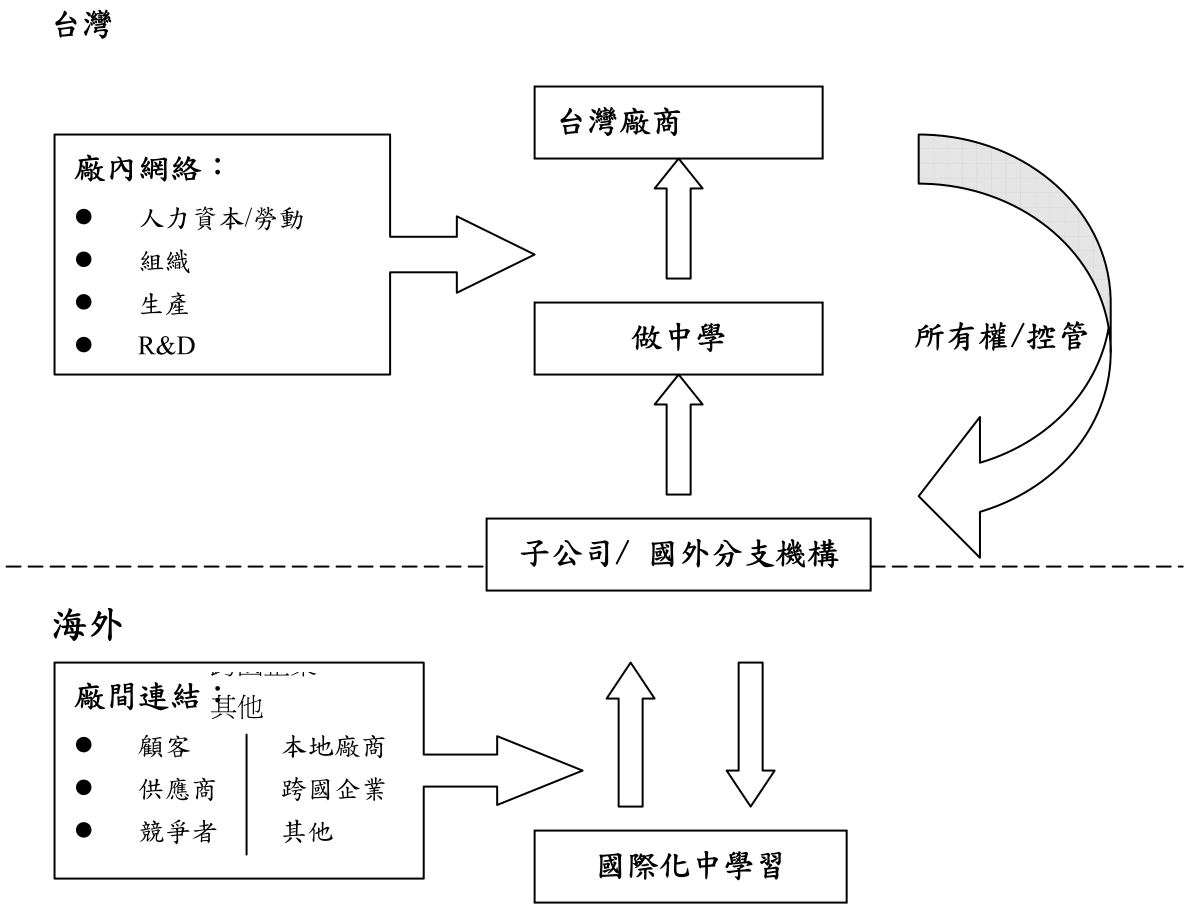
在研究架構上，本研究將分成幾個部分來分析：

（A）資訊業台商台商在矽谷與北京、上海的子公司：這部分包括在當地的顧客、使用者與供應商都將視為在產品與製程上創新的重要來源，我們將考察這種互動學習的關係，包括（1）新產品/製程的使用者與顧客，（2）替代性技術解決方案的提供者，（3）競爭者，（4）提供廠商有關技術解決方案的制度機構。這些外在的互動者有些是當地的廠商或研發機構，有些則是可能來自其他國家或地區的投資者。另外，區域勞動力市場的形態，包括知識人員的供需、訓練以及雇用，轉換工作形式等都必須放進考量。

（B）在台灣的母廠：這部分的考量放在前述的子公司如何將他們在地主區域所學到的技術，透過廠商的網絡，藉以轉移、分享並且在母廠中運作起來，提身母廠的核心知識與技術，或者進而開拓母廠在當地的市場。可以預期這些在其他地區進行研發活動的子公司提供了一個增加母廠知識含量的含量，也擴大了知識的領域搞度，增加附加價值的可能，但有一前提在於母廠本身具備吸收的能力，這往往有賴於母廠本身在內部同時建立研發機制，或者藉由發包給專業的廠商或研究機構來協助才能有效轉移，當然這種廠商內部的轉移要比不同廠商外部的轉移來得容易一些。經常決定這種遊子公司轉移到母廠的內部轉移的形態往往依廠商的組織與生產活動而定，也會因廠商的規模以及所研發的產品/製程內容有所不同。在本計畫主持人的過去研究中，也發現藉由技術社群的人員流動經常是技術有效轉移的重要條件，不論是廠商之間，或者同依廠商的部門之間，或者同一廠商同部門但不同地區的技術轉移都是如此。

研究架構可以約略以下圖表示：

台灣廠商的技術獲取概念圖



<u>研究設計與方法</u>

首先，如同前面提及，主持人已經先後在相關矽谷與新竹的高科技區域研究中，建立了一些相關的研究成果，可以作為本研究的基礎，這包括了：(一）已經建立了矽谷華人在不同產業（包括電腦、半導體、光電與其他高科技微電子產業）的人數與創業、經營的統計資料；(二）針對台灣的廠商與創投資本家、新竹與矽谷兩地的工程

師與企業家進行深入的訪談。選擇的廠商將集中在半導體、電腦工業與其他微電子產業的企業家與經理人。訪談的問題集中在資本、技術、經營管理模式、技術與資訊的來源，以及在兩地經濟體系中的個人與廠商之間的非正式與較正式的合作關係。訪談也擴及到一些相關的機構與組織，例如矽谷地區的華人工程師協會（玉山科技協會，中國工程師學會、華美半導體協會與其他），以及在新竹地區的工研院、大學校友會與政府機構。（三）收集兩地的基本資料，藉以建立經濟結構的檔案，並加以分析。這些資料將包括從 1970 年代以來廠商的數目與規模的變遷、雇用人數的變化、部門的集中度變化、職業的細分以及創投資金的來源與規模的發展。因此，對於資訊業台商在矽谷的一般性投資活動有了一個概括性的掌握。

另外，包括正在進行的專題計畫在內的過去一年半時間，主持人也訪談了主要集中在上海地區的高科技台商，也發現了投資活動的內容逐漸轉向研發創新的行為在內，並逐步在擴充。在這研究中，也建立了資訊業台商的網絡關係、區位分佈、組織型態以及生產鍊的發展等面向資料，可以作為本研究計畫的基礎。也對於資訊業台商在大陸投資，尤其是在大上海地區的佈局，有了基本性的掌握。

在這些條件下，以及考量分析架構下，本研究採取一般問卷(survey)以及廠商訪談(corporate interview)作為主要研究策略。

在一般問卷的取樣上，首先將針對既有相關文獻與報導，包括了學術研究報告、證券公司、財經智庫、投資理財分析報告以及主要報章雜誌，所提出有關台商（特別是高科技資訊電子產業）到大陸投資的初步報告，進行整理，並選擇高度集中於蘇滬地區進行投資的部門，包括電腦零組件業、筆記型電腦以及半導體產業的廠商，作為本研究的研究範圍。另外也將利用經濟部投審會、各地高科技台商組織（包括矽谷地區與大陸）的會員名錄、以及這些上市公司的年報，甚至需要上網再一次確認資料（因此，這將非常耗人力，需要助理以及工讀生的投入），可以挑選不同特徵（包括規模、成立時間、專業的產品等）的廠商，郵寄問卷。問卷的設計上將使用的代理變數(proxy)以及涵蓋的衡量指標，如下表所示。蒐集到的資料將一方面使用描述性的統計（包括初步結論、變數分析、以及 *t*-test 的檢定）。

問卷與訪談使用到的代理變數(proxy)與衡量指標

(1)廠商特徵
●大小(營業額、資產、員工)
●年齡(設立時間)
●產品/部門
●所有權型態（在台灣或美國、大陸上市與否）

(2)績效面向
●廠商成長率(營業額、稅前盈餘)
●出口值
●出口強度
●行銷支出

(3)創新活動(研發，或 R&D)
●研發支出
●研發強度
*●設計策略
●產品創新
●過程創新
●過程／創新的地理起源
*●研發時的問題

(4)人力資本／勞動力
●雇員（工程師／技術人員數）
●技能勞工的教育描述(大學、教育程度、專業化)
●勞動力流動
*●訓練
●品質控制

(5)組織
*●母-子公司關係(控制和資源層級)
●控制方式(如擁有直接投資,策略聯盟)
*●功能互相依賴(部門和研發單位的接觸頻率)

(6)生產
●整合形式(內部或外部生產)
*●內部產品／過程技術的機制

(7)地主國（美國矽谷或大陸北京、上海）的競爭狀況
●產品／過程技術的資源(競爭者、供應商、貿易展覽會的區位/鄰近性)
●和機構的關係（如大學、專業協會、貿易展覽會）
*●母公司創新能力的衝擊

(8)技術移轉
*●符碼化知識
*●市場領導
*●織織概念

*　這些變數將預期透過仔細地在地訪談和觀察才會產生。

**　大部份的變數是有時間向度(包括過去、現在和未來的評估)

在下一個步驟中，應該就初步統計資料中得到非預期性的部分，藉由電話訪談方式，嘗試找出解釋的可能。但這些作法經常僅能找到統計相關，並不保證存在因果關係，因此，研究的下一階段則要針對重要廠商，進行實地訪談。也就是廠商訪談的部分，藉此挖掘並解釋在問卷中無法觸及的議題（例如對於地主國地區在不同階段的研發環境評估、對創新的重要性的具體評估機會與障礙等等）。

這種研究方法通常有三種特點：一、有利於展示廠商作為一個行動者，其所具有的複雜與不斷變化的策略，可以豐富問卷調查或一般統計資料的內容。二、廠商訪談對於廠商如何回應外在環境變遷的能力，尤其在面臨跨界組織變遷時的統理機制的改變，以及生產網絡體系的調整，較問卷調查能掌握動態分析的面向。三、同時廠商訪談著重歸納推論的分析方式，對於廠商行為組織的變遷理解，尤其是對快速巨變的生產體系而言，具有比一般統計方法檢定假說的方式，提供較全面性假設的基礎(Schoenberger 1991)。

具體研究成果以兩篇英文的論文呈現。

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The geography of learning and knowledge acquisition among Asian latecomers

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The geography of learning and knowledge acquisition among Asian latecomers

Abstract

This paper examines the geography of technological learning and knowledge acquisition among Taiwanese and Korean firms. As industrial latecomers, these firms are predominantly oriented towards learning than innovating in the manufacturing sector. The Asian latecomer model of learning is characterized by a triangular spatial division of knowledge sourcing and technological production. At the regional level, Korean and Taiwanese firms rely on local learning systems in the form of science parks to create favorable domestic agglomeration economies that are conducive for knowledge thickness and development. At the trans-regional level, non-core R&D and the manufacturing of technology-driven products are geographically concentrated in China. Lastly, at the international scale, East Asian firms are directly locating and investing in R&D facilities in the United States (US) to acquire and source for new knowledge forms and products that help move them from technology latecomer to technology newcomer status.

Keywords: Knowledge sourcing, learning, Taiwan, Korea

JEL classification: O31, O33, N65, L6,

1. **Introduction**

The process of technological diffusion and learning among firms has been a subject of interest among economic geographers recently. Literatures directly resulting from this interest have spawned a number of spatial concepts including notions of the learning region (Florida, 1995), innovation milieu (Camagni, 1995) and systems (Lundvall, 1992), technology district (Storper, 1997) and industrial cluster (Britton, 2002; Porter, 1998). Much of this literature has one common goal, that is, to unravel the spatiality of knowledge forms and processes within the context of its (re) production and transmission. While contributing much to the geography of innovation, this literature overwhelmingly focuses on the regional competences of firms, particularly those of native firms in European and North American regions. Perhaps because of this spatial fixity, explanations of knowledge exchanges, particularly those surrounding tacit knowledge, are biased towards the local context giving the impression that learning and knowledge acquisition is superior with local indigenous insiders.

The problem with such a spatial bias is that it neglects a parallel development in international knowledge production and transmission, namely technological learning and acquisition among foreign firms in knowledge-rich environments, particularly foreign firms from industrializing countries. Unlike early technology comers from

North America and Europe, industrializing countries such as Taiwan and South Korea (henceforth Korea) are latecomers to the technological process. The phenomenon of innovation, in the sense of Schumpetarian invention, technical change and diffusion, is much more alien to firms from these countries (Viotti, 2002). The Asian story is one of learning, acquisition, re-innovation and knowledge sourcing than strictly innovating. The question is raised as to what the nature of learning might be among foreign firms that are not as locally embedded as indigenous firms? This paper seeks to answer this question. We propose that the geography of technological learning and knowledge acquisition among Asian firms requires a multiscalar perspective that intertwines local-domestic, trans-regional and international spaces in the organization and coordination of technology and knowledge flows. More specifically, we focus on the process of international learning among these firms through their foreign direct investment in the United States (US). In the next section, we detail the process and mechanisms of technological learning and knowledge sourcing among Asian latecomers. The geography of learning is investigated next using survey data that was collected between 2003 to 2004. The paper caps with some implications of the findings.

2. Knowledge production and learning among Asian firms

A recurrent theme in the economic geography of innovation and knowledge is that "the enduring competitive advantages in a global economy lie increasingly in local things – knowledge, relationships and motivations – that distant rivals cannot replicate" (Porter, 1998: 78). The notion that a local scale of geography optimizes the creation and transmission of knowledge and innovation and thereby the potential for technological learning, stems from the presumption that the viscosity of knowledge exchanges, particularly tacit knowledge, is high, so that spatial proximity enhances knowledge production, recombination and utilization among firms and between knowledge agents. There is no shortage of literature in economic geography on the negative relationship between knowledge flows and distance, and recent excellent reviews include Malmberg and Maskell (2002), Gertler (2003) and Bathelt et al. (2004). One concomitant effect of this interest on the role of proximity in facilitating knowledge exchanges is that a rich literature has emerged on relatively self-contained and socially embedded relationships within a region that are thought to hasten and intensify innovations among native firm residents, and articulated through spatial regimes such as the innovation milieu, learning region or industrial cluster.

Three themes are particularly pertinent to the research in this paper from this literature. First, information sharing increases when social bonds proliferate as this encourages a firm to adopt more cooperative forms of behavior as the basis for exchange. This in turn contains firms' inclination to act opportunistically through the reduction of uncertainties. Social bonds intensify trust-based, cooperative transactions and to the extent that knowledge in technology involves some form of proprietary information, the willingness to communicate and relay some of this information is increased between two cooperative than uncooperative parties. In this case, the transmission of knowledge is greater when firms interact considerably with one another, and the latter is enhanced if firms are located close to one another. Relational and interaction-based learning, particularly between customers, suppliers and distributors, constitutes the major mode of learning here (Gertler, 1995; Dyer, 1996; MacPherson, 2002; Britton, 2002).

Second, firms do not interact and learn in a spatial vacuum. Hence local knowledge assemblers are necessarily institutionally and socially constitutive. Institutional knowledge assemblers include universities, research institutes and laboratories, financial institutions or venture capital (Keeble et al., 1997) and legal firms, agencies or organizations that help protect proprietary knowledge and that thicken skilled labor markets (Fields and Cohen, 1999). Areas or regions with a thicker institutional infrastructure are said to be better incubators for new knowledge formation (Cooke at al., 1997). More recently, Gertler (2003) has argued that national institutions also matter in that they determine the market rules and framework within a country driving innovations and knowledge creation at the regional level. Gertler's point that national than regional institutions matter more may be illustrated in national regulatory frameworks governing genetic manipulation or research using embryos which have strong implications for knowledge production in applied biotechnology research in the United States and Europe.

Third, despite mounting criticisms of the tendency of the economic geography literature to assume that "tacit=local versus codified=global" (Bathelt et al., 2004: 32), for purposes of understanding the process of learning among Asian firms, it is nonetheless useful to recognize that codified knowledge that is explicitly articulated in more objective forms such as publications, blueprints or manuals, enjoys a greater efficiency in spatial transmission because it is less idiosyncratic in terms of time and location. This is not to say that all codified knowledge is much more readily transmitted and learned as pointed out by Nonaka, Toyama and Nagata (2000). A highly customized machine for instance requires simultaneous conversions between explicit and tacit knowledge. Further, a recent study of Swedish transnational firms (TNCs) suggests that the less articulable the knowledge, the greater the transfer of knowledge among Swedish MNCs despite the higher level of complexity in more tacit forms of knowledge as compared to codified knowledge (Nobel, 1999). However, consistent with the discussion earlier, this greater transfer of knowledge may be explained by firms' fear of the appropriation of knowledge by their competitors through codified forms. By keeping the transfer of knowledge in more tacit forms, they seek to minimize knowledge leakage. What this implies is that while tacit knowledge can also be distanciated (between TNCs and foreign units), the preferred mode of transmission among TNCs may also be relational and organizational proximity that resists or reduces the potential conversion of proprietary knowledge to a public good.

In addition to growing criticisms on the overly local focus of the geography of innovation, two points are also noteworthy here. Schumpetarian innovation is "the privilege of industrialized countries" (Viotti, 200: 657) whereas that of industrializing Asian countries is more accurately described by a process of learning including the absorption and improvement of innovation from industrialized countries. For this reason, a model of reverse product cycle has been suggested to theorize the experience of Asian learners (Abernathy and Utterback, 1977; Hobday et al., 2004). In this model, Asian firms first acquire knowledge that is associated with more mature technologies, that is process-based technologies. Over time, they progress to product innovations as technological capabilities strengthen. This contrasts with the experience of North America for instance where firms progress from product innovations and then to process-based technologies that focus on product improvements.

Next, the literature has also been much less informative about how foreign firms might fit into regional innovation systems in North America or Europe. As noted by Phelps and Ozawa (2003), foreign direct investment (FDI) has become more important in contemporary regional economies than in the past. This is particularly true for Korean and Taiwanese firms whose recent internationalization of research and development (R&D) in the US is primarily driven by FDI than other modes of entry. Little is known, however, of the nature of this process of international learning. This question appears to be important as Gertler (2003) has noted that firms need to bridge major institutional- contextual boundaries, and this is more so for Asian firms whose language, institutions and culture back home are quite divergent from the US compared to their European counterparts.

We propose that the geography of learning among industrializing Asian countries reflects a pattern of sourcing and practice of knowledge and technology at three spatial levels. First, within the national and domestic context, there is emulation of regional systems of knowledge formation from North America as outlined in the literature on industrial clusters and innovation milieux. In both Taiwan and Korea's case, industrial policies aimed at promoting R&D activities among domestic firms are articulated through the construction of regional institutional systems that potentially enhance inter-firm and organizational cooperation. This may be illustrated in the establishment of Daedeok Science Park (DSP) in Korea, and the Hsinchu Science-based Industrial Park (HSIP) in Taiwan. HSIP for example is modeled after California's Stanford Industrial Park, and both science parks are thought to be two of the more successful technology-learning regions in developing countries (Castells and Hall, 1994; Mathews, 1997).

Second, the emergence of China as a low-cost country for trans-regional R&D production and operations constitutes the next spatial level of explanation in Asian firms' technological learning and acquisition experience. The China factor is more than just an abundance of cheap labor: Chinese labor is also becoming highly skilled and top Chinese universities graduate a number of engineers and scientists every year whose wages are about one-third that of Korean and Taiwanese engineers.[1] Geographical proximity to China has encouraged a trans-regional division of labor where more mature technologies or less proprietary operations of R&D are relocated to nearby regions like Guangdong, Fujian, Zhejiang and Shandong. The Beijing area also attracts considerable Asian R&D plants because of its thick skilled labor market as a result of the presence of the elite Beijing and Tsinghua universities. With a

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[1] This information was consistently relayed to us in on-site qualitative interviews with twenty Taiwanese and Korean parent firms.

trans-regional division of technological labor however, key R&D knowledge are produced and retained in parent firm operations back in Taiwan and South Korea.

Third, the most important spatial level of analysis, and one that constitutes the main focus of this paper, is at the international level where Asian firms directly invest in facilities or operations in the US that help them source new knowledge and technology, both of which are done so with the objective of upgrading and augmenting their home-base knowledge. As will be described in a later section, much of these investments are concentrated around regions of active innovations and knowledge buzz (Storper and Venables, 2002) like the Silicon Valley or Boston-New York City area.

One final point is worth pointing out. Technological learning among Asian firms operates through three mechanisms; namely institutional learning (e.g articulated through Hsinchu Technology and Daedeok Science Parks), interactive learning that is largely relational between and within firms and organizations, and embodied technology learning that is associated with more accessible public or objective forms of knowledge. In embodied technology learning, major mediums of communication involve higher aggregation levels such as manuals, publications, industry certification, trade shows and reverse engineering. But it could also contain significant tacit knowledge involving that of US consultants as well as

Taiwanese/Koreans engineers and scientists trained in US universities or who have worked for US companies.

3. The geography of learning and knowledge acquisition

3.1. Regional and transregional learning and practice

Among the three modes of learning identified in the previous section, institutional learning is most evident at the local regional level within the domestic context of Korea and Taiwan. In Korea, national science and technology policies promote government research institutes (GRIs) over university R&D because Korean universities are traditionally oriented towards undergraduate teaching (Kim, 1997). The more successful Daedeok Science Park (DSP) in Korea was created in 1978. Coordination between the country's Ministry of Science and Technology (MOST), Ministry of Education and Ministry of Construction ensured that DSP, built some 120 miles south of Seoul, became relatively well-endowed with research institutes; indeed the number of research institutes in Korea is nearly three times that of Taiwan.[2] As of 2002, there were nearly 30 publicly funded and 29 private research institutes, and 130 venture businesses in the science park. Despite criticisms that DSP was forced

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[2] Korea has a total of 50 public research institutes and some 10,427 private research institutes (Korea Industrial Technology Association or KOITA) in the country. Taiwan has fewer than 20 public research institutes and the number of private research institutes in not known.

upon private industries with the result that there is little local knowledge spillovers (Castells and Hall, 1994), some evidence is emerging that the park has become relatively successful in forging institutional learning over time: more than 1000 applications in international patents were filed in 2002 among the park's public and private research institutes (Park, 2004), and over 100 local firm spin-offs have occurred (Shin, 2001). Institutional learning may also be illustrated with one of DSP's research institutes (Korean Electronic and Telecommunication Research Institute or ETRI) mastering the CDMA (code division multiple access) knowledge and technology in 1995 which was subsequently transferred to the telecommunication industry.[3] Acquiring the CDMA knowledge is important because despite the industry's relatively stronghold in telecommunication products such as Samsung and LG Electronic's cellular phones in international markets, this key technology was then largely imported and licensed from the US company Qualcomm until the mid-1990s.

In Taiwan's case, the state also established the Hsinchu Science-based Industrial Park and the park is supported by the Electronic Research Service Organization (ERSO), a public lab, that is also the research arm of the government. Most of the key high-technology firms today are spinoffs from ERSO. The HSIP and its neighboring corridor to Taipei is home to Taiwan's most rapidly growing microelectronics

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[3] CDMA is part of an ultra high frequency wireless telephone system that allows many signals to be transmitted through a single channel.

industries such as Integrated Circuit (IC) and Personal Computer (PC). In contrast to their Korean counterparts, these firms, mostly small and medium sized (SMEs), collectively built up a vertically disintegrated industrial system. Local companies dominate the international market for a large and growing range of computer-related products, from notebook computers, motherboards and monitors to optical scanners, keyboards and power supplies. In addition, Taiwan's state-of-the-art semiconductor foundries account for two-thirds of global output.

Because of their small size, many of Taiwan's high-tech firms are disadvantaged in terms of internal resources both financially and technologically, and this forces them to rely external partners in the manufacturing process. Under these circumstances, a more refined model of regional learning is necessary in order to understand Taiwan's decentralized high-technology industrial system. The Taiwanese firms have to be open to their customers, suppliers and partners in order to discuss and negotiate the possible paths of product development. They benefit by learning from external resources, in addition to the internal resources through the coupling of R&D, production and design functions. Hence, on the one hand, Taiwan's case appears to confirm the regional innovation literature's conclusion on the merits of vertically disintegrated inter-firm transactions that are largely collaborative to build technological assets. On the other hand, HSIP is not regionally self-contained because a significant dimension of knowledge flows in the region is that they are associated with international knowledge sources, more specifically, from knowledge networks in the Silicon Valley (Hsu 2004).

HSIP's global links with the Silicon Valley are articulated in several ways: Taiwanese companies recruit overseas engineers, they set up listening posts in Silicon Valley to tap into the knowledge networks there, or they attract successful overseas returnees to start up their own businesses. All of these linkages are mediated by US-based industry organizations (e.g. the Monte Jade Science and Technology Assocation in California) that enable domestic firms to integrate into US-based social networks to gain access to technological and market-related information and to absorb them effectively (Hsu & Saxenian 2000).

State-initiated institutional learning appears at least to have kick-started a culture of R&D among the firms that was previously missing, though in Taiwan's case, the state's nurturing role soon gave way to that of a demonstrator's role where it did not target, as the Korean government did, large companies for R&D development. Sakakibara and Cho (2000) observe that compared to Japanese firms, Asian firms, at least before the 1990s, tended to be much more indifferent to R&D activities. Institutional learning however encouraged applied R&D among firms and quickly transformed firms from passive learning where GRIs led in tacit knowledge production, to active learning where firms play a greater role in scouting for new technological knowledge themselves. Institutional learning is also complemented by embodied technology learning that deploys reverse engineering, technology licensing and returnees from the US or who had previously worked in US firms. In initial stages of technological upgrading, most of the firms used technology licensing to source for knowledge. The second largest Korean chaebol LG electronics even hired a German engineer at early stages of its R&D process to access tacit knowledge. However technology licensing often met with limitations since foreign firms are reluctant to impart their key technological assets to Asian firms. Hence while LG electronics may have learnt to produce black and white televisions in the 1960s through a licensing agreement with the Japanese Hitachi, it failed to acquire technology on color television when the former ran the course of its product cycle. Institutional learning through joint R&D with a GRI (Korean Institute of Science and Technology) helped overcome this problem to some extent, however, the company also engaged in reverse engineering such as taking apart microwave ovens imported from Japan and the US to supplement the learning process (Kim, 1997).

Beyond the regional level, trans-regional R&D activities in China among Asian firms are predominantly oriented towards R&D production than knowledge creation through the availability of plentiful skilled labor. A recent survey of 100

Taiwanese firms in China by one of the authors indicates that whereas 40% of the firms reported "access to skilled labor" as being critically important, and another 30% as somewhat important, comparable statistics for US indicate that the shares are only 17.5 and 10% respectively. The proximity of a relatively large pool of skilled but cheap labor in neighboring China has meant that R&D costs are kept at a reasonable level thereby allowing both countries to overcome the problem of size given their relatively small population base. Indeed the influence of R&D cost is one major reason why Asian firms are locating most of their R&D plants in China while retaining more marketing-oriented R&D learning systems in the US. This triangular division of R&D across the US, Taiwan and China is summed up by a venture capital firm's executive in Taiwan who specializes in the information and communication technology (ICT) industry: "the best business model in the ICT industries today is to combine the locational advantages of the three regions: while the Silicon Valley is good at innovation in business and management model, product design and technology frontier, the newly industrializing countries such as Taiwan and Korea can collect funding from the booming capital market, commercialize the product and improve the production very quickly by a well-trained engineer teams. Finally, you can go to China to find the huge amount of cheap engineers and workers and a rapidly rising market to get the final products done." (Authors' interview, June

2004).

3.2. International learning and knowledge sourcing

The previous section discusses two major modes of learning, namely institutional and embodied technological learning at a regional and transregional level. In addition, an increasing source of knowledge is associated with interactive and relational learning at the international level. Evidence for international learning is obtained from a survey of Taiwanese and Korean manufacturing firms in the US conducted between 2003 and 2004. This survey consists of two stages: (1) telephone interviews with 74 Taiwanese and 50 Korean subsidiaries in the US from a population base of 210 and 113 respectively; and (2) on-site qualitative in-depth interviews with 20 parent companies in Taiwan and Korea.[4]

Telephone interviews solicited quantitative data on technological learning and R&D activities in addition to qualitative information on the subsidiary's role in knowledge transfers back to its parent company. Qualitative interviews on the

[4] The targeted populations were based on manufacturing firm directories obtained from Taipei's Cultural and Economic Office and the Korean Chamber of Commerce and Industry. The service sector is not very internationalized in both countries hence this sector was omitted from the study. A content analysis of company websites as well as telephone clarifications ensured the currency of the targeted populations and confirmed firms' direct investment and location of R&D facilities in the US.

other hand were used to build embedded case studies that help clarify statistical findings from stage 1. Most of the interviews were conducted in native languages and the analysis below reflects translations of these interviews.

A comparison of the quantitative survey data between Korea and Taiwan indicates two main differences: (1) Taiwanese firms are predominantly small and medium sized enterprises and nearly 95% of them have worldwide sales of less than $250 million. In contrast, Korean firms are much larger reflecting a history of chaebolization with slightly over 40% indicating worldwide sales four times the size of their Taiwanese counterparts, that is, over $1 billion; (2) Korean firms are also older internationalizers in the US with nearly 80% having established operations for more than 10 years. In contrast, the entry of Taiwanese firms to the US is more recent with 53% reporting as having been in the US for less than 10 years. Tests for survey response bias using the Armstrong and Overton (1997) method of early and late responses further suggest no significant differences in age, sector and size.[5]

Interaction-based learning began in the 1970s when Asian firms operated as

[5] Non-responses bias analysis for sector, age and size reveals the following statistics: (i) Korea: Sector (χ^2= 8.78, (p=0.553), age (χ^2= 1.38, p=0.710) and size (χ^2= 7.45, p=0.209). The corresponding statistics for Taiwanese firms are sector (χ^2= 15.16, p=0.105), age (χ^2= 3.42, p=0.378) and size (χ^2= 3.51, p=0.561).

OEM and ODM suppliers to American and other TNCs (Mathews and Cho, 2000). However, Asian firms are becoming more than just passive recipients of knowledge from foreign TNCs and their inward investment. Many are actively sourcing for knowledge through outward FDI to knowledge-rich regions in the US. Firm addresses at the zipcode level reveal that approximately 70% of the firms are located in five of such US regions, namely, the New Jersey-New York city as well as Austin-Dallas conurbations, the Silicon Valley, Los Angeles-Riverside and Raleigh Research Park.

Table 1 shows an analysis-of-covariance that controls for firm size of the influences on firm location with 1 being very unimportant and 7 being critically important. Market expansion, proximity to users and competitors, market intelligence and distribution networks are ranked amongst the most important reasons for firms' investment including R&D investment.[6] The importance of developing "relational market-based assets" (Srivastava et. al., 2001), particularly with respect to the US market, customers and distributors in part stems from the need to interpret large amounts of market and technical information, a process made more complex by cultural and institutional gaps that Gertler (2003) has suggested. These factors appear far more important in Table

[6] R&D investment on the average constitutes between 5 to 10% of total investment though a few firms reported a much larger share of more than 50%

1 than technological building factors such as prototypical or technology process development. The only explicit technological building factor that is somewhat important is that location in the US is associated with improvement in product performance and quality (mean=4.3). The case of a Korean auto supplier, Firm A, illustrates Table 1's findings.[7]

Firm A is an auto maker that supplies components to the US big three carmakers, namely Chrysler, Ford and General Motors (GM). While the company has a manufacturing plant in Montgomery County in Alabama, its US R&D unit is located in Detroit. R&D in Detroit focuses on applied research on vehicular movement and brake systems (anti-lock braking systems). According to the interviewee, a senior R&D manager, while the firm could have located all of its facilities in Alabama, which is preferred by its US-based engineers because of a warmer climate, "being there" in Detroit helps strengthen relational market assets with its principal customer GM in particular. Emphasizing its long term relationship with GM, which began some 12 years ago, our interviewee indicates that the most important dimension of interaction-based learning with GM is associated with its being among the first suppliers to be notified of GM's new car models when the specifications are formulated, and considerable access to its

[7] Where necessary, firms are assigned letter labels to preserve their anonymity.

customer for interpretation of the information. This lead time, together with the supplier's ability to shorten delivery time by as much as 65% compared to its US competitors, have enabled the development of brake systems that are customized for and cost-efficient to GM's newer models. Particularly noteworthy is that R&D investment in brake systems is highest with respect to their design and this tends to be undertaken back in Korea by its parent company rather than by its R&D team in Detroit. However, subsidiary (Detroit) to parent (Seoul) knowledge flows significantly contribute to parent companies' knowledge on the design process, a point that we will return to in a later discussion.

The F-statistics in Table 1 also indicate that Taiwanese firms attach greater importance to the development of relational market assets than Korean firms in locational considerations.

Part of the explanation lies in the small size of many Taiwanese firms which forces them to rely far more heavily on external relationships including those associated with partnerships with US companies in order to acquire complementary assets. In contrast, the larger size of Korean companies implies that more R&D may be conducted in-house. Despite these differences, the mean scores for several relational market asset factors among Korean firms are still well above the neutral score of 4.0. More importantly, how successful are these factors in internalizing learning among Asian firms? The answer to this may be found in Table 2 that uses an ordered probit regression to determine the relevant locational factors, including industry sector as a control variable, that influence firms' ability to capture learning rents through the introduction of new products as a result of relocation to the US.[8]

The regression results in Table 2 indicate that partnership with a US firm and the development of new prototypes are common positive contributing factors among the two countries in enabling firms to successfully introduce new products with their US FDI. However, new product introductions are also significantly related to Korean firms' proximity to competitors and product improvements, while the development of distribution networks has a significant impact for Taiwanese firms. Interestingly, development of process technology in US locations is negative and significant for firms from both countries. What Table 2 suggests is that tacit knowledge transferred through complementary partners (including certain strategic alliance relationships), competitors and

[8] An ordered probit regression is used here because the response variable is of an indexed nature (that is, ranked from 1 to 7 in degrees of importance). It takes the form of $y_i^* = x_i\boldsymbol{\beta}_i + \varepsilon_i$ where $\mathbf{x}_i$ is a vector of explanatory variables, $\boldsymbol{\beta}_i$ is a column vector of parameters to be estimated with the first element being the intercept, y_i^* is the latent variable and ε_i is the random error term which is assumed to follow a normal distribution. The ordered probit model is derived from a measurement model where the latent variable, which ranges from $-\infty$ to ∞, is mapped to an observable variable y such that the extreme interval categories $\varphi_0 = -\infty$ and $\varphi_j = \infty$.

distributors constitute the main transmission mechanism for interaction-based learning. While firms consider proximity to customers to be important in Table 1, this locational factor does not directly result in any knowledge and innovation rent indicating that, at least in the Asian case, the benefits of user-producer interactions are not obvious in knowledge creation. One possible explanation may lie in the negative finding for process technology development. If firms are seeking to improve their process technologies in the US arising from pressures from their users to lower costs or enhance performance, this is more likely to result in incremental product improvements than new product development since learning here is much more associated with production and improvement capability than innovation capability.

On the other hand, knowledge transfers from distributors and competitors may have a more significant impact because innovations like new product development require changes in design and core features of products. The case of a major Taiwanese scanner maker illustrates this. The company was founded by three US-educated Taiwanese returnees who had worked in the image-engineering department at Xerox. From the beginning, this company pursued the brand creation of its products. This is quite unique since most Taiwanese firms are quite weak in original brand manufacturing. Its first product was the in-circuit microprocessor, which sold well and won a prize for its innovativeness at a computer trade show in 1981. The company decided to enter the scanner industry in 1983, as the founders responded to market intelligence gathered from its competitors while working in the Silicon Valley. It produced the world's first 300-dpi black-and-white sheet-fed scanner in 1985, and the world's first USB and SCSI scanner in 1999. In fact, the firm was responsible for over 30% of the world's scanners at its peak in the late 1990s. It set up three subsidiaries in the US, one in the Silicon Valley, that assumed primary roles of innovation and marketing. It developed significant technological capability in the scanner industry and was effectively responsible for introducing image processing in personal computers.

However, mastering the imaging technology and first mover advantage do not guarantee sustained competitive advantage. The company's market share was gradually eroded due to the entry of strong competitors such as HP and Epson which possessed more comprehensive marketing and distribution channels in early 2001. The profit erosion was attributed to the lack of distribution channels. The firm's vice president concluded: "Even though our innovative capability was good enough to set the product standard in the early stage, it lost control as these established PC companies joined the game. They could promote their scanner products with their PC marketing channels and strong brand names. But we did not carry such an advantage, and what we could do was to focus on the niche market such as industrial-specific image processing equipment." (Authors' interview, November 2004). Enjoying innovation rents from its initial success with the scanner technology, the company failed to develop extensive distribution networks that potentially support wider market-derived innovations. Part of the reason lie in the complaint that contrary to perception, the US is not a monolithic market, so that success in distribution requires considerable knowledge of the nature of forward integration, the latter of which also requires cultural bridging across several regional markets. Indeed once its Japanese competitors successfully distributed its scanner-printer technology, US demand for Taiwanese scanners declined.

In Korea's case, domestic rivalry has been a traditional source of competitive advantage among its firms (Kim, 1997). What Table 2 suggests is that international rivalry and competition are complementing domestic rivalry as a source of knowledge rent; a dimension that Malmberg and Maskell (2002) note is under-appreciated in the literature. Taken together, for Asian firms to move from process to product innovations under the reverse cycle theory, a combination of interaction-based learning and competition or rivalry is expected to aid the transition.

The above provides support for the positive effect of interaction-based learning on the development of production and technological capability that realizes new product introductions. However, core R&D activities tend to be undertaken back home by parent companies with the R&D team being relatively small in the US. In other words, distanciated knowledge is largely transferred back to Taiwan and Korea rather than locally produced in the US. A key reason, observed in an early section, is to retain proprietary knowledge within the organization. Another reason would seem to be that conversion of knowledge into production and innovation capability, or, absorptive capacity, requires an optimal body of indigenous knowledge stock that supports new knowledge formation. The case of a Taiwanese company that manufactures connectors for computers is insightful. The key engineering knowledge for this product is mechanical and contains a higher level of tacit knowledge than most electrical components. Such mechanical engineering knowledge resists standardization and coding in objective forms particularly with respect to the product's design and development dimensions. R&D activities here require engineers with "very full experience" and who have "worked in-house for a period of time, and know what is our resources" because the technical process consists of "alot of knowledge that is cumulative". The need for considerable communication with respect to the conversion of knowledge, in this case, from tacit (design) to explicit (drawing) and back to tacit (development) is all the more necessary because customization is high. This customized knowledge is provided by the firm's R&D support team in the US. It was the US R&D subsidiary that brought to the parent company's attention, Apple's demand for a change in the connector's material, which the vice-president maintained was far more expensive than the material is uses for customers in Asia**.** This demand for more costly materials had puzzled the parent company initially, a response worth noting because it reflects a learning process that forces the supplier to think beyond costs in favor of design. Furthermore, Apple's industrial design extends beyond the objective requiring "the feeling, the touch … something like art" that is reminiscent of Allen's (2002) description of aesthetic knowledge. Knowledge sourcing in the US in this case by its subsidiary has resulted in considerable learning for the parent firms by increasing its sensitivity to industrial and product design which has generally been a weakness among Asian firms.

To unravel the role of organizational proximity in subsidiary to parent knowledge transfers, Table 3 provides quantitative data on firms' internal organization in terms of their interactive and communicative patterns. Clearly, the simplest and most frequent mode of communication is by phone, fax or emails of new technologies to parent companies (and other subsidiaries) with means of over 5.0

on a scale of 1 to 7 (1 being very unimportant and 7 being critically important). Email content however is more than just textual. Digital pictures and drawings are also common features in using the internet for information transfers. Visits of engineers from parent companies to their US plants and facilities as well as visits of engineers from US plants to parent companies both receive slightly above the neutral mean scores of 4.0 for Taiwanese companies. The frequency of visits is high, with some firms reporting up to bi-monthly visits particularly from parent to subsidiary plants. Knowledge circulation via intra-organizational rotations is ranked well below 4.0.

Intra-firm subsidiary to parent knowledge flows appears to have yielded innovation rents for both countries. Table 4 correlates each of the organizational variable to the firms' ability to secure US patents. Visits by parent engineers to the US as well as visits by subsidiary engineers to parent companies appear to be the most common form of knowledge exchanges that have contributed positively to patent making. The least helpful and insignificant medium of communication relates to telephones, faxes and emails. This is hardly surprising since telecommunications use is more likely to be associated with product improvement with subsidiaries largely conveying relatively non-complex information pertaining to product defects than more abstract knowledge that is difficult to codify through such mediums. Overall the analysis here indicates that the transfer of distanciated knowledge contributes to the augmentation of Asian parent companies' technological assets and that international technology sourcing necessarily supplements more local models of knowledge production for technologically weaker Asian firms.

4. Conclusion

Prevailing literature on innovation focuses on technological and scientific changes that are aimed at innovation in industrialized countries. A common theme finds the region to be a superior spatial architecture for knowledge creation and reproduction though this literature is increasingly being criticized. The tendency of this literature to correlate innovation with regional systems neglects the fact that knowledge systems are frequently not self-contained and regional spillovers in fact occur. Such spillovers result in extra-regional and international circulation and appropriation that leads to the creation of new knowledge elsewhere. Knowledge spillovers, when absorbed by foreign firms, contribute to international learning that stimulates innovations outside of the region. This essay has examined such knowledge re-appropriation and reproduction by unpacking the geography of technological learning among

Taiwanese and Korean firms, particularly learning that is articulated through their investment in the US.

The geography of Asian learners may be understood at three spatial scales. To catch up, state-initiated effort involves the establishment of regional production systems that the literature maintains has successfully created innovations in the US and Europe. These regional systems such as Korea's Daedeok Science Park and Taiwan's Hsinchu Science-based Park are thought to have fostered domestic institutional learning through the accretion of technological linkages between firms and research institutes. However, regional knowledge incubators are insufficient for narrowing the knowledge and technological gap between industrial countries, and, industrializing Asian countries whose competitive advantage until very recently has been largely based on cost advantages and mass production rather than advanced technologies. As OEM and ODM suppliers, institutional learning is often complemented by embodied technology learning that relies on more objective and publicly accessible forms of knowledge. To supplement regional systems of domestic learning, firms are also broadening their knowledge-acquisition base to the international scale through outward FDI, including R&D investment, in the US. Because the US is the largest market for most Taiwanese and Korean firms, this geographical bias in knowledge sourcing is not surprising. US-sourced knowledge is largely interaction-oriented and transferred back to parent R&D facilities in Asia, but material production of knowledge is increasingly farmed out to China where skilled scientists and engineers are plentiful and relatively cheap. Key tacit and proprietary knowledge, however, is retained in Taiwan and Korea.

The survey evidence suggests that firms are predominantly located in knowledge buzz and knowledge fertile areas, and the reasons for locating and investing in the US, and by implication these regions, are associated with developing relational market-based assets such as proximity to customers, distributors and the collection of market information. What Malmberg and Maskell (2001) have termed the horizontal dimension of locational advantages or competition also emerged as important for Korean firms. While technology-acquisition considerations like prototypical and technology process development are somewhat important, firms gave lower mean scores to these factors. It appears that tacit knowledge that resides in people is a stronger locational motivation perhaps because social interactions and relational-based knowledge access constitute the main mechanism of knowledge transfer here.

However, not all relational market-based factors translate into learning and thereby innovation rents in the form of new product introductions. Collaborating with US partners to access proprietary knowledge is significantly associated with new product introductions. This positive relationship may also be found for proximity to competitors among Korean firms, and, a good network of distributors in the US among Taiwanese firms. User or customer-oriented factors including proximity to customers and market intelligence both yield no learning rent. Furthermore, it would appear that learning is largely internalized within the organization through subsidiary to parent knowledge exchanges. Intra-organizational transfers indicate that R&D engineers from parent companies visit their subsidiaries and R&D plants in the US frequently. The reverse too happens, that is skilled personnel from the subsidiary also visit R&D plants in Asia. Both forms of personnel mobility are positively correlated with the securing of US patents thereby indicating that intra-organizational knowledge transfers are achieved largely through such proximate communicative forms. This is supplemented by rotations of skilled personnel among the various units, which together, appear to have contributed to the spread of knowledge within the organization.

Finally, the comment of one electronics Taiwanese company best conveys the importance of knowledge leakage or spillovers that enables international learning among Asian firms: “We’ve continuously transferred technology from such cultural regions as Britain and US to Taiwan”. Asian firms increasingly view the need to source and transform new knowledge from various cultural regions in the world essential to making the transition from low-cost suppliers to medium or even high technological producers. Over time, the ability to successfully integrate various spatial scales of knowledge flows may well help firms from these countries to move from learners to innovators status.

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Table 1. Reasons for location of technology-related facilities in the United States (analysis-of-covariance)

Reasons	Taiwan (mean)	Korea (mean)	F-statistics (p-values)
1. Take advantage of skilled labor	3.2	3.1	0.03 (0.854)
2. Collect market information	5.3	5.2	0.02 (0.879)
3. Develop distribution networks	5.6	5.3	0.97 (0.327)
4. Proximity to competitors	4.6	4.5	0.23 (0.634)
5. Proximity to customers	6.3	5.4	5.24 (0.020)**
6. Build partnerships in US	4.4	3.3	3.83 (0.05)**
7. Develop new prototypes	4.0	3.7	0.43 (0.511)
8. Develop new process technologies	3.2	3.3	0.26 (0.612)
9. Improve product quality/performance	4.3	4.5	0.00 (0.986)

** Significant at 5 percent level

Means are based on a likert scale of 1=very unimportant to 7=critically important

Table 2.
The effect of locational factors on firm's success in introducing new products since relocation to the US (ordered probit regression)

Locational factor	Taiwan Parameter estimate (p-value)	Korea Parameter estimate (p-value)
1. Sector	0.054 (0.103)	0.037 (0.356)
2. Skilled labor	0.034 (0.604)	0.003 (0.980)
3. Market information	-0.151 (0.155)	-0.180 (0.149)
4. Distribution networks	0.203 (0.086) *	-0.073 (0.473)
5. Proximity to competitors	-0.039 (0.622)	0.312 (0.029) **
6. Proximity to customers	-0.124 (0.406)	-0.191 (0.880)
7. US partnerships	0.214 (0.009) ***	-0.265 (0.013) **
8. Development of new prototypes	0.182 (0.065) *	0.418 (0.032) **
9. Development of new technology process	-0.248 (0.029) **	-0.540 (0.006) ***
10. Improvement of product quality/performance	0.120 (0.157)	0.608 (0.001) ***
α_2	0.358 (0.719)	0.0416 (0.961)
α_3	0.093 (0.925)	-1.147 (0.179)
α_4	-0.043 (0.966)	-1.525 (0.077) *
α_5	-0.593 (0.522)	-2.313 (0.009) ***
α_6	-1.300 (0.194)	-3.209 (0.000) ***
α_7	-1.823 (0.071) **	-4.092 (0.000) ***
Loglikelihood ratio	34.076 (002)***	

***, **, * denote significance levels at 1, 5 and 10 percents respectively

Table 3. Intra-organizational interactive and communicative patterns

(analysis of covariance)

	Taiwan (mean)	Korea (mean)	F-statistics (p-value)
1. Visits to parent company/plant or other US subsidiaries by engineers/technicians from US subsidiary	4.1	3.2	3.09 (0.08) *
2. Visits to US subsidiary/plant by engineers/technicians from parent company	4.2	4.4	0.36 (0.548)
3. Rotation of engineers/technicians between companies and facilities in US and Taiwan/Korea	2.2	1.7	1.23 (0.271)
4. Communication of new technologies to parent company and other subsidiaries by phone, faxes or emails	6.1	5.2	0.029 (0.029)**

Means are based on a likert scale of 1=very unimportant to 7=critically important

Table 4. Correlations between intra-organizational communication and securing of US patents

US patents	Visits from subsidiary to parent firm/plant	Visits from parent to subsidiary firm/plant	Intra-organizational rotation of personnel	Telephones, faxes, emails
Taiwan	0.313 (0.008) ***	0.329 (0.005) ***	0.198 (0.099) *	0.137 (0.252)
Korea	0.251 (0.09) *	0.321 (0.029) **	0.160 (0.310)	-0.029 (0.846)

External Leveraging and Technological Upgrading Among East Asian Firms in the United States

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External Leveraging and Technological Upgrading Among Asian Firms in the United States

ABSTRACT

This paper aims to investigate the stages and trajectories of industrial and technological upgrading for East Asian newly industrializing economies, such as Taiwan, South Korea, and Singapore. Three stages characterize East Asian firms' technological development. At the first stage, circa the 1960s, East Asian firms benefited from knowledge spillovers through forward and backward linkages that were forged with foreign transnational corporations (TNCs). During this time, East Asian firms specialized in labor intensive industries and targeted mainly the domestic markets while technology transfer was largely realized through learning-by-doing. During the second stage in the late 1970s, East Asian firms used OEM (original equipment manufacturing) partnerships with global firms to acquire technology and learning-by-doing was increasingly supplemented with learning-by-interacting. These leading Asian firms took advantage of their OEM positions to leverage technologies from key global buyers. However, the OEM model of technological learning met its limit by the late 1980s due to low entry barriers and the relative absence of research and design capabilities among these Asian firms. The third stage in the 1990s saw a number of East Asian firms actively sourcing for foreign technologies through outward foreign direct investment (FDI) in the United States. This process involved setting up research and design branches, particularly in applied R&D, in the US to acquire new knowledge processes and products. Based on original survey data and personal interviews in the US and East Asia, we propose that the OEM model is being complemented by an OBM (original brand manufacturing) model of technology development among leading Asian firms. We identify empirically the different methods of technological leveraging and sourcing activities among East Asian firms in the US. We examine the policy implications of this organizational change for technological sourcing and upgrading among the East Asian NIEs.

Keywords: Technological sourcing; Latecomer firms; Technological upgrading; Newly industrialized economies; East Asia

1. Introduction

A considerable body of research exists that attempts to explain the remarkable speed and level of technology development among firms from Asian newly industrialized economies (NIEs) (Hobday, 1995; Mathews and Cho, 2000; Choung et al., 2000; Amsden, 2001; Mathews, 2002). Traditionally, firms in industrializing Asian economies (henceforth the IAFs) acquire technology through interactions with the foreign operations of transnational corporations (TNCs). They do so by exploiting technology and knowledge spillovers from inter-firm linkages that are established between foreign affiliates and domestic firms (Dunning and Narula, 2004). However, with the emergence of "Third World" TNCs (see Yeung, 1999), particularly from South Korea, Taiwan, and Singapore recently, the IAFs are apparently becoming sources of technology generation, developing firm-specific technological capabilities as opposed to their more traditional role as importers of foreign technology from the United States (US), Japan and Europe. To date, however, the literature has only begun to document the technological catch-up of the IAFs recently. Learning capacities of the IAFs are attributed to two major sources: namely, forward integration with more sophisticated markets in the US or Europe (Hobday, 1995), and technology and resource leverage through original equipment manufacturing (OEM) or through own design and manufacturing (ODM). As OEM suppliers, the IAFs secure contracting manufacturing jobs from TNCs or retail outlets in industrialized countries, although technology and market access are largely supplied by foreign contractors. As ODM suppliers, the IAFs are able to execute their own designs and technological capabilities (Mathews and Cho, 2000).

This paper aims to investigate the trajectories and processes of industrial and technological upgrading among leading firms in East Asian NIEs, such as Taiwan, South Korea, and Singapore. We document the process of learning by shedding light on the major sources of knowledge acquisition that enhance technological capabilities internally and externally. Specifically, our empirical research shows that the IAFs are directly investing in the US and setting up R&D operations there to acquire knowledge that enables them to become more innovative. We found a variety of technology sourcing strategies practiced among these IAFs, depending on their firm-specific variables (e.g. size and sector) and their prior technological capabilities. The types of technology and knowledge sources also go beyond conventional technological know-how to embrace the entire production chain from manufacturing technologies to expertise in marketing and distribution. Our empirical analysis is based on a large-scale quantitative survey of Taiwanese, South Korean, and Singaporean firms in the US that was conducted between 2003 and 2004. This dataset is supplemented by qualitative interviews with senior executives from parent companies in Taiwan, South Korea, and Singapore that offer unique insights into the specific mechanisms and complicated processes of knowledge transfers. These interviews originate from our longitudinal fieldwork involving personal on-site visits with various companies from the three economies between 2001 and 2004.

In the next section, trajectories of technological upgrading will be described to outline the different stages of technological development for East Asian latecomer firms. This section provides the organizational context for us to understand the recent direct acquisition of knowledge and expertise in the US by these leading Asian firms. In the third section, we explain in detail the various sources of knowledge acquisition in the US. The paper concludes with some implications of our findings for understanding and developing R&D policies in the East Asian NIEs and, possibly, other developing countries.

2. Trajectories of Technological upgrading

Trajectories of technological upgrading have become a critical issue for latecomer firms (see Amsden and Chu, 2003). The product cycle model is commonly used to describe the pattern of a product's development and production during its entire lifespan in firms from advanced industrialized countries (Vernon, 1966; Utterback and Abernathy, 1975). The model proposes that firms in these countries engage in R&D that results in new product innovations. Over time, product innovations give way to process innovations as the product moves through its life cycle. But it is doubtful if this theory is relevant for the IAFs from South Korea, Singapore, and Taiwan. In contrast to technologically advanced firms, latecomer firms from the Asian NIEs have adopted quite a different pathway of upgrading (Hobday, 1995; Shin, 1996; Kim, 1997; Kim and Nelson, 2000; Hobday et al., 2004). They move backward from mature stages of the product cycle (process innovation) to early stages (product innovation) – a reversal of the product life cycle. For these firms, the future is somewhat path dependent in that they approach the technology frontier through the transfer of technology from firms in more advanced countries. In fact, Forbes and Wield (2000) have suggested that the innovative activities of the latecomer, as well as follower, firms manifest a number of features that are distinctive from those of the leaders in advanced industrialized countries. Latecomer innovation is characterized as incremental in nature, process-based, shop floor- situated, and design and development dominated, in contrast to leader innovation that is more radical in nature, product-based, laboratory-located, and R&D-driven.

For developing countries, the effective acquisition of foreign technology has been an essential prerequisite for building their own technological capabilities that are taken as an important element in constituting their dynamic competitive advantage in the global economy (Ernst et al., 1998; Kim and Nelson, 2000). However, technological learning is also complicated by several fundamental factors such as uncertainty, cumulativeness, embeddedness, and externalities. These factors make it difficult for technological learning to be analyzed in standard economic models that assume rational and maximizing agents with a unique equilibrium state as the point of reference (Lall, 2000). The complex interaction of these factors also mean that trajectories of technological learning are mostly evolutionary and incremental as each new stage usually represents the (re)combination of technological capabilities between the previous stages and new added ones leveraged from external resources (Nelson and Winter, 1982).

Three stages characterize East Asian firms' technological development. At the first stage, circa the 1960s, East Asian firms benefited from knowledge spillovers through forward and backward linkages that were forged with foreign TNCs. During this time, East Asian firms specialized in labor intensive industries and mainly targeted the domestic markets while technology transfer was largely realized through the movement of personnel and technical people on the one hand, and training of local suppliers on the other hand (Dicken, 2003). From the TNCs' perspective, foreign direct investment (FDI) was preferred than licensing and exports for the purpose of fully exploiting the rents of intangible assets, particularly their technologies and knowledge competence (Dunning 1993). This mode of internationalization was particularly important if their intangible assets could in some measure be moved across national borders and could not be patented easily. As IAFs started industrializing and were not equipped with any significant technology, TNCs from industrialized countries were generally welcomed, at least among the Asian latercomers, to bridge the technology gap between the sending and receiving countries (Hobday, 1995; Kim, 1997; Dunning and Narula, 2004).

The key issues involved are often the quality and degree of embeddedness of FDI in the host regions (Poon and Thompson, 2003; Hsu, 2004; Phelps and Raines, 2004). Different types of embeddedness are examined in terms of affiliate autonomy and local sourcing (Amin and Thrift 1994).[9] Schive's (1990) 1973 survey of 311 exporting firms in Taiwan reveals that 86% of TNC subsidiaries applied their parents' technology in their production, and increased their local purchasing over 8 times in the 1970s.[10] And the most important vehicle through which foreign-owned firms disseminated technologies acquired from their home countries to Taiwan's domestic firms was labor mobility, i.e. worker movement from foreign-owned companies to Taiwanese firms. Former employees of foreign-owned firms are considered to have

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[9] Poon and Thompson (2003) explore the relationship between the embeddedness of technology-oriented functions among different types of foreign subsidiaries in Asian cities, and make a distinction between developmental subsidiary, which actively exploits location-specific advantages and pursues R&D activities in host locations, and quiescent subsidiary, which rarely develops new products and less than often engages in R&D activities in host localities. Their study shows that different types of foreign subsidiaries create divergent types of technological linkages to developing countries. For a similar empirical study, see Ivarsson and Alvstam (2004) on technology transfer in India through the investment of Sweden's Volvo.

[10] However, foreign companies that are located in export processing zones purchased less than those outside, and thus transferred less technology to local suppliers (Schive, 1990).

contributed greatly not only to domestic firms' improved technology and product design, but also to their managerial and marketing technology (Hou and Gee, 1993:389).

In the second stage in the late 1970s, some of the East Asian firms, particularly in Taiwan and South Korea, used OEM (original equipment manufacturing) partnerships with global firms to acquire technology. Learning-by-doing was increasing supplemented with learning-by-interacting.[11] Asian firms took advantage of their OEM positions to leverage technologies from key global buyers. Within the global commodity chains (GCC) literature, a common route of progressive upgrading is for producers that enter the chains to link up with their buyers and customers (Gereffi, 1999; Schmitz and Knorringa, 2000; Humphrey and Schmitz, 2002). Key global buyers help local producers in East Asia to improve technical and organizational skills to raise their product quality and production speed. An example of this is illustrated in the success of Taiwan's electronic producers in Figure 1 whose OEM relationship with leading US and Japanese companies helped stimulate knowledge creation, technology transfer, and improve domestic capabilities (Ernst

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[11] The different stages do not necessarily describe all Asian countries. As demonstrated by Hobday (2003), while the OEM system dominates Taiwanese and Korean firms, TNC-led growth is more important in Singapore and Malaysia. Nevertheless, all of these three stages in various sequences represent the major technology strategies adopted by latecomer firms to compete in the global economy.

2000, Borrus 1997, Dedrick and Kraemer 1998). Many of these Taiwanese firms have since become significant ODM/OBM players in the respective segments of the electronics industry today. In this OEM model, manufacturing activities are not only the driving force but also the economic precondition for technological investment and learning. In other words, manufacturing activities can generate and support the development of technological capacity. Learning-by- doing predominantly characterizes this phase of the manufacturing process, especially if needed technologies or skills are not in stock, but are still required to develop or produce the product. In these OEM arrangements, the latecomer firms "not only make an acceptable level of profit but also avoid the risk in developing the technology by themselves" (Hou and Gee, 1993: 404).

[Figure 1 here]

However, the OEM model of technological learning met its limit by the late 1980s due to low entry barriers and the relative absence of research and design capabilities among these OEM firms.[12] Meanwhile, the OEM makers were forced to upgrade their design and integration skills to serve their buyers better and more flexibly. In developing design and marketing competence, Asian firms faced obstacles

[12] Ernst (2002) shows that overwhelming reliance on OEM renders South Korean PC companies incapable of launching their own brand name products in direct competition to the world market leaders.

because such upgrading encroached on their buyers' core competence. The model of ODM (original design manufacturing) was introduced to describe the new role of the latecomer firms in East Asia.[13] In this newer model, a global buyer first provides a local company a set of product ideas and/or concepts. The local company, in turn, designs the system, sources the components, and builds a product prototype according to these concepts from its buyers. The emergence of ODM represents a new international division of labor between the first-tier IAFs in Taiwan, South Korea, and Singapore, the second-tier ones in Southeast Asia and China, and, the global buyers. Gereffi (1995) has proposed a role of "triangle manufacturing" for semi-peripheral manufacturers to move from direct suppliers for the US market to intermediaries in global production chains. The essence of triangle manufacturing is that the first-tier Asian subcontractors and their located regions take the orders from their global buyers, and then shift part of the requested production to affiliated offshore factories in other peripheral Asian countries. In so doing, the intermediary manufacturers could upgrade their position in the global value chain.

Technological upgrading through learning-by-doing in the early 1980s was however somewhat passive. To be competitive in the late 1980s, a firm had to acquire

[13] The design part in the ODM model is defined as the deliberate conceptualization of a product to achieve certain desirable performance characteristics (Forbes and Wield, 2000). More importantly, the design prototype and functional requirement are mainly designated by the key buyers, rather than by the ODM makers.

aggressively as early as possible a firsthand knowledge of the products, and to design accordingly their own product models. This urgency also means a learning process that is different from learning-by-doing - a process of learning-for-doing (Lin 2000).[14] In other words, learning is not only a by-product of manufacturing, but also an activity of deliberate research and development (R&D) that is increasingly engaged by the IAFs. Establishing R&D divisions has become one of the major sources of competitive advantage for some IAFs across sectors. At the same time, it is widely acknowledged to be difficult to create and exploit technological capabilities by individual firms. A firm's competitiveness now depends not only on its own internal capabilities, but increasingly on the effectiveness with which it can gain access and utilize different sources of technological knowledge and capabilities beyond its firm-specific boundaries (Howells et al., 2003; Love, 2003). It is particularly true in technology-intensive industries where rapid technological change, growing technological complexity and shortening product life cycles prevail (Prahalad and Hamel, 1990; Teece et al., 1994; Bannert and Tschirky, 2004). Hence the early 1990s

[14] As observed by Lin (2000), in a mode of learning by doing, a producer does not design the product and may not bear the related technological knowledge and skills before undertaking the production. In a mode of learning for doing, however, a producer will be the designer of a product or the so-called fast follower. It therefore has to acquire to certain degree the related technologies and skills before even the phase of product design. From the late 1980s onward, formal and specific R&D units and design teams were gradually organized among leading Asian firms.

saw a number of the IAFs actively sourcing for foreign technologies through outward foreign direct investment to the US. This involved setting up research and design divisions, particularly in applied R&D, in the US to acquire new knowledge processes and products (see also Chen, 2004, for the case of China). At this stage, the OEM model is being complemented, rather than substituted, by an OBM (original brand manufacturing) model of technology development. Here the firm seeks to develop and sell its products under it own brand name rather than market its products under the brand names of its users and customers as is the case with OEM and ODM status. In Figure 2, we illustrate these changing organizational relationships between Asian firms and their global buyers. In particular, we argue that Asian latecomers at different stages of technology development cater to different segments and tasks of global production networks and they consequently obtain the matching value-added embedded in these networks.

[Figure 2 here]

The transition to OBM, nevertheless, has not come easy for Asian latecomers. First, they have to build their own R&D teams that tend to be costly, particularly for small and medium sized information technology (IT) firms. Second, competing with their contract buyers potentially hinders IAFs from building their own brands.[15] To

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[15] Hobday (2004) has posed this issue as an innovation dilemma. He questions if the latecomer firms should compete as R&D and brand leaders in the international stage

handle these issues, IAFs are beginning to source technologies both internally and externally to save R&D costs and to remain dynamically competitive. They are also targeting at different products and market locations to avoid direct competition with their key buyers and to search for a complementary way to coexist with the latter (Hobday et al 2004). Acer's focus on the Middle East and Eastern Europe, other than the conventional North American and Western European markets, is a case in point.

3. Technological Learning and Upgrading in the US

3.1 Technological learning and transfer

The above section suggests that the IAFs are turning to direct investment in the US to augment and supplement indigenous OEM and ODM strategies of technological learning and upgrading. This investment takes the form of establishing support facilities that include R&D units in well-know US innovation areas such as Silicon Valley, North Carolina's Raleigh Research Triangle, and the New Jersey/New York City area.[16] A major aim of this direct presence in the US is to develop new product capabilities through deploying R&D personnel, and developing strong local relationships with customers. Firms also take advantage of geographical proximity and use R&D labs as listening posts to monitor new developments in their major

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or if they should continue with their tried and tested formula of low cost catch up to enhance competitiveness.

[16] For example, a sample of Taiwanese companies that have R&D activities in the US include Multitech (Acer), Plus & Plus (America Research Corporation), Mitac, Tatung, and Advanced Data (see Liu, 1987).

product lines (see Gertler, 2003; Storper and Venerables, 2004; Boschma, 2005 for a critical review of the relation between innovation and proximity). As these Asian firms grow older and become more embedded in the US, they have increasingly turned to the sourcing and internalization of more sophisticated knowledge forms, particularly that associated with tacit scientific knowledge that is much more difficult to transfer and acquire (Dougherty et al., 2000).

One of the major goals of learning and sourcing is to cultivate indigenous technological capabilities.[17] To understand how knowledge is transferred and subsequently absorbed and transformed amongst the IAFs, we need to separate 'material transfers' and 'design transfers' from 'capacity transfers' (Lall, 1987). Material transfer is characterized by the import of new materials and techniques and knowledge is typically built through reverse engineering or industrial certification processes. Local adaptation is not conducted in an orderly and systematic fashion. The local adaptation of borrowed technology and the development of new machines tend to occur primarily as a result of trial and error, i.e. 'learning-by-doing'. Design transfer is primarily carried out through the transfer of blueprints, formulae, publications

[17] According to Bell and Pavitt (1993: 163), technological capabilities consist of the resources needed to generate and manage technical change, including skills, knowledge and experience, and institutional structures and linkages.

or seminars. The knowledge contained in these design materials is predominantly coded and much more explicit, and must be adapted to local conditions. In addition, competitor products in an industry trade show also constitute an important source of knowledge for design transfers. Capacity transfer refers to the transfer of scientific knowledge that leads to the production of locally adaptable technology, based on technology prototypes that exist abroad. A critical element in the process of capacity transfer is the mobility of scientists and engineers, as most of the innovative knowledge is human-embodied and diffuses through personal contact and association. Capacity transfer is therefore much more dependent on tacit knowledge forms. Sources of such knowledge may also come from external sources such as strategic alliance with another firm, or through the hiring of technical consultants. While technology transfer involves management and investment, it is difficult to rely exclusively on the transfer of machines and blueprints. Therefore, mobility of skilled personnel and external sources must be considered an essential element in the effective transfer of technology. In fact, among a number of ways for firms to tap into external technological knowledge and expertise, recruiting personnel directly from other companies or even competitors has been identified to be important (Kogut and Zander, 1993, Koruna, 2004).

Recruiting experienced engineers and designers in the Silicon Valley is illustrated in the case of MXIC (Macronix International Co.), a firm that has intended to compete on product innovation, not cost reduction. Min Wu, the founder and CEO who had previously worked for major US semiconductor firms, said that: "were it not for these adept engineers, MXIC would not have been able to stay on the right track. The upgrading of product levels could not have been possible without their inputs. To remain on the technology frontier, we had to recruit new engineers from Silicon Valley every year. I went to Silicon Valley to find the right people every year. They are like the roots of a tree, absorbing nutrients from outside. You've got the right people, you've got the right technology."[18] By 2001, MXIC became the world's 8th largest supplier of the non-volatile memory. Besides luring skilled people back to Taiwan, MXIC also set up a technical development and marketing department in San Jose as a listening post to tap into the powerhouse of IC product innovation. Through this department, MXIC subcontracted some product development jobs to overseas Taiwanese engineers. The department allowed those engineers who were reluctant to return to Taiwan to contribute their

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[18] Authors' interview with Min Wu, 26 September 2001 and 9 July 2004.

knowledge and experience to MXIC. The case of MXIC is not unique. High Tech Computer, a recent rising star in the smart phone design in which phones and other wireless gadgets perform many of the functions of a PC, such as email checking and internet surfing, was managed by a team of three Taiwanese engineers who had worked in Digital Equipment Co. They developed a relationship with Microsoft and "learned the value of innovation", according to an industrial insider (Dean, 2004).

Of the three Asian NIEs, Taiwanese firms have been the most active in investing in overseas facilities to take charge of R&D and marketing in Silicon Valley. Some Taiwanese small chip design houses even establish Silicon Valley divisions to monitor the development of new technologies. As Mr. C-C Huang, the president of Realtek, a small ASIC (application-specific IC) design house, argued: "Basically we recruit locally trained engineers that is sufficient to handle normal operations. If we want to maintain our place in the PC related market, however, we must also put a foot in Silicon Valley. This is why we decided to purchase Avance (a small Silicon Valley design house started by overseas Taiwanese engineers) as our division in Silicon Valley, the center of ASIC design. Through it, we are able to get access to first-hand marketing information, PC system development trends, and experienced talent in these areas."[19] On the other hand, while Silicon Valley is also home to many South Koreans, a significant share (nearly half) may also be found in northeastern US, particularly around the Boston-New York City conurbation. Clearly, skilled labor mobility through inter-firm transfers constitutes a relatively common technological solution for shortening the learning curve among the IAFs. However, this is often complemented by other sources of knowledge acquisition in the US.

3.2 US Sources of Learning: Quantitative Survey Evidence

To examine the major sources of knowledge in the US that potentially contribute to IAF's learning and technological upgrading, we conducted a telephone survey of Taiwanese, South Korean and Singapore firms and their manufacturing FDI in the US between 2003 and 2004. Databases containing firm directories were obtained from Taipei's Economic and Cultural Office (New York), the Korean Chamber of Commerce and Industry, and Singapore's Science and Technology Board (now known as A*Star, Agency for Science, Technology and Research). Confirmation of the firms' investment activities in the US was supported through a web search of the companies and supplemented by telephone calls to companies whose activities were not hosted in any website.

From company websites and telephone clarifications, we identified target populations for each of the three countries: 210 for Taiwan, 56 for

[19] Authors' interview with C-C Huang, 21 September 2004.

Singapore, and 113 for South Korea. All 383 firms were contacted and a total of 151 responses were collected resulting in response rates of respectively 35% (Taiwan), 44% (South Korea), and 48% (Singapore). Those who did not respond included individuals who refused to participate in the survey citing company policies, or, who were out of the country despite three or more attempts to contact them.

Our survey indicates important differences among the US subsidiaries of firms from these three Asian NIEs in terms of size and age. 95% of Taiwanese and 90% of Singaporean manufacturing firms tend to be small with worldwide sales of less than US$250 million. In contrast, South Korean firms tend to be large with more than half reporting worldwide sales of over US$250 million and at least a third over US$1 billion. These findings are generally consistent with the industrial profile of the three economies. Outward FDI in the case of South Korean firms tends to be undertaken by large conglomerates known as *chaebols* (Shin, 1998; Sachwald, 2001), while larger Singaporean companies typically reflect the activities of government-linked corporations than small private companies (Yeung, 2002). Inward FDI to the US is also fairly recent among both Taiwanese and Singaporean firms with 75% of them directly investing in the US only in the last 10 years. On the other hand, 78% of Korean firms have been in the US for more than 10 years. In terms of sectoral distribution, computers, electronics, telecommunication and information technology account for 85% of the total FDI from these Asian NIEs in the manufacturing sector of the US.

Table 1 reports the results of an analysis of covariance that controls for sectoral differences on the sources of knowledge that are important to the IAFs' technological upgrading. Firms were asked to rank on a Likert scale of 1 to 7 the importance of the various sources to their technological upgrading with 1 being very unimportant and 7 being very important. The mean score results and F-statistics indicate interesting differences among the three Asian NIEs. Taiwanese firms appear to rely on multiple sources of knowledge transfers involving material transfer (reverse engineering, industrial certification), design transfer (trade shows) and capacity transfer (local relationships with customers, strategic alliance). Firms from South Korea and Singapore, on the other hand, rely much less on explicit knowledge forms that are associated with material and design transfers, and much more on customers, and in the case of Singapore, on strategic partners and technical consultants as well. What is clearly common to all three Asian NIEs are the high means scores given to local relationships with customers in the US. This finding indicates that relocation of facilities, particularly R&D operations, to the US reflects a learning strategy that is becoming more relational or interaction-based. Interactions with customers are ranked equally highly at around 6 by firms from all three Asian NIEs and points to the rising significance of disembodied tacit technological knowledge in augmenting more explicit forms of knowledge acquisition. Indeed, South Korean and Singaporean firms did not rank codified knowledge forms highly as sources of technological upgrading.

[Table 1 here]

To evaluate the effect of the above technological sources and transfers on firms' technological capability in terms of knowledge and innovation rents, we perform an ordered probit regression that relates these sources to firms' introduction of new products since investing in the US. Ordered probit regression is used in this case because the dependent variable, new product introductions, is ordered from 1 to 7 in increasing scale of importance.[20] In

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[20] More specifically, an ordered probit regression may be expressed as: $y_i^* = x_i\boldsymbol{\beta}_i + \varepsilon_i$ where $\mathbf{x}_i$ is a vector of explanatory variables, $\boldsymbol{\beta}_i$ is a column vector of parameters to be estimated with the first element being the intercept, y_i^* is the latent variable and ε_i is the random error term which is assumed to follow a normal distribution. The ordered probit model is derived from a measurement model where the latent variable, which ranges from $-\infty$ to ∞, is mapped to an observable variable y such that the extreme interval categories $\varphi_0 = -\infty$ and $\varphi_j = \infty$.

addition to the sources of knowledge, three control variables were included, that is sector, age and firm size (worldwide sales) since earlier discussions suggest that the three Asian NIEs differ in these attributes. Table 2 reports the results. Technical/engineering consultants and industrial certification are found to be positive and marginally significant at the 10 percent level in firms' ability to introduce new products. Local relationships with customers emerge as the most positive and significant in contributing to firms' technological capability through new product introductions (p=0.000). Tables 1 and 2 thus collectively suggest that firms' local relationships with customers, typically users, are the most important source of knowledge transfer in the US because these relationships provide access to market information. Successful product development often flows from a detailed assessment of customer needs.

[Table 2 here]

While the importance of customers may be explained in part by firms' OEM and ODM relationships with their US clients, it also reflects a strategy of external technological leveraging and upgrading - a shift to the acquisition of knowledge that encourages the development of OBM. Transition to OBM, however, requires not only the accumulation of capability that is technologically or scientifically-oriented. Innovation of this sort typically requires an additional non-technological dimension that is related to marketing and distribution capabilities, a point that we will return to in a later section. One of the oldest electronics companies in Taiwan, Tatung, for example became successful as an OEM and ODM supplier to American TNCs. However, it found the transition to OBM much more difficult because of serious marketing and distribution challenges. Its vice-president suggested that "Tatung" was linguistically unappealing as a brand name, hence marketing the product would require that the company considers changing and repackaging its brand name to a more culturally acceptable term in the US. However, this would hurt its reputation in Asia because Tatung is a household name in Asia, particularly in Taiwan (Authors' Interview, June 2004).

3.3 External Leveraging Strategies

Effective technological learning requires absorptive capacity that contains two important elements: the existing knowledge base and the intensity of effort (Cohen and Levinthal, 1990; Kim, 1997). Accumulated and existing knowledge increases the ability to make sense of, assimilate, and use new knowledge. The intensity of effort acts upon the dynamic learning strategies of the firms and refers to the amount of energy expended by firm members in new knowledge formation (Teece et al., 1994). As noted in the previous section, knowledge and innovation rent is quite significantly related to the IAFs' relationships with technical consultants in the US. Here, we might differentiate between two major types of leveraging strategies in technological upgrading. The first strategy of technical consultancy and patent licensing agreement is characterized by a low level of social interactions and commitment. Technology transfer occurs mainly through the market mechanism. In this type of technology outsourcing, once the agreement is signed, it requires little communication between the participating sides and the interactions are maintained by routine administration. In most cases, patent-licensing is chosen by firms that have already engaged in the development of the technology and require the patent so that they can produce without fear of infringing the intellectual property rights of the patent holder. From the viewpoint of technology transfer, patent licensing by itself is not a useful strategy since most knowledge contained in the patent is codified and requires complementary channels, like personnel training, if the licensee is to assimilate the tacit part of a complete technology.

A higher level of social interactions tends to characterize the second strategy. Table 1 suggests that complementary technological assets that are acquired from strategic alliances are an important knowledge source for Taiwanese and Singaporean firms. Compared to other sources and channels of technology acquisition, some strategic partnership like joint development allows firms to stand on a more equal footing, since in most cases the parties to the agreement are involved under conditions of relatively similar levels of technological capability. Hence firms are better positioned to take advantage of the opportunities presented by collective learning. It is more effective than other, more market-transaction forms of technological acquisition (e.g. patent licensing), in allowing firms to exploit newly developed technologies because it encourages more intensive interaction between the members of participating firms. Knowledge embodied in personnel is critical for technology transfer in high-technology industries and the pooling of personnel in product development allows knowledge to be shared more directly. Joint development agreements allow firms to monitor the technological developments of competitors and appropriate tacit knowledge of new technologies. It is thus both a mechanism for absorption of information and knowledge and technological learning. To a large extent, collaborative alliances can be seen as "learning experiments" (Ciborra, 1992). As Robert Tsao, chairman of Taiwan's UMC (United Microelectronics Corporation) argued, "UMC collaborated with the semiconductor giants such as IBM and Infineon to develop new generation technologies in 2001. These joint development agreements with foreign companies provide us opportunities to observe what progress our competitors are making and, at the same time, keep track of new advances which we are incapable of developing on our own. Through our people, who work closely with our partners, we are able to obtain first-hand knowledge and then apply it to our own production."[21] It is common for semiconductor manufacturers and design houses to set up R&D labs in global technology hubs, particularly in Silicon Valley, to negotiate and engage in the development process with their partners (Mathews and Cho, 2000).

Equity purchasing is another channel of technology transfer, particularly for those IAFs with huge capital accumulated from their previous OEM business. This involves high social interactions and commitment to ensure that the operation is smooth. Acquisition is usually used to tap directly into the core competence, particularly the brand design and market, of the targeted firm by the investing firm (Teece, 1986).[22] However, it is one thing to acquire a stake in a firm, but quite another to transfer technology back to the parent company. Two conditions are at stake here. First, the success of the acquisition strategy hinges

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[21] Authors' interview with Rober Tsao, 25 November 2001.

[22] Bobo Wang, President of Microtek, commented on his company's participation in the acquisition of Mouse Systems: "This deal provides a good example of how local manufacturers can enter the international market by acquiring worthwhile foreign companies, technologies and sales channels. Our strategy is to produce, through acquisition, products which can rank Microtek among the top three in those specific fields worldwide, and thus guarantee competitiveness and profitability" (Quoted in Peng, 1990: 16).

on the absorptive capacity of the investing firms because of knowledge tacitness and asset specificity in the technology transfer process. Some firms can do this relatively proficiently because they are building on a good base of in-house capability and sophistication, as Mowery and Oxley (1995) have shown in the case of Japanese IC companies.

Second, articulating and mobilizing the core competence of the acquired firm is the goal of most acquisitions, but there is typically a conflict between the management styles of the two firms involved in the alliance. Further, acquisition potentially leads to the loss of key personnel of the acquired firm, resulting in the investing firm gaining nothing but the physical assets. Such cases are not uncommon when the investing firms are relatively late entrants to the technology frontier and the acquired firms are relatively well established. One well known example is Acer Computer's acquisition of Counterpoint Computers Inc. in November 1987, and Altos Computers System in 1990. Stan Shih, the founder and Chairman of Acer, recalled the experience of acquiring Counterpoint and Altos as the highest price Acer ever paid for globalization: "These two companies were sold to Acer at a premium. That is, besides the net value, Acer also paid for goodwill and other intangible assets. Not only did we incur extra expenses, we also suffered from serious 'indigestion' due to the overall merger approach. Employees of the acquired companies were unable to adapt to the new corporate culture on a timely basis, and the deteriorating market condition also made them lose confidence, and they gradually left the company. At the end, Acer not only lost money but also lost the people."[23]

What the above analysis suggests is that using strategic alliance for knowledge transfer is filled with challenges. However, this strategy tends to be pursued by smaller Singaporean and Taiwanese companies that are forced to pool resources because of their size. In the final section, we examine market and customer-oriented technological leveraging among the IAFs where the acquisition and deployment of innovation knowledge involves heavily non-technological forms, that is marketing and distribution.

3.4 Market-Oriented Technological Upgrading

Obtaining market information, developing distribution channels, and building brands among customers must complement the more technological dimensions of learning and upgrading for the IAFs that aim to become OBM (original brand manufacturers). Barriers faced by the IAFs in the global markets are increasingly related to customer and marketing failures. Lacking control over marketing channels has been a major weakness among the IAFs to compete in more advanced markets.

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[23] Authors' interview with Stan Shih, 16 June 2002.

Two case studies, SIN from Singapore[24] and Acer from Taiwan, illustrate this point.

SIN is a small IT firm that was founded by six Singaporeans. It originally built multi-function systems for small businesses or "Soho" (small office-home office systems). Small and home businesses typically cannot afford to purchase separate servers for its IT needs (e.g. print server, email server, file server, etc.) as it is rather costly. SIN's role is to provide low cost integrated systems that consolidate these servers for small businesses. US customers constitute almost all of the company's sales. However, with the purchase of its major US competitor Cobalt by SUN in the early 1990s, the Soho market declined as SUN's purchase virtually eliminated this market segment. This was complicated by the crash of dot.com in general in 2000. Since then, the company has realized that it has not been paying close attention to market trends and its relationship with its customers, and has embarked on an aggressive marketing of its products:

> [SIN] today is very US driven. Before the Singapore company was calling the shots. Today we let the US office lead us. We conduct constant debates through teleconferencing. We visit the customer frequently – there is a quarterly review from customers. The partners go to the US every quarter. Our software engineers go there to support the product. The US R&D team is a new addition. Previously, Singapore engineers were sent there for three months. They then returned to solve the problems of customers. This wasn't working … We want to build products that the market wants. We didn't see ourselves going into security systems before. The US market led us to security systems

[24] The Singaporean company is given a fictitious name to protect its anonymity. All information presented is based on authors' interviews in the US and Singapore.

(Authors' interview, December 2003).

Security system is a new product that has emerged out of the company's increased attention to customers' relationships and market needs. In this case, the company has begun building firewalls for their small business customers.

While SIN's case illustrates the IAFs' growing attention to the market and customers as a potential source of technological knowledge and capability, the transition to OBM is much more difficult. Taiwan's Acer has been pursuing its own brand name business since it was founded in 1976. At the beginning, it aggressively innovated by reverse engineering to catch market shares domestically and then internationally. To enter the US market, it engaged in acquisitions to gain access to local assets such as experienced engineers and distributive channels in the late 1980s, but failed nonetheless to make much headway. It tried to launch its Aspire computer in the US market again in 1995, but found it difficult to control local retail channels. As a result, the management soon found they had to keep a balance between OEM and OBM businesses, as the former had a faster cash turnover and low inventory cost, while the latter provided the company with value-added distribution (Shih, 1996).

The continuing efforts of internationalization began to bear fruit in the early 2000s. A new opportunity for transition to OBM arose in the European market in the late 1990s. Acer acquired the laptop department of Texas Instrument (TI) in 1996 to use its brand for the product "Travelmate". Following this, the management and engineering team of TI's notebook computer department in Europe was merged into Acer Europe. Meanwhile, HP merged with Compaq in September 2001 to become the No.1 PC company in the world, and pushed a business model of direct sale. As a result, several of HP's established distributors joined Acer's European operation team. In contrast to the US market where the dealers played a critical role in sales, the European market was mainly controlled by distributors. Thus, acquisition has allowed Acer to gain access to the relevant marketing channels and experiences in the European context. However, to avoid repeating the previous failure of acquisition that resulted from the loss of experienced people in the acquired companies, Acer managers spent considerable amount of time negotiating with TI's leader, Gianfranco Lanci, and his team. To build up mutual trust, managers from both sides communicated by telephone every week, by videoconference each month, and by meeting in person every quarter (Shih, 2004). Stan Shih of Acer convinced Lanci that the TI team could take thorough control of Acer's operation in Europe, and would get full logistic support from Acer's headquarter in Taiwan.

Through intensive communication and negotiation, the merged entity did not lead to the loss of personnel, but instead enhanced Acer's competitiveness by adding local knowledge in marketing. Acer became the number one laptop in

Europe, and Lanci was promoted to become the CEO at Acer's headquarter in 2004. This is the first time a major Taiwanese-founded company has promoted a non-Taiwanese marketing manager to the CEO position to handle the management and planning of a national champion.[25] As argued by Stan Shih, "By promoting Lanci, an Italian marketing manager, to be the CEO, Acer aimed to emphasize its continuing efforts in pursuing its OBM and go-global strategy. Acquiring a good team would help lots and save us huge tuition in learning the foreign market… But risk always existed in the A&M investments, and we had to move carefully step by step. We were small company, and could not keep people by money. Only through intensive negotiation and build up mutual trust, we could gain the cooperation from the targeted company and its running team. Gaining access to local knowledge through the channel of local marketing people is the short-cut to success in the new local market" (Shih, 2004).

To sum up, moving beyond low-cost manufacturing is vital for the IAFs, but current OEM/ODM practices are under constant pressure to shrink profit margins from more powerful PC buyers such as Dell and HP that usually play suppliers against each other to obtain the lowest price. An analysis by Merrill Lynch estimates that Taiwan ODM's gross profit margin for notebook PCs will slip to between 4% and

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[25] An interesting comparison is Sony's recent decision to promote the president of its US operation to Sony's CEO in March 2005.

7% in 2005, from just over 6%-9% in 2003 (Dean 2004). Under such circumstances, the OBM path is opted as a complementary strategy among firms to keep upgrading along global value chains. In contrast to the conventional practice where the IAFs' engineers mainly worked with foreign partners to configure components, the new strategy implies a more aggressive strategy in technological upgrading that increasingly focuses on marketing.

The transition from OEM/ODM to OBM strategies is not always smooth, as conflicts between the IAFs and their global buyers potentially lead to the loss of orders or even relationships with customers. For example, BenQ, formerly Acer Peripherals – a noted Taiwanese component supplier, began its own brand business after December 2001. In 2001, the Acer Group underwent another round of major reorganization that led to the founding of four independent companies. Acer Peripherals was successfully spun off into an independent brand-name electronics and lifestyle manufacturer, BenQ. But BenQ soon found its OEM contract with Motorola diluted because BenQ had promoted its own cellular phones. Despite this, Kun-Yao Lee, its chairman and CEO, vowed to develop BenQ to become Taiwan's answer to Sony and Philips (Authors' interview on 15 July 2004). The immediate challenge facing the IAFs' transition to OBM hinges on their abilities to target different products and market locations to avoid direct competition with their key buyers, and to search for a complementary way to coexist with the latter. The case of Acer's transition to OBM through the European market supports this point.

4. CONCLUSION

To develop firm-specific technology, a firm first needs to accumulate some basic technological know-how. East Asian firms attain this know-how capability initially by forging backward and forward linkages with the affiliates of foreign TNCs in Asia. The problem with relying on imported technology, however, is that the IAFs are unlikely to acquire more advanced forms of knowledge since the latter constitutes the principle ownership advantage of TNCs' operations abroad and they are notoriously tacit and difficult to be transferred beyond the firm's boundaires. Over time then, technological catch-up and narrowing involve firm strategies that enable the IAFs to acquire, build, and indigenize technologies through setting up R&D operations in technology rich environments such as the US. As we have empirically shown in this paper, such a direct presence allows the IAFs not only to imitate and internalize technologies from leading US competitors and rivals, but also to engage directly in knowledge transfers with sophisticated buyers. In doing so, these IAFs can accumulate new stocks of technological competencies and eventually transfer them back to their Asian headquarters for further development into specific products.

As the IAFs increasingly use external relationships to acquire new knowledge, they need to develop the capability for acquiring know-how and know-why through external sources. The IAFs' technology sourcing in the US is associated with market-based product innovations where the market constitutes the most important source of learning for product development. Therefore, Asian firms have invested directly in their US facilities to source for the latest market knowledge. In addition, product innovations in the IAFs are not nearly as radical as their industrialized counterparts. Most of the innovations involve the improvement of existing products they supply as OEM and ODM subcontractors to their customers. This process is supplemented by new ideas leveraged from core and sophisticated markets such as the US. As the IAFs move further from ODM to OBM, they will need more external knowledge about markets and customers. In so doing, the IAFs move backward from mature stages of the product life cycle to early stages of product innovations, thereby chartering a reversed path of the product life cycle (Hobday, 1995; Kim, 1997). This finding tends to contradict the standard product life cycle hypothesis.

We found an interesting variety of technological leveraging methods that involve different degrees of social interaction with the IAFs' external environment. Effective technology transfer involves the movement of personnel, and, the establishment of marketing channels, and close customer relationships in the US because such knowledge is often tacit and embodied. These strategies are complemented by other knowledge sources including technical consultants and strategic alliances with companies in the US. Together, these strategies may well enable the IAFs to move from OEM to ODM and OBM in the global division of labor. On the other hand, it also impinges on the IAFs to invest in in-house R&D that help realize absorptive capabilities, even though this might have the effect of direct competition with their buyers. Nonetheless, actively searching for complementary technology and knowledge in more sophisticated markets such as the US should move the IAFs away from their hitherto heavy reliance on subcontracting relationships as the major source of technological growth in favor of more independent and indigenous technological accumulation – an emerging pathway of firm-specific development that mirrors very much the national R&D policy of many East Asian newly industrialized economies.

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FIGURE 1. The Relationship of Global Brand Name Manufacturers and OEM Producers in Taiwan

Brand Name Manufacturers / Products	Intel	Dell	IBM	Motorola	HPQ	Apple	NEC	Gateway
IC	TSMC ASE OSE		TSMC	TSMC UMC ASE	Macronix			
PCB	Compeq Advtek WUS	Compeq GCE Unimicron	Compeq GCE Advtek Vertex Precision	WUS Unitech Yeti Electronic Unimicron Qualitek	Compeq TPWC GCE Advtek Vertex Precision	WUS		
Desktop			Acer		FIC Tatung Mitac			
Laptop		Wistron Quanta Compal	Wistron Quanta		Compal Quanta Arima Inventec	Quanta Compal ESC	FIC Quanta	Quanta
Monitor		Liteon BENQ	Advtek Tatung BENQ		Tatung	ADi		MAG
Power Supply	DELTA	DELTA Liteon	DELTA Liteon	Liteon	DELTA		Liteon	
Case		Foxconn	Foxconn		Foxconn ENlight			
Power Connector	Foxconn	Foxconn	Foxconn		Foxconn	Foxconn		
Main Board			Gigabyte MSI USI			USI	ECS Gigabyte MSI	MSI
Server			Quanta		ASUS			
Ethernet Card	Accton D-LINK							
Keyboard		Silitek (Liteon Group) Chicony	Chicony		Silitek (Liteon) Chicony	Silitek (Liteon) Chicony		
Scanner					Avision UMAX			

Source: *Wealth Magazine* No. 264, pp. 23-25, March 2004; and authors' interviews.

FIGURE 2. The Combination of Production and Value Chains of OEM, ODM, and OBM

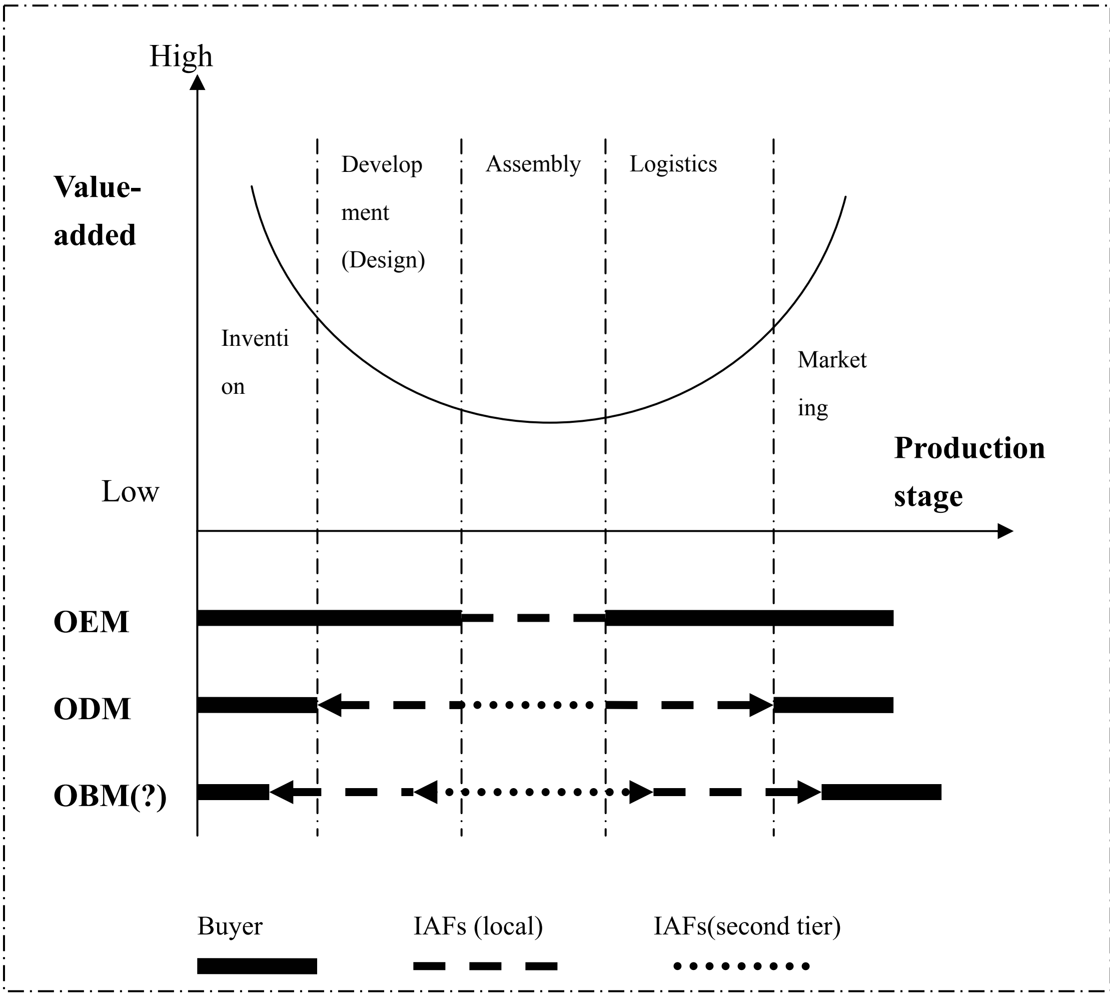

TABLE 1. Analysis of Covariance Among Different Sources of Learning in Technological Upgrading and Knowledge Acquisition in the US

Sources	Korea (mean)	Singapore (mean)	Taiwan (mean)	F-statistics (p-value)
Technical consultants	1.9	4.4	3.6	15.49 (0.000)***
Industry trade shows	3.7	3.5	4.6	3.23 (0.042) **
Blueprints/publications	3.0	3.3	3.7	1.27 (0.283)
Reverse engineering	3.4	3.3	4.4	3.79 (0.025) **
Industrial certification	2.2	3.7	4.5	14.54 (0.000) ***
Strategic alliance	2.5	5.2	4.3	15.92 (0.000) ***
Local relationships with customers	5.5	6.2	6.0	1.54 (0.218)
Seminars/training	3.8	4.2	3.7	0.51(0.600)

***, ** Significant at 1 and 5 percents respectively

TABLE 2. Ordered Probit Regression Analysis of The Effect of Knowledge Sources on New Product Introductions

Variable	Parameter estimate (p-value)
Sector	-0.008 (0.659)
Age	0.039 (0.693)
Size	0.0005 (0.334)
Technical consultants	0.096 (0.090) *
Industry trade shows	0.016 (0.778)
Blueprints/publications	-0.037 (0.565)
Reverse engineering	0.005 ((0.929)
Industrial certification	0.095 (0073) *
Strategic alliance	-0.043 (0.424)
Local relationships with customers	0.225 (.000)***
Seminars/training	0.832 (0.192)
α_2	-0.627 (0.222)
α_3	-1.135(0.027)
α_4	-1.351 (0.009)
α_5	-1.873 (0.004)
α_6	-2.609 (0.000)
α_7	-3.275 (0.000)
Likelihood ratio	36.64 (0.000) ***

*** , * denote 1 and 10 percents significance respectively.