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The globalization of R&D's implications for technological capabilities in MNC home countries: Semiconductor design offshoring to China and India

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ABSTRACT

This paper addresses the empirical question of the impact of the offshoring of semiconductor design to India and China on the generation of semiconductor design skills in the offshoring multinational corporations' (MNCs) home countries. There are four main findings. First, there is a specific technology skill ladder for training "design leads" or design managers within this industry that entails direct exposure to a wide range of design activities. Thus, offshoring has potentially serious implications for development of further design leads. Second, the paper also finds that the impact on skills activities and thus potential skills generation at home from offshoring to India has been limited and gradual and from offshoring to China has been even more limited although the activities done in each country by MNCs have risen over time. Third, the fuzzy set qualitative comparative analysis pinpoints that the operations with design leads and large design teams in 2003–2007 in conjunction with other attributes are generally the ones that pursued the most extensive expansion of semiconductor design offshoring during the subsequent 2009–2013 period. Finally, the evidence for a gradual process of offshoring from the second and third points suggests that offshoring in semiconductor design will most likely not displace the large amount of design activities in the home countries of the MNCs in the near future.

1. Introduction

This paper addresses the empirical questions of the impact of the offshoring of semiconductor design[1] to India and China on the generation of semiconductor design skills in the developed home country of the offshoring multinational corporation (MNC) and the development of technical skills in the host country. This paper refers to both moving a company's own activities abroad and the outsourcing of technical activities to external actors abroad as offshoring. However, the analysis differentiates between internal offshoring and outsourcing. The offshoring companies in the study are fabless design firms and integrated device manufacturers (IDMs)[2] headquartered in developed economies. The offshoring sites under study are India and China because these developing world locations are near the top in the hierarchy of foreign R&D locations (Contractor et al., 2010; D'Agostino et al., 2013) as well as being major locations for semiconductor R&D offshoring in the developing world (Brown and Linden, 2009).

The core issue of the paper is the effect of offshoring on innovation capabilities in the original home base using the case of semiconductor design. Much of the debate over the impact of offshoring on innovation has arrayed a group of proponents of globalization optimistic about the benefits of offshoring outweighing the costs (Bhagwati, 2004; Mann, 2003) against those more pessimistic about the costs of offshoring on wages and employment opportunities at home (Freeman, 2005; Gomory, 2010; Gomory and Baumol, 2000; Hira, 2003, 2005; Samuelson, 2004). There have been empirical studies that explore the impacts of offshoring on advanced OECD economies' workforces from the wider perspective of globalization's effects on employment (Autor et al., 2013; Kletzer, 2001; Feenstra and Hanson, 1996), and ones that directly investigate the connections between offshoring to employment outcomes in advanced economies (A.T. Kearney, 2004; Hira, 2003, 2005; Sturgeon, 2006). Other studies have taken a global labor supply perspective by evaluating the numbers of engineers trained and their quality across offshoring countries and major sites of offshoring, such as China and India (Gereffi and Wadhwa, 2005; Freeman, 2005; McKinsey Global Institute, 2005; Simon and Cao, 2009). Brown and Linden (2005, 2009) have addressed both the employment and foreign supplies of engineering talent issues for the semiconductor industry specifically. Others have addressed the issue in terms of the extant or imminent loss of competitiveness and/or the ability to innovate on the part of the outsourcing country, particularly the United States, although

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[1] This paper will use the terms semiconductor, integrated circuit (IC) and chip interchangeably to describe the industry and product category under study although the authors recognize the technically broader meaning of semiconductor vis-à-vis IC.

[2] Fabless design firms are firms that design but do not fabricate (manufacture) chips. IDMs are firms that combine the design and fabrication functions in-house.

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there are disagreements over whether offshoring is the cause or the effect of eroding competitiveness and declining innovation capabilities (Autor et al., 2016; Gomory, 2010; Grove, 2010; SIA, 2009; AEA, 2005; NAS, 2005, 2010).

There is also a very large literature on the motivations for offshoring[3] with recent examples emphasizing the expanding scope of service offshoring (Kenney et al., 2009). For the semiconductor industry, scholars generally have acknowledged a mix of some of the same factors that traditionally determine location of activities including proximity to customers/markets, cost advantages and access to skilled labor motivate offshoring in semiconductor design (Brown and Linden, 2009; Ernst, 2004). Ernst (2004) for the semiconductor industry and Lewin et al. (2009) and Thursby and Thursby (2006) for a wider scope of innovation activities emphasize the demand for skilled labor emanating from multinational corporations (MNCs) combined with the increasing supply of quality engineers in many Asian offshoring sites as important drivers behind offshoring of innovation activities. Contradicting claims about the globalization of R&D, Macher et al. (2007) have questioned the extent of globalization of semiconductor R&D based on analysis of R&D investment and US patent data, but their data analysis stops at 2001 and 2003 for investment and patents, respectively.

The debate over the impact of offshoring for innovation, especially in semiconductor design, has generally not focused on the micro-level investigation of innovation activities within firms' offshoring sites. Micro-level research is particularly important for assessing what specific activities are being moved offshore because it is precisely these activities that are hard to observe from more macro-level data of flows of investment, patents and employment.[4] Furthermore, a micro-level analysis can provide leverage on the issue of whether specific activities placed offshore are actually displacing specific activities at home that are critical for future skills generation there. In effect, the micro-level analysis gives insight into whether or not training regimes at home continue despite offshoring.

The paper has four main findings. First, from interview interlocutors, the paper uncovered a technology skills ladder within the IC design industry in which a design engineer progresses through a number of steps in order to become a design lead, effectively a manager in charge of whole design projects. Progression up this ladder requires hands-on exposure to a wide range of design activities. Second, the paper also finds that the impact on skills activities and thus potential skills generation at home from offshoring to India has been limited and gradual and from offshoring to China has been minimal although the activities done in each country by MNCs have risen over time. Third, to the extent that there has been a significant increase in sophisticated offshore IC design, it is driven by firms with existing design leads and substantial design operations offshore. This finding helps to explain why more extensive offshoring has occurred in India due to the greater MNC activities at an earlier date there than China and demonstrates that the offshoring of design activities by MNCs is typically a quite gradual process in which local subsidiary capabilities accumulate over relatively long periods of time. This gradual process points to a final finding that offshoring of design to India and China will most likely not displace the large amount of design activities in the home countries of the MNCs any time soon. In other words, the slight shifts of activities from MNC home bases to India and China that have occurred are best measured in decades or half-decades rather than years and further shifts in the future will likely take equally long. Given the relatively high speed of the product life cycle in the IC industry, it is particularly striking how relatively slow the offshoring has been.

In India, MNCs have offshored wholly owned operations and outsourced to local firms, but these MNCs have kept design functions up and down the ladder at home as well. Among the MNCs, American ones are the most active in offshoring activities to India, but this pattern of keeping design functions at home holds true for non-American firms as well. Furthermore, the ability of local teams in India to undertake design leadership remains relatively weak if improving. Therefore, offshoring does not seem to have heavily impacted the training and skills regime at home thus far. For China, the MNCs have been quite wary about outsourcing to local firms and have been cautious in deepening the technical capabilities of their own design operations in China.

This paper proceeds as follows. The first section addresses the methodology and data. The second section describes the skill ladder in semiconductor design. The third section describes MNCs' activities in India and China in 2007–2008, assesses the impact of these 2007–2008 activities on whatever subsequent shift in activities from the MNC home countries towards China and India occurred in the 2009–2013 period and consequently the impact on skill ladders in IC design in the MNC home countries. This section employs interview data, patent data and fuzzy set qualitative comparative analysis (fsQCA). The conclusion, drawing on the smaller set of follow-up interviews in 2014–2015, discusses the issue of how sustainable skills ladders in offshoring MNC home countries are in the medium-term in the face of the developing industry activities in India and China.

2. Methodology and data

This paper presents both qualitative data gathered from semi-structure interviews and quantitative data on US utility patent holdings. In terms of the qualitative data, the research employed the grounded theory approach to data gathering and analysis of institutions (Glaser and Strauss, 1967; Strauss, 1987; Strauss and Corbin, 1990). The purpose of this approach is to explore social phenomenon in order to build theory. Theory building encompasses a range of analytic tasks including concept creation, identifying causal relationships and patterns of behavior. The qualitative grounded theory approach provides opportunities to create new understandings rather than a method to provide rigorous, empirical testing of existing theories, an area where various quantitative methods may be more useful. Out of our qualitative research we came up with the concept of the technology skills ladder in IC design.

From 2007 to 2008, our team interviewed in China and India 21 of the top 75 global publicly listed semiconductor firms by 2006 sales revenue[5] and 19 of the top 50. We also interviewed critical suppliers for IC design, such as intellectual property vendors and electronic design automation (EDA) tool vendors. Given the sensitive nature of the topics covered in the interviews, our team promised to keep the interview subjects' individual and corporate identities anonymous in any research output. However, it can be stated that our interviews with the IC design operations of MNCs were all conducted with high-level managers of these operations. Through this set of interviews with diverse industry participants, we were able to triangulate data in order to ensure reliability. Our interview data provided information with wider generalizability for two additional reasons. In India, we took a census approach and were able to interview 28 of the 42 firms listed as being active in IC design in India as of 2007 according to the Indian Semiconductor Association (2007:5). In China, there was no comprehensive list of industry participants so we could not undertake a census. Nevertheless, the firms we interviewed employed 4153 members of the IC design population, which is approximately 40% of the total population of such workers

[3] See Lewin et al. (2009) for extensive review of this literature on the causes of offshoring.

[4] An excellent example of this type of analysis is Fuchs and Kerchain (2005) although they analyze the impact of offshoring in a manufacturing sector.

[5] List of top firms is from Hurtarte et al. (2007), pp. 235–237. This list excludes pure-play foundries and assembly and testing firms as well as IC industry suppliers, such as EDA tool vendors and semiconductor capital equipment makers.