Essays on Volatility and the Division of Innovative Labor

by

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Submitted to the Sloan School of Management
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Abstract

Economic liberalization has brought a widespread belief that strengthening supply-side institutions is not only a necessary condition but also a sufficient one for economic and technological development. Yet uneven growth in advanced economies and a tenacious 'middle-income' trap tests this view. This dissertation, composed of three essays, examines persistent challenges to social, technological and economic development. A key aspect of my approach is to understand whether states can control the environment in which local firms make decisions. In particular, I argue scholars have exhibited a significant bias towards the supply side of markets as sources of innovation and growth. I exploit this bias by examining cases in which the characteristics of global demand markets significantly shape firm strategies.

The first essay, based on a five-year dataset of Hewlett-Packard's social audits along with extensive fieldwork in their global supply chain, identifies demand volatility as a significant cause of persistent labor standards violations in the global electronics industry, in contrast to the conventional wisdom. The second essay uses a critical case study of the Penang semiconductor cluster to examine the challenges late industrializers face when confronted with stalled technological upgrading in a world of horizontal production networks. In common with efforts to improve labor standards, the real obstacle to technological upgrading is demand volatility. I argue the case of Penang shows that it is volatility, not the search for low wages, which increasingly determines the international division of labor in emerging economies. The third essay uses a unique dataset of production firms founded with MIT-licensed technology to examine whether the U.S. captures the long-term benefits of its investments in technological innovation. Through interviews with senior managers and founders, it finds that the U.S. ecosystem provides fertile ground to start firms; yet when these firms need to take the significant leap into larger-scaled processes, both the need for additional capital as well as the search for production capabilities pulls many firms to move critical knowledge abroad. The three essays demonstrate that demand increasingly shapes global production and innovation architectures, not the opposite as is widely assumed.

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A great part of the fun of MIT is its rich commitment to multi-disciplinary work. This requires the faculty to be open, not only theoretically but also practically, to scholars from other traditions. I doubt there are many places like MIT in this regard and I have had the great fortune to benefit from so many of these open-minded folks. Ezra Zuckerman Sivan early on identified with my views on volatility, pushing me to develop them into more coherent papers and in the process, strengthening my conviction that I was onto something. Liz Reynolds, who I had the good fortune to meet during the PIE project, not only invited me to join the scale-up team but also willingly shared her extensive knowledge of clusters and economic development thus allowing me to extend my research beyond its original domain in labor markets. Richard Lester and Charlie Sodini brought their considerable talents to the problems of scaling up, enlarging my understanding of industry dynamics enormously. Don Lessard and Fiona Murray encouraged my interests in global strategy, innovation and entrepreneurship, sharing their extensive knowledge whenever asked. And like Rick, none of this would have been possible without the help of Ed Roberts and John Van Maanen, who willingly supported not only my admission but my continuing progress.

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I've learned from an earlier life that the staff is the heart and soul of any institution. MIT is no exception and I have been blessed to have the active encouragement and support of so many. They helped me navigate the tortuous road through not only the administrative, but also the personal(ities). They are an invaluable resource and welcome friends. Sharon Cayley and Hilary Ross helped me in so many ways through the PhD process, Anita Kafka was the sage of PIE (and much more), Janine Claysmith, Kate Searle and Katy Bertman ensured that my committee members were up to speed, and finally the E62 3rd and 4^{th} floor crew, Adele Donegan, Annie Weiss, Lisa Miyake, Alexis Ertzner, Petra Ailberti, Michelle Fiorenza and Pam Liu were helpful in every possible regard.

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Finally, undertaking a PhD program, particularly at my young age requires a number of sacrifices, not the least the loss of so much personal and family time. My wife Brigid has borne the brunt of this. Nevertheless, she has been my most tireless supporter, listening to all my complaints and failings, (mostly) gently pushing me forward. Our children, Noah, Evan and Anna have done the same even while wondering why I was missing yet another event. Most importantly, Brigid and they have kept me laughing throughout. To them, I dedicate this work.

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1. Introduction

As economic liberalization continues and global markets become increasingly dynamic, scholars and policymakers struggle to identify policies that will enable durable economic and social development. In addition to economic policy interventions, states have placed significant emphasis on industrial policy—whether stated as such or not. Within this domain, strengthening supply-side institutions is widely viewed not only as a necessary condition but a sufficient one for economic growth.[1] Emerging economies pour resources into improving human capital, subsidizing FDI and actively building complementary assets to attract advanced technology firms (Chesbrough, Birkinshaw, and Teubal 2006; Hobday 1995) Advanced economies, especially those at the technological frontier, focus on similar human capital policies while subsidizing investments for further research and development. Given the right macroeconomic setting, scholars believe in both cases economic development should follow.

Nonetheless the recent uneven growth in advanced economies coupled with the inability of most middle-income states to develop into advanced economies raises questions about this direction. At first, these questions centered on what additional resources were necessary and to where should they be directed (Giuliani, Pietrobelli, and Rabellotti 2005; Hobday and Rush 2007; Saliola and Zanfei 2009). Later after recognizing these additional interventions have yielded lower than expected results, policymakers, with the encouragement of scholars, have redoubled their investments and efforts into the same policies. Yet growth is still a challenge. Why?

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[1] See Gill and Kharas (2007) for an excellent review of state supply-side intervention.

This dissertation, composed of three essays, seeks to help answer this question by exploring persistent challenges to social, technological and economic development. In particular, why after numerous state efforts to incent and otherwise encourage firms to grow through local policy interventions, do firms follow a different path than the state intended? And why does this path, which by itself may not seem surprising, result from rational strategic actions by firms that are distinct from those predicted by both scholars and policymakers? Exploring the paths firms take is important because it illuminates the process by which firm strategies and state policy shape the global division of labor. Only by understanding the determinants of firm strategies can present outcomes be changed.

Rather than solely conducting micro-level analysis that seeks to explain firm-level heterogeneity or examining how state policy impacts local sectors (where often firm performance is aggregated), my research approach combines these levels of analysis, examining the relationship between the two over time. In doing so, I move beyond the tendency for scholarly research to be conducted at just one level of analysis, assuming that the other levels are not only homogeneous but independent of each other (Di Stefano, Gambardella, and Verona 2012). First, I seek to understand the meso-level--whether and how state policy shapes the external environment firms operate in and second I explore the micro-level--how firms develop strategies to manage this environment. Finally, I suggest how these firm-level strategies might impact macro-level anticipated growth outcomes.

A key aspect of my approach is to understand whether states can control the environment in which local firms make decisions. In particular, as will be shown in all three essays, I argue scholars (as well as policymakers) have exhibited a significant bias towards the supply side of markets as sources of innovation and growth. However, the broad financialization of the global economy resulting from market liberalization has significantly impacted how firms (and the corresponding division of labor) are organized—for example through the shift to a managerial focus on core competency (Fligstein and Shin 2007), the fragmentation of production (Sturgeon 2002) or the rapid consolidation of retail merchants (Feenstra and Hamilton 2006). Such shifts in firm organization coupled with the obligatory regulatory loosening brought on by liberalization have substantially changed the nature of market demand.

I exploit this bias by bringing the demand side of markets into my research, whether this is upstream activity in global production networks, product uncertainty in technologically dynamic industries or the varying nature and origin of demand-pull activity for high technology sectors. To gain analytical traction, I analyze cases in which the characteristics of global demand markets significantly shape firm strategies. I investigate these cases first, by considering how industrial policy interventions affect the demand and supply side of national innovation and labor markets and second, by analyzing the strategies of entrepreneurial firms in response to these interventions.

Like many graduate students, the questions I examine have evolved over time. Opening one door leads to another …until the larger agenda presents itself. My interest in labor standards has been serendipitous because there is no better window into work organization and firm performance than studying what takes place at the establishment level. The phenomena I discovered through my work on labor issues—demand volatility and market uncertainty—became the core of my dissertation work. It unambiguously illuminated how the proverbial light under the lamppost has often blinded scholars into believing the source of all problems must be where the problems are found. It suggests that in a world with an increasingly liberal market orientation, scholars need to understand that states can no longer control all aspects of their external environment, in particular the shape of market demand, and that policies will need to adjust to incorporate this shift. Demand increasingly shapes global production architectures, not vice versa as was widely assumed; supply side (industrial) policy will require demand complements in the future to succeed.

My dissertation essays follow this research evolution. Each of the three essays addresses a persistent challenge to one aspect of development. In order, these are social development (labor standards), technological development (upgrading) and economic development (scaling firms with novel technology). The first dissertation essay, *Looking in the Wrong Places: Labor Standards and Upstream Business Practices in the Global Electronics Industry*, joint with Richard M. Locke, examines labor standards in the electronics industry's global supply chain. Studying the process by which firms address labor standards offers 'on the ground' perspective on managerial preferences and practices. In particular, we were able to gain access to both a unique social audit dataset and the extensive supply chain of one of the world's largest and best known IT firms—Hewlett Packard (HP). HP's financial strength and legacy of commitment to community—embodied by the HP Way—allowed us to structure the research as a most-likely case.

On the basis of field research in HP's Southeast Asian supply chain, a five-year dataset of social audits conducted by Hewlett-Packard's auditors, and an analysis of the industry's market segmentation, we find that significant labor standards problems persist in an industry where scholars might have predicted far more change, given the actors' scale, resources and commitment. This persistence is driven not only by behavior at the site of production, but also by practices the industry utilizes to manage the volatile demand resulting from the structure of upstream consumption markets. The findings have implications not only for labor scholars and policy makers, but for the firms themselves as evidenced by the substantial press dedicated to Apple's continuing labor challenges. Additionally, the labor market policies highlighted in the paper point to how policies designed for earlier periods of rapid labor absorption build local managerial expertise and practices that enable a different set of opportunities than those intended when states shift policies towards technological development.

My second essay, *Upgrading under Volatility in a Global Economy*, explores this last issue in much greater detail. It uses a critical case study of the Penang semiconductor cluster to examine the challenges late industrializers face when confronted with stalled technological upgrading in a world of horizontal production networks. The liberal market orientation of Malaysia, the state's active role in building supply-side institutions and the forty-year legacy of frontier technology MNCs in Penang creates an excellent research setting that allows me to control for many of the existing explanations for lack of technological upgrading. The paper proposes an alternative set of hypotheses about upgrading in emerging economies. In common with efforts to improve labor standards, the real obstacle to technological upgrading is demand volatility. The problem is not necessarily lack of capabilities; rather there are plenty of firms with high capabilities. Contrary to conventional wisdom, many firms do not compete away profits or solely rely on cheap labor. These firms—the prime set of candidates to upgrade due to their long tenure, exposure to the technology frontier and large resource base--have succeeded by excelling in fast response to shifts in demand. Under the present technology-push policy regime, they have no incentive to do otherwise.

Counterfactually, the local entrepreneurial firms that upgrade take a different route, avoiding volatile markets altogether. Rather than depending on technology transfer from frontier-technology MNCs, entrepreneurs define and develop advanced products through iterating with local back-end wafer processing firms to optimize assembly. The assemblers' constant demand for flexible equipment to absorb volatility creates a 'protected space' for these technology entrepreneurs to iterate their products. On the other hand, because volatility has evolved into the primary demand characteristic of an industry with strong network effects, rapid product proliferation and increasing brand concentration, the larger, longer-tenured firms—the natural candidates for upgrading--opt to strategically leverage local resources to manage it rather than upgrade technologically despite the robust state policies (resources) that encourage such activities.

The case of Penang shows that it is volatility, not the search for low wages, which increasingly determines the international division of labor in emerging economies. The paper has implications for the political economy of development literature, which has previously treated the demand side of markets as homogenous. It also brings empirical support to the possibility that the long-held Marchian view of strategy scholars that firms must explore new opportunities under conditions of environmental turbulence (March 1991; Posen and Levinthal 2012) might be wrong.

My third essay, *Learning by Building: Complementary Assets and the Migration of Capabilities in U.S. Innovative Firms*, joint with Elizabeth Reynolds and Joyce

Lawrence,[2] extends my enquiry into how differing levels of institutional support for technology supply and demand impacts economic development—in this case the ability of an advanced industrialized nation (U.S.) to capture the long term benefits of its investments in technological innovation. The paper uses a unique dataset of production-related firms that were founded with technology licensed from the Massachusetts Institute of Technology (MIT). Through interviews with senior mangers and founders, it identifies the pathways firms take in scaling complex products and processes. Because these firms' innovations are often at the technological frontier, they generally need highly complex, advanced manufacturing capabilities that require more time and capital to scale than non-production firms. In this way, they provide an important test of the U.S. innovation ecosystem and its ability to support such firms.

We find that the U.S. provides fertile ground as they prepare to enter the commercialization environment, iterating prototypes, developing pilot production facilities, and in some cases entering into commercial production. However, when these firms need to take the significant leap into larger-scaled processes, both the need for additional capital as well as the search for production capabilities pulls many firms to move production abroad. This movement, which often entails the temporary relocation of key personnel with tacit knowledge, leads to the migration of key skills, capability generation and knowledge development outside of the country. We argue the migration of these capabilities has two consequences: one, expected returns to public investment in innovation are not fully realized and two, the movement offshore of vital capabilities may put at risk the U.S.'s future capacity to innovate.

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[2] This research was conducted as part of MIT's Production in the Innovation Economy project.

The findings suggest that in sectors where market uncertainty is reduced through regulatory or state policy (defense, biotech), these partners are often firms from advanced industrialized economies. In industries without these mechanisms, where firms must manage both technological and market uncertainty (energy, advanced materials, semiconductors), the partners are increasingly firms from emerging economies that are willing to generate demand to reach scale production. In both pathways, the innovative firms iterate with their production partners to learn how to scale production. This process generates new, often-unique capabilities consistent with the novelty of the technology. However, in the first instance these capabilities reside locally, while in the second they migrate overseas.

The dissertation continues with the three essays, each with its own references, tables and figures and concludes with a discussion of why demand matters.

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Sturgeon, Timothy. 2002. "Modular production networks: a new American model of industrial organization." *Industrial and Corporate Change* 11(3): 451–496.

2. Looking in The Wrong Places?: Labor Standards and Upstream Business Practices in the Global Electronics Industry[3]

This essay examines why despite decades of debate and efforts to improve global labor standards, multiple problems still persist. Whether arguing for a more active role for the state, persuading firms to adopt codes of conduct, improving monitoring and sanctioning processes or seeking a higher degree of commitment between supply chain actors, scholars still lack an adequate explanation for why labor problems do not show improvement. Existing theories, while they will help, are not sufficient to solve this issue because they are focused on the production side of markets—the result both of an intellectual and policy bias towards production and the tendency to look for solutions where problems occur. Using a case study of Hewlett-Packard's (HP) supply chain, qualitative and quantitative data from field visits to plants in South East Asia and a unique dataset of HP's code of conduct audits, we demonstrate that even under the most-likely conditions that favor previous theories of labor standards, code of conduct violations, in particular excess working hours, exhibit widespread persistence. Having

[3] This paper was co-authored with Richard M. Locke. We wish to thank Mathew Amengual, Suzanne Berger, Rose Batt, Josh Cohen, Thomas Kochan, Margaret Levi, Gary Herrigel, Edward Steinfeld, Kathleen Thelen, Ben Ross Schneider, Jen Hainmueller, Greg Distelhorst, Ben Rissing, and Timea Pal for their comments on previous drafts of this paper. We also wish to thank participants at various workshops and seminars where we presented earlier drafts of this paper, including the MIT Institute for Work and Employment Research seminar, the MIT Political Science Comparative Politics Workshop, the Annual Meeting of the American Political Science Association, and the Annual Meeting of the Society for the Advancement of Socio-Economics (SASE).

explained this, we demonstrate that this persistence is the product of a set of policies and practices designed and implemented *upstream* by global buyers and their lead suppliers

2.1 Introduction

Notwithstanding years of debate and controversy, and numerous interventions by national regulatory authorities, global brands, lead suppliers, and transnational non-governmental organizations to improve labor standards in factories producing for global supply chains, poor working conditions, low ages, excessive work hours, and precarious employment practices, persist. Scholars have argued that this persistence is due to either inadequate government regulation or ineffective private compliance systems. As a result, they argue for either the revitalization of state regulatory agencies and enforcement capacities (Piore and Schrank 2008; Seidman 2007) or for improved private monitoring and capability-building initiatives aimed at coaxing firms to solve their labor problems (Locke, Amengual, and Mangla 2009; O'Rourke 2003; Weil 2004).

This paper argues that although more effective regulation and better designed private compliance systems would certainly help enforce labor standards in these global supply chains, they are not in and of themselves sufficient to tackle these persistent workplace issues. This is because all of these proposed interventions – be they more stringent enforcement of national labor laws or better-designed private compliance programs – focus solely (or primarily) on the locus of production, on the factories producing for global buyers. Although this focus on the workplace ostensibly makes sense, given that this is where most labor standards violations are manifest, the reality is that many of the workplace problems we observe in global supply chains are, in fact, the product of a set of policies and practices designed and implemented *upstream* by global buyers and their lead suppliers. In other words, in a business environment characterized by dynamic consumer demand, shorter product life cycles, and concentrated retail channels, global brands have reorganized their supply chains in order to optimize efficiencies and minimize financial and reputational risks. Timely delivery of the latest products to the market is essential for global brands competing in these dynamic markets. Labor costs, although important, are often a second order consideration (Jack and Raturi 2002; Minnich and Maier 2007). As a result, global brands and their lead suppliers have developed production planning and manufacturing systems that minimize the risks (both financial and reputational) of not meeting consumer demand in a timely manner.

Although these techniques allow for a broader selection of products, faster product introductions, and reduced inventory of poor-selling products for brands, they create all sorts of labor problems *downstream* for factories and their workers. The production architecture necessary to operate this more "lean" system exhibits very high volatility at the point where products are assembled. As a result, order volatility is met through a Taylorist work organization, where products are assembled by hand, enabling the rapid scaling up and down of production. Such a system requires a very flexible labor supply, often in the form of migrant workers who work long hours at low wages -- a situation that ultimately leads to persistent labor standards violations.

The findings presented in this article have implications for our understanding of how best to address labor standards issues, especially in industries with short product life cycles and volatile consumer demand (i.e., many consumer goods industries). Yet to date there has been very little attention paid to the "upstream" sources of poor working conditions in these global supply chains.[4] This is due primarily to the way most labor scholars study and understand these issues. On the one hand, we focus on the workplaces and factories because this is, in fact, where workers are employed and where we observe the vast majority of the violations in labor standards and worker rights. On the other hand, we "look under the lamppost" because of our own intellectual traditions and biases towards production (where people make things) as opposed to how these products are sold and consumed. Yet shifting patterns of consumption are provoking significant changes in supply chain governance, manufacturing practice, and ultimately, employment conditions for the thousands of workers who make the goods each of us consume every day. Although some scholars have explored the impact of ethical consumption and various certification schemes on consumer behavior (Hainmueller, Hiscox, and Sequeira 2011; Hiscox and Smyth 2006; Renard 2005), and others have analyzed the politics underlying consumer credit and consumer protection in various advanced industrial nations (Trumbull 2011, 2006), there has been very little systematic examination of how the practices firms develop to respond to dynamic consumer markets can impact work organization and working conditions downstream in the factories making their products[5]. This is the focus of this article.

2.2 Data and Methods

[4] Although the scholarly literature has for the most part ignored the impact of upstream business practices on downstream labor conditions, two NGOs -- Oxfam International and the Clean Clothes Campaign -- have in fact focused on this relationship. See Clean Clothes Campaign 2008; Daanarajan 2005; and Raworth and Kidder 2009) for more on this work.

[5] One exception is the pioneering work of Piore and Sabel (1984), which examined how fragmented demand in the advanced economies was shifting manufacturing practices away from mass production and towards flexible specialization.

This article draws upon a unique dataset of supplier audits that Hewlett Packard (HP) selectively administered to its network of global suppliers. HP shared over five hundred original reports from audits conducted between June 2004 and January 2009 with us. This sample describes 276 unique facilities, 137 of which received multiple audits. These audits assessed supplier compliance with the HP and the Electronics Industry Code of Conduct (EICC), and were conducted by HP employees explicitly trained to evaluate suppliers' compliance with the EICC. Audits were performed onsite at supplier facilities and a subsection of audit reports were verified by an external organization to ensure the accuracy of assessments and to enable improvements. As seen in Table 1, of the 276 facilities in our dataset, only seven complied fully with all requirements included in the HP code of conduct at the time of their last audit. In addition, HP has initiated a separate pilot program on working hour violations with thirteen plants in China and has provided monthly details from January 2008 to November 2009.

------------Insert Table 1 here---------------

This quantitative analysis was complemented by qualitative field research in several countries (China, Mexico, Czech Republic, Hungary, Thailand, Malaysia and Singapore).[6] For this article, we visited seven HP first-tier facilities in Malaysia, Singapore and Thailand in June 2009, conducting 27 interviews with plant managers, HR managers, production managers, supplier's CSR managers, regional HP SER auditors, corporate officers and labor NGO representatives. All plant interviews were conducted in

[6] The results of the quantitative analyses are presented in a companion paper. See Richard M. Locke, Gregory Distelhorst, Timea Pal, and Hiram Samel, "Production Goes Global, Standards Stay Local: Private Regulation in the Global Electronics Industry".

the absence of HP personnel and lasted between one and three hours. Some plant visits also yielded detailed quantitative data on production, employment, and purchasing practices. Facilities were selected for variation on audit outcomes and work performed as well as the institutional setting of the plant's location.[7] Table 2 describes the characteristics of the seven plants studied for this article. Finally, we draw on published papers by members of HP's production planning group.

--------------Insert Table 2 here-------------------

2.3 Improving Labor Standards in Global Supply Chains: A Review of the Literature

The current era of globalization is characterized by fragmented ownership and geographic dispersion of production. This economic transformation poses a new set of opportunities and challenges for emerging economies. Involvement in global supply chains may bring new work opportunities, technological spillover, or higher wages to local firms and their workers. Yet integration into global production networks can also create a series of labor issues (e.g., poor working conditions, excessive working hours, etc.) at these workplaces. Given the competitive pressures, power asymmetries between buyers and suppliers (Gereffi, Humphrey & Sturgeon 2005), and a worldwide decline in workplace legal protections (Standing 2007) it is unsurprising that multiple sources have documented harsh working conditions and negative environmental impacts across a

[7] In this paper, given that we only had one month of data for 2009 and we were examining compliance with a specific issue over annual periods, we dropped the January 2009 data. Thus the sample for this paper contains 271 initial audits that were comprehensive; follow-on audits periodically would not examine areas previously found to be in compliance resulting in total audit count of between 477 and 494 audits depending on category.

variety of global industries (Connor & Dent 2006; Verite 2004; GoodElectronics 2009; Pruett 2005; SwedWatch, SACOM & SOMO 2008; makeITfair 2009; Bormann & Plank 2010). While many developing countries appear to possess strong regulations on their books, in practice these states often lack the ability (Laffont & Tirole 1993; Baccaro 2001; Elliott & Freeman 2003; Estache & Wren-Lewis 2009) or willingness (Bhagwati 1995) to enforce their own laws.

In recent years, a lively debate has developed over whether or not, and under which conditions, labor and environmental standards can be enforced in an era of globalized production. Some argue that workplace conditions and environmental practices can be improved only through strong national legislation and state enforcement of these laws (Weil 1996; Reich 2007; Piore 2005; Schrank 2009). Others see potential for consumer pressure to incentivize suppliers to compete for the best combination of ethical practice and price (Fung, O'Rourke & Sabel 2001; Moran 2002). Indeed, lead firms across many industries have developed private regulatory systems that set standards—often called "codes of conduct"—and monitor their supply chains for compliance. One stream of research in international political economy focuses on *how* developing countries engage with global production, arguing that foreign direct investment raises labor standards while subcontracting relationships—such as those we examine in this study—depress them (Mosley & Uno 2007; Mosley 2011).

Formative work on private regulation has examined codes of conduct within athletic footwear (Strasser & Becklund 1993; Rosenzweig 1994; Korzeniewicz 1994; Barrientos & Smith 2007; Locke, Qin & Brause 2007), apparel (Elliott & Freeman 2003; Esbenshade 2004; Bartley 1996; Weil 2005; Rodriguez-Garavito 2005; Barrientos &

Smith 2007; Locke, Amengual & Mangla 2009), and agriculture (Barrientos & Smith 2007; Riisgaard 2009). These studies of low-technology industries have observed generally poor compliance with international labor and environmental standards and modest-to-no improvement as a result of private regulatory efforts. Recent scholarly inquiry has suggested that rather than voluntary private regulation functioning effectively in isolation, a mixture of systems involving public and private actors is key (Amengual 2010; Weil 2005; Locke, Kochan, Romis & Qin 2007; Locke Qin & Brause 2007; Utting 2005; Pessoa 2006; Haufler 2001; Kolben 2007). In fact, it appears as if private compliance efforts are often "layered" upon more traditional forms of state regulation (Bartley 2011; Trubeck and Trubeck 2007) and that under certain circumstances, these two forms of regulation can either complement or undermine one another.

In this article, we focus on the global electronics industry, a setting where one might expect higher degrees of compliance with labor standards and hence, improved working conditions. The suppliers operating in this industry are for the most part themselves large multinational corporations, in some cases producing components that command high price premiums. Their sophistication and market position may create new dynamics of interaction with global buyers (Gereffi, Humphrey, and Sturgeon 2005). Furthermore, whereas nearly all lead firms in previous studies adopted supplier codes of conduct in response to consumer pressure or public scandal, HP anticipated these pressures and moved early to develop internal and industry-wide strategies for monitoring and improving conditions in the supply chain. The company also promoted various "capability building" programs, an approach that some have argued is more effective at promoting improved working conditions than more traditional compliance practices

(Locke, Amengual, and Mangla 2009). And yet notwithstanding all of these efforts, workplace problems and poor labor standards persist.

This article argues that although more effective regulation and better-designed private compliance systems would certainly help improve labor standards in these global supply chains, they are not in and of themselves sufficient to tackle these persistent workplace issues. This is because they target production facilities and workplace practices on the shop floor (where various labor issues are manifest) rather than the source (or root cause) of these same problems, which are often located in the upstream business practices of global buyers and suppliers. In what follows we will illustrate the impact of these upstream business practices on poor working conditions in various electronics plants and suggest an alternative, complementary approach to addressing them.

2.4 The Global Electronics Industry

The global electronics industry[8] is one of the largest and fastest growing manufacturing sectors, characterized by disaggregated production networks involving numerous suppliers located throughout the globe. In the late 1980s, leading electronics firms transitioned away from vertically integrated production structures to a new model of outsourced manufacturing, opting to concentrate almost exclusively on discrete competencies that rarely involve production. The vast majority of leading U.S.

[8] We use the term 'electronics industry' to describe the population of firms that actively produce or manage the production of computer hardware. These firms directly manufacture or coordinate the assembly of computers, computer peripherals, communications equipment, and similar electronic products. While these hardware firms may engage in other diversified technology services, a core aspect of their business focuses on the production of physical computer hardware. Lead firms in this industry almost always classify themselves within North American Industry Classification System (NAICS) codes for "Electronic Computer Manufacturing" (334111) and "Other Computer Peripheral Manufacturing" (334119). These lead firms and their interactions with suppliers are the focus of this research.

electronics firms, including IBM, Nortel, Apple, 3Com, Hewlett Packard, Maxtor and Lucent, followed this trend during these years (Gereffi, Humphrey, and Sturgeon 2005; Sturgeon 2002; Sturgeon and Lester 2002) . These firms typically sold off their manufacturing and production facilities to leading contract manufactures. This in turn resulted in the rapid growth of contract manufacturers in the industry, although much of this growth has been concentrated among a small number of companies – Flextronics, Celestica, Sanmina, Jabil, and Hon Hai (Foxconn) -- that control much of the market share in the industry. By 2000, leading contract manufacturers had plants in as many as 70 countries with the bulk of manufacturing activities occurring in two or three regions in the developing world (Ernst 2004; Lüthje 2002).

The global electronics industry today is highly concentrated with a bifurcated structure involving a small number of international buyers and suppliers that control much of the market (Sturgeon and Lester 2002). Table 3 presents financial and employment data for the leading electronics and contract-manufacturing firms. Corporations producing branded hardware largely control the industry's product definition, design, and innovation trajectories and thus continue to capture value associated with high-end markets and new technologies (Sturgeon 2002). There is, however, some evidence that this dynamic may be changing. Table 3 indicates that electronics contract manufacturers such as Foxconn and Flextronics rival electronics lead firms like Apple or Dell in terms of revenue and employment. Moreover, several large and internationally diverse contract manufacturers, such as ACER (2009 revenue of \$17.9B with 6,727 employees) have recently begun to establish their own computer hardware brands. Notwithstanding these recent developments, much of the profit continues to be captured by branded lead firms rather than the contract manufacturers responsible for production activities. While the collective net income of the five electronics lead firms present in Table 3 totaled $37.8 billion in 2009, the industry's top five contract manufacturers collectively lost $4.4 billion in the same period.

-------------Insert Table 3 here----------------

Fluctuating market demand and shorter product life cycles have produced a volatile manufacturing environment within the electronics sector (for a detailed review of risk factors specific to the electronics industry see Sodhi and Lee 2007). Advances in technology have led to the rapid obsolescence of consumer electronics (Byster and Smith 2006). According to one executive at Dell Computers, "Inventory has the shelf life of lettuce" (CAFOD 2004).

In response to variable demand and intense cost pressures, contract manufactures have adopted flexible employment policies. These work relationships are characterized by long work hours, precarious or temporary work, and high concentrations of women, minority, and migrant employees. Many of the migrant workers are also subject to high recruitment fees that they pay to the labor agencies that matched them with these temporary jobs (CAFOD 2004; Chan and Peyer 2008; Smith, Sonnenfeld, and Pellow 2006). Contract manufacturers employ significant numbers of contingent or agency workers in order to limit worker benefit coverage and enable suppliers to hire and fire employees rapidly in response to variations in production demand. A representative from the electronics supplier Foxconn went as far to say "[Foxconn] believes that it would be better to hire all workers directly; unfortunately our variable manufacturing volumes do not allow us to do it"(Centre for Reflection and Action on Labour Issues (CEREAL) 2007). This combination of low-skilled assembly work by large numbers of contingent and/or migrant workers have led to labor rights issues surrounding working hours, benefits, and safety (Good Electronics 2009; Schipper and de Haan 2007; Smith, Sonnenfeld, and Pellow 2006). The harsh working conditions in the industry were most vividly manifest by the tragic worker suicides within Chinese electronics facilities owned by Foxconn (Dean and Tsai 2010). It should be noted that these recent suicides rallied coalitions of investors (Interfaith Center on Corporate Responsibility 2010) and NGOs (ICCR 2010b) to condemn abusive workplace conditions in the industry and call for stricter oversight.

In response to poor labor and environmental conditions in the electronics industry, Hewlett Packard (HP) and other lead firms launched corporate social and environmental responsibility (SER) programs in the late 1990s. Moreover, prominent lead firms such as HP, Dell, and IBM were able to initiate a collaborative approach to monitoring supplier conduct through the establishment of the Electronics Industry Citizenship Coalition and Code of Conduct (both commonly referred to EICC).

Hewlett Packard

HP is a leading electronics firm with a globally dispersed supply base and a strong commitment to social and environmental responsibility. At the time of our research (2009-2010), HP employed 304,000 individuals and generated revenue of $114 billion. HP has four operating divisions: Imaging and Printing (IPG), Personal Systems Group (PSG), Enterprise Business, and Financial Services. HP annually ships 48 million personal computers (PCs) and over 52 million printers, which include a vast array of different printer models and possible laptop and desktop customizable configurations (Ward et al. 2010). During fiscal year 2009 Hewlett Packard operated in over 170 countries, contracting with approximately 700 direct material suppliers in over 1,200 locations. These suppliers provide product materials and components, in addition to manufacturing and distribution services. Most suppliers are located in developing countries in four main geographical regions: Asia Pacific, Central and Eastern Europe, Greater China and Latin America.

Established in 1939, HP has been committed to social and environmental issues throughout its history. The "HP Way" refers to a management philosophy that emphasizes integrity, respect for individuals, teamwork, innovation, and contribution to customers and the community (Collins and Packard 2005). Although HP has a history of union avoidance at its facilities, it has exhibited a strong and longstanding commitment to social and environmental responsibility. Consistent with this culture, HP became an early advocate of global labor standards. In the late 1990s HP relocated printer-manufacturing activities that were previously based in Vancouver, Washington to outsourced production locations overseas. As HP engineers supervised this transition, they became aware of the consistently poor working conditions and absence of labor standards within select supply chain partners. During one supplier visit, these engineers took multiple photographs surreptitiously, which they then assembled into an album and distributed internally within the company. In 2002, the company developed its first supplier code of conduct in response to both this internal mobilization and to external pressures from NGOs and other civil society groups concerned with labor conditions in the industry. This was the first code of conduct in the electronics industry and provided an important foundation for the industry-wide standards that were later established through the EICC. HP has received accolades from Fortune Magazine, which ranked the firm first in social and environmental responsibility within the computer industry.

The Electronics Industry Citizenship Coalition (EICC) and Code of Conduct

The EICC was established in 2004 when eight leading electronics firms, including HP, sought to improve the working conditions within and environmental impact of their suppliers through the development of an industry-wide code of conduct. By 2008, EICC membership had grown to include 45 members with 1.2 trillion in revenue, employing 3.4 million workers (EICC 2009a). EICC-affiliated firms require their suppliers (and for contract-manufacturer members, their own plants) to comply with the EICC code. The first EICC code was written in 2004. In 2005, the EICC partnered with GeSi, a primarily European group of electronics companies interested in sustainability, to develop a self-assessment questionnaire for suppliers that would be used as the basis for audits and performance improvement. The EICC code has been revised twice with the most recent code issued in 2009. Although the Code was initially implemented more or less independently by each member of the EICC, they have made significant progress over time to coordinate these efforts by moving towards a common pool of auditors and sharing audit results in an effort to reduce audit fatigue among suppliers and eliminate conflicting standards, two issues that often hamper private monitoring efforts (Locke, Qin, and Brause 2007; Nadvi and Waltring 2004; O'Rourke 2003)

The code is divided into seven sections, the first covers broad code of conduct compliance issues, and is followed by six more specific sections addressing labor, health, environment, labor management, environmental health and safety management, and ethics. Each of these sections contains between three and eleven subsections that are assessed for compliance outcomes. If a problematic area is observed it can be flagged as an "observation," "minor violation," or "major violation" depending on the severity of the issue. A "major" violation (also referred to as nonconformance) refers to the inability of a supplier's management system to comply with a core EICC standard. Select major non-conformances can also be denoted as zero tolerance items. Such issues include the utilization of underage child workers, forced labor, health and safety issues posing immediate danger or serious injury, and violation of environmental laws posing serious and immediate harm to the community. "Minor" violations refer to more isolated findings. A temporarily blocked emergency exit or missing safety equipment would be examples of such "minor" violations. Finally, "observations" are generally a recognition that a superior means of documenting or monitoring a process or procedure may exist. Audit items flagged as observations are not considered to be a nonconformance to the code.

2.5 Audit Results

Notwithstanding significant efforts by both HP and the EICC, an analysis of the audit reports reveals persistent problems. As seen in Figure 1, the top seven major violations comprise three labor-related violations and four environmental, safety and health violations[9]. Nearly 60% of audited facilities, including those with follow-up or periodic audits, had routine workweeks longer than 60 hours per week. 40% of audited plants, including those subjected to follow-up and periodic audits, had no or poor emergency planning, training and evacuation procedures. Some had blocked fire escapes. Finally, 32.5% of audited firms had some troubles with their management of hazardous materials and 30.2 % manifest wage and benefit problems, indicating that wages may not have met local minimums and/or failed to include a premium for overtime work.

--------- Insert Figure 1 here--------------

When the top four major violations are examined by year of audit and by the number of audits conducted at particular plants, whether as follow-up audits or part of a periodic audit process, a clearer picture of persistent trends emerges. Analyzing these audit data by year of audit helps us explore possible mechanisms that might lead to improvements in audit results, (i.e., increased compliance through more frequent inspections and policing; better working conditions through a plant's enhanced capabilities and management systems; plant management's growing appreciation of and ability to implement code requirements; and diffusion of best practices across the supply chain over time). In all cases, we would expect plants to demonstrate improvement as audits become more recent or as multiple audits occur.

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[9] For a more granular analysis of the audit results, see our companion paper, Richard M. Locke, Gregory Distelhorst, Timea Pal, and Hiram Samel, "Production Goes Global, Standards Stay Local: Private Regulation in the Global Electronics Industry". This paper focuses on the persistence of the largest major violation, working hours.

----------- Insert Figures 2a and 2b here ----------------

However, as seen in Figure 2a, the rate of failed audits in all four areas more or less increased between 2004 and 2008, with some improvements in wage and benefits requirements occurring more recently. A similar trend emerges when looking at audits by how often a particular plant was audited. In other words, one would expect that compliance with HP's/EICC's code of conduct should improve as audits are repeated and learning takes place. Again, other than wages and benefits, code violations actually increased. Moreover, working hour violations now occur at nearly twice the rate as the next most common violation, emergency preparedness (67% vs. 35%). To better understand the persistence of these workplace problems, we will examine the most frequent violation, excessive working hours, in great detail. NGO's frequently cite working hour violations as a highly significant, recurring issue (Good Electronics 2009; Level Works 2006; Verite 2004) confirming what we find in the HP audit data. Likewise, an extraordinary 90% of EICC members admitted that excessive working hours is an ongoing challenge for them (EICC 2009a). This concern is particularly noteworthy given that the working hours stipulation is the only EICC code item (out of 37 items) that specifically defines the standard: "[...] a workweek should not be more than 60 hours per week, including overtime, except in emergency or unusual situations" (EICC 2009b, 2).

As seen in Figure 3, an examination of working hour violations by region reveals the most frequent violations, more than 83%, occur in Chinese plants. This is consistent with the literature on Chinese labor issues (Ngai 2005; Yu 2008). Plants in Asia-Pacific, primarily Southeast Asia, violate working hours on 34% of audits. Together these two regions constitute 75% of HP's total purchases. In the Asia-Pacific region where purchasing is concentrated, we find violations do not vary significantly in the countries with the largest number of audits conducted: Malaysia, Singapore & Thailand (36-45% of audits contain violations) notwithstanding their distinct economic profiles and institutional arrangements. [10]

------------Insert Figure 3 here --------------

Interestingly enough, code violations regarding excessive working hours occurred not just in low-wage China, a setting often depicted as not possessing a strong commitment to enforcing labor regulations, but also in Singapore, a high-wage economy characterized by strong institutions, well-trained managers, and more stringent regulatory enforcement. How can we explain the persistence of poor working conditions and excessive working hours in electronics factories owned by different contract manufacturers, producing for different global buyers, and located in countries with distinct institutional arrangements?

2.6 Explaining Persistent Working Hours Violations

[10] An examination of the audit documents of Malaysian companies revealed that labor violations in Malaysia were underreported. This is due to the auditors' belief that the Malaysian national labor law (which allows 72 hours per week) took precedent over the EICC. The EICC states that working hours shall not exceed 60 hours per week, independent of national laws.

As discussed above, within the scholarly literature on labor standards, two distinct accounts seek to explain the persistence of various workplace issues. One view claims that persistent labor violations are the result of inadequate government regulation and thus argues for increased state monitoring and enforcement of labor conditions in factories operating within their national boundaries (Piore and Schrank 2008; Schrank 2006; Seidman 2007; Weil 2004). The second view argues that the persistence of poor working conditions in global supply chain factories stems from various design and implementation weaknesses in these private monitoring programs. To remedy these weaknesses, various scholars have proposed that private compliance programs become more transparent (Fung, O'Rourke, Sabel 2001) and/or better coordinated among firms in the same industry (Nadvi and Waltring 2004; O'Rourke 2003), and/or focused on providing suppliers with the capabilities (technical know-how, management systems) needed to run more efficient and ethical businesses (Locke and Romis 2007; Locke, Amengual, and Mangla 2009). However, when we look more closely at our findings, neither of these accounts can sufficiently explain the persistent workplace problems we observe among HP's suppliers.

Contrary to accounts that argue for a stronger role for state regulation, excessive working hours and other workplace problems were observed in factories operating in both "strong" and "weak" regulatory environments. In Singapore, a country with strong regulatory institutions and high wages, excessive working hours was extensive. Moreover, both plants visited in Singapore for this study employed significant numbers of foreign migrant workers at lower wages. The Malaysian and Thai plants visited for this study routinely met with government officials to discuss ways of cooperating in order to enhance compliance with national labor laws and the EICC. Yet even these plants manifest repeated work hour violations.

Efforts to improve private compliance initiatives either through greater coordination among the different firms in the industry (e.g., EICC) or through more targeted capability-building programs also appeared unable to fully tackle these workplace issues. As seen in Table 2 previous, four of the plants analyzed in this article are owned by parent companies that are members of the EICC. In the various countries covered in this study, HP created training and capability-building programs for its first-tier suppliers to probe root-cause issues and foster solutions. Likewise, these plants had regularly scheduled compliance meetings with HP's auditors in order to improve coordination between auditors and suppliers. All plants visited for this study claimed HP auditors were very cooperative and helped build capability among their production staff. HP process engineers visited most of these plants on a regular basis and in some of the larger plants, HP maintained a full-time employee on site. HP and these suppliers shared detailed information and practiced root cause analysis. And yet still, all of these efforts failed to fully tackle certain workplace issues in these factories.

2.7 Our Argument: The Cascading Effect of Upstream Business Practices on Labor Standards in the Global Electronics Industry

Although the alternative explanations reviewed above may help explain (and provide guidance for improving) working conditions and labor standards in certain sectors and/or nation-states, they appear unable (in and of themselves) to explain why we see persistent working hours violations in numerous electronics factories. We argue that the policies and practices implemented *upstream* in response to highly dynamic consumer and retail markets shape supply chain practices, production architectures, and work organization *downstream* in the factories manufacturing these goods. Labor standards problems, exemplified by excessive working hours, are not only (or even primarily) the result of poor managerial practices and behavior in the plants, but rather stem from the series of supply-chain responses to these dynamic market conditions that have become routinized and optimized by global buyers in an effort to mitigate their financial and reputation risks and meet demand for their products in a timely manner.

In seeking to minimize uncertainty, firms routinely utilize product design, demand-signaling and production-planning practices that mandate modularity of design and assembly; allowing for the building of buffer inventories of lower-cost standardized intermediates, while postponing the final assembly of differentiated and much more costly finished goods. Although these practices mitigate risk by producing only those goods demanded by consumers, they create labor problems by structurally constraining the supply chain's downstream production architecture and corresponding design of work organization. In what follows we describe in great detail the evolution of these upstream business practices and their consequences for work organization and working conditions in the factories.

The Starting Point: Increasing Industry Dependence on Consumer Markets

Since the advent of the personal computer, the electronics industry has evolved from being primarily a supplier to governments and large commercial organizations to one whose growth opportunities now originate in consumer markets. A 2008 survey of semiconductor firms found that integrated circuit manufacturers derive 60% of their revenue from chips that are placed in consumer electronics products (KPMG, Consumer Electronics Association, and Global Semiconductor Alliance 2008). Respondents further estimate that this will climb to 80% of revenue within five years. Consumer markets are continually subject to disruptive innovation, motivating firms to advance the technological frontier while reducing costs to prevent disruption from below (Christensen 1997). Increasing consumer technology-adoption rates have also shortened product life cycles.

In order to maximize market share over such short life cycles, retailers engage in constant promotions that rapidly erode selling prices. Given an average product life cycle of 8 months, prices may drop as often as every two months. This price erosion, along with the need to carry a broad product assortment, limits retailer appetite for large inventories. Instead retailers opt for more frequent shipments, often by air cargo, to meet consumer demand (Leinbach and Bowen 2004). Yet, brands and retailers do not want to find themselves out of stock if a product is successful, given that consumers may choose a competitor's product if their own is no longer available.

This balancing act is complicated by the concentration of electronics retail channels that has occurred in recent years. As seen in Figure 4, the top four competitors in the US consumer electronics and computer retail distribution channels control close to 75% of their respective markets. Oligopsonistic buying power allows retailers to maintain margins, thus forcing price drops on the brands as the electronics firms move products through their life cycles. Retailers also seek to differentiate product from their competitors in order to prevent consumers from price shopping products, a process easily facilitated by the growth of on-line commerce.

--------Insert Figure 4 here--------

As a result, brands often make small functionality changes to products to disguise any potential similarity between rival retail customers. Short product life cycles and the need for thinly differentiated products lead to a constant parade of new product introductions punctuated by rapid phase-outs. For example, in 2009 Hewlett-Packard maintained over 2,000 laser printer SKUs, more than 15,000 server and storage SKUs and over eight million possible configure-to-order combinations in its notebook and desktop product lines (Ward et al. 2010).

How the Electronics Industry Responds to Dynamic Consumer and Retail Markets

The result of these various practices creates great uncertainty within the industry. Buffeted by rapidly changing technology, volatile consumer demand, and powerful retail customers, brands are obligated to optimize supply chain management practices to remain competitive. Kaipia et al looked at the demand and production volatility of a major European electronics manufacturer (Kaipia, Korhonen, and Hartiala 2006). As shown in Figure 5, even with a relatively linear demand (as evidenced by the retail channel sell-through) volatility is extreme at the contract manufacturer level with production changes of 80% on a week-by-week basis. Kaipia et al present their case as one of classic bullwhip effect where amplification is progressive throughout the supply chain. The consequences of this bullwhip effect--excess inventories, low capacity utilization, late or unfulfilled deliveries—significantly adds to costs and weaken brands' reputations.

-------- Insert Figure 5 here -----------

The electronics industry has sought to manage these supply chain challenges through three broad strategic responses: modular product design, buffer inventories of intermediates, and postponement of final assembly until signaled by pull-based ordering systems. Products are designed with standardized, substitutable components that can also be assembled when necessary into common modules. These modules and components, known as intermediates because of their unfinished state, have separate production schedules, allowing for the buildup of buffer inventories that can be easily reallocated among different products at final assembly, depending upon consumer demand. Finally, assembly of finished goods is postponed until accurate demand signals are available. This triggering of orders is known as pull-based ordering due to the dependence on consumer demand (as evidenced by retail point of sales data) for releasing orders into a production system rather than production minimums, as was done during the era of Fordist mass-production. Final products have a significantly higher cost than just the sum of their parts because of the threat of rapid obsolescence. This system works because postponement reduces the financial and reputational risks of unsold finished goods inventory.

In order to mitigate volatility during the production of intermediates and encourage the buildup of component inventory, brands choose to take the financial risk of maintaining ownership of and selling components to assemblers on an as needed basis. In a series of articles, scholars working with HP planners laid out the basis for this practice, referred to as "price masking". Originally conceived as an exercise in bargaining power, the practice has become widespread over time (Amaral, Billington, and Tsay 2006; Ellram and Billington 2001).

On the production side, contract manufacturers are reluctant to absorb inventory risk, unless they have the opportunity to markup components as well as assembly services. Brands, operating under the premise that they only pay for value-add, will not agree to these markups. Instead, they negotiate component pricing directly with the component producer. Contract manufacturers may order these parts from these component producers and have them billed directly to the brand or they may purchase them directly and the component supplier rebates the brand for the difference between the brand's negotiated price and the price charged to the contract manufacturer. In either case, the contract manufacturer is prevented from knowing the brand's component price (Ellram and Billington 2001). This policy minimizes inventory risk to the assembler, while allowing the brand to spread its own risk among a portfolio of products. By design, price masking encourages the buildup of buffer inventories at the intermediate stage under the assumption that the financial risk of substitutable components is substantially less than that of finished goods that cannot be reworked.

A byproduct of pull-based systems is that demand volatility is magnified at the final point of assembly. Because brands want to avoid inventory of finished goods and thus postpone final assembly of their products for as long as possible, production volumes exhibit periodic spikes of 300-500% over baseline levels. This volatility can be further amplified by the timing of frequent new product introductions that require large ramp-ups. The need to plan for this volatility is well known to brands and suppliers and is regularly optimized. HP has played a major role in this effort by encouraging its supply-chain professionals to publish their research in scholarly journals. Figure 6 highlights the forecast volatility for the introduction of an inkjet printer by HP's planning department. In addition to the planned peak-trough volatility of 100%, adjusted low and high forecasts vary as much as 250%. For example during the month of November, this differential is 500,000 units.

--------Insert Figure 6 about here---------

How these Policies and Practices Play Out on the Factory Floor

As seen in Table 4, five of the seven plants visited for this study (Companies A-E) had working hour violations in 2007[11]. Four of these plants were re-audited in 2008 and two again failed to pass the audit. The two that passed did so for exogenous reasons. Company C is a very small part of a much larger conglomerate that had failed to innovate in the competitive hard-disk drive space. As a result, their business dropped off and was put up for divestiture. Company E moved their assembly operations to Malaysia[12]. Closer plant-level analysis shows that, independent of country, product or use of lean manufacturing practices, working hour violations occurred in plants with *high volatility and unit volumes*, and *low product mix* (with the exception of a cartridge assembly plant in Singapore which had high volumes but stable demand due to the cartridges also being

[11] Tables 2 and 4 are ranked from left to right in descending order by the demand volatility reported by plant mangers, with Company A having the highest volatility and Company G the lowest.

[12] Company E has two distinct operations, mold-making/injection molding and assembly of molded components. Skilled machinists and machine operators perform the former, while unskilled workers handle the second. The working hour violations occurred in the assembly operations, which have since been moved to Johor, Malaysia.

sold for replacements). The plant mangers in these five plants stated that they believe managing working hour requirements is the most significant labor problem they face.

To help manage production swings, all five of the working hour violators utilize large numbers of agency or contract workers. At the time of interviews, which occurred in the summer when plants are ramping up for fall deliveries, more than one-half of the employees in all five plants were contract workers. Conversely, Companies F and G, which had no working hour violations had low to medium volume, low demand volatility and consequently less than 30% of their employees were on short-term contracts.

--------- Insert Table 4 here-----------------

The plants visited for this study use manual labor for final assembly of modules and products, with five out of the seven employing conveyor assembly lines[13]. The five plants with conveyor assembly lines operate with two 12-hour shifts, six to seven days a week, depending upon orders[14]. Managers at all the plants covered in this study claimed that it was often impossible to fulfill orders and meet the production schedules by working only five days a week. Each assembly station involved work tasks of between 20 and 30 seconds. Depending upon the sophistication of the product being assembled, assembly lines can grow from 80 to 220 operators, each performing a very narrow task. Managers at all of these plants were well aware of alternative (cell) assembly options. One plant, Company A, tries to run both styles of work organization whenever possible;

[13] In conveyor or linear assembly, the positions of operators are fixed and assembly occurs in a sequential manner as product travels past these operators on a conveying system.

[14] Company B, recently switched to 8-hour shifts as recorded in Table 4. However, during 2007 and 2008, when the working hour violations occurred, they were working two 12-hour shifts 6-7 days per week.

however, the plant manager reports that ultimately 95% of employees worked on conveyor assembly lines because of shifting demand. Plant managers claim that they opt for this more Taylorist form of work organization because it permits very short training periods, often less than a day, for new operators. These managers indicated that this work organization (conveyor assembly) was independent of any specific brand or global lead firm they work with.

Managers in every plant visited for this study, with the exception of Company E which designs and make highly engineered injection molds, reported that the majority of engineers in their plants were process engineers, focused on assembly line efficiencies. Employee turnover at these plants is high and mobility between factories is facilitated by the common work organization of conveyor assembly. Most operators on the assembly lines are migrant workers[15] hired on two-year contracts[16]. Managers indicate that migrant workers seek to maximize their earnings by working overtime whenever possible for two reasons. First, they have little or no local connections and given their short-term contracts, prefer to maximize their pay. Overtime hours are earned after an aggregate total is achieved[17], such that workers can double their wages by working weekends. Second, many migrant workers are indebted to the agency that recruited them, which takes up to their first-year's base pay as a fee; overtime pay is the only wages they can send back home.

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[15] Migrant workers in China and Thailand are in country, while workers in Malaysia and Singapore are foreign.
[16] In the 5 plants reporting gender, women made up 85% of total employees in four plants and 55% in the fifth.
[17] By contrast, this policy differs from those common in advanced industrialized countries where overtime can be achieved by working more than 8 hours any day, independent of aggregate hours.

Because production orders are highly volatile, factories break their labor contracts with these migrant workers on a regular basis (Bormann, Krishnan, and Neuner 2010; Good Electronics 2009). The conveyor assembly operations they use allow for both the quick absorption of new workers as well as the ability to rapidly shed these workers when demand suddenly drops. To illustrate this work system in greater detail, we now turn to a case study of an inkjet printer manufacturer in Malaysia.

The Case of Inkjet Printers

Company A's plant in Malaysia[18] is a vertically integrated producer of inkjet printers that at its historic peak in 2007 produced one million units per month for HP. The plant exhibited the most extreme case of demand volatility among the seven plants visited for this study. It currently produces six to eight models per year with an average product life of less than nine months. As seen in Figure 7, monthly volumes can increase by up to 250%. Employment levels can also swing (up and down) by 58%.

-------- Insert Figure 7 about here -----------------

To manage its highly volatile production schedules, the Company A plant regularly hires 60% of its workforce through Malaysian government-certified contract agencies. These agencies recruit Bangladeshi and Nepalese workers who sign two-year

[18] Company A's plant was originally not noted for working hours violations. Upon inspection of the audit reports, it was noted that the plant workers regularly worked 72 hours week, but because this was legal under Malaysian labor laws at the time, the auditors mistakenly believed Malaysian law too precedent over the EICC. The plant is correctly noted as a violator in this paper.

contracts with the agency and start work at the plant usually in June, in time for product ramp-up. Notwithstanding their two-year employment contract, the plant regularly lays off the vast majority of these workers six months later, due to decreased production orders. Malaysian laws allows for these contracts to be broken as long as workers receive a payment of one month's base wage as severance. Thus, while this process of hiring and firing migrant workers on a regular basis is not a technical violation of the EICC, this practice certainly violates the spirit of the Code.

Interestingly enough, our interviews at this plant revealed that it tries to be a good employer. Both the plant and the dormitories housing the migrant workers are modern and in good shape. The plant promotes an extensive Kaizen program. Production Supervisors, whenever possible, promote cell assembly, though this is most often limited to low-volume, high-mix production (less than 5% of total production). Management clearly understands the value of skilled assembly workers and encourages teamwork, despite the length of its assembly lines, which can reach 220 workers or more. Thus, the issue at this plant is not one of managerial bad will or lack of technical know-how or inadequate management systems but rather of how various upstream business practices constrain production and work organization practices on the shop floor. Given the highly volatile production orders they receive, plant managers at Company A believe that there is no other way they can profitably run their operations. They simply do not think that there is an alternative, more labor-friendly way to run their plant and deliver their products on time when demand is so volatile.

2.8 Volatility, Production Practices and Labor Standards

Volatility and its disruptive effects on manufacturing practices and employment relations are not new but rather have a long history in an array of different industries.[19] But the way that it is being "managed" in today's electronics industry seems to create serious problems for workers manufacturing these products. Manufacturing practices in the electronics industry appears to be an odd amalgam of both "lean" and more traditional Taylorist work practices. On the one hand, the industry is characterized by a variety of practices – pull-based ordering, modular design and assembly, price masking, postponement of final assembly – that all appear to enhance efficiencies, reduce waste, and mitigate risks for both global brands and their lead suppliers. On the other hand, these "lean" practices are complemented by an organization of production and work, especially in plants with high volume, low variety production schedules, that appears to be as Taylorist as factories of a by-gone era (Lüthje 2002; McKay 2006; Smith, Sonnenfeld, and Pellow 2006). Pull-based ordering coupled with postponement of final assembly requires that plants have the ability to scale (up and down) quickly. Automation, while conceptually a possible solution to this volatility, runs the same risk that an earlier era of mass-producers faced: under-utilization of capital-intensive equipment. Given the magnification of volatility through postponement as seen in Figures 7 and 8, where peak-trough volatility reaches 500%, final assembly plants would be burdened with unsustainable high fixed costs.

Instead, contract manufacturers employ large-scale hand-assembly coupled with lean manufacturing techniques. Operators work on products in a sequential manner with

[19] See (Piore and Sabel 1984) for an historical overview for how both mass production and flexibly specialized firms responded to previous shifts in demand conditions. See (Katz and Sabel 1985) for how volatility was "managed" historically in the US automobile industry.

each operation taking 20-30 seconds. Lines average 80-200 workers and can be reproduced in a rapid manner to meet demand. In this manner, demand/production order volatility is met primarily through the flexible use of labor. Firms periodically hire and shed large numbers of readily available contingent workers, primarily in-country or foreign migrants. Intentionally or unintentionally, Taylorist conveyor assembly is reinforced by the use of price masking policies. While brands may be absorbing contract manufacturers' inventory risk through this practice, they are also taking away some alternative opportunities for contract manufacturers to earn additional profit, thus forcing them to maximizing labor efficiency as the main way they earn profits (Linden, Kraemer, and Dedrick 2009)[20]. This drive to squeeze as much profit out of the work process inevitably leads to an array of different labor standards problems (excessive working hours, low wages, over-reliance of contingent migrant workers, etc.).

Through a case study of Hewlett-Packard and the global electronics industry, we have sought to demonstrate how some persistent labor problems originate in various upstream business practices. Some scholars have argued that as industry dynamics evolve, the governance systems that shape buyer-supplier relations will also change to adapt to more balanced power and/or capabilities between these key players in global supply chains (Gereffi, Humphrey, and Sturgeon 2005). Thus, we might expect that the Taylorist work systems and frequent labor problems described in this article to eventually disappear as supply chain governance becomes more "relational" as opposed to "transactional". This may be possible but in electronics, where brands may control 80% of the margin (Linden, Kraemer, and Dedrick 2009), their suppliers are not small firms

[20] Linden et al 2009 estimates that Apple captures 79.5% of the total margin created in the production and sale of a 30GB video IPod. The financial results of the largest brands and firms in Table 3 exhibit a similar patter of value capture.

but rather global multinationals with revenue in the billions and operations spread around the world. These contract manufacturers are highly capitalized, publicly traded firms with deep capabilities. But neither they nor the brands they supply appear able to eradicate persistent labor problems notwithstanding various compliance and/or capability-building efforts.

Others have argued that the only way to enforce labor standards and improve working conditions, given the absence of a “market for virtue” (Vogel 2005)– that is a business case for resolving these workplace issues – is through greater regulatory enforcement by the state (Reich 2007; Seidman 2007). In a companion paper (Locke, Distelhorst, Pal and Samel 2012) we too illustrate the importance of strong national regulations for enhancing workplace conditions. Yet the Taylorist workplace practices, excessive working hours, and extensive use of migrant labor we describe above are present in both “strong” and “weak” regulatory environments. Interestingly enough, some of these governments (wittingly or unwittingly) have enabled certain exploitative labor practices by promoting policies that protect core workers at the expense of migrant workers who make up the majority of the labor force in the electronics industry.

All of this suggests that if we are serious about improving working conditions and promoting labor rights in global supply chains we need to move beyond our traditional debates over public vs. private regulation and/or particular models of supply chain governance and begin to examine systematically how patterns of consumption impact workplace practices in the factories producing the goods most of us purchase every day. Currently, discussions of ethical consumption focus primarily on the impact of various certification schemes on the willingness of different types of consumers to pay more or buy more of these supposedly ethically sourced products. We believe that we need to broaden these discussions to include policies aimed at shaping consumption patterns that may lead to "fair" prices" for goods produced through "fair" working conditions. In the past, such forms of "regulated competition" existed in which rival firms shifted their competitive strategies away from cutthroat pricing and towards more innovation-based and sustainable production and distribution practices. Private firms still competed fiercely with one another but the terms of competition were regulated (mostly, self-regulated by the industry associations themselves) in order to protect standards for both firms and their workers. (Berk 1996). Given the growing awareness of and concern for more sustainable business strategies, and the fact that for many of the actors involved in the electronics industry, current practices do not seem to be generating the kinds of high-wage, high-skill, high-margin opportunities they had hoped for, perhaps we are at a moment when we could actually begin such a conversation. Whether or not this is possible in today's global economy, and if so, how to structure it, is beyond the scope of this paper but this broader discussion is essential if we are going to promote a more sustainable and just economy.

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2.10 Tables and Figures

Table 1: Distribution of fully compliant facilities (last audit) by National Setting and Issue

	Asia Pacific		CE Europe		Greater China		Latin America	
	Total Facilities	Percent of Total	Total Facilities	Percent of Total	Total Facilities	Percent of Total	Total Facilities	Percent of Total
All sections (Full compliance)	4	6.06	1	4.00	1	0.67	1	2.78
All sections (No major violation)	21	31.82	9	36.00	2	1.34	13	36.11
Labor (Full compliance)	34	51.52	22	88.00	8	5.37	9	25.00
Labor (No major violation)	42	63.64	23	92.00	16	10.74	26	72.22
Health & safety (Full Compliance)	20	30.30	5	20.00	4	2.68	11	30.56
Health & safety (No major violation)	46	69.70	17	68.00	36	24.16	18	50.00
Environment (Full compliance)	26	39.39	12	48.00	14	9.40	14	38.89
Environment (No major violations)	47	71.21	21	84.00	62	41.61	22	61.11
Labor mgmt system (Full compliance)	26	39.39	14	56.00	17	11.41	5	13.89
Labor mgmt system (No major violations)	57	86.36	23	92.00	110	73.83	26	72.22
H&S mgmt system (Full compliance)	22	33.33	8	32.00	36	24.16	12	33.33
H&S mgmt system (No major violations)	55	83.33	23	92.00	119	79.87	30	83.33
Total	66	100	25	100	149	100	36	100

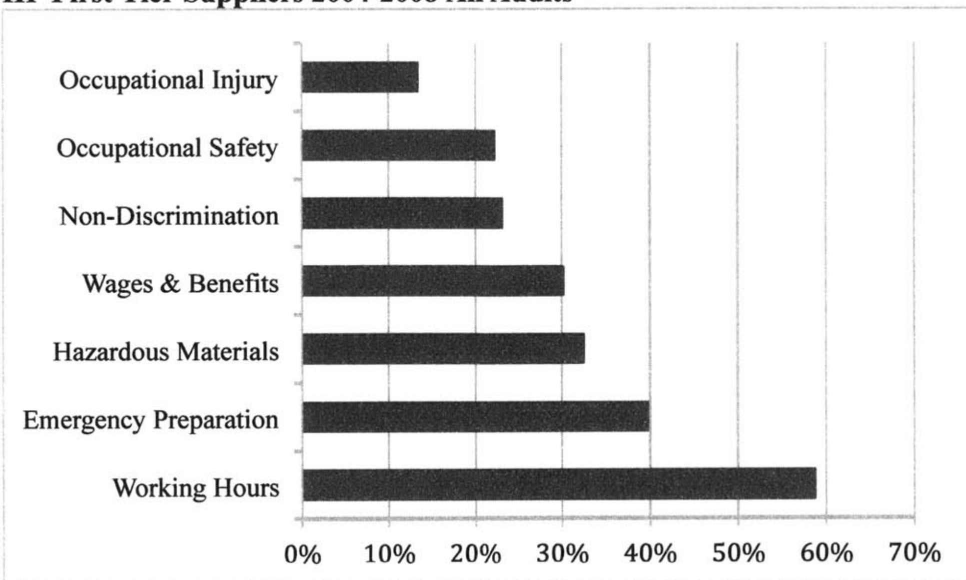
Table 2: HP First Tier Supplier Facilities Visited—SE Asia 2009

Company*	A	B	C	D	E	F	G
Location	Malaysia	Thailand	Thailand	Singapore	Singapore	Thailand	Singapore
Parent HQ	US	US	Japan	Canada	Singapore	Taiwan	US
Publicly Traded (Exchange)	Yes (NASDAQ)	Yes (NYSE)	Yes (Tokyo)	Yes (NYSE)	Yes (Singapore)	Yes (Bangkok)	Yes (NASDAQ)
Member EICC	Yes	Yes	No	Yes	No	No	Yes
ISO 14001	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OHSAS 18001	Yes	Yes	Yes	No	No	Yes	Yes
Company Code	Yes	Yes	Yes	Yes	No	Yes	Yes
Product	Inkjet Printers, Multi-Function Printers	2.5" & 3.5" Internal HDD	2.5" Internal HDD	Inkjet Cartridge Dry/Wet Assembly	Mold Making, Injection Molding	DC-DC Converters	Rack Mount Servers
Technology	SMT, IM, Box-build	Man & Auto Assembly, Test	Auto Assembly, Test	Auto Assembly	CAD Tool & Die	SMT, Hand-Insertion	Box-build
Employees at Last Audit	12,000	15,600	4,500	300	100	12,000	297

Table 3: Top Electronics Lead Firms and Contract Manufacturers by Revenue

Rank	Firm	2009 Revenue (Billions)	2009 Net Income (Billions)	2009 Return On Sales	Employees
Electronics Firms Producing Computer Hardware					
1	Hewlett Packard	$114.5	$7.7	6.7%	304,000
2	IBM	$95.8	$13.4	14.0%	410,830
3	Dell	$61.1	$2.4	3.9%	94,300
4	Apple	$42.9	$8.2	19.1%	34,300
5	Cisco	$36.1	$6.1	16.9%	65,550
	Total Top 5	$350.4	$37.8	10.8%	908,980
Electronics Contract Manufacturers					
1	Foxconn (Hon Hai)	$67.8	$2.9	4.3%	800,000
2	Flextronics	$30.9	$(6.1)	-19.7%	165,000
3	Jabil Circuit	$11.7	$(1.1)	-9.4%	61,000
4	Celestica	$6.1	$0.1	0.9%	25,000
5	Sanmina-SCI	$5.2	$(0.1)	-2.6%	31,698
	Total Top 5	$121.7	$(4.4)	-3.6%	1,082,698

Figure 1: Largest Code Violations by Total Audit Percentage
HP First Tier Suppliers 2004-2008 All Audits*



Major Code Violation	Audits with No Violations	Audits with Violations	Total Audits	Percent Audits in Violation
Working Hours	204	290	494	59%
Emergency Preparation	292	193	485	40%
Hazardous Materials	322	155	477	32%
Wages & Benefits	337	146	483	30%
Non-Discrimination	361	109	470	23%
Occupational Safety	355	102	457	22%
Occupational Injury	407	63	470	13%

271 Initial Facility Audits, Follow-On Audits Vary as Above

Figure 2a: Largest Code Violations by Year of Audit
HP First Tier Suppliers 2004-2008 All Audits*

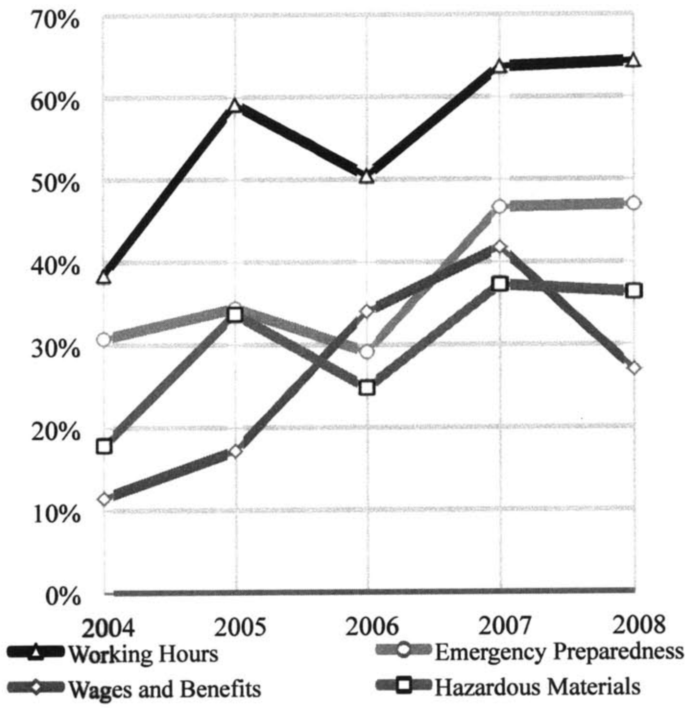
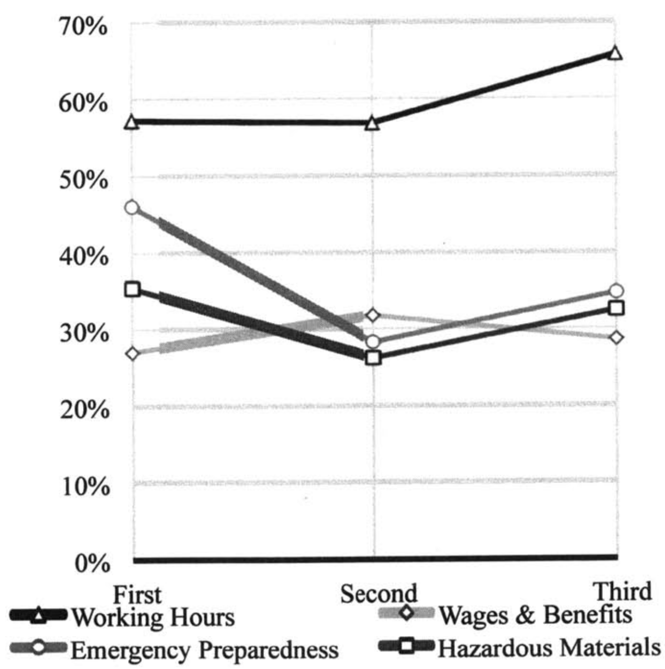
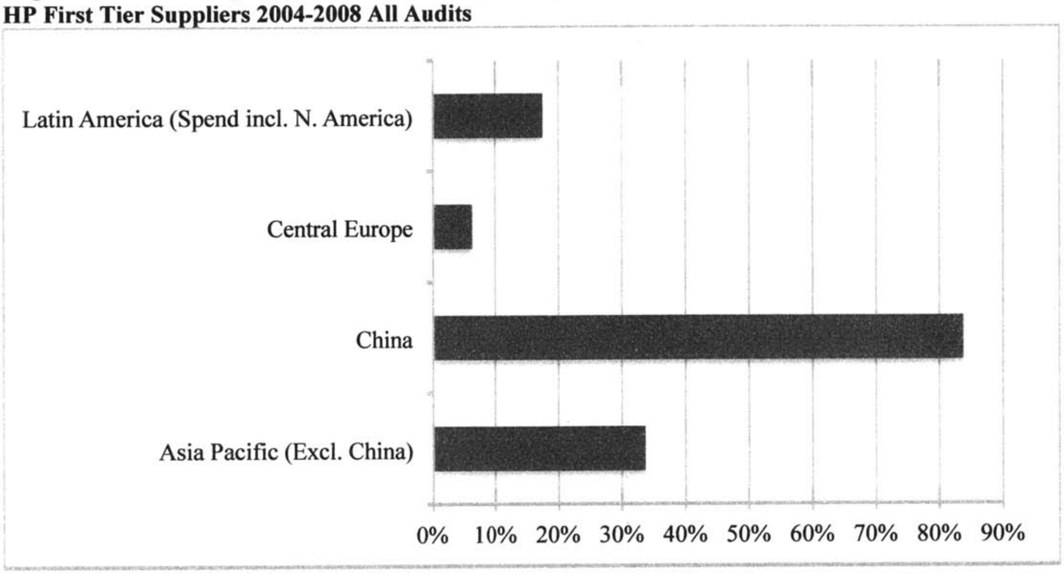


Figure 2b: Largest Code Violations by Audit Number
HP First Tier Suppliers 2004-2008 First-Third Audits*



461-476 Audits: 260-271 First Audits, 126-132 Second Audits, 70-73 Third Audits

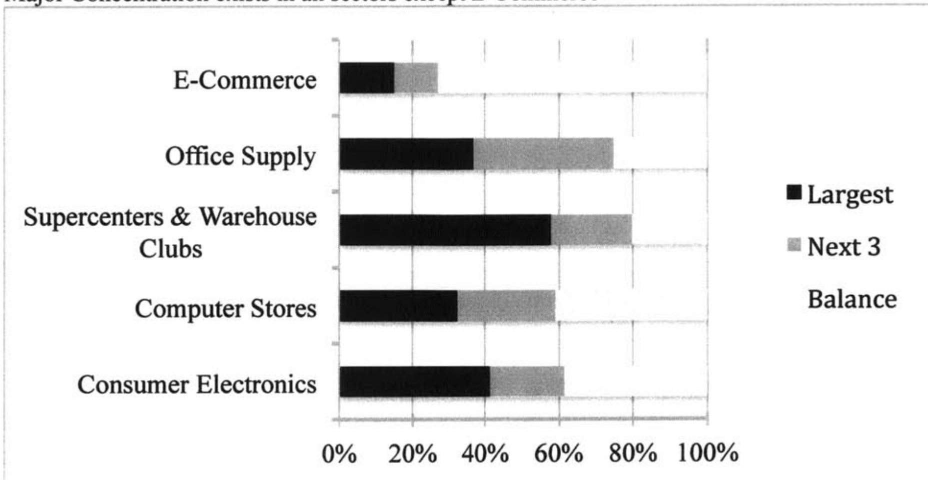
Figure 3: Working Hour Violations by Geographic Region
HP First Tier Suppliers 2004-2008 All Audits



Percent of Total Annual HP Spend	HP Region	Audits with No Violations	Audits with Violations	Total Audits	Percent of Audits in Violation
75%	Asia Pacific (Excl. China)	63	32	95	34%
	China	48	248	296	84%
5%	Central Europe	46	3	49	6%
20%	Latin America (Spend incl. N. America)	47	10	57	18%
100%	Total	204	293	497	59%

Figure 4: U.S. Electronics Market Concentration by Retail Sector

Major Concentration exists in all sectors except E-Commerce



Retail Sector	Largest Retailer	Largest	Next 3	Balance
Consumer Electronics	Best Buy	41.5%	20.0%	38.5%
Computer Stores	Best Buy	32.2%	26.9%	40.9%
Supercenters & Warehouse Clubs	Wal-Mart	57.9%	21.8%	20.3%
Office Supply	Staples	36.7%	38.0%	25.3%
E-Commerce	Amazon	15.0%	11.7%	73.3%

Source: Ibisworld 2010

Figure 5: Delivery Quantities of One Product through Three Echelons of a European Electronics Firm's Supply Chain

30 Week Period Incorporating Introduction and Maturity Phase (Kaipia et al 2006)

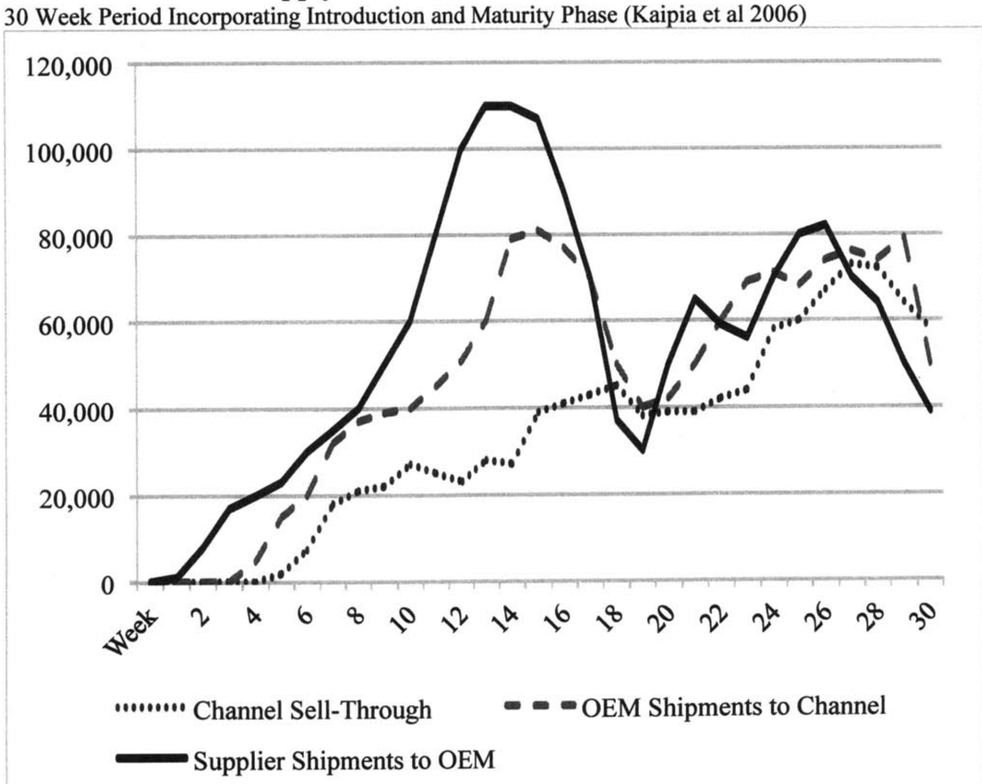


Figure 6: Forecast Variation for CM Shipments of Typical HP Ink Jet Printer
12-Month Period Reflects Seasonality and Price Drop (Burruss and Kuettner 2002)

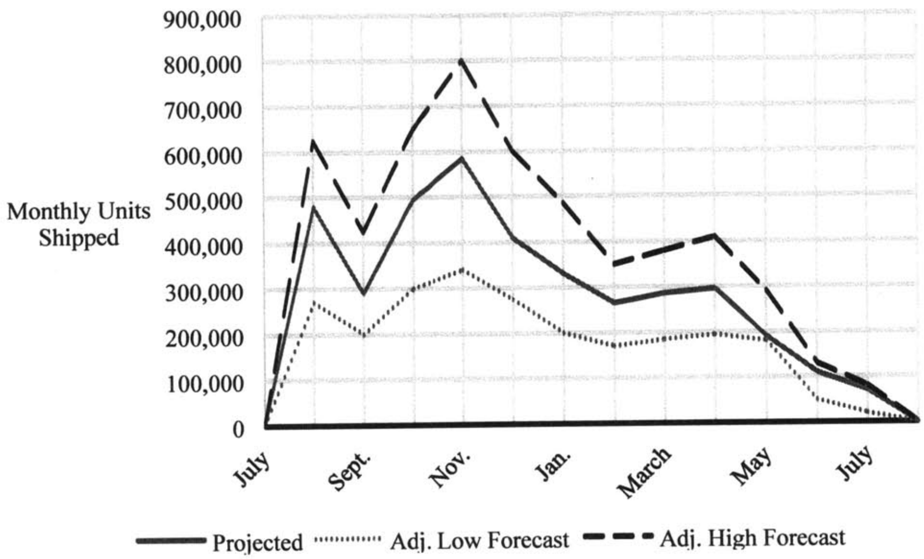
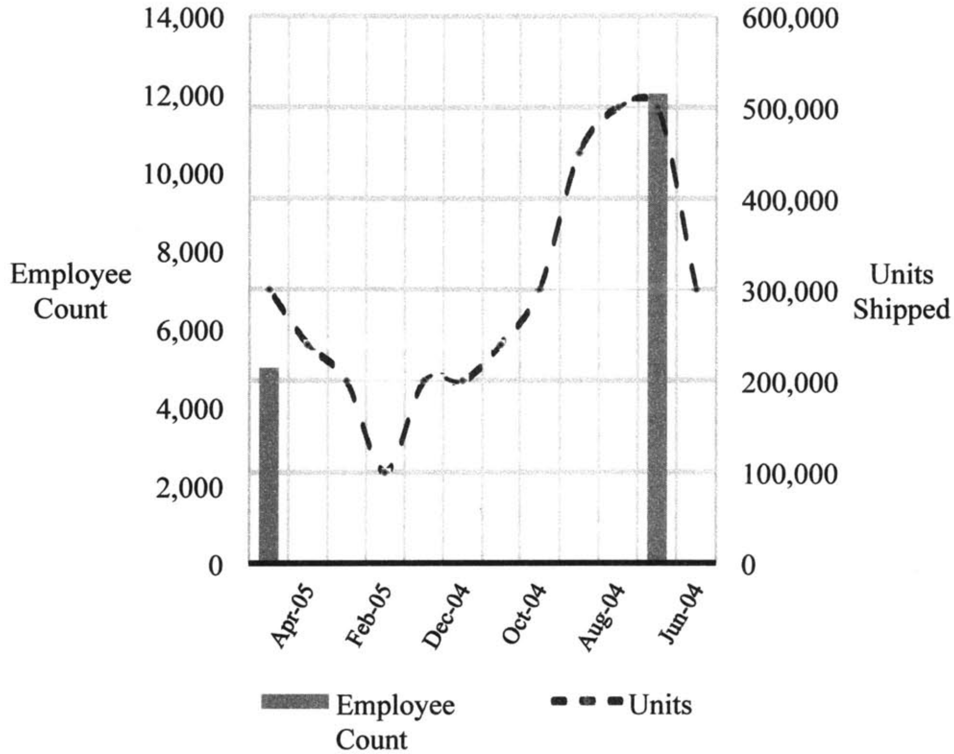


Table 4: Volatility, Product Market Demand Pressure and Work Organization Selection

Company*		A	B	C	D	E	F	G
Location		Malaysia	Thailand	Thailand	Singapore	Singapore	Thailand	Singapore
Product		Inkjet Printers, Multi-Function Printers	2.5" & 3.5" Internal HDD	2.5" Internal HDD	Inkjet Cartridge Dry/Wet Assembly	Mold Making, Injection Molding	DC-DC Converters	Rack Mount Servers
Intermediate or Final Assembly		Final	Intermediate	Intermediate	Final	Intermediate	Intermediate	Final
HP as % of Total Plant Production		95%	25%	25%	100%	50%	5%	100%
Product Market Demand Pressures	*Volume*	*High (>500K printers monthly)*	*High (>8 million units monthly)*	*High (~3.8 million units monthly)*	*High (> 7 million cartridges monthly)*	*Low*	*Medium*	*Low*
	Product Mix	*Low*	*Low*	*Low*	*Low*	*Medium*	*Medium*	*High*
	Demand Volatility	*High*	*High*	*High*	*Medium*	*Medium*	*Low*	*Low*
	HP Use of Price-Masking as % of Total Components	Yes (~80%)	No or limited (Has own magnetic operations)	Yes (n/a)	Yes, (100%) HP owns all equip. and components	No	Yes (n/a)	Yes (~80%)
Working Hours Audit Results		**2007-Yes** **2008-Yes**	**2007-Yes** **2008-Yes**	**2007-Yes** 2008-No	**2007-Yes**	**2007-Yes** 2008-No	No Violation	No Violation
Work Organization	Production Line Change requires HP Approval	Yes	No	Yes	Yes	Yes	n/a	Yes
	Type of Assembly	Conveyor	Conveyor	Conveyor	Conveyor	Cell	Conveyor	Cell
	Kaizen/Lean Practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Employees in this Facility 2008 (pre-recession)	12,000	28,000	8,500	550	570	8,800	297
	Union	No	No, believes in strategic HR	None, has welfare committee	Branch of National Union	Branch of National Union	Company Union	Branch of National Union
	Use of Contract Workers	*>60%*	*Was 70% until 2008 when completely phased out*	*77% of employees were subcontractors before recession*	*Dual Market: 55% of total workforce at lower wages*	*Dual Market: 45% of total workforce at lower wages*	*Phased out starting 2005*	*Dual Market: 20-30% of total workforce at lower wages*
	% of Total Employees that are Migrant Workers	>50% (Bangladeshi, Nepali)	greater than 50% (in country:Isan)	greater than 50% (in country:Isan)	~60% (mainly Malay)	45% (mainly Malay & Chinese)	less than 5%	20-30%
	Women as % of Total Employees	55%	85-90%	85%	85%	n/a	84%	n/a
	Number of Shifts	2-12hr	3-8hr	2-12 hr	4-12 hr	2-12 hr	2-12 hr	3-8hr
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 7: Ink Jet Shipments (All Products)—Company A 2008-2009
Malaysia Plant, Average Product Cycle-9 months, 6-8 models



3. Upgrading Under Volatility in a Global Economy[21]

Upgrading has been a main policy focus of the development literature for the past two decades. The predominant model has firms with low capabilities moving up the value chain through learning in global production networks and support of robust local institutions. Time after time when upgrading efforts fail, the recommended solution is to pour in more resources: new investments, more subsidies and more training. Yet little has changed. Using a critical case study of the Penang semiconductor cluster, this essay proposes an alternative set of hypotheses about upgrading in emerging economies.

The real challenge for upgrading is demand volatility. The problem is not that there are only firms with low capabilities, but rather there are plenty of firms with high capabilities. These firms, by leveraging local policy, have developed sophisticated capabilities to meet the increasingly volatile production demand of global industries, in this case electronics. Contrary to conventional wisdom, they do not compete away profits or solely rely on cheap labor. The challenge is that these firms—the prime set of candidates to upgrade--have become sufficiently successful in this specialty that under the present policy regime, they have no incentive to do otherwise. They have created a

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[21] I wish to thank Suzanne Berger, Richard Locke, Thomas Kochan, Edward Steinfeld, Michael Piore, Robert McKersie, Alan Benson and Andrew Weaver for their invaluable support and insightful comments.Thanks are also due to participants in the MIT IWER Workshop, the Upgrading in Global Value Chains session during the 2012 SASE Annual Meeting and the August 2012 WBI-KDI Conference on Leadership in Late Industrialization for their feedback and help. Shahid Yusuf and Phillip Schellekens of the World Bank were very generous in sharing their familiarity with and networks in Malaysia. Finally, Hamdan Abdul Majeed and K. Gopalan of Khazanah Nasional Berhad were incredible hosts during my stay in Penang. This work benefited greatly from their willingness to share their extensive knowledge of Penang's history and people.

sustainable niche, but one with no upward pathway. Firms that upgrade take a different route, avoiding volatile markets altogether. The case of Penang shows that volatility increasingly determines the international division of labor in emerging economies, not the search for low wages.

3.1 Introduction

Taking firms with low capabilities and 'moving them up the value chain' has been the traditional model of upgrading in emerging economies for the past two decades. To move from low-value assembly to high-value development, firms build capabilities through integration in global production networks (GPNs). To complement this effort, the state creates local research and training institutions often with the hope of developing industrial clusters and the external economies that accompany them. Time after time when these upgrading efforts fail, the solution is for the state to pour in more (better) resources: new investments, more subsidies and more training to jumpstart the process. Despite all these efforts, there has been little change; industrial productivity continues to slow in emerging economies as incomes rise (Gill and Kharas 2007; Lim 2011).

Using a critical case study of the $25 billion Penang semiconductor cluster[22], this paper argues there is an alternative explanation for the failure to upgrade. The real challenge for upgrading in emerging economies is volatility. The problem is not that there are only firms with low capabilities or that the state has failed to do enough to help them. Ironically it is the opposite, that there is a set of firms with high capabilities that *do not*

[22] See Appendix A

move up because they have little incentive to do so. This set of firms, by taking advantage of favorable local policy, has developed sophisticated capabilities to meet the volatile production demand of global industries. Contrary to conventional wisdom, they do not compete away profits or solely rely on cheap labor. The challenge is that this set of firms—the prime set of candidates to upgrade--has become so successful in this specialty that under the present policy regime they have entered a local equilibrium (optimum). This equilibrium, though sustainable has no upward trajectory and uses the majority of local resources.

The historical motivation for GPNs was access to cheap labor. Newly industrializing states, in order to attract foreign firms, created an institutional setting that strongly favored business interests—often including low wages, lax regulation and suppression of independent unions. Less known however, this environment also enabled buyers to push market uncertainty (in the form of order volatility) down the supply chain. Facing little labor market regulation, firms were free to hire and fire workers in order to meet changing production schedules (Ernst 2002). A small factor in the early days of GPNs, volatility in technology and consumer-driven markets has increased significantly over the last fifteen years for many reasons: shorter product life cycles, product proliferation, higher technology adoption rates and increasing consolidation among brands and big-box retailers to name a few (Jack and Raturi 2002; Minnich and Maier 2007a).

This dynamic has led to larger orders with more permutations, shorter lead times and little predictability, a manufacturing problem combining scale and scope that is quite distinct from the basic assembly many observers believe take place. Yet a set of firms has developed in emerging economies with the capabilities and resources to manage this complicated task. Many would argue that this set of firms, which have historically been grouped under the umbrella of 'commodity manufacturers', are not of high quality, that they have built their business on the back of exploited labor, that they compete their profits away in a brutal race to the bottom (Steinfeld 2004). But the evidence does not support this argument, at least with regard to the most-capable firms (Mathews and Cho 2007). [23]

There is a high degree of variation; while certainly we can find firms with these and other characteristics that are not able to upgrade, we can also find sets of long-lived firms with the strong capabilities that would (should) lead to upgrading. By utilizing local resources such as flexible labor supply and highly skilled engineers/managers and rapidly absorbing, even innovating new process technologies, certain firms have developed the complex capabilities necessary to meet the highly volatile production demand of global industries.

However, these high capability firms accomplish this task in a manner that is in many ways antithetical to the traditional view of upgrading. These firms, whose skills have been honed by years of competition and thus should be the prime candidates to upgrade, *specialize* in the niche of producing for markets with highly volatile demand. They do *not* take on new activities—the kind scholars connote upgrading with like R & D and product development—not because they are incapable of doing so, but because they have *no need or desire to.* The ease with which they can leverage local resources

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[23] Apple executives makes this claim as well in a January 22, 2012 *New York Times* article explaining why they make their products in Asia. Contrary to media reports, they argue their choice is about capabilities, not just costs (Duhigg and Bradsher 2012)

combined with the risk of competing with one's own customers leads these firms to increase their specialization in volatile production, not move upstream into new activities. While their margins are not high and their systems of labor control hardly empowering, they have developed sufficient scale and expertise to construct strong barriers to entry.

Counterintuitively, the state's incentive structure reinforces this behavior by providing the necessary set of resources—flexible labor, highly educated managers, technician training and long-term exposure to the highly dynamic semiconductor subsector among others. But does every firm respond similarly? While the vast majority does, there exists alongside these specialized assemblers a very small cluster of domestic firms that take on high value activities that build upon Penang's legacy of flexible production. These firms have also learned to leverage Penang's expertise in volatile markets but in an entirely different manner. Through iteration with local assemblers, they produce test equipment that accelerates the continued optimization of flexible production, raising the Penang cluster's competitive advantage and thus attracting global customers. In contrast to Penang's assemblers, they sell into industrial markets where demand is more stable. Moreover, these firms have succeeded without any direct state help.

Where does this leave the newly industrializing state? Based on the critical case of Penang, this paper proposes a set of alternative hypotheses about upgrading. First, we need to advance a new understanding of the international economy in which volatility increasingly determines the division of labor, in place of (or addition to) the search for low wages. Second, adept firms select business strategies predicated on capabilities. In emerging states that support flexible labor market policies (which most do), capable firms opt to specialize in managing volatile demand as success creates barriers to entry, even with higher than market wages. Third, the volatility of many global industries (and respective production networks) leads to discontinuities in upgrading. Local firms rarely move up in GPNs from assembly to product development, whether by choice or competence. High potential new firms either develop abilities that allow them to join the group of specialists in volatile production or they avoid the volatility of global production networks altogether, instead focusing on more stable industrial or domestic markets. Fourth, in this regard, a firm's access to end-users is critical as it allows iteration of development ideas. Finally, the tendency of volatility to drive capable firms into a local equilibrium suggests that the present structure of global production will at some point inhibit the upgrading process it was intended to facilitate.

Volatility, uncertainty and the means to manage them are not new phenomena, as documented in Section 2. In Section 3, I describe the research setting of the Penang semiconductor cluster, illustrating why it may be considered as a most-likely case for upgrading. But upgrading in Penang appears to be stalled. Section 4 reviews evidence of this stagnation and shows how volatility has a profound impact on firm strategy. I demonstrate how firms leverage local resources and state policies to develop the complex capabilities of meeting volatile demand. Firms with these high capabilities prefer a niche that can generate barriers to entry rather than risk moving up into a new and different set of activities. Section 5 establishes how domestic firms enter new markets through local product development by drawing upon this legacy of volatile production. I then explain why the case of Penang leads to an alternative set of hypotheses to explain upgrading in emerging economies. The paper concludes by asking what might occur if the set of incentives that actors encounter in these countries were to change.

3.2 Uncertainty, Demand Volatility and Production Architectures

Volatility in historical perspective

Volatility is inherent to a market economy. Firms have devoted numerous strategies and significant resources to help reduce, if not eliminate it. The historic management of volatility relates to this paper for two reasons; first, it reveals the tension between supply and demand (producer needs versus consumer wants) and second, it highlights the tenuous relationship between labor and the firm. As economic power has shifted from producers to consumers over the last one hundred years, technology has enabled firms to shift production architectures from mass-production to mass-customization. Labor continues to absorb the economic risk of volatility. The benefits to consumers in the form of increasing product variety, ready inventory and low prices are partially derived from and supported by a system of employment relationships that passes economic uncertainty down to labor through outsourcing. Though substantial, this shift in labor uncertainty has conflated the present basis for outsourcing as the search for low wages rather than the increasing search for flexible production.

Initially, producers set the conditions of consumption. Alfred Chandler argues that modern industrial corporations sought monopoly (or at least oligopoly) positions to help minimize the variability in demand brought by competition (Chandler 1995). Fordist systems of production required capital-intense specific-purpose equipment whose cost could best by amortized by running continuously. Minimizing demand variation reduced the uncertainty of investing in assets that might lie idle. The well-known consumer problem for this system was lack of selection and innovation—Henry Ford's aphorism, "any customer can have a car painted any color he wants so long as it's black" succinctly sums up early attempts to manage volatility (Ford, Crowther, and Bodek 1988).

As technology advances spurred innovation and competition, firms sought buffers to mitigate production volatility. Michael Piore points out that labor is the traditional variable factor in production, as workers can usually be hired and fired as demand varies (Piore 1980). This method works well in industries that utilize unskilled labor, but are more problematic in capital-intensive industries, which require skilled labor with firm-specific training and a steady flow of orders to keep its equipment fully utilized. Firms in these industries would seek out only enough business to keep their production lines running, outsourcing order spikes to smaller firms where possible.

As a practice, outsourcing was not as common in the U.S as it was in Europe[24]. Suzanne Berger argues that large industrial firms in Italy and France outsourced production to small firms in the traditional sector to avoid raising fixed labor costs and to offset labor power (Berger 1980). Smaller firms paid lower wages, preserving the cost structure of the larger firm and reducing the larger firm's substantial severance liability in the event of a downturn. Contrary to the conventional wisdom, the state supported this activity unintentionally reinforcing the expansion of the system and foreshadowing a similar story in Penang fifty years later.

Globalization and technology changed production demands drastically. Competition from East Asia provided customers with increased product selection as well

[24] Outsourcing during this period in the U.S. was mainly due to specialization in the form of subcontracting as opposed to Europe where the same part was replicated in both the larger plant and outsourced company (see Berger 1980, p. 106).

as lower costs. Vertically integrated mass production firms could not keep up with product diversity or costs. To address this shifting environment, Michael Piore and Charles Sabel described an alternative model--flexible specialization, based on the practices of Northern Italian industrial districts, where networks of firms populated by multi-skilled workers and flexible equipment, cooperated to master volatile markets (Piore and Sabel 1984). Its demonstrated success allowed Piore and Sabel to argue that mass production is not intrinsically technically superior, but rather results from social and political considerations.

At the same time as globalization raised the competitive stakes, the consumer became the focus of an equally significant revolution in retailing. Wal-Mart and the advent of large discount and specialist chains focused on adding selection and lowering prices to generate new business. They looked abroad for appropriate products. Robert Feenstra and Gary Hamilton argue that the nature of the Korean and Taiwanese manufacturing systems can be explained by this revolution (Feenstra and Hamilton 2006). Electronics retailers seeking complex products in high volumes, such as television sets, went to Korea where the vertically integrated chaebol could meet their needs. Discount retailers that desired a larger selection of products in smaller quantities went to Taiwan where networks of small businesses could supply their needs. This neat sorting of scale and scope eroded with increasing retail consolidation, advancing technology and shorter product life cycles. Never sure whether sales will be in the thousands or millions, buyers now demand that final assemblers offer both scale and scope. The capabilities to meet quickly shifting demand begin to overshadow cost.

By plotting product variety against product volume, as seen in Figure 1a, we can see how production architectures have evolved in response to the increasing combination of scope and scale conditions. Craft production offers the most flexibility as products are often individually customized but this system has no ability to scale. Conversely, mass production offers enormous scale but it requires fixed-purpose equipment restricting variety. Flexible specialization allows for a mixture of scale and scope but is only used for medium scale. However, the more recent system of high flexibility global production networks has evolved to deliver the combination of scale and scope required by buyers and consumers. Kaipia et al in their study of a European electronics manufacturer stress that it is not uncommon for orders at a contract manufacturer to vary by 80% or more on a weekly basis (Kaipia, Korhonen, and Hartiala 2006, 103). Figure 1b portrays this variation by depicting the degree of volatility, in a stylized fashion, that each style of production architecture can accommodate.

-------------Insert Figures 1a & 1b here-----------------------

Volatility in global production networks

The evolution of deverticalization, outsourcing and the rise of global production networks is well known and not reviewed here[25]. There are, however, three key points relevant to our discussion. First, Timothy Sturgeon argues that GPNs are a new form of industrial organization because GPNs shift previously embedded relationships into contractual ones. Digitalization and codification of standards foster lower switching costs,

[25] See Gereffi 1994, Sturgeon 2001, Bair et al 2008 for excellent reviews

easing the ability of firms to search for new partners. The benefit to firms is that they are free to even out their production by selling to potential competitors of their customers; an outcome that buyers willingly accept because of the newfound freedom to order only what they need (Sturgeon 2002).

Second, as Gary Gereffi, Dieter Ernst and other scholars of this school argue, GPNs will allow emerging economy firms to upgrade their capabilities by exposure to foreign technology and demanding buyers, while increasing productivity due to competition (Ernst 2004; Gereffi 2009). While not perfect, the theoretical implication of GPNs is that they offer a means of improving all network participants, a shift from its origin in dependency theory. Third and decidedly less theoretical, the competition produced by standardization will drive inefficiencies out. Leveraging Japanese manufacturing practices, firms had to eliminate waste, especially work in progress and finished inventory. Cost reduction became the focus of corporate supply chains. The debate shifted to firms competing in a race to the bottom. Edward Steinfeld describes the shallow integration of Chinese firms in global production networks as symptomatic of firms competing away profits to stay alive (Steinfeld 2004).

However, do we understand what motivates firm behavior in global production networks? Current GPN theorists take a more granular, contextual approach to governance arguing that varied sets of relationships based on complexity, coordination and power predict different upgrading outcomes (Gereffi, Humphrey, and Sturgeon 2005; Gibbon, Bair, and Ponte 2008). Labor scholars debate the merits of private voluntary regulation and the role of state regulators in bringing improvement to factories (Locke, Qin, and Brause 2007; O'Rourke 2003; Piore and Schrank 2008). Economic geographers measure the benefits of nascent industrial districts and the effect that clusters have on firms embedded in GPNs (Coe, Dicken, and Hess 2008). All of these issues impact firms, but these scholars have either discounted or missed a principal driver of firm behavior in networked production--the shape of market demand[26].

Bringing supply chain operations back in

Operations scholars, seldom cited in the development debate, see a completely different set of problems with global production networks. Their main concern is the original dilemma seen in the older literature on dualism—uncertainty and volatility; but greatly magnified by demand considerations. Hau Lee argues managers of production networks must ensure that agility and flexibility are the primary outcomes of their efforts (Lee 2002). Lee claims that firms with high levels of uncertainty need to reduce their exposure by seeking agile partners that can ramp up production quickly to meet changing demand and technology. In doing so, firms will need to develop new systems, technologies and processes to compete. It is no longer a contest of costs, but of capabilities.

Building on this argument, Dennis Minnich and Frank Maier propose that time is now the single most important variable that retailers and brands must contend with in sourcing products. Given the rapid price erosion due to short product life cycles, buyers are reluctant to inventory finished goods (Minnich and Maier 2007b). Contrary to the historical means to manage volatility by limiting selection or building inventory buffers,

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[26] In "Looking in The Wrong Places?: Labor Standards and Upstream Business Practices in the Global Electronics Industry", R. Locke and I examine the impact of market demand on labor standards in the supply chain of a major computer brand.

current production networks require a production architecture that can postpone final assembly until data from point of sale is available. As a result, final production is held to the last minute leading to high volatility at manufacturing and assembly, most of which takes place in emerging economies. An illustration of the evolution and extent of this volatility is shown in Figures 2a and 2b. Both examples, which are from products in the electronics industry, display the high peak to trough volatility of short-lived products. Figure 2a, which uses a Hewlett-Packard inkjet printer circa 2000 as an example, shows two variances. The first is the significant swing between ramp-up and ramp-down periods and the second is the 250% difference from low to high forecast. Figure 2b, which describes a mobile phone variant, illustrates the increased volatility over time as product life cycles shorten; by 2006, volatility spikes over an eight-week period rather than the previous eight months. The production architecture and capabilities to manage this demand varies from previous systems because it requires scope to manage large variety and scale to handle to the large swings in production demand on short notice and with short delivery times.

----------------------Insert Figures 2a and 2b here------------------

The advent of flexible labor scaling

Scale-up (and down) is accomplished by adding (or subtracting) flexible labor. Manual assembly lines prevail in both high and low technology assembly because they can be easily reproduced when additional output is required and dismantled when output declines. Labor can be added or substituted with one or two days of training. I term this necessary condition, flexible labor scaling, to describe the type of production architecture used in final assembly. Is this modern version of Taylorist assembly easy to operate? I argue that it is not, at least at large scale; the capabilities to coordinate the complex supply chains that feed assembly lines along with engineering to set up highly technical equipment require educated, competent management.

The ability to manage large groups of flexible labor that turnover regularly, despite the extensive systems of labor control observed in many studies, is not easily acquired. Firms that can reliably meet production swings of 500% and millions of units over short periods of time have specific and learned capabilities. They form the foundation of the modern global production network, an essential component to today's high-speed, high-volatility industries. Where do they come from? Why don't these firms (or at the minimum, the local firms) choose to upgrade or not? Are these firms (and the corresponding production architecture) a technical necessity for highly dynamic consumer durable industries or are they the outcome of state policy? I examine these questions in one location that has all the right theoretical conditions for upgrading and yet has not done so, at least in the predicted direction of moving up the value chain—the large and mature semiconductor cluster of Penang, Malaysia.

3.3 The Most-Likely Case of Penang

Malaysia successfully liberalized its economy, attracting FDI and global exposure

As market advocates, Malaysia has been the best pupil of liberal economic policies since the early 1980s. The state rapidly liberalized trade and aggressively subsidized FDI to diversify economic control away from the ethnic Chinese minority[27]. By many accounts, Malaysia is a success story; it is one of only eight middle-income countries that have grown at an average rate of 7% or more for at least twenty-five years. Its 2010 GNI per capita of US$ 7,900 places it among upper middle-income countries. By 2008, Malaysia's trade/GDP exceeded 160% and the World Bank rated it first on a firm's ease of getting credit (World Bank 2010). Exemplifying its successful industrialization and export-orientation, Malaysia had a larger global share of electronics exports than all other middle-income countries (and larger than Taiwan) by 2006. Its exports are highly technology-intensive, higher than its wealthier neighbor, Singapore (World Bank 2010).

Malaysia and Penang have attracted frontier MNCs to drive learning and growth

Malaysia's policymakers have long understood the importance of sophisticated and technologically intense MNCs. Penang's semiconductor cluster exemplifies the state's sustained ability to attract sophisticated, frontier technology firms. The cluster originated during the first phase of Malaysia's industrialization in the early 1970's. Taking advantage of Penang's tax-free status at the time, surplus supply of English-speaking labor, and generous state incentives, the American pioneers of the semiconductor industry, Intel, AMD, Fairchild, Hewlett-Packard and National Semiconductor opened assembly operations in Penang. The cluster has grown considerably since that time. In addition to the original firms, most MNC semiconductor

[27] Malaysia does have tariff protection for certain state-owned industries, such as the automotive sector, in addition to its well-known affirmative action (Bumiputera) programs for Malays, but it is still considered one of the more economically liberal countries in the world. IMD ranked Malaysia 10th, well ahead of countries such as the Netherlands, Israel, the UK and Chile in its 2010 Competiveness Report (IMD 2011)

firms now have a presence including Altera, Avago, Osram, Renesas, as well as product manufacturers and assemblers such as Agilent, Jabil, Flextronics, Bosch, Sony, Motorola and Seagate.

The Penang cluster now consists of over 200 firms that are active in the semiconductor industry, of which MNCs comprise approximately 40% by firm count. Given its major position in the global semiconductor production network and the active role of the state in subsidizing new entrants, Penang continues to attract frontier MNC firms capable of transferring advanced technology. The cluster is able to regenerate itself with recent diversification into high growth markets such as the PV and LED subsectors with the addition of thin-film maker, First Solar and Philips Lumileds. In 2010, Penang ranked first in FDI in Malaysia, receiving investments totaling US$3.3 billion including plants for Bosch Solar Energy and National Instruments (Lim Guan Eng 2011).

Malaysia has invested in frontier-technology firms, while coordinating shared training and research

To bring Penang closer to the technological frontier, the state invested close to US$2 billion in Silterra, a semiconductor wafer fabrication plant (Rasiah 2010). The facility located a short distance from Penang started 180-nanometer wafer production in 2001, progressing to 110-nanometer production in 2009. The intent of the investment was to build local technological capabilities at the frontier of the semiconductor industry and to catalyze the creation of Malaysian fabless design houses.

To supplement federal programs, Penang has developed strong local institutions in conjunction with the private sector. The Penang Skills Development Corporation

(PSDC) is a well-established and respected training institution that is now imitated in other middle-income states (Muller and Saxenian 2005). In addition to the PSDC, which trains 10,000 workers per year, Penang has established the Collaborative Micro-Electronics Design Excellence Center (CEDEC) at the University Sains Malaysia. CEDEC is a shared facility for local and MNC firms, operating on a pay-per use basis to lower the barrier to entry for start-up firms. Along the same lines, the PSDC has developed another shared facility for RF testing to promote local wireless technology firms[28].

To facilitate information exchange, Penang maintains strong employer networks through membership in the PSDC and the local employers' association, the Malaysian Electronics Industry Association (MAEI). Penang's island geography facilitates informal gatherings of managers, with many managers of local and MNC firms living in close proximity. Employers have increased coordination with non-industry actors, recently petitioning the state in conjunction local academic and development organizations to fund a single research-clearing house for the electronics industry--The Collaborative Research in Engineering, Science and Technology Centre (CREST) in Penang. Likewise, the regional development corporation, Penang Development Corporation, has established well-managed industrial parks in a cohesive fashion.

Though the population of Penang accounts for only 5.4% of Malaysia's total population, the Penang semiconductor cluster makes an outsize contribution to the Malaysian economy. In 2009, the United Nations Industrial Development Organization

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[28] Interview with senior official, public-private partnership, August 4, 2011

(UNIDO) rated Penang the most vibrant industrial cluster in the developing world[29] (UNIDO 2009). Penang accounted for 37% of all Malaysian patents over the period from 2001-2006 (Athukorala 2011). It produces 24% of total Malaysian exports and 46% of Malaysian electronics exports (Malaysia DoS 2010). Total 2009 exports from Penang exceeded US$30 billion, 83% of which originated from the semiconductor cluster. The cluster generates 53% of total manufacturing employment in the state, not surprising given 21% percent of total FDI in Malaysia went to Penang (Kharas, Zeufack, and Majeed 2010). At the state level, Penang's GDP per capita is 58% higher than the national average.

As seen in Figure 3, with the exception of the demand shock resulting from the global financial recession in 2008, Penang exports have an annual average growth rate of 12.2% over the period 1990-2009 (Athukorola 2011). Yusuf and Nabeshima (2009) claim that Penang has a very high product sophistication mix using a product-space analysis; Penang in 2006 exported a basket of goods normally found in a country with a gross national income per capita of US$13,768, double the Penang gross national income (Yusuf Nabeshima 2009).

-----------Insert Figure 3 here----------------

Upgrading in Penang is stalled

The characteristics of Penang would lend us to believe that if technological upgrading is to occur anywhere, it should happen here; in a location with a long-term

[29] UNIDO studied 10 highly dynamic industrial clusters representative of developing economies, ranking Penang the best along a number of dimensions (UNIDO 2009)

presence of a leading MNCs, a dominant role in one of the world's most dynamic industries, a well-respected local agglomeration economy, access to global markets and the support of robust local institutions.

Yet notwithstanding the state's investments in subsidizing the attraction of MNCs, funding frontier-technology firms such as wafer-fabs, facilitating training institutions, expanding science education and creating research centers at local universities, Malaysia's (and Penang's) productivity has stalled. Kim and Shafi'i (2009) decompose the determinants of total factor productivity (TFP) in the Malaysian electronics industry for the period from 2000-2004. During this five-year period, they find the Malaysian electronics industry not only experienced decreasing TFP, but decreasing technical efficiency as well as decreasing technical progress (Kim and Shafi'i 2009).

As part of the Malaysia's 2010 Economic Transformation Plan (ETP), the state's Performance Management and Delivery Unit (PEMANDU) assessed the tasks conducted by electronics firms across the country. Using a methodology that assumes value-added has a linear progression from assembly to R & D, the state surveyed the range of tasks conducted by electronics firms in Malaysia, Singapore and Taiwan. By this criteria, as seen in Figure 4, Malaysia (and Penang) lags behind its wealthier neighbors, Singapore and Taiwan, in every segment of electronics, maintaining a high density of assembly and product manufacturing and very low density of every high value-added activity (ETP 2011).

-------------Insert Figure 4 here-----------

How can we explain this paradox?

It is evident that stalled upgrading in the face of all the 'correct' institutional and market interventions is increasingly yielding fewer returns. What might explain this outcome? Jeffrey Henderson and Richard Phillips (2007) argue that the state's efforts to ensure abundant resources for business may have had the perverse effect of constraining upgrading. In particular, they claim that the state's implicit guarantee of surplus supply of a single resource—labor--can explain Malaysia's stalled upgrading (Henderson and Phillips 2007).

Malaysia's labor market policies have long formed the foundation for Penang's production system. The country's decision in the 1970s to diversify control of the economy through foreign direct investment led to the pro-business labor policies found today. Because the initial goal of FDI was rapid labor absorption—Penang's unemployment rate exceeded 15%--the state discouraged any worker activity that might intimidate firms from relocating to or moving away from Penang. Trade unions were actively discouraged across the country and banned in the electronics industry. The state additionally promised to maintain tight control over any potential labor unrest (Mosedale 2005). In-house unions were allowed in the 1980's but they offered little bargaining power. Only since 2009 can workers in the electronics industry seek union representation beyond the firm and that is only allowed at a regional level. Private sector trade unionism remains very low in Malaysia and workers rarely engage in any kind of significant collective action across industries.

As unemployment dropped to the low single digits in the 1990s, the state agreed to increase labor supply by allowing for the importation of foreign workers, fearful that MNCs might relocate outside of Malaysia due to increasing wages and labor power. While the additional supply initially suppressed wage growth, it also offered employers a different system of labor control (Malaysia has significant severance policies for local workers). Foreign workers are subject to a single two-year visa with the possibility of an additional one-year renewal. Primarily from Nepal, Bangladesh and Indonesia, foreign workers tend to have poor English language skills and thus segregated on the work floor. In 2009, foreign nationals comprised 30 % of Penang's operator and plant assembly workers (MoHR 2011).

Henderson and Phillips claim that the ready availability of foreign workers in conjunction with the industry's shift to contract manufacturers explains stalled upgrading in Malaysia's electronics industry. Malaysia's migration policy has offered local manufacturers a continuous supply of low skilled, foreign workers that allow for the maintenance of labor-intensive activities, buffering them from Chinese competition. Given the surplus supply, firms do not have an incentive to invest in labor saving activities, wages remain low and capital is never substituted for labor. Technology advances and firms miss an "upgrading window" as newer skills and processes relocate to more knowledge-driven states (Henderson Phillips 2007). Yet I argue this is not, or not solely, the case.

3.4 Local Resources, Firm Capabilities and Volatility in Penang

Flexibility, not supply-side policy is the dominant market dimension

Given the highly dynamic nature of the electronics industry, particularly the semiconductor subsector, it is not surprising that managing the rapid pace of technological and market change is a key challenge to sustaining either a firm's or the Penang cluster's success. Field interviews, however, revealed a clear mismatch between policymakers and mangers in how this process evolves. Policymakers are focused on supply-side issues; how to drive value-added through human capital interventions, education and skill building, or generating new technologies through building research institutions or continuing to attract more frontier technology MNCs. The relative abundance of resources seen in Penang speaks to policymakers' past success in generating new institutions. Their present focus builds on these policies. How can they better coordinate firms and research institutions as evidenced in the CREST initiative? What new resources do they need to invest state funds in; should it be photovoltaic assembly or polysilicon production? What new shared testing resources should they build? What part of the LED supply chain do they need to attract?[30]

While supply-side issues, especially the supply of skilled design engineers, are very important to managers and all support private-public initiatives such as CREST, the most salient point that emerges from the firm interviews is the acute awareness of product and demand volatility—an issue never mentioned by any state official. Managers at twelve of the thirteen firms studied for this project focused discussion on how time, flexibility and volume demands shape their firm strategy, whether assembling products,

[30] Malaysia's 2010 Economic Transformation Plan outlines 15 entry-point projects (EPPs) in the electronics industry with an estimated public investment of RM 8.5 billion (US$ 2.8 billion) by 2020. (ETP 2010, p. 394)

building equipment that goes into assembly or designing or manufacturing semiconductors used in short-lived products. While aware of technology, their day-to-day activities are targeted on reducing uncertainty in a rapidly changing field. All the managers talk about increasing specialization or developing a niche in the market that offers their firm stability. Managers describe their specialty in terms of solutions--a product or service that helps their customers address rapid change, whether technological or market driven.

As seen in Figure 5, twelve of the thirteen firms interviewed directly confront volatility in the everyday running of their businesses[31]. Managers at local assemblers and back-end wafer processors (Firms A, B, C and D) state how they must deliver products 'yesterday' and how the increasing variety of products and the need to quickly ramp production along with short notice order changes are normal affairs. They would like to invest in automated equipment to meet high demand but fear losing their investment if the product is not successful or the customer leaves for a competitor. Managers at buyers believe that assemblers automate certain processes only when technology requires it, not when there is a choice or possibility of using labor[32].

The assemblers' need for flexibility is not a surprise to the managers at the local machine and jig builders (F, L, M and I). They see that their business as one to design and deliver equipment that optimizes flexible assembly and test, but often in the form of semi-automation to keep costs low. They term this strategy appropriate for the way products are assembled and tested in Penang, a strategy that we shall see later in Section

[31] Company names are anonymized in keeping with the confidential nature of the data discussed. Appendix 1 provides relevant descriptive information
[32] MNCs interviewed are buyers of domestic assembly and test firms

5 leads to market success in other export-oriented Asian countries. Managers at companies E, H and K work one level higher, focusing on the design of semiconductors and products for the highly dynamic computing and wireless industries marked (plagued) by extremely short product lives. Managers at Company J offer a different solution to address flexibility, designing programmable logic chips that increase product assortment through late stage differentiation. Company G is the exception manufacturing increasingly customized scientific and measuring equipment under relatively stable demand conditions. Given the implied focus on flexibility and the degree of specialization seen in this regard in Penang, one could easily substitute 'flexibility' for 'semiconductor' to describe Penang's cluster economy. While policy is directed towards supply-side issues, the private sector is entirely demand-driven.

-----------Insert Figure 5 here-----------------

Assembly and test firms dominate Penang

As noted in the ETP study depicted in Figure 4, the vast majority of, as well as the earliest, firms in Penang are principally in electronics assembly and test. Of the twenty-five largest MNC plants in Penang in 2008, twenty-one had assembly and test operations. The top fifteen largest local electronics firms by headcount all had principal operations involved in assembly and test[33]. Plant operators, assemblers and technicians comprise 69% of the state's total manufacturing workforce[34]. Assemblers' tenure, size and

[33] Firm rankings were derived from Athukorola (2011)

[34] Estimated from the Malaysia National Employment Returns (2009) and Penang Economic Monthly Outlook (2011)

relationship to frontier technology MNCs have long made them the natural candidates for upgrading. Conversely, other scholars see them as exploitive, low-margin enterprises that compete away profits leaving scant resources for future investments.

Multinationals helped establish the local assemblers either formally through a 'vendor development program', an outright sale or informally by supporting an ex-employee entrepreneur. The most recent assembler was spun out of Company H five years ago. In all cases, the MNC served as a first customer and would finance the early operations through extension of credit for the equipment being outsourced or by issuing purchase orders that an entrepreneur could use to secure loans from local lenders. All firms resulted from MNC efforts to outsource previously in-house assembly and test with the express goal of reducing fixed costs. Company K, a leading global semiconductor company, is the only exception in the sample; it purposely retains assembly and test to help iterate new products being developed locally. Company H also believes in local iteration, but chose to outsource the operation while maintaining a minority equity interest. All four local firms (A-D) sell mainly to foreign MNC buyers. With the exception of the youngest firm, the firms do not conduct product development.

Local managers claim that constantly changing orders require a different set of work practices. A senior manger commented on another company, "In May their bookings went down 30%, in June they went down another 30% so they retrench workers and in July they spike up--60%. In one month they make up what they lost in two months"[35]. The American Malaysian Chamber of Commerce, the parent organization of

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[35] Head of Inari Technology commenting on anonymous company, Oct. 8, 2009, http://www.youtube.com/watch?v=AY_9pbUOYDo

the Malaysian Electronics Industry Association (MAEI) states the annual turnover rate for production operators in the electronics industry is 15 to 50% (MAEI 2010).

All five firms (A-D and K) use linear assembly operations that require operators to conduct short-duration, singular tasks. There is little training of workers and firms scale by adding workers and assembly lines on an as needed basis. The four firms would like to improve their high mix/low volume selection of products, but they were still producing mainly high volume/low mix products. All companies employ similar human resource systems to manage a Taylorist production system. Asked whether firms might change these practices, a senior official of an employer association commented, "One (the same) type of HR system in all companies makes it tough to change"[36].

To meet the volatile demand, all five firms employ foreign workers, either directly or indirectly through labor suppliers (firms often used both practices concomitantly). Malaysian law sets a ratio of local to foreign workers, but firms can bypass laws with outsourced workers provided by a labor agent, "even the government-owned companies have foreign workers on their floors"[37]. Registered foreign workers comprise 30% of plant operators and assemblers in Penang (MoHR 2011), though the percentage is likely quite a bit higher due to the informal outsourcing sector. Managers at the assembly firms have developed a preference for foreign workers because the workers have no local attachment to distract them, "if we need them to work on Saturdays and Sundays, they come"[38].

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[36] Interview with board member, employer association, August 9, 2011
[37] Interview with senior official-federal government, July 28, 2011
[38] Interview with senior manger, assembly & test, August 10, 2011

Flexible labor, not low wages prevail in many assemblers

Henderson and Phillips' (2007) argument may be consistent with those scholars that see upgrading as a sequential process but their argument rests on the key assumption that higher wages will force firms into higher value-added activities. Yet, the four assemblers in the sample paid high wages to unskilled workers for activities no different than those prevailing when Henderson and Phillips examined the industry--tasks that involve only one to three activities such as placing ICs in jigs. Experienced workers earn US$400-600 per month (1,250-1,800 Malaysian Ringgit (RM)) for six 8-12 hour days of work per week. Figure 6 shows 2009 wage distributions for manufacturing workers in Malaysia. Despite the claims of Henderson and Phillips, foreign and local workers from the sample firms are among the top quartile of all earners within their occupation in Malaysia and foreign workers within the top decile of non-nationals. Even median wages across the entire Penang sector are 110% of the national average (MoHR 2011). This is not to imply that that high wages overcome Taylorist work practices. Yet, we can conclude that at least for better performing firms, wage costs are not the primary driver of firm strategy. Employee churn however is a different matter.

----------------Insert Figure 6 here --------------------

As noted previously, annual turnover averages over 25%. Given the relatively high wages in Penang and an informal agreement among firms to limit poaching[39],

[39] Managers mentioned that assembly firms have informal agreements that limit worker mobility. An ex HR-manager at a disk-drive company referred to the practice as agreeing to not pay for

workers rarely search for better paying jobs within the industry. A more telling indicator of the motivation to maintain labor market flexibility is in a recent effort by Malaysia to limit the importation of foreign workers to drive skill building and encourage upgrading—along the lines of Phillips and Henderson's argument (Gooch 2009). In opposition, the MAEI has filed a position paper to defend the practice; "MAEI is supportive of the government's efforts to increase the level of automation in all the sectors of the economy for reasons of enhancing skills sets of workers, and to reduce the dependency on foreign workers. Members of MAEI group have continuously implemented productivity improvements programs, on a yearly basis, to remain competitive. These initiatives have reduced the dependency on manpower. However, for the reasons stated above (turnover), a certain level of foreign ratio is still needed for expansion and in order to ensure stability of their production lines" (MAEI 2010). In other words, the better employers are happy to pay higher wages but they require a flexible labor supply (foreign workers) to scale up and down to meet demand, particularly in light of the more restrictive labor market policies on local labor. Like the case of midcentury Italy, using foreign workers limits the expansion of assemblers' fixed-costs (severance liabilities). Flexibility is the necessary condition for Penang's assembly & test success, not low wages.

Management and technology capabilities are high

A trade association board member, with extensive senior MNC management experience overseas, explained why MNCs choose Penang, "80 to 90% of electronics

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experience, "if a worker is paid 1,500 ringgit a month after five years and goes to another company, she will start at 800 ringgit like any new worker" production is automated. This business therefore requires skilled managers and good leaders. They need to understand a multinational's capacity, building safety and standards. Malaysians have become very good at dealing with this kind of business; discipline in Penang's factories is very high. Most multinationals seek Malaysians because of this to send to their overseas factories. Multinationals come to Penang because all new companies meet targets; people make it happen."[40]

Another interviewee noted that Intel, one of the original MNCs in Penang, routinely sends all of its global assembly and test managers to Penang for training. He stated that at one point in the last decade, Malaysian managers were running all or almost all of Intel's non-fab production operations globally[41]. A senior state official commented that part of the supply-side issues he faced was convincing senior Malaysian MNC managers and their families who had been relocated to the United States to return after their tour was over[42]. While much of the return issue is tied to Malaysia's Bumiputera affirmative action policies, it also can be seen as a compliment to Malaysian management that they are so readily absorbed into senior management positions overseas.

The local assembly and test sample firms use appropriate technology, but they are not at the technology frontier. Semiconductor packaging is the process of preparing an integrated circuit (IC) for connection to a substrate, usually a printed circuit board. The technology milestones of this process, in order, are: surface mount technology, flip chip on die/board and wafer-level packaging (Topper 2009). None of the sample firms yet handle wafer-level packaging, which is the leading edge of semiconductor packaging.

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[40] Interview with board member, employer association, August 9, 2011
[41] Interview with senior manger, wireless semiconductors, August 5, 2011
[42] Interview with senior government official, July 29, 2011

The newest company (B) uses flip-chip mounting and wafer-sort processing—the next highest level of packaging technology. The remaining firms employ wire-bonding techniques, a technology that has been available for over a decade.

However, as seen in Figure 7, semiconductor assembly and test is a highly complex process involving three major stages: wafer processing, assembly and final test. Wafer processing alone involves seven steps that require taking complete semiconductor wafers (200-300mm wide), testing the quality of the wafers, thinning the wafers and then sawing the wafer into individual dies (at a level as small as 55 microns). The assembly process, which involves over twenty steps, incorporates the die attach and wire bonding (or flip-chip) attachment process and the final testing process involves a further six steps (with a capacity of handling tens of millions of chips per month). The entire process is moderately capital intensive, on the order of US$20-50 million to equip a high capacity plant.

------------Insert Figure 7 here---------------

While much of the technology is embodied in equipment, firms must maintain sufficient technical competence to design processes, set-up, calibrate and maintain highly technical equipment and continuously seek ways to optimize their processes. In addition to managing a flexible labor supply, process engineers must incorporate shop-floor product flow systems with statistical analysis to maintain quality control. All firms draw upon Malaysian university graduates for the necessary process and industrial engineers to manage and develop their operations. Managers at assembly and test firms did not have the same complaint about a skills shortage as those MNC firms engaged in IC design.

Financial returns, barriers to entry and no desire for risk

With regard to financial performance, the Malaysian semiconductor industry's net profits have averaged close to 5.0% on an annualized basis over last six-years, 2005-2010. While profits may be less than semiconductor firms in advanced industrializing nations, Malaysian firms manage the well-known cyclicality of the semiconductor industry extremely well. At the worst of the global recession, the industry still maintained a 3% profit and at the peak of the industry in 2007, the profit was 6.5%[43]. The small variation demonstrates both the flexibility firms are able to build into their operating models and also the imposition of an upper bound on profits. This upper bound is often construed to be an example of a low-value added model. Rather the consistent profits and the higher return on assets in this sector speak to a highly sustainable model with reasonable returns.

The value chain profit curve is often used in policymakers' briefings to depict moving up the value chain. As seen in Figure 8, production is at the nadir of the curve with design and R & D at the top. The implication of this curve is that production is a low-margin affair where firms must compete away profits to exist; firms either have to move up one direction or the other or face never-ending competition. But we have seen that the Malaysian assembly and test firms, who are squarely in the production category,

[43] Source: ISI Emerging Markets and Compustat

have not lost money in the last six years. Moreover, their revenue continues to grow. Financially and operationally, Malaysian assemblers have found a local equilibrium.

-----------Insert Figure 8 here----------------

Malaysia's policies, intentionally or unintentionally, provide the resources that allow these firms to build significant barriers to entry. Henderson and Phillips were correct to theorize that Malaysia's labor market policies had something to do with Malaysia's upgrading status; it just wasn't the perpetuation of low-cost labor-intensive activities (though certainly some still remain). Instead, the steady supply of surplus workers with limited labor rights allows Penang's assembly firms to ramp up and down as fast as necessary. This ability to scale alone creates a significant barrier to entry.

Penang's long-standing involvement in assembly and test has built enormous skills in senior local managers that are now being transferred to younger generations. These skills may be limited to assembly and test, but they are of sufficient quality that frontier MNCs still seek them out. The proximity of local companies to iterate appropriately priced semi-automated and automated equipment for their operations gives them a competitive advantage in countries that are trying to compete on wages alone.

The commitment of Penang to training and education ensures a supply of technicians and other medium skilled workers to assimilate new technologies as they become available. Management routines have evolved to provide both meaningful direction and discipline in Penang's plants. Management continuity allows firms to develop tacit skills within each step of the manifold complex processes involved in back-end wafer processing. Malaysia's desire to attract frontier MNCs also gives production managers access to leading edge technologies. As upgrading theories might predict, Penang has a virtuous cycle. What they did not predict was that this cycle resulted from a combination of volatile market demand and state policies and that it would lead to a local equilibrium.

Given the sustainable profits and the capabilities that allow these firms to compete globally, why do we not see them move along the value chain? Why do they appear to be so locked-in? Penang's assemblers still have a large dependence on a single or small group of MNC customers. They do not believe the risk of losing this customer to be worth the effort to take on development tasks. The manager of the best assembler (B) stated that co-production would be the highest activity he would be willing to take on and that would happen only if the major customer was the partner. Malaysian assembly and test firms also face implicit volatility, in addition to the explicit volatility that we have seen in demand markets. The standardization of production networks was theorized to allow participants forward visibility by insuring a broad spectrum of customers. Instead, at least in Penang, the increasing specialization of assemblers has yet to overcome the threat of substitution, which continues to limit capital investment in novel, higher risk activities.

Managers are comfortable in their niche; the niche is competitive but not cutthroat. The vast majority of the larger local firms are publicly traded on the Malaysian Bursa, which makes their activities subject to scrutiny. Flexible assembly and test is a known factor in Penang with very reasonable returns. Malaysia's policies have been good to assemblers; they know this and stick to their competence. Profits are sufficient to sustain their growing operations, but not ample enough to take chances on higher risk activities. These activities, the ones that involve local research and development, design and marketing must come from elsewhere—new entrants.

3.5 Volatility Provides an Alternative Set of Hypotheses to Explain Upgrading

Notwithstanding all the resources thrown into the Penang cluster, the local firms that have successfully navigated the riskiest set of activities (R & D, product development) as measured by revenues and overseas market penetration are the machine builders. Penang's dependence on flexible production created an environment that required process optimization. The increasingly volatile nature of semiconductor markets coupled with advancing technology opened a space for novel means to handle, inspect and test semiconductors. The two companies in the sample (L, M), along with two others identified late in the interview process are known as world-class firms. Their founders all worked for large MNCs in assembly and test processes. The original entrepreneur in this market then served as a mentor to the younger entrants.

The machine builders understand the capital sensitivities of their local customers, working together to design appropriate equipment, often in the form of semi-automation. Penang's leadership in assembly and test has honed their product development to the point where they sell in all overseas markets, without discount to their American and European competitors. Customers claim their equipment just works better for what they do. None of these firms benefited from direct state help; they financed their start and ensuing growth through family, friends and operating cash flow. They all have operating margins in excess of 40% and two firms have gone public. These firms obviously benefited from the rich ecosystem in Penang. They specialize in a product that helps manage volatile production, but two of the founders made a point of saying that they like being close to the end-user because it reduces their uncertainty in iterating new products. The irony of their success is it may be the least likely place the state would have looked for winners. Their technology is highly applied to a local problem that only serves to reinforce the barriers to entry of the assemblers. Yet the machine builders have used Penang's legacy to good. It has given the cluster its first set of locally owned world-class firms.

The case of Penang illustrates how even in a location with all the resources for upgrading, in a location where the state continues to pour in new investments, supply-side policies can only go so far. Firms embedded in global production networks are shaped as much by demand-side issues, as by the resources locally available. As demand markets become increasingly volatile, firms continue to specialize to reduce the uncertainty brought about by such conditions. This is no different a strategy than semiconductor machine-builders take in advanced industrialized nations. These firms know that by specializing they can prosper in upswings, squirreling away the reserves for when the downturn ultimately comes. As Penang competes in a market with very little final domestic demand, it is subject to swings set in motion continents away. The reason that the local firms do not upgrade, is that the conditions found in Penang—flexible labor, skilled engineers, tacit skills developed over time, continued exposure to frontier MNCs—lend themselves to their present business model, not one that might put their entire operation at jeopardy.

The response of firms to the volatility exhibited in Penang leads us to a set of alternative hypotheses about upgrading. First, we need to advance a new understanding of the international economy in which volatility increasingly determines the division of labor, in place of (or addition to) the search for low wages. Second, adept firms select business strategies predicated on capabilities. In emerging states that support flexible labor market policies (which most do), capable firms opt to specialize in managing volatile demand as success creates barriers to entry, even with higher than market wages. Third, the volatility of many global industries (and respective production networks) leads to discontinuities in upgrading. Local firms rarely move up in GPNs from assembly to product development, whether by choice or competence. Volatility significantly dampens the presumed role GPN's play as a conduit for upgrading. High potential new firms either develop abilities that allow them to join the group of specialists in volatile production or they avoid the volatility of global production networks altogether, instead focusing on industrial or domestic markets. Fourth, in this regard, a firm's access to end-users is critical as it allows iteration of development ideas. Finally, the tendency of volatility to drive capable firms into a local equilibrium suggests that the present structure of global production will at some point inhibit the upgrading process it was intended to facilitate.

Should the state change its incentive structure in response to volatility? Malaysia has long tried to address its labor market policies, but it has repeatedly met with resistance, not from the electronics industry, but from the non-tradable sector—mainly construction and other local service providers. Malaysia has recently implemented a minimum wage and is currently considering an increase in the foreign worker levy, but most firms in Penang already pay higher wages. As we have seen, Penang need flexible labor to reduce the fixed costs of assemblers and is less concerned about wage costs.

As seen in the examples of the successful upgraders, the existing ecosystem offers distinct comparative advantages. Local machine-builders need assembly and test to iterate novel technology. Management skills continue to develop in competitive, time sensitive industries. Acknowledging the existing high capabilities within the cluster while working at the margin to raise costs for lower capability firms (by increasing foreign worker levies) may offer one path forward.

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3.7 Figures and Tables

Figure 1a: Increasing Scale and Scope Leads to Higher Volatility and New Production Architecture: *Flexible Labor Scaling*

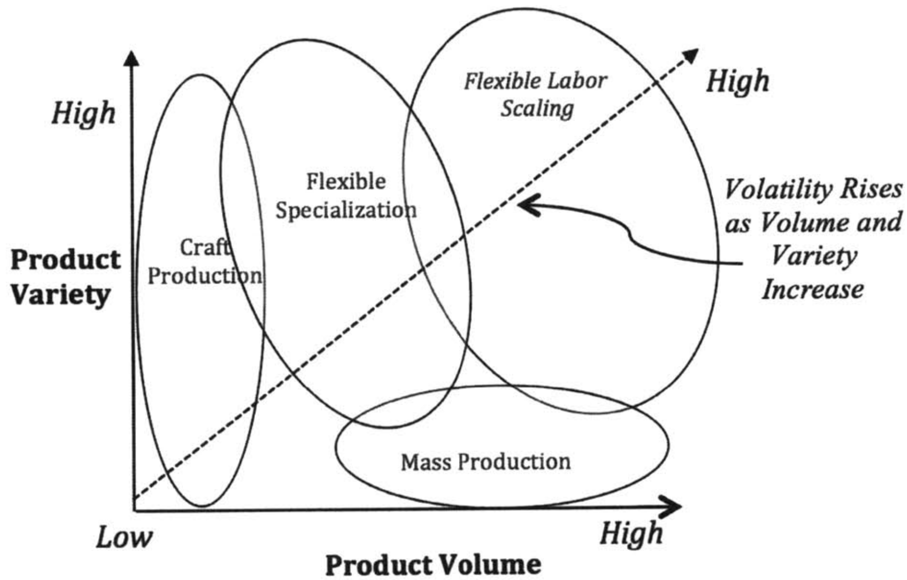


Figure 1b: Stylized Volatility By Production Architecture at the Firm Level

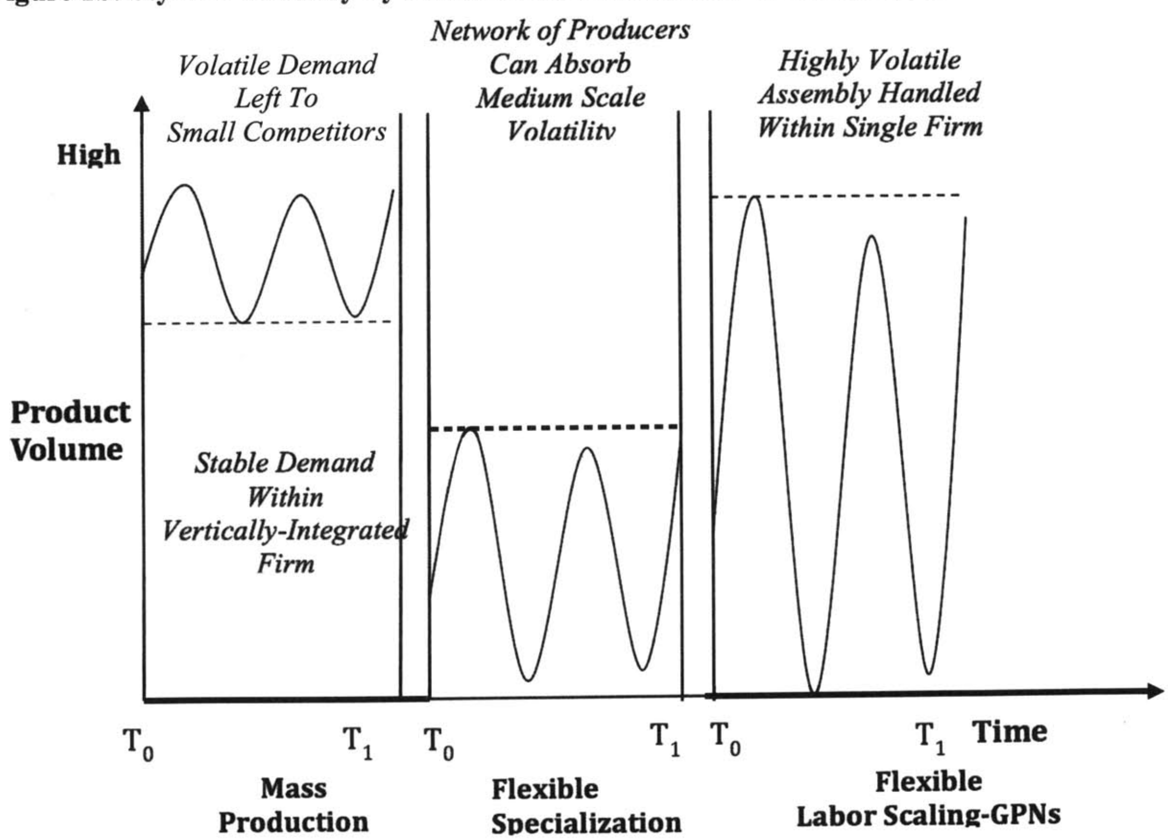


Figure 2a: Forecast Variation for CM Shipments of Typical HP Ink Jet Printer
12-Month Period Reflects Seasonality and Price Drop (Burruss and Kuettner 2002)

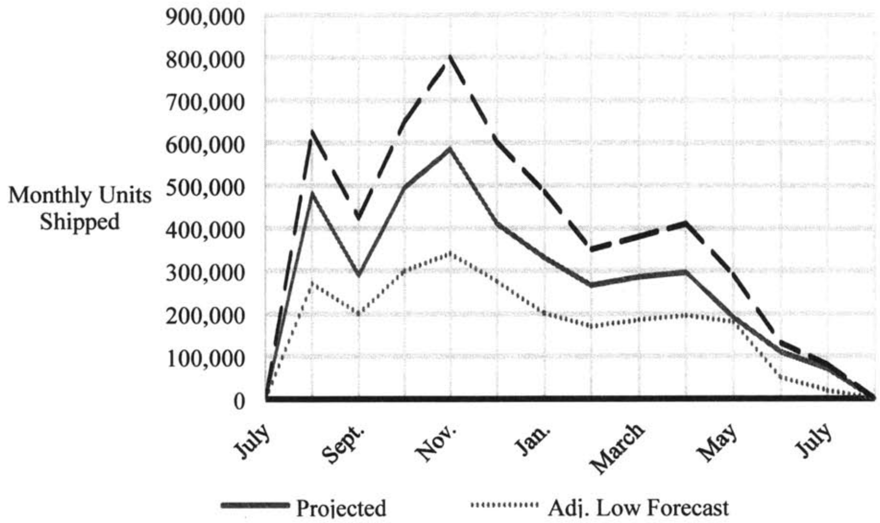


Figure 2b: Delivery Quantities of One Product through Three Echelons of a European Electronics Firm's Supply Chain
30 Week Period Incorporating Introduction and Maturity Phase (Kaipia et al 2006)

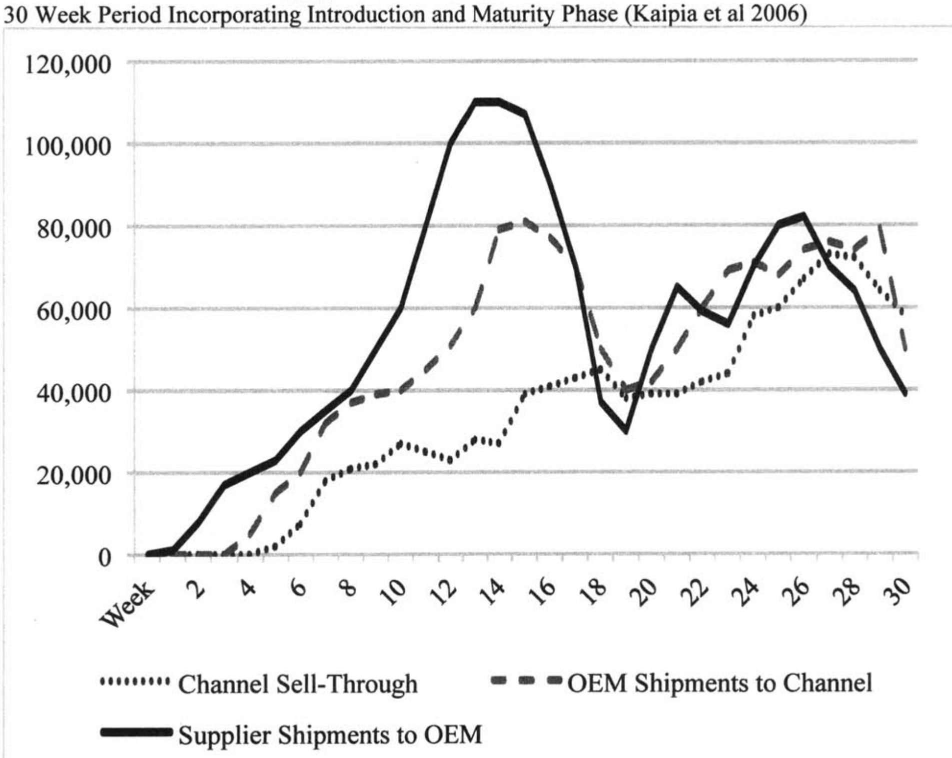
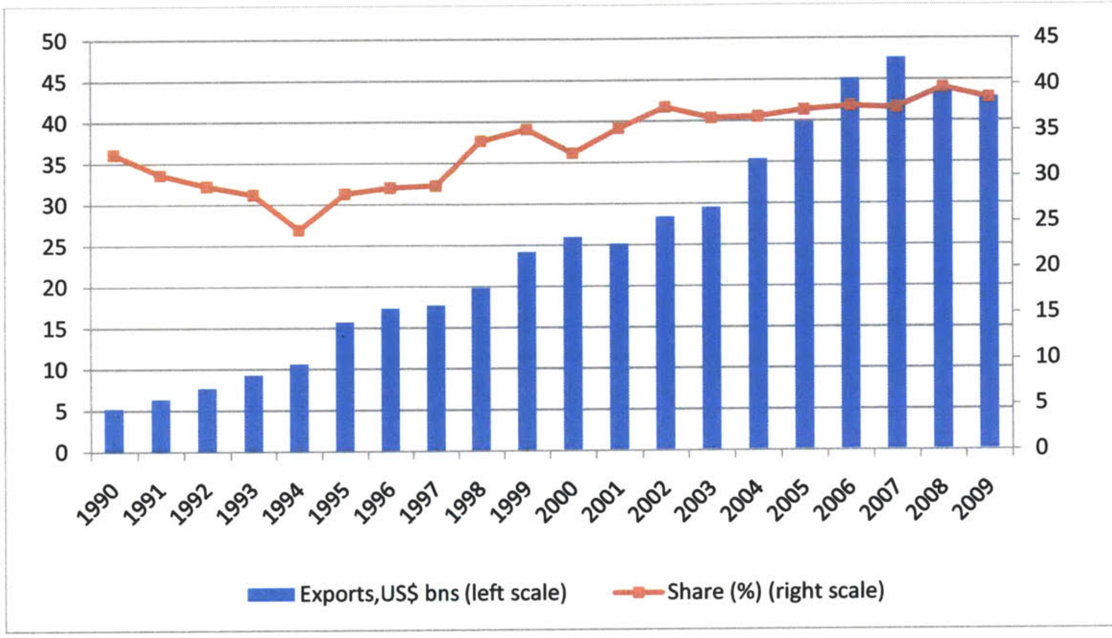


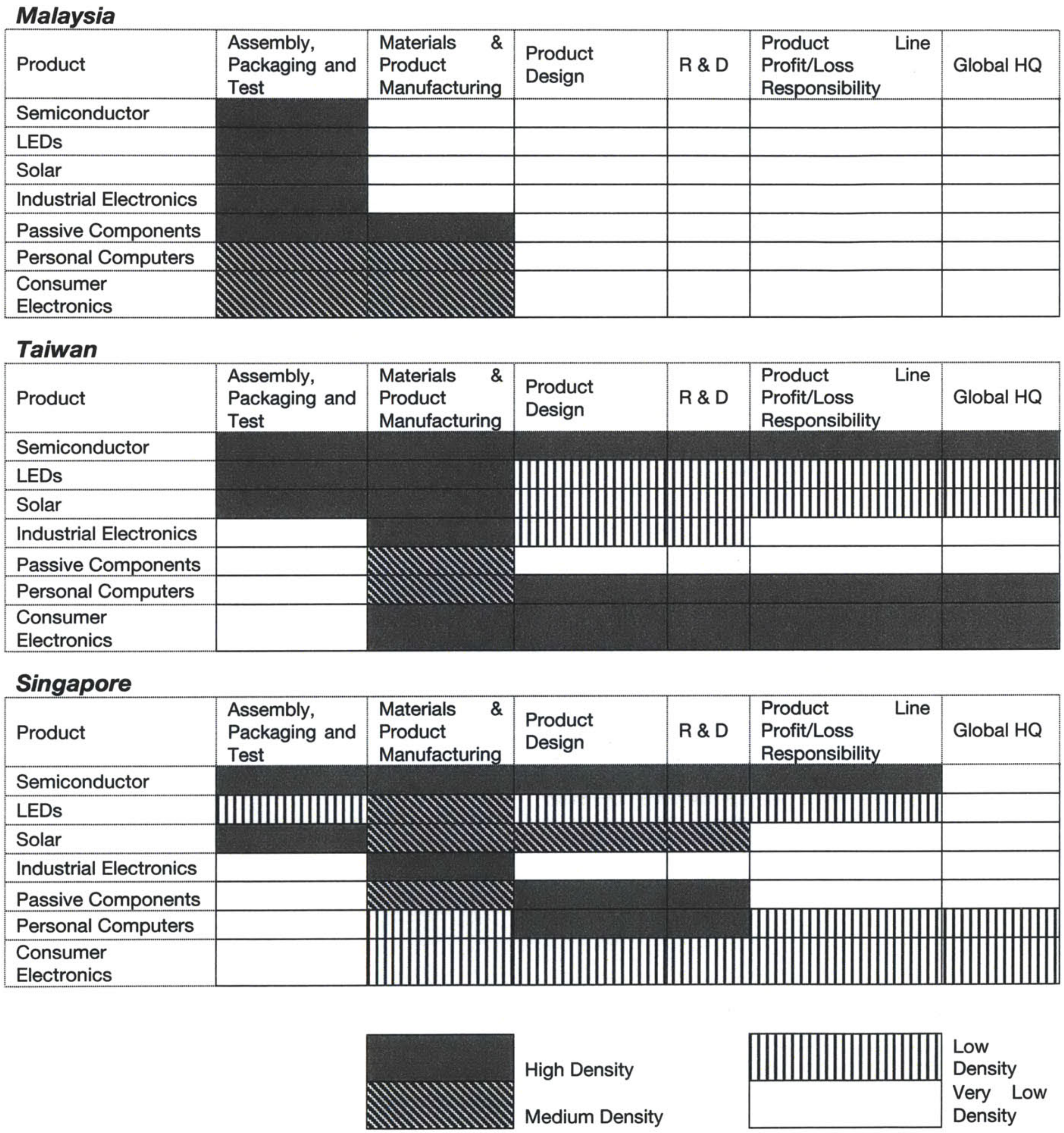
Figure 3: Penang Manufactured Exports 1990-2009 (Value in US$ Billions-left axis, Share of Malaysian Exports-right axis)



Source: Athukorola 2011

Figure 4-See Next Page

Figure 4: Task by Firm Density
Electronics Industry by Country
June 2011



Source: Malaysia ETP NKEA Report (2011)

Figure 5: Characteristics of Penang Sample Firms

Company	Activity or Product	Firm Age[1]	MNC or Local	Market Drivers	Draws on Local Institutions	Customer	Customer Location	Firm Strategy
A	Assembly & Test	39	Local	Low-Cost	Technician Training	MNC Buyers	Local	Cost Reduction
B	Assembly & Test	5	Local	Volatile Demand	Technician Training	MNC Outsourced	Local	Optimize around Flexibility
C	Assembly & Test	13	Local	Volatile Demand	Technician Training	MNC Buyers	Local	Optimize around Flexibility
D	Assembly & Test/Lead Frame	37[2]	Local	Volatile Demand	Technician Training	MNC Buyers	Local	Optimize around Flexibility
E	RF Wireless	6[3]	MNC	Product Development	Technician Training	Sells Direct	Global	New Products
F	Continuous Process Automation	5	MNC	Optimize Flexible Wet Fill	No	MNC Buyer	SE Asia	Flexibility and Reliability
G	Electronics Test Measurement	38[4]	MNC	Customized Equipment	Technician Training	Sells Direct	Global	Customization
H	Semiconductors	12	Local	Mature Technology for Quick Moving Industries	No	Niche Markets	Asia	Niche Markets
I	Micromachining	27	Local	Jigs for Flexible Assembly	CNC Training	MNC Buyers	Local	Iterate through Deployment
J	Programmable Logic Chips	17	MNC	Customizable Design	Design Training/Research Institute	Sells Direct	Global	Productivity
K	Semiconductors and Components	39	MNC	Frontier Design & Volatile Demand Assembly	Design Training/Research Institute	Sells Direct	Global	Frontier of Technology and Iterate Flexible Assembly
L	Vision Inspection Equipment	11	Local	Optimize Flexible Assembly	No	Sells Direct	Global	Iterate through Deployment
M	Test Equipment	7	Local	Optimize Flexible Assembly	No	Sells Direct	Global	Iterate through Deployment

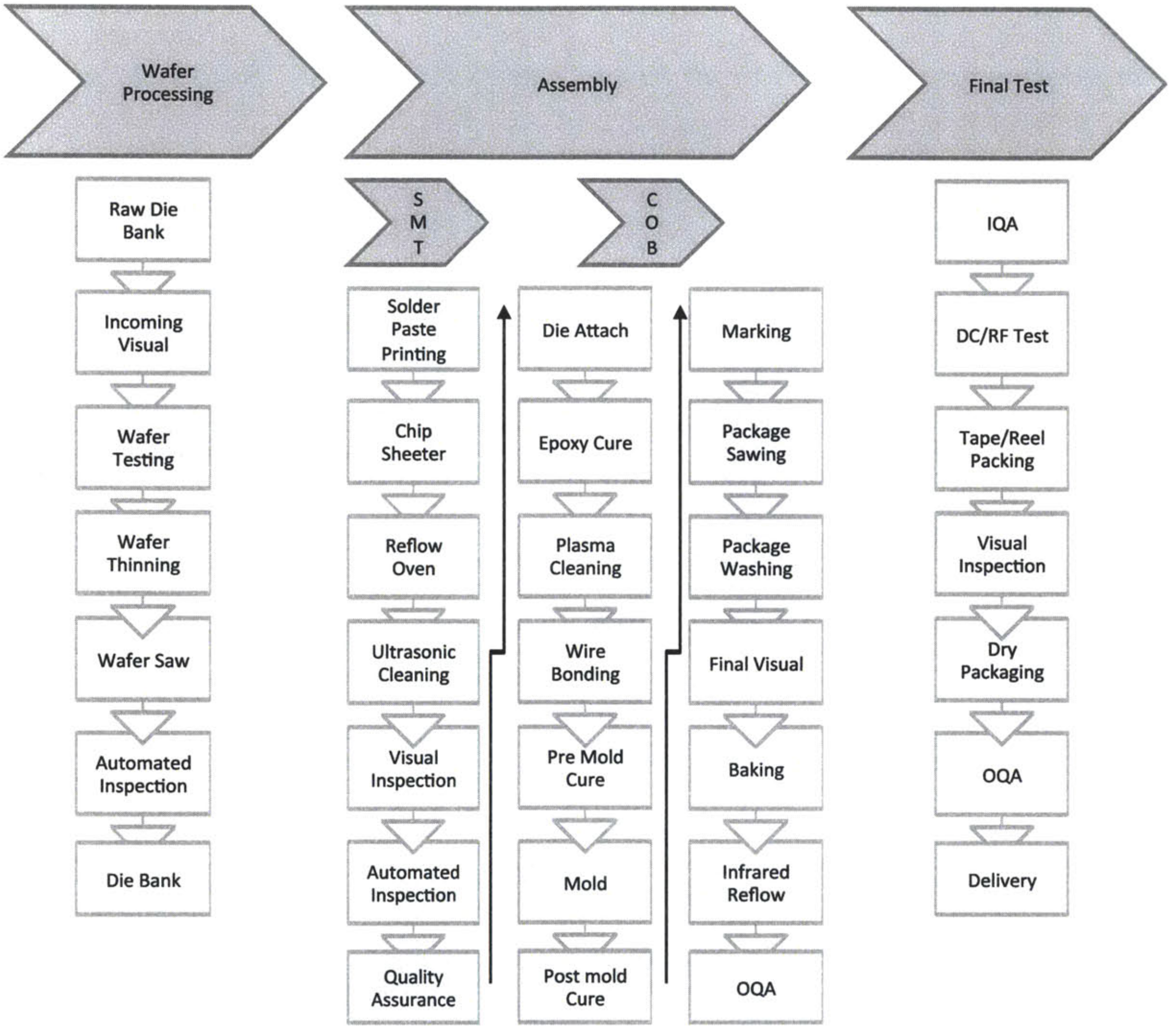
1--Since founding if local, since Penang branch founded if MNC

2-Prior to 1996 was a subsidiary of US MNC, now independent

3-Prior to 2006, part of US MNC

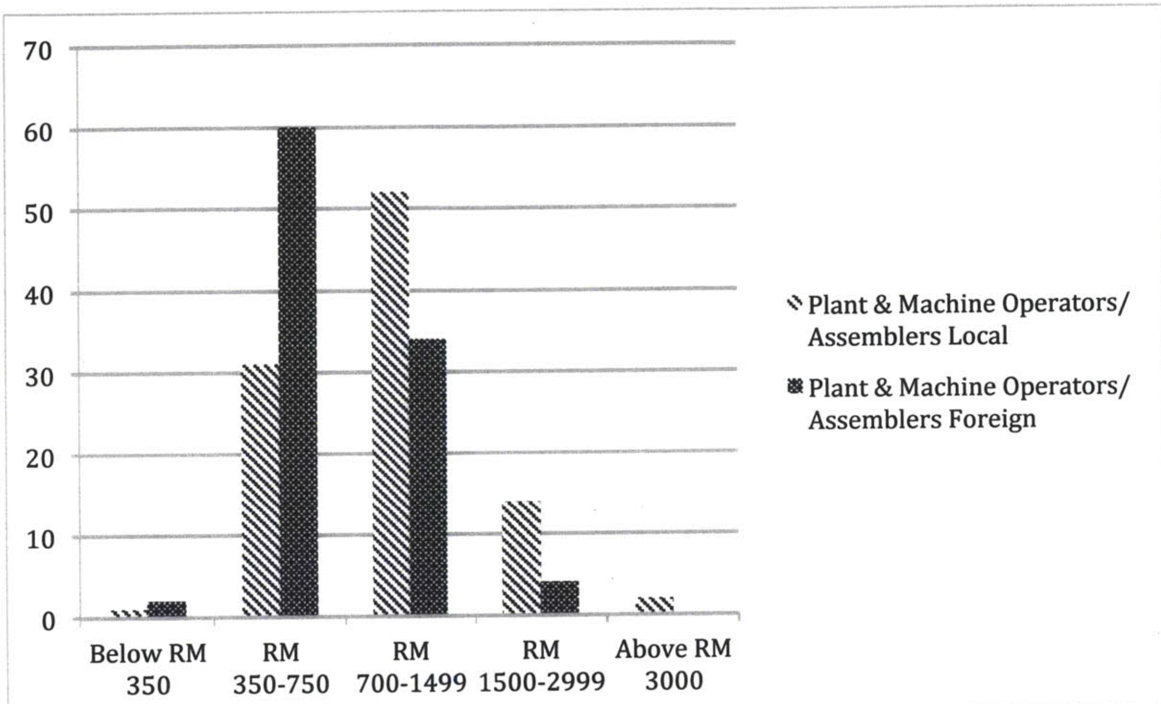
4-Prior to 1999, part of US MNC

Figure 6: Stylized Penang Semiconductor Assembly and Test Workflow Involves Complex Management Coordination and Technological Knowledge



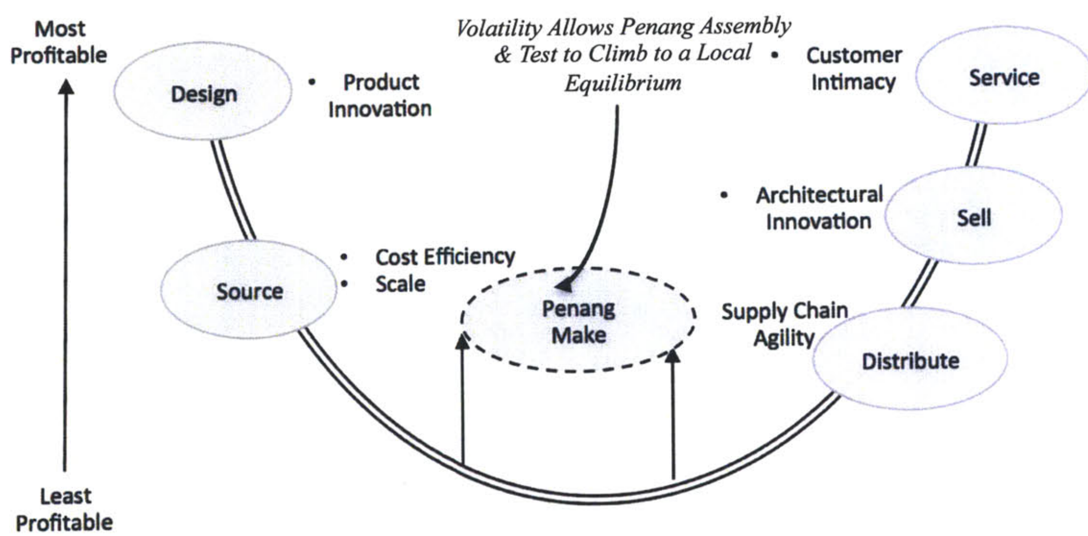
Source: Adapted from Inari Berhad Prospectus (2011)

Figure 7: 2009 Malaysian Wage Distributions for Foreign/Local Plant Workers



Source: Malaysia National Employment Returns 2009 (NER 2009)

Figure 8: Value Chain Profit Curve Make Assumes Race to the Bottom, Volatility and Local Resources Allow Penang Assemblers to Reach Local Equilibrium (Optimum)



Source: Adapted from Cisco IBSG, Cho (2009)

Appendix 1: Table of Interviewees and Additional Research Methodology

Distribution of Institutions/Firms and Persons Interviewed

Federal Government			
Branch		*Role*	*Number*
Prime Minister's Office			
	PEMANDU	Senior Manager	1
	STI-Human Capital Development	Senior Manager	1
Ministry of Human Resources		Senior Manager	1
Sovereign Wealth Fund		Regional Directors	2
Socialist Party		Elected Official Regional Head	1
State Government			
Regional Development Corporation		Senior Manager	1
Trade Unions			
Malaysian Trade Union Congress (MTUC)		Senior Official	1
Employer Associations			
Malaysian American Electronics Industry		Board Member	1
Federation Malaysian Manufacturers		Senior Official	1
World Bank			
Regional Experts		Staff Members	2
"		Academic Advisor	1

Firms

Company		*Type*	*Role*	
A	Local	Assembly & Test	Senior Manager	1
B	Local	Assembly & Test	Senior Manager	1
C	Local	Assembly & Test	Senior Manager	1
D	Local	Assembly & Test	Senior Manager	1
E	MNC	RF Wireless	Local Senior Manager	1
F	MNC	Continuous Process Automation	Expat Senior Manager	1
G	MNC	Electronics Test Measurement	Team Leaders	2
H	Local	Semiconductors	Senior Managers	2
I	Local	Micromachining	Senior Manager	1
J	MNC	Programmable Logic Chips	Expat Senior Manager	1
K	MNC	Semiconductors and Components	Corporate Affairs	2
L	Local	Vision Inspection Equipment	Senior Manager	1
M	Local	Test Equipment	Senior Manager	1
			Total	29

This paper draws on four weeks of field research in Malaysia, two weeks in Kuala Lumpur in July 2011 and two weeks in Penang in August 2011. Industrial policy in Malaysia is created through a central planning department, the Economic Performance Unit (EPU) in the Prime Minister's Office. The EPU considers policy options in consultation with federal ministries, state governments, the private sector and trade unions.

To understand this broad array of interests and motivations, I conducted twenty-nine interviews with a diverse group of senior decision-makers within the state, multinational corporations, local firms and employer/worker associations. On the federal level, I interviewed senior mangers at PEMANDU, a recently established federal agency to oversee the implementation of Malaysia's industrial policy, the Ministry of Human Resources (MoHR), the state's Human Capital Section and a Sovereign Wealth Fund.

On the regional level, I interviewed active and retired senior managers from local development corporations and training institutions. To assess the role of associations in shaping policy, I interviewed elected and appointed officials at employers associations and trade unions. Finally, I interviewed senior regional officials with the World Bank for internal validity.

To understand managers' views on upgrading, I wanted to sample the breadth of firms that either were previously or are presently identified by policymakers to have been (be) a candidate for upgrading or have upgraded already. Key policy makers were asked for names of local and MNC firms they believe represented firms that a) have failed to upgrade, b) have successfully achieved higher value-added activities and c) have the highest potential for upgrading their present activities[1].

Of the thirteen firms selected, five firms were chosen due to the interviewees' consensus view of upgrading status and five randomly selected among those where informants' views differed. Three interviews of senior managers generated names of unfamiliar firms that appeared noteworthy for their upgraded capabilities, yielding three more cases. The interviewees for this project, as well as additional methodology are given in Appendix 1. All interviews lasted from 2-4 hours and were conducted in open-ended format. No state officials were present during interviews with firms.

As additional evidence, I compiled and analyzed data including financial statements of Malaysian semiconductor firms publicly listed on the Malaysia Bursa and secondary ACE market for the period 2006-2010 and global semiconductor firms for the same period as compiled by Standard & Poor's. I examined wage, occupation, skill and demographic information from the MoHR's labor and wage survey (National Employment Returns) for the period 2007-2009. I also utilized survey data compiled by the Federation of Malaysian Manufacturers from 2007-2010.

4. Learning by Building: Complementary Assets and the Migration of Capabilities in U.S. Innovative Firms[44]

This essay uses a sample of production-oriented start-up firms that licensed their core technology from the Massachusetts Institute of Technology (MIT) from 1997-2008 to track the growth trajectory of 150 firms and conduct in-depth interviews with senior managers of a subset of these firms to understand the critical factors in their scale-up process. Because these firms' innovations are often at the technological frontier, they generally need highly complex, advanced manufacturing capabilities that require more time and capital to scale than non-production firms. In this way, they provide an important test of the U.S. innovation ecosystem and its ability to support such firms. We find that the U.S. provides fertile ground as they prepare to enter the commercialization environment, iterating prototypes, developing pilot production facilities, and in some cases entering into commercial production. However, when these firms need to take the significant leap into larger-scaled processes, both the need for additional capital as well as the search for production capabilities pulls many firms to move production abroad. This movement, which often entails the temporary relocation of key personnel with tacit knowledge, leads to the migration of key skills, capability generation and knowledge development outside of the country. We argue the migration of these capabilities has two

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[44] This paper was co-authored with Elizabeth B. Reynolds and Joyce Lawrence. We would like to thank the Kauffman Foundation for their generous support of this research as well as members of MIT's Production in the Innovation Economy (PIE) Scale Up team, Olivier de Weck, Richard Lester, Fiona Murray and Charlie Sodini for the excellent discussion and feedback on scaling innovative companies. We want to thank in particular Suzanne Berger, Richard Lester, Richard Locke and Rachel Wellhausen for their very helpful comments. Finally, we thank Jonte Craighead, Clara Liu, Sam Packard and Yun Hwan-Sul for their research assistance.

consequences: one, expected returns to public investment in innovation are not fully realized and two, the movement offshore of vital capabilities may put at risk the U.S.'s future capacity to innovate.

4.1 Introduction

As policymakers in the U.S. debate how the economy can regain its vitality following the Great Recession, many see innovation as the key to prosperity. The U.S. excels in product, service and business model innovation, particularly where this innovation leverages technological advances. The U.S. is also one of the leading countries for venture capital financing[45], which supports the creation of many innovative start-up companies every year. While innovation by young firms is common today, it represents a relatively new economic model. Large vertically integrated firms with centralized R&D were once the primary drivers of innovation in the U.S. However, within the last thirty years, we have seen smaller, entrepreneurial firms within innovation ecosystems develop into a large source of innovative activity (Lerner 2012). This shift from large firms that moved ideas to products within the boundaries of the firm, to a model of smaller, entrepreneurial firms working in conjunction with multiple external innovators and partners to generate new inventions and technologies has become a vital source of innovation and economic growth for the country.

Given the critical role young firms play in the country's innovation engine, it is important to understand the process and pathways by which they scale their innovations and technologies. The decisions start-up firms take early on will have consequences for

[45] The U.S. is second only to Israel in venture capital as a percentage of GDP (OECD 2011).

how and where the firm grows, if at all, in the future. Unlike large, vertically integrated firms, these smaller, entrepreneurial firms often seek out specialized complementary assets, such as distribution or manufacturing capabilities, to help them avoid sunk investments at the early stages of growth (Gans and Stern 2003; Teece 1986). The need for complementary assets pushes these firms to look outside their boundaries to external actors in order to find the critical inputs they need to scale. Young firms that scale novel technology often manage loosely codified knowledge that requires significant iteration to bring a product to market. This iterative activity, which generates significant new capabilities, often occurs across firm boundaries. With whom and how does this activity occur? Does it matter? We argue the nature of this iterative activity, where most of the knowledge is at the technological frontier, is critical to the innovation process and has important implications for national innovation capabilities.

There is an extensive strategy and innovation literature that examines how young firms choose to profit from their innovations[46]. There is also an equally large economic geography literature that explores the role agglomeration and external economies play in enabling such activity[47]. While these literatures address overlapping issues, they differ in their unit of analysis, with strategy focusing on the firm and economic geography on industry clusters. There is very little scholarly work that seeks to connect firm-level decisions with long-term national competitiveness outcomes. This research brings together analysis of firm scale-up strategies with a broader perspective on innovation and economic growth, and identifies potential unintended consequences for the American innovation system.

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[46] (Chesbrough, Birkinshaw, and Teubal 2006) give an excellent review of this work on the occasion of the 20th anniversary of Teece's seminal work on profiting from innovation.
[47] See (Delgado, Porter, and Stern 2012) for a substantive review of this literature.

Our research explores how innovative young firms develop and scale their novel technologies, and the critical factors that shape that process. What are the implications of firm scale-up strategies for the U.S. innovation "ecosystem" and for American economic growth more generally? Much has been written recently about weaknesses in the U.S. innovation ecosystem, whether from the point of view of the loss of capabilities in the "industrial commons" (Pisano and Shih 2009, 2012) or regarding the limitations of the financing model for these small, entrepreneurial firms (Lerner 2012). Building on existing theories of innovation strategy, our interviews offer empirical examples of how firm-level decisions highlight weaknesses in the present American innovation model. In particular, our research demonstrates how advanced capabilities developed over long periods of time are pulled offshore endangering future economic activity and innovative capacity in the U.S. We examine the early stages of scale up for a sample of highly innovative firms that are just entering or soon to be entering the "commercialization environment" (Gans and Stern 2003).

Our work contributes to the literature on commercializing innovation in two ways. First, we combine existing frameworks with a more nuanced understanding of product development stages. We emphasize how the search for complementary assets for complex technologies in production industries often occurs at a time when knowledge is loosely codified. Second, we extend this work into the area of economic geography by examining the consequences of firms' innovation strategies for the larger innovation ecosystem. The market for ideas as described in Gans and Stern (2003) influences firm strategy, but it also has the potential to alter future capacity for innovation across regions. While we acknowledge the robust local availability of inputs for early stage innovation that other scholars have noted (Delgado, Porter, and Stern 2012; Moretti 2012), we find evidence that foreign actors play a larger role at later stages of development. This trend disputes the conventional wisdom that the U.S. can maintain a virtuous cycle of innovation.

Using a sample of 150 production-related start-up firms that licensed their core technology from the Massachusetts Institute of Technology (MIT) from 1997-2008, we track their growth trajectories. In order to understand the choices the firms made along these trajectories, we conducted in-depth interviews with senior mangers of a subset of these firms. Because these firms' innovations are often at the technological frontier, they generally need highly complex, advanced manufacturing capabilities that require more time and capital to scale than non-production (e.g. software) firms. These firms provide an important test of the U.S. innovation ecosystem's ability to support the scaling up of firms producing innovative technologies.

Using a critical case methodology, we find the U.S. provides fertile ground as firms prepare to enter the commercialization environment, iterating prototypes, developing pilot production facilities, and in some cases entering into commercial production. Start-up firms in our sample are able to find the skills, financing and general resources they need to advance through the exploratory stages of technology development:[48] basic R&D, applied R&D and early market demonstration. However, when these firms need to take the significant leap into larger-scaled processes to prepare for commercial production, the need for additional capital coupled with the search for production capabilities or lead customers willing to be early adopters, pulls many firms to move production abroad.

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[48] See (Grubb 2004) for a staged typology of technology development

This move comes at a critical stage in which much of the firm's technology and related manufacturing processes are not yet codified or fully modularized. Firms are developing capabilities through multiple iterative steps in the technology's development over extended periods of time. We term this process "learning by building". Tacit knowledge is still critical to the development process. Tacit knowledge, as opposed to codified knowledge, requires proximity and face-to-face interactions, which makes knowledge 'sticky' and thus less mobile and harder to communicate over distances (Gertler 2003). While this stickiness has historically protected work from easily being offshored, in our interviews we find firms are now willing - or required - to move advanced technology and manufacturing processes before they are fully codified. This movement, which often entails the temporary relocation of key personnel with whom the tacit knowledge resides, leads to the migration of key skills, capability generation and knowledge development outside of the country. We argue the migration of these capabilities has two consequences: one, expected returns to public investment in innovation may not be realized in terms of economic growth and two, the movement offshore of vital capabilities may put at risk the future capacity to innovate in the US.

Each firm's decision to move technology development and related production processes abroad is based on rational criteria, at least within the realm of the economic incentives available to them in the current innovation ecosystem. However, the collective shift of these innovative firms' productive activities offshore at this critical stage of their technological and economic growth represents a loss for the country as a whole in the knowledge, skills and capability-generation that come with this next stage of scaling. Public resources are often invested in university research and early start up firms in order to foster greater innovation. Those resources are successfully encouraging new generations of innovative, entrepreneurial firms. We suggest, however, that it is not enough to start the firms in the US; we must also pay attention to how to grow them in the US. While creating incentives for individual firms to manufacture in the US has a long history that has produced mixed outcomes at best, we do believe there is a public interest in finding ways, where appropriate, to help firms to scale production in this country. While it is not realistic to keep all production in the US, the innovation ecosystem depends on continued demand for the skills and capabilities required for the new and emerging industries represented by our sample of firms.

4.2 Profiting From Innovation Strategies in Entrepreneurial Firms

Young entrepreneurial firms, especially those that focus on technological innovation, have a distinct set of characteristics that regularly place their long-term survival in jeopardy. In addition to the significant uncertainty that surrounds any early stage technology, new firms require capital to offset negative cash flow in starting their enterprises. They must be sensitive to protecting their intellectual property from possible imitators, including fellow start-ups that seek first-mover advantage and/or industry incumbents that seek to defend their market positions. Many scholars have studied the strategies innovative entrepreneurial firms use to address the unique circumstances that they face. In particular, there has been extensive research on the factors that determine whether new innovative companies will compete or cooperate with incumbent firms. With limited resources, young firms must decide whether to invest in upstream activities such as materials development or downstream ones like marketing and distribution.

Young firms engaged in manufacturing (generating new products) may face additional constraints including longer innovation cycle times, higher capital needs and highly complex technology. Ultimately, they must decide whether to make their own product inside the firm or contract part or all of the manufacturing externally. In other words, young firms constantly face a series of critical decisions as they move from idea to prototype to commercial production and finally distribution.

Complementary Assets

An extensive literature found on entrepreneurial strategy and the economics of innovation seeks to understand how firms profit from innovation. Teece (1986) identifies two key factors that influence entrepreneurial firms' decisions to compete or cooperate with existing firms: technology appropriability (ease of imitation) and ownership of complementary assets in production, distribution, and marketing. Following Teece's seminal work, many scholars have built on this framework to understand how young firms profit from innovation. Focusing on young technology firms, Gans and Stern (2003) note that incumbents who have incentives to expropriate the inventors' technology own many of the complementary assets sought by firms. This represents a paradox for entrepreneurs who need to disclose extensive product details to receive the highest valuation for their technology, but fear disclosing too much information to large firms who are both potential partners and potential competitors. In an environment where young firms are better at development, but incumbents control complementary assets, young firms may be better off cooperating than competing with the incumbents. To that end, young firms may seek complementary assets during the exploration (discovery) and/or exploitation (production) phases of their development[49]. They must differentiate between assets that might be generic and thus substitutable, and those that are specific and offer competitive advantages (Chesbrough, Birkinshaw, and Teubal 2006). In either case, they must decide whether investing in assets like production facilities, or marketing and distribution networks on their own risks duplicating assets held by others, leading to the inefficient use of scarce resources and potentially unreasonable sunk costs (Gans and Stern 2003).

Financing and the Emergence of New Sources of Complementary Assets

A critical factor in determining whether start-up firms invest in new assets is their access to capital. Technology entrepreneurs most often raise funds for their firms from providers of high risk capital—primarily independent venture capital (VC) and/or corporate venture capital (CVC) firms. While VC funds are well established as the major source of entrepreneurial finance, they are shaped by particular dynamics inherent to their business, for example, the composition and the objectives of investors that potentially limit long-term investments in young firms. Boom and bust cycles are another challenge that lead to the underfunding of novel technologies (Lerner 2012). This uncertainty, well beyond the control of young firms, may affect young firms' ability to raise capital for large fixed cost projects. Moreover, the increasing specialization of venture firms, which leads them to focus only on certain stages of a firm's development, forces founders to constantly maintain an eye on the next round of financing, unsure if current or future will accept their investment plans.

[49] See March (1991) for a discussion of exploration and exploitation.

Interestingly, multinational corporations are taking an increasingly active role in funding new firms through corporate venture capital (CVC) subsidiaries. Intel and General Electric are well known examples of historic corporate venture investors. The National Venture Capital Association reports that 2011 was the largest year for total CVC investments since the dot-com bubble of the late 1990s (National Venture Capital Association 2012). This trend is important because, unlike traditional VCs, CVCs have extensive resources including a supply chain and manufacturing network to help entrepreneurial firms commercialize a technology without investing in fixed assets. As complementary assets have become increasingly global and with the emergence of a secondary market for trading of intellectual property rights, young start-up firms are increasingly attractive to multi-national CVCs as partners. Together, these trends increase the likelihood that an upstream or downstream complementary asset holder will place more value on young technology firms.

In addition to CVC partners, national governments in emerging economies have begun to make available complementary assets to innovative American start-up firms (Chesbrough, Birkinshaw, and Teubal 2006). In an effort to seed the development of new technologies and advanced manufacturing capabilities in their country or region, foreign governments are providing direct capital for development as well as indirect capital in the form of plant, equipment and workforce training. Singapore's aggressive efforts in biotechnology, Russia's efforts in nanotechnology and China's initiatives in clean energy are salient examples of this trend.

Ultimately, where firms find complementary assets has implications for future economic activity. Whether the means are acquisition, investment, alliance or just strategic choice, the (re)location of complementary assets overseas may not be costless to the US economy of the start-up firm. As Teubal and Avnimelech (2003) show, globalization has favored the acquisition of local start-ups by foreign firms, thereby truncating the R&D leverage of downstream production and any associated economic growth.

The ability to access complementary assets is an essential ingredient for the growth strategies of many young entrepreneurial firms. In an effort to supplement new technologies and build capabilities, US start-up firms are turning to multinational firms and foreign governments that play an increasingly important role in providing complementary assets. Such partnerships, while important to the growth of the individual entrepreneurial firm, may shift investments and capability-building abroad, away from the national and local economy of the firm, with potentially negative consequences for future innovation and economic growth.

4.3 Research Methods and Data Collection

The MIT Technology Licensing Office Sample

In order to understand firm decision-making related to production in innovative start-up companies, we examine the population of firms founded on technology licensed from the Massachusetts Institute of Technology's (MIT) Technology Licensing Office[50] between 1997 and 2008. The MIT Technology Licensing Office's (TLO) mission is focused on bringing inventions from MIT laboratories into the economy, and in this activity, it has been among the most successful bridging agents linking US university

[50] In all but a few cases, the firm was created based on technology developed at MIT. In a few cases, firms licensed MIT technology after a firm was formed.

research and private industry (Di Gregorio and Shane 2003). In 2011, for example, the TLO registered 694 invention disclosures, filed 305 patents, had 199 U.S. patents issued, and facilitated the start-up of 16 firms (with a minimum of $500,000 in initial capital).

While MIT TLO firms may not be a representative sample of national technology start-ups, they offer the distinct advantage of being among the most likely advanced technology start-ups to succeed (*Ibid*). These firms consistently seek to commercialize products at the technological frontier and are well connected to academia and the venture capital industry. Given the historic role of MIT and Boston in successfully commercializing new ideas (Massachusetts is continually ranked among one of the top innovation hubs in the country[51]), we consider this to be a 'critical case'.[52] We would expect that firms within our sample should be among those start-up firms most likely to succeed at scaling up. Conversely, if firms in our sample, which enjoy extensive local resources, encounter significant challenges in reaching scale, we can only imagine how start-ups not located in the Boston/Cambridge ecosystem and not affiliated with an elite innovation-focused university might fare.

The 1997 to 2008 time frame allows us to look at firms five to fifteen years after their founding. During this period, 189 firms started with technology licensed from MIT patents. We focused only on firms that were engaged in some form of production. We eliminated 29 software firms and 10 firms for which we could not locate any recent data from further investigation, leaving a sample of 150 production-oriented firms[53].

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[51] See (Information Technology and Innovation Foundation 2012)

[52] See (George and Bennett 2005) on critical case methodology.

[53] We were careful to include those firms that integrated software into products with the proviso that the product was specifically engineered with this software in mind. We conducted extensive checks of archival records to determine the status of the these 10 firms but were unsuccessful/

By looking at firms that are between 5 and 15 years old, we cover the stages from company formation to prototype and in some cases pilot facilities and commercial production. For the older firms, many will have entered into a mass production stage in which a product is commercially produced and brought to market.

Methodology

For this study, we gathered historical data on financing, ownership, and operating status for all of the firms in our dataset in order to better understand the growth trajectories of these firms. In addition to data provided by the TLO, we utilized online databases from VentureXpert, Lexis-Nexis and Compustat to build a longitudinal database. Using semi-structured interviews with a subset of these firms, we developed a more in-depth understanding of how firms choose strategies to scale up by tracing the pathways from innovation to production. Together these methods allow us to understand how young technology firms make decisions about how to commercialize their innovations and move from R&D toward production.

For the interviews, we chose only firms in the sample that had demonstrated an ability to reach scale, starting with the 15 firms with over $5 million in revenue[54]. Given that firms must signal continued progress to potential investors even before they have the possibility of generating significant revenue, we also looked for firms that had received in excess of $50 million in high-risk capital as a proxy for continued market potential. This added another 11 firms to our potential interviews. From this set of 26 firms, we

[54] Revenue of $5 million exceeds the typical amount of research funds start-up companies report as revenue.

conducted a total of 17 interviews[55]. Not surprisingly, these highly innovative firms are predominantly located in high-skill, technology leading regions in the U.S. Of the seventeen firms in which we conducted interviews, seven firms were based in Boston, nine in the San Francisco/Silicon Valley region, and one firm was in Berlin, Germany.

------------**Insert Table 1 Here:** *MIT TLO Licensed Start-Ups 1997-2008*-----------

Sample Characteristics

As seen in Table 1, of the 150 production companies, 59 percent are still active as independent firms while another 21 percent were acquired and 20 percent have closed. This survival rate is 150% higher than what Hall and Woodward find in their national study of venture-backed start-up firms (Hall and Woodward 2010). Firms in the biopharmaceutical and medical device industries make up 60 percent of our sample while semiconductor and electronics firms constitute an additional 17 percent. Geographically, 63 percent of the sample firms are headquartered in Massachusetts, 15 percent in California and the rest are spread across the country. Three percent of the firms in our sample are based overseas. The vast majority of firms had little or no revenue. As noted above, fifteen firms had revenue over $5 million in 2011. Of these firms, three had sales over $100 million, and only one had sales over $1 billion.

[55] See Appendix 1 for more detailed information on the companies interviewed. Interviews typically lasted between one and three hours with two or three researchers present.

4.4 Innovation Ecosystem during Exploration Phase

Financing the Scale Up of Innovative Firms

Using the VentureXpert database, we identified 82 (of the 150 production) start-ups in our sample as having received VC and/or CVC capital. These 82 firms raised a total of $4.7 billion, of which 71 percent came from venture capital and 12 percent from corporate investors.[56] Some firms have raised significant capital: 33 firms raised over $50 million and of these, 14 firms raised over $100 million in investments, which suggests a strong market belief in the technology they are developing. Fifty-seven percent of the firms in our sample were still raising capital after their fifth year.[57] Of these firms, 39 percent were still raising funds after the seventh year, and 15 firms or 17 percent of the sample were able to raise high risk capital after ten years.

Almost half of the 82 venture-backed firms received a financial investment from at least one corporate investor in addition to venture capital. While strategic corporate investors represented only eight percent of total funds raised by biopharmaceutical firms (of $1.7 billion), they represented triple that amount or 21 percent of total investment ($1.1 billion) in semiconductor firms. Another way to raise significant funds for firms seeking to scale up is to sell shares to the public through an initial public offering. Only nine firms of the 82 in our sample followed this path. Of these nine, eight were in the

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[56] Of the 82 firms for which we have data, eleven closed and nineteen merged with or were sold to another firm, leaving 52 independent firms. Revenue for merged firms is not included, as unconsolidated sales figures for the acquired firms are not available. Appendix 2 contains figures of the distribution of funds raised by the 52 operating firms.

[57] Venture funds are traditionally structured as partnerships, with the active fund manager serving as general partner and investors as limited partners. Most partnerships are structured with a seven-year investment cycle.

biopharma or medical device industries (the exception was a battery manufacturer). On the whole, the data demonstrate that these young start-up firms have had little trouble raising significant amounts of capital during the exploration stage of their technology development even when this phase has taken place over an extended period of time.

Thick Labor Markets and Network Nodes

Rapid access to diverse talent is the critical input for these young entrepreneurial firms, particularly in the early stages of growth. It is at this point that iterations between lab and production are taking place, road blocks in developing the technology may appear, and new strategic directions might evolve based on what can and cannot be done with the technology. "High intellect" talent, as described by one semiconductor executive, is essential at this stage. One firm estimated that salary for these highly skilled employees represented 70 percent of its budget. Firms locate in or close to labor markets where they can find diverse yet specialized sets of skills.

The ability to hire quickly is important. One firm, which needed equipment engineers, process engineers, device engineers, and a MEMS (micro-electromechanical systems) device team, hired 25 people almost over night. This need to draw from a diverse set of skills and to hire a workforce in a relatively short period of time drives these firms to locate near educational institutions with strong track records for graduating well-trained engineers or in regions with reservoirs of engineering talent from previous rounds of industrial creation. This was true for all five of the semiconductor companies we interviewed on both the East and West Coasts. The situation was similar with the biopharmaceutical firms we interviewed in Boston as well.

The importance of connecting start-up firms to networks of capital, human resources, potential strategic partners, and early adopters and customers has been studied extensively in the literature on entrepreneurship[58]. In the small, innovative firms we studied we usually found that there was at least one individual playing a critical role in the initial formation of the firm as well as in connecting the firm to resources, talent and partners. These unique individuals, who have deep industry knowledge and experience, as well as strong local networks, are especially important at three points in the firm's development: firm formation, testing market viability and integrating novel technology into existing systems.

In several cases, a venture capitalist saw the potential for a new technology and pooled the IP from different universities, assembled the initial team, and formed a firm. The individuals acted in these cases as visionaries who understood the potential for a particular type of technology and assembled the right intellectual property and team to help build a firm. In one medical device company case, this involved assembling IP from five different universities and funding a team that would ultimately build a billion dollar firm.

After the firm is formed this unique individual might be a person who is intimately connected to a particular industry and who can make important introductions to potential funders or partners. Within each of the industries we studied there are several critical people who had worked in a particular industry for years, participated in building several firms, and had achieved great respect in both the national industry and regional innovation networks. These individuals guide firms as they test the market viability of

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[58] See (Powell et al. 2005) for an excellent discuss of the role networks play in innovation ecosystems

their technology and help to identify the most appropriate capital providers. In one case, this key actor arranged to have a major potential customer from Asia come to MIT to see the prototype. Based on the potential customer's enthusiasm for the product, the team went forward, created the firm, and began hiring a team and raising money.

In the early stages of scale up, as a firm decides how to integrate its technology into incumbent systems, a key agent is represented by seasoned industry executives who have deep knowledge of the prevailing industry production architecture, understand how new technology can be incorporated into it, and are familiar with specific facilities that are best suited for introducing the technology. For one set of firms, these individuals were retired production executives of large integrated petrochemical firms who understood what plants had the managerial and technical ability to successfully integrate a new technology. They also could bring in experienced production engineers on an as needed basis to ensure that the technology could be inserted into existing larger production lines, without the sort of disruptions that have scuttled other previous projects.

Our sample firms' ability to access networks through these individuals appeared integral to their success. While not limited necessarily by distance, these networks are often enhanced by proximity and encourage firms to locate in places where there are dense networks within their specific industry.

Thick Supplier Markets

While these firms draw on a deep and specialized talent pool, they are also drawing on a range of suppliers for certain products, services and skills. The firms in our sample are engaged in complex engineering and manufacturing. One medical device firm that has successfully scaled production has a product with 10,000 components, and 300 suppliers of custom pieces, 65 percent of which are provided by local suppliers. When start-ups begin product development, they are more concerned with speed and quality as opposed to cost. Being located near a strong supplier base that can turn around product very quickly is a priority.

Initial prototypes often come out of the university lab in rough form and need iteration, either within a lab setting, or in partnership with suppliers. This process, while time-consuming and labor-intensive, must emphasize speed and quality. Thus, firms like to have their suppliers near at hand. In the case of one East Coast semiconductor firm, the loss of control and time that came with working with a third-party semiconductor fabricator in the U.S. pushed them to build their own fabrication plant. They did not consider going offshore because of the expense both in time and money of transferring people and technology, as well as the fact that the novel work they were doing would have required 18 months to transfer the process offshore. It took two years to get their prototype to be a fully functioning product. During this process, they benefited significantly from the proximity of talent and suppliers.

In the case of another semiconductor equipment firm on the West Coast, they built a prototype in four months and continued to iterate it every six months for three years before they were ready to ship product to a potential customer. This is consistent with other semiconductor firms located in the Silicon Valley area; these firms could find a relatively strong local supply chain during the prototype stage. One firm described how they kept eight machine shops busy for two weeks at full capacity in order to ship a prototype system to a potential customer.

4.5 Financing and Capabilities Migration at an Inflection Point

The findings discussed above paint a picture of a very robust regional innovation ecosystem for new firms that are in the exploration phase. For these firms, finding advanced skills across a wide range of disciplines, suppliers that can help them iterate prototypes, networks that can provide contacts with both funders and potential customers, and most importantly, early stage capital to support the firm's growth, are all readily available. This ecosystem helps incubate the early development of the technology and allow the firms to focus on quality and speed to market.

However, the local ecosystem falters as firms seek to scale production from the pilot stage to a commercial scale. To help explain this stage of growth, we have adopted a framework for the development of novel technologies from Lester and Hart (2011 – see Figure 1). As firms move from the exploration phase toward the exploitation phase they are both demonstrating the viability of their product while also building it at scale. The two activities are inseparable - as is often said in bioprocessing, "the process *is* the product." We call this space the "inflection band" to convey both the critical nature of this stage for the firm and the fact that, rather than a point in time, this stage can last for a relatively long period of time, up to several years.

-------------Insert Figure 1:Inflection Band Here----------------------

Financing

During the early stages of development, the innovative companies we interviewed were able to raise significant amounts of risk capital over extended periods of time. However, as they moved into pilot and demonstration phases of their technology, they needed a new influx of significant capital to finish codifying their technology processes and bring it to commercial scale. Traditional venture capitalists, who invest in the earlier stages of the company, do not typically fund at this stage and at these levels (anywhere from $15 to $40 million) so these companies must look elsewhere for funding. We find that during this inflection band, the money often comes from corporate investors (MNCs) or national investment funds of emerging economies. For example, an advanced materials firm that had withdrawn an earlier IPO received a $30 million investment from an Asian multinational firm twelve years after founding. At this stage, "venture investors [in the firm] look for certainty; they are willing to trade upside for certainty. The investors understood the possibility of acquisition by a foreign firm when they took the money [from the Asian multinational firm] in the last round"[59].

In another case, the CEO of an advanced materials company said, " the VC model does not work for manufacturing companies. VCs cannot make any money on something that costs $100 million and takes at least 10 years to build. The technological risk is high and there is a high burn rate. They are much more comfortable with a software deal that will cost them $20 million. They have to pull away at what is a critical time for the company – just as [the company] is trying to finalize the product and get it ready for commercial production… eventually people won't start companies like this because they

[59] Interview—CEO, advanced materials firm 4/25/12

can't get financing." Ultimately, the company raised $40 million from an emerging economy government investment fund with a *quid pro quo* that some R&D and manufacturing would be set up in that country.

Those rare firms that went public offer a counterpoint to this pattern. A senior manger at one firm, an integrated surgical device manufacturer, stated that having the money from an IPO allowed them to get through an extended stretch to develop their technology for the market, after they had consumed most of the $125 million they had raised in venture funds. The tendency of the board was to sell the firm, "98% of the conversations in Silicon Valley are around an M & A exit, not an IPO"[60]. The firm remained independent, however, which may be the result of a product that fell 'in a crack' between the diagnostics and interventional equipment industries as well as the willpower of management to resist the board of directors' desire to sell.

Life sciences as an industry seems more likely to follow this pathway. Eight out of the nine firms in the TLO sample that went public were in the life sciences sector. These companies benefited from an IPO, raising capital that has helped fund their long development cycles. For these firms, the complexity of the early stage scale up of their products and the close interface with R&D teams leads them to develop capabilities in-house, even while they might work with a contract manufacturer on clinical production.

Capabilities Migration

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[60] Interview--CEO, integrated surgical device manufacturer 4/25/12

While the firms we interviewed could find the skills and capabilities they needed during the initial phases of scale up, they had greater difficulty finding the know-how and capabilities for production at scale. As described earlier, the knowledge being developed within the inflection band is not yet codified, and will only become standardized through future iteration over months and years. To find the capabilities required at this stage to both iterate the technology and develop it at scale, the TLO firms sought out partnerships to provide the complementary assets required. Whether for reasons of a lack of skills ("in certain industries, a whole generation of engineers is missing" according to the CEO of a nanotechnology firm), pull from an industry where the center of gravity has moved abroad, and/or market demand that is growing faster outside the U.S., more often than not, the TLO firms developed partnerships to scale production offshore. These factors, combined with financial resources, make the pull to scale abroad very compelling.

For example, in one biomedical device company we studied, we learned that it needed to design a product that could be manufactured at high volumes (involving precision injection molded plastics and rubber components). First, the company tried to partner with small firms in the US to develop this capability but ended up with a very low yield rate (less than 10%). Then it turned to large U.S. chemical and electronics companies. However, the product the start-up produced was so different from conventional technologies, the large companies had little interest. One called it "really stupid", another a "fool's errand," while a third wanted $5 million for a feasibility study. After a global search for manufacturing capabilities at scale, the company settled on Singapore because it offered three things: capital ($30 million investment from the government), a willingness to draw on their semiconductor experience to build the right capabilities, and intellectual property protection. The company was one of the first to move its production to Singapore and others have followed, creating a center of capabilities in biomedical manufacturing. The company has since gone public.

For several of the companies we interviewed, almost all of their future customers are in Asia. One company, a semiconductor equipment firm founded in 2007, has only 10 potential customers in the world for its product, and five of them (the most important) are all in Asia. Volume is low for these high margin systems and commercial production would represent approximately 100 units a year. They chose their first partner for testing the equipment carefully since some of these players are considered aggressive and would "eat you alive"[61]. Their plan at this stage is to support the customer in the field during the testing phase. The six months after completing the prototype are critical, so the CEO will be moving to Asia for a couple of months. They will have two to three people on site and set up an office next to the customer. Their partner has spent two years already evaluating the technology and paid $1million up front for the demonstration phase. The pilot will cost $30 million and a full commercial production facility will cost $150 million. They expect to engage the customer for the investment going forward.

Suppliers as well as capital draw firms into overseas partnerships. In another case, a manufacturer of devices utilizing specialized silicon inks was only able to survive by working with suppliers who had a long -term incentive to develop their technology together. The CEO says, "The only reason we are alive is because of several strategic partnerships". [62] They work with one Japanese company and one American company. The easiest way to ramp up the process is to find equipment that already fits

[61] Interview—CEO-semiconductor equipment company 4/26/12
[62] Interview—CEO, silicon ink device company 6/14/12

with what they do, even if it is designed to work on a different process. The Japanese company they partner with has resources abroad for manufacturing, and it is cheaper for them to build a large-scale plant in Japan (although they haven't done so yet). The CEO doesn't see a choice when it comes to building a 50 billion-unit plant; it will have to be in Asia. The CEO further states that he believes this is common for many production related companies due to the complexity of the technology coupled with the capital needs to develop it, "When they transition from the normal VC model, there is no other model to jump to, so they go abroad. They end up offshore 99% of the time. M&A deals happen at that point. The partner thinks 'we're going to manufacture this stuff, so why not acquire the company instead of being a partner?' Both manufacturing and technology companies go abroad looking for partnerships because it is easier for investors".[63]

4.6 Discussion and Implications

The emergence of the high-tech entrepreneurial firm has created a new model for innovation in which these firms, trying to both scale novel technologies and enter the global marketplace, must seek out complementary assets. The nature of the US innovation ecosystem for these new technology firms, in terms of financing, demand from growing markets and customers overseas, and the lack of capabilities for scaling production in the US, creates momentum for these companies to find these complementary assets offshore at a critical point in their scale up process. The aggressive pull of emerging economies seeking to build capabilities in advanced technology reinforces this behavior. Of course, in a global marketplace, we would not expect all

[63] Ibid

investment and all parts of a supply chain to be located within the U.S. The firms are acting rationally and taking advantage of a global economy that prizes innovation. But it is the crucial point in these firms' development that raises concerns about important capabilities migrating offshore.

While some might argue that the iterative process of innovation that we describe is not critical to the U.S. as long as the country continues to drive the idea generation and early stage research and development, we believe this is a mistaken view of the risks and stakes involved. The transfer or sharing of this advanced knowledge across national borders, which often took years to develop, risks the potential loss of the national competitive advantage these capabilities have created in three ways. First, the loss of this learning by building deprives the country's innovation ecosystem of new learning and thus reduces the accumulation of knowledge and capabilities, ultimately diminishing the potential for future and as yet unknown innovation. The "industrial commons" is made poorer for it. Second, as we have seen in other industries, it increases the movement of the center of gravity for established and new industries away from the country, with implications for future industry growth. As underscored by others, where process innovation goes, product innovation follows (Pisano and Shih 2012). Finally, it limits the benefits the country could gain from the economic growth generated by the downstream activities these firms will create with scaled production in terms of investments and jobs.

Independent of whether the company preferred to scale in the U.S. or not, these companies have little choice but to go overseas to continue the commercialization process. While they are acting in the firms' best interest, as Teubal and Avnimelech (2003) observe, "there is no a *priori* reason for the market solution to be optimal or adequate to the country" (p. 37). The loss of the capabilities generated by these leading edge companies creates ripple effects for the country over time. Chesborough et al. (2006), discussing a similar phenomenon, state, "it is open to debate whether local policymakers should have invested more in helping to create the complementary assets to allow *in situ* development.' (p. 1098). Given the outcomes we observe in our research, we would agree that there is a case to be made for both private and public interventions to create complementary assets within the country that will enable more scaling locally.

We see four possible areas for exploration in terms of interventions: 1) increasing financing options for later stage development, 2) creating institutions and incentives that provide opportunities for firms to build capabilities in advanced manufacturing in the country ("learning by building"), 3) changing the contours of market demand through state procurement or standard setting, and 4) continuing efforts to encourage firms to raise capital through initial public offerings.

We believe initiatives in all four of these areas will extend the time and capital available for these firms to cross the "inflection band" and do so within their local economy. Given the country's focus on and investment in the early growth of innovative companies (university and company research grants, seed capital, tax incentives, etc.), we believe there should be an equal focus on the later stage scaling of these companies and how to encourage more of it to take place in the country. Likewise, many of these firms have benefited from U.S. R&D programs, whether in research grants, shared production facilities or tax treatment. It is reasonable to ask whether the country should care how those investments pay off in the long run.

4.7 References

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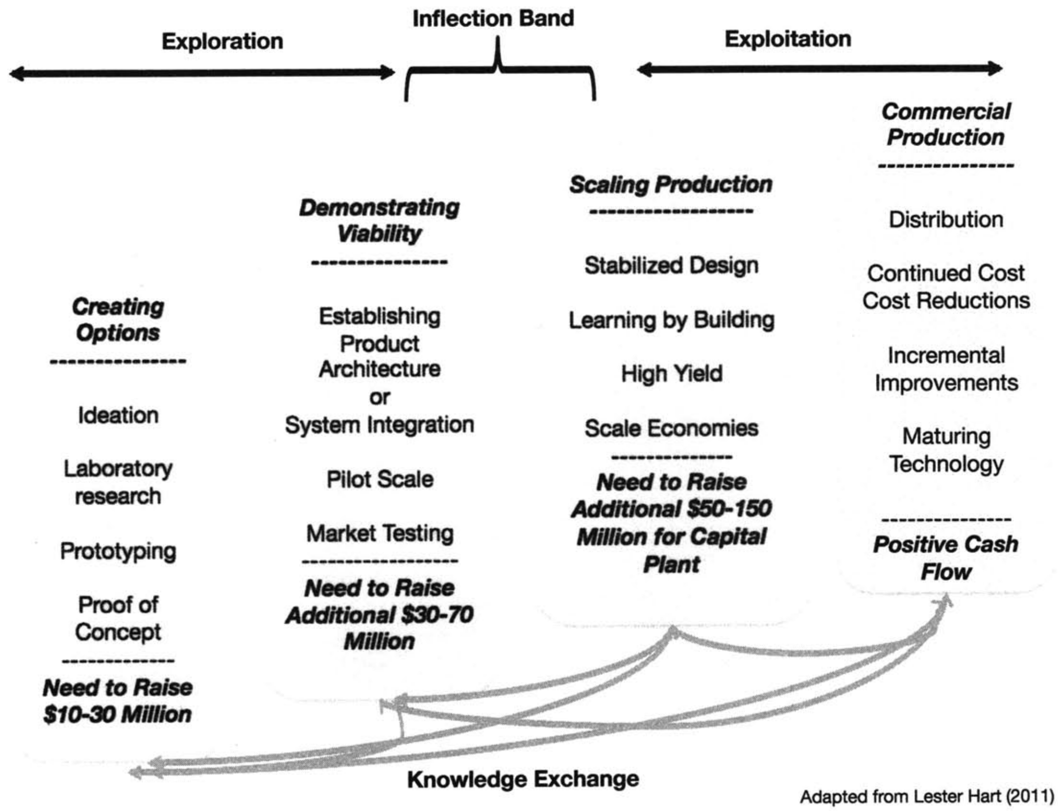
4.8 Tables & Figures

Table 1: MIT TLO Companies 1997-2008

Industry	# of Firms Started	% of Total	% Receiving Venture Capital*	% Operating^	% Closed	% Merged
Advanced Materials and Energy	15	10%	33%	73%	27%	0%
Biopharma	58	39%	59%	55%	26%	19%
Medical Devices	31	21%	52%	65%	3%	32%
Robotics	5	3%	0%	60%	20%	20%
Semiconductors and Electronics	26	17%	85%	62%	19%	19%
Other	15	10%	33%	47%	27%	27%
All Production Companies	150	100%	55%	59%	20%	21%

*Reported by VentureXpert
^-As of June 2012

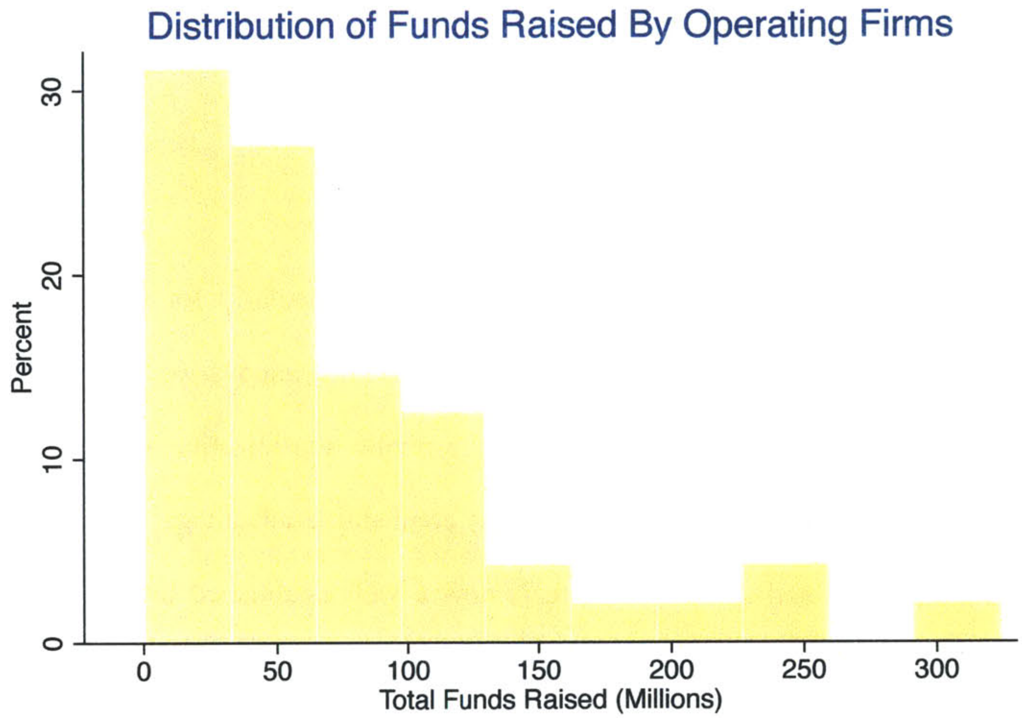
Figure 1: Inflection Band During Scale-Up Process

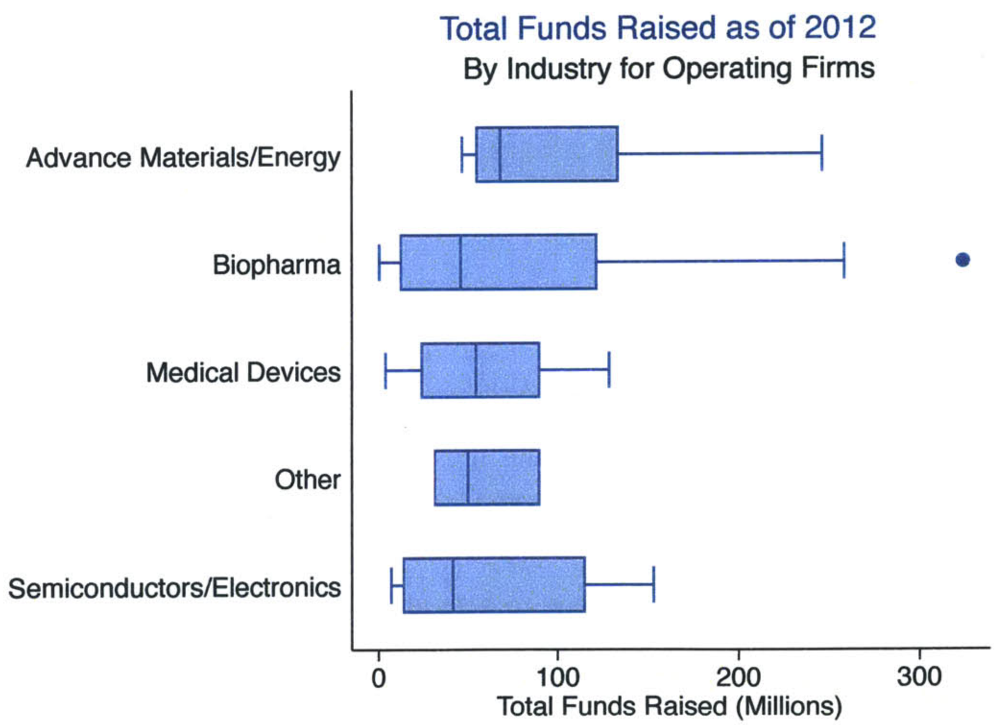


Appendix 1: MIT TLO Companies Interviewed

Firm	Year Founded	Industry	Revenue	Public	SBIR	Exploration	Exploitation	Foreign Corporate or (State) Investor	Amount Raised ($M)	Motivation for Offshore
A	1997	Medical device	Yes	Yes	Yes	CA	US/Mexico	No	56	Low-cost production of low-value parts
B	2001	Biomedical	Yes	Yes	Yes	CA-R & D Prototype	Singapore	Yes (Singapore)	216	Capital, Capabilities, Cost at Scale
C	2001	Semiconductor	Yes	No	No	CA-R & D Prototype	Japan	Yes	77	Capital, Supplier, Cost at Scale
D	2001	Semiconductor	No	No	No	MA-Prototype, Pilot	MA, Asia, Europe	Yes (Russia)	108	Capital
E	2001	Biopharma	Yes	Yes	Yes	MA-Pilot	Multi-National Supply Chain	Yes	120	Capital, Distribution Marketing
F	2001	Biopharma	Yes	No	No	Germany	N/A	Yes	117	
G	2001	Medical device	Yes	No	Yes	MA	MA	No	74	N/A
H	2002	Battery Manufacturing	Yes	Yes	Yes	MA	Asia/US	Yes	243	Capital, Capabilities, Cost at Scale
I	2002	Biopharma	Yes	Yes	Yes	MA-Pilot, US-Clinical	N/A	Yes	100	N/A
J	2003	Advanced materials	Yes	No	Yes	CA/Ohio	South Korea--production?	Yes	95	Capital, Capabilities, Customers
K	2004	Advanced materials	No	No	Yes	MA-Prototype	US-Bulk, Taiwan-Application	No	55	Capital, Customers
L	2004	Semiconductor	No	No	No	CA	Taiwan	Yes	153	Capital, Suppliers
M	2006	Biotech	Yes	No	Yes	CA	N/A	No	<10	N/A
N	2006	Geothermal Drilling	Yes	No	No	CA	N/A	No	<10	N/A
O	2007	Semiconductor	Yes	No	No	MA	N/A	Yes	46	Capital
P	2007	Semiconductor	No	No	No	CA-Prototype S.Korea-Pilot	Asia	Yes	75	Capital, Capabilities, Customers
Q	2007	Advanced materials	No	No	No	CA-R & D Prototype	US/Russia	Yes (Russia)	36	Capital, Natural Gas Supply

Appendix 2: Venture Funding Of TLO Operating Firms (52)





4. Why Understanding Demand Matters: Implications and Future Work

The last essay raises a very important question, particularly for scholars and policymakers interested in the micro-level mechanics that link innovation to economic growth. First, if an underlying assumption for the public subsidization of basic and applied research in the U.S. is to gain (maintain) competitive advantage that leads to durable economic rents and second, if there is now a well established theoretical and empirical need for young production-related technology firms to utilize external complementary assets to grow, does it matter (to the subsidy provider) whom these firms seek out for strategic partners? If so, is it important to understand what determinants firms use to select partners?

Though not a direct line of inquiry for our scale-up research[64], it was nevertheless suggested in a number of interviews with founders and CEOs that the ability to limit equity dilution (for investors as well as themselves) was a key determinant in choosing their strategic partners. Foreign strategic partners apparently were willing to place a higher value on the entrepreneurial firm and thus take less equity than an alternative capital source in the U.S. because they had access to low-cost long-term capital and/or because they could deliver market demand to help grow the technology firm. Though it was unclear which was the cause of the higher valuation, the interviewees implied that

[64] We did not discuss individual equity interests due to the personal nature of the subject.

the second condition helped reduce market uncertainty and provided a much-needed setting for iteration and further technology development.

4.1 Technology versus demand as a source of innovation and growth

Despite this tentative empirical link between demand, technology development and firm success, there is not an extensive literature on the role of demand as a necessary condition for innovation. In a bibliometric analysis of the most highly cited papers in science policy and innovation studies[65], Di Stefano et al (2012) find that science and technology were viewed as the overwhelming source for the majority of technological innovation--75% of the papers studied (Di Stefano, Gambardella, and Verona 2012). This result is hardly surprising given that almost all innovation and technology policy is focused on increasing the supply of basic and applied science. On the other hand, demand was hardly noted and where it was, it took the form of lead user involvement articulated primarily by Eric von Hippel[66]. This customer-driven model accounted for approximately 12% of the papers. Systems of innovation, where demand complements the supply of science, is present in only 4% of the total group.

It is this small group, however, where innovation systems are maintained on a sectoral basis, that I believe holds the promise for rich research and policy returns. Franco Malerba has been the primary advocate of sectoral studies as a critical element to understanding the relationship between technological advancement, innovation and economic development. In his initial theoretical framing, he proposes that sectors have

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[65] The study's goal was first, to categorize the dominant literature addressing the sources of innovation and second, by doing so to reflect the current scholarly view that technology and demand play as the principal sources in the debate.
[66] See (Von Hippel 1986; von Hippel 1994) for examples

specific knowledge bases that are structured not only by technologies but also by demand. He draws on Michael Porter's early work to support his view that differences in demand lead to differences in a firm's ability to develop technological competence (Malerba 2002; Porter 1976). Learning processes are sector specific and cannot be generalized; homogeneous demand may lead to a dominant product design and heterogeneous demand often leads to market fragmentation (Malerba 2002, 259).

While well cited, Malerba's theories are primarily focused at the firm level and, at least based on Di Stefano et al's study, have gained little following empirically. In the most recent iteration of his work, Malerba and his co-authors argue that the changing nature of firms and rapid technological change has pushed knowledge boundaries beyond the firm and the nation-state. While not surprising in principle, it is one of the few articulations that states may no longer be able to impact the learning process within firms because a significant part of that learning is dependent upon the sectoral division of innovative and productive labor. As a result, they argue firms must develop broad knowledge-integration abilities (Adams, Brusoni, and Malerba 2011).

Yet his initial paper holds a theoretical lead that (while not developed extensively in his later work) should be followed. Malerba theorizes that institutions shape not only contractual and intellectual property law, but also more specific sectoral activities such as anti-trust regulation, standard setting, sectoral labor markets and regulations (Malerba 2002, 257). To this, we could add sectoral activity in state purchasing, local content laws, retail zoning laws and financial innovations such as asset securitization to name a few. Expanding on his view, if learning increasingly takes place beyond the boundaries of the firm, we could further theorize that institutions play a significant role in shaping how and with whom knowledge exchange takes place. Likewise, following on Arrow (1962), if learning by doing differs from learning through research (Arrow 1962; Nemet 2009), identifying the process by how this knowledge exchange occurs and what activities take place at each step in the process (and by whom) should illuminate possible future sources of economic rents and consequent growth.

This outlook holds great promise in further understanding the scale-up challenges identified in the third essay. While the majority of MIT firms allied with foreign strategic partners, the origin of these partners varied by sector. The vast majority of partners in biopharma firms were from advanced industrialized nations, primarily European. On the other hand, firms in the energy, advanced materials and semiconductor sectors overwhelmingly allied with partners from Asian countries.

I believe sectoral institutions and the corresponding nature of demand mediate the matching process. In biopharma, FDA regulations and production inspection regimes coupled with a normative belief that health should be improved at any cost keep much of firm activity in the United States. The knowledge that demand will be both robust and highly profitable (due to regulatory fencing) if a compound is approved reduces market uncertainty, allowing investors to limit their exposure to only technology risk. In energy advanced materials and the semiconductor sectors, where technology supply does not guarantee demand, firms and their investors face the potentially fatal combination of taking on both market and technology uncertainty. As a result, finding future demand plays a much larger role in these firms decision-making process when seeking partners. Future work that can show this process empirically might suggest that supply side (technology push) policies work better if combined with a demand complement, as has been noticed in the role the U.S. Department of Defense played in developing many now prevalent consumer technologies[67].

The same questions can be asked for middle-income countries, such as Malaysia, where public funds are routinely used to attract foreign direct investment. Does it matter what kind of customers and markets the foreign MNC's maintain? Does it matter that as surplus labor markets shrink and labor seeks better working conditions, assemblers depend on customers that have little ability (or desire) to control market demand—particularly when they can move a great deal of the risk downstream? The first and second essays show that it matters at least in regard to whether firms make the choice to replace labor with capital. In the first essay, the need for local firms to meet volatile product demand, exogenous to the state's control, precluded both public and private efforts to improve working conditions by requiring institutional support for flexible labor markets. In the second essay, firms leveraged these same markets to build managerial experience (and correspondingly rents) in absorbing volatility. In both cases, the maintenance of existing labor regimes superseded capital replacement.

Yet it is the serendipitous nature of the counterfactual example--steady assembler demand and the 'protected' market space it created--that enabled the entrepreneurial machine builders in Penang to develop into engines of growth and technological upgrading. In other words, the supply side institutional focus successfully drove a certain type of learning—technical expertise, but this was not sufficient. Stable, local market demand, while too small for foreign makers, created an opportunity for the necessary learning by doing. Supply mixed with demand was the sufficient condition for upgrading

[67] See Nemet (2009) for an excellent description of an early debate during the 1960's on the subject. Project HINDSIGHT advocated defense demand as the sole source of most innovation while NSF-funded Project TRACES leaned towards basic research as the main source.

in Penang. It appears this is similarly the case for young U.S. firms seeking to develop novel technology. Can a state manage this process by focusing on more demand-oriented policies, in addition to supply side ones?

Greg Nemet, in a study of demand-pull policies on innovation outcomes in the U.S. wind industry claims not necessarily. Consistent with Malerba's prediction, Nemet argues the homogeneous demand of a mature sector (regulated utilities), along with long-term market uncertainty, led to a dominant design for wind turbines and little future innovation (Nemet 2009). Margaret Taylor, in a study of state policies in the California solar industry, further argues that technology-push versus demand-pull may be a false dichotomy for policymakers. She points to the fading nature of this debate in the economics of innovation literature—a point confirmed by Di Stefano et al's bibliometric study (Taylor 2008).

4.2 Future Work

Yet the empirical findings in this dissertation do not point to this conclusion. Part of the problem may be the difficult to define nature of demand (Nemet 2009). Scholars have a hard time delineating demand beyond lead user innovation. A weakness of my present work is that I have also loosely characterized demand. This descriptive effort needs to be further developed. In particular, specific institutional efforts that intentionally or unintentionally shape demand need to be studied. For example, Richard Feenstra and Gary Hamilton argue that the advent of big-box retailers in the U.S. were instrumental to the differential technological and organizational trajectories of Korean and Taiwanese production systems (Feenstra and Hamilton 2006). While this causal argument has strong empirical support, it neglects the role that shifting anti-trust policy and liberalizing financial markets (in the form of asset securitization) played in creating the conditions for the retailers' growth in the first place. Understanding the origins of firm behavior raises the possibility that later policy corrections or interventions will have more effect.

Following on the conundrum of U.S. scale-up challenges despite robust innovation ecosystems, one project I plan to undertake in the near future is a study of the market and non-market incentives state actors offer to innovators and entrepreneurs. State-owned and/or state-directed enterprises and sovereign wealth funds in emerging economies have been actively creating demand for technology entrepreneurs from advanced-industrializing nations. This is clear from the scale-up project. Understanding how these actors define and build the necessary complementary assets to attract these firms will be the first step in this effort. Delineating the decision set entrepreneurial firms face in making choices between domestic and these overseas partners is the second. Finally, I believe identifying matched pairs (by sector) that choose different paths and following their organizational and economic development over time will yield analytical traction on where long-term growth and R & D leverage occurs. In addition, it should also shed light on Chesborough's question (Chesbrough, Birkinshaw, and Teubal 2006) of whether a liberal market system of laissez-faire venture capital leads to excess early-stage innovation but very little *in situ* development—a critical question for a system that relies on entrepreneurial finance as the primary means to facilitate the privatization of public innovation.

4.3 References

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