Journal of International Business and Economics
December 2017, Vol. 5, No. 2, pp. 24-27
ISSN: 2374-2208(Print), 2374-2194(Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/jibe.v5n2a3
URL: https://doi.org/10.15640/jibe.v5n2a3

South-North Technology Spillovers in the Semiconductor Industry

Gerald P. W. Simons[1] & Paul N. Isely[1]

Abstract

We explore how the shift in semiconductor manufacturing to Asia over the last two decades has affected South-to-North knowledge spillovers in the industry. As newer manufacturers of semiconductors move from imitation to innovation, do older manufacturers learn from their younger counterparts? Using patent citation data, we find evidence of South-North knowledge spillovers, contrasting with the traditional view of North-South competition.

Keywords: Innovation, Patents, Semiconductors, Spillovers.

1. Introduction

There is an extensive literature on technological diffusion, including much research on the factors that influence international spillovers of knowledge. Knowledge may be spread internationally through personal connections made by innovators, by trade and technical journals, and by reverse-engineering imported products, but there has been much interest in how knowledge is spread through patenting systems, building upon the work of Pavitt and Soete (1982), Jaffe (1986), Jaffe, Fogarty, and Banks (1998), and others.

The last two and a half decades have seen a transformation in the makeup of the global semiconductor industry. World Semiconductor Trade Statistics Inc. estimates that approximately 85% of global semiconductor sales in 1991 came from manufacturers in Japan, the U.S.A., and various countries in Europe. By 2013, these countries' share of global sales had fallen to 43% (WSTS, 2015), with half of their loss in market share due to an explosion of production in China, which made up around 21% of global sales in 2013, up from just over 2% in 2000 (PwC, 2014).

The semiconductor industry also has a high level of innovation. In 2014, semiconductor firms worldwide spent approximately $56 billion on research and development (R&D) (ICInsights, 2015), and from 2010-2014 over 160,000 semiconductor-related patents were issued by the USPTO (www.uspto.gov).

In this paper we use patenting data to look at how the innovative activity of semiconductor firms has changed in response to the shift in global production towards Asia Pacific. The "North-South" theory of product cycles based on the endogenous growth models of Grossman and Helpman (1991a, 1991b) indicates that as manufacturers in the South increase their production, manufacturers in the North will increase their rate of innovation in order to stay ahead of the new competition. In this approach, South manufacturers are seen purely as imitators, versus the innovators of the North. However, China has shifted its focus from imitation to innovation (The Economist, 2016), and countries such as South Korea have moved from middle- to high-income levels in part due to their emphasis on innovation. This then opens the possibility that the North can learn from the innovations of the South, resulting in a South-North flow of knowledge.

[1]Professor of Economics, Grand Valley State University, L. William Seidman Center, 50 Front Ave. SW
Grand Rapids, MI 49504-6424, U.S.A.

The question we seek to address here is: as semiconductor production has shifted from North to South, has there been a flow of knowledge from manufacturers in the South to manufacturers in the North?

2. Methodology

2.1 Data

We use R&D spending to measure the input in the innovation process and patent data to measure the output of the process. For data on a firm's R&D spending and sales revenues, we use the EDGAR database and the company's annual reports. We convert all monetary amounts into real 2009 values using the U.S. GDP Deflator (available at www.bea.gov). For regional semiconductor production data we use the World Semiconductor Trade Statistics website (www.wsts.org). The time period for our study is 1991-2013, where the starting date is governed by the availability of the above data measures. Note though that not all of the companies in our study existed in 1991, so we do not have 23 years' worth of observations for every firm. We obtain all our patent data from the U.S. Patent and Trademark Office's (USPTO) online patent database (http://www.uspto.gov), counting the number of granted U.S. patents from the Current U.S. Classifications 438 (Semiconductor Device Manufacturing: Process), 257 (Solid State Devices), and 174 (Electricity: Conductors and Insulators). Once an application is filed, it can take several years for a patent to be granted, so we use a 2013 cutoff date.

Patent citations have been extensively used in the literature to measure international knowledge spillovers. For example, patent citations are used by Branstetter (2006) for spillovers from Japanese multinationals undertaking direct investment in the U.S., by Hu and Jaffe (2003) for spillovers from the U.S. and Japan to South Korea and Taiwan, and by Isely and Simons (2002) for spillovers in the U.S., German and Japanese automobile industries. Jaffe, Trajtenberg, and Fogarty (2000) find that "aggregate citation flows can be used as proxies for knowledge-spillover intensity…between countries" (p. 218).For each patent, the USPTO database includes identifying information about the owner of the patent (the "assignee", usually a company) and the inventor of the patent. This allows us to see if the inventor is in a different country than the assignee. Each patent also lists "prior art" – citations of existing patents which were deemed to be instrumental in the creation of the new patent. These citations indicate the country of origin of the cited patent. The information about the citations and the inventor then give us a way to identify international knowledge spillovers. We can conclude that an international knowledge spillover exists if the inventor is in a different country than the assignee, or if the patent cites existing patents from a different country.

We separate semiconductor firms into one of two groups, to reflect the changing nature of global semiconductor production during our time frame. For Group 1, we select firms using the following criteria: The firm must (1) be located outside of Asia Pacific (other than Japan); (2) be among the top 20 largest semiconductor producers in 2013; (3) either describe itself in annual reports/SEC filings as a semiconductor company or report R&D separately for the semiconductor division of the company, and (4) have a minimum of 10 consecutive years of patenting, semiconductor sales, and semiconductor R&D, within the time period of our study. We use figures from the industrial research company IHS Technology for point (2) above. These four criteria give us the following Group 1 firms: Advanced Micro Devices, Broadcom, Freescale, Infineon, Intel, Marvell, Micron Technology, Nvidia, Qualcomm, Renesas, Sandisk, STMicroelectronics, Texas Instruments, and Toshiba. Their countries of origin are France, Germany, Italy, Japan, the Netherlands, and the U.S.A.

Group 2 consists of semiconductor firms located in Asia Pacific (excluding Japan). This group includes firms located in South Korea, Malaysia, China, etc. No firm-specific data is needed for the semiconductor manufacturers in Group 2. However, the aggregated data for Group 2 reflects the production of companies such as SK Hynix, MediaTek, PowerChip, HiSilicon Technologies, TSMC, and Malaysian Pacific Industries. We note that South Korea does not perfectly fit with the traditional notion of the "South" in growth theory models. However, for our time period, South Korea does not fit perfectly within the concept of the "North" either. In 1991, South Korea's GNI per capita was $7550, with the World Bank placing the country in its "developing countries" category (World Bank, 1992). South Korea did not consistently meet the World Bank's "High-Income" classification cut-off (and thereby leave the developing countries category) until 2001. Moreover, South Korea's patenting activity shows a similar pattern. South Korean companies received only 134 semiconductor patents in 1991, a mere 4% of the 3380 semiconductor patents obtained by Japanese firms; it was not until 2001 that this ratio had grown to 15%.

2.2 Model

We are looking at knowledge spillovers that take place through the patenting system. The volume of spillovers would therefore depend on the number of patents a company has, which depends partly on the amount of resources the company directs to R&D. Separate from R&D spending, the amount of patenting is also a factor of the size of the firm, as well as how much competition it faces. The amount of competition would also likely influence the amount of spillovers. We therefore model knowledge spillovers as dependent on the number of patents obtained by the firm, the sales of the firm, the sales of all of its Group 1 competitors, the sales of all of the Group 2 competitors, and the amount of its R&D spending.

(1) $SPILLOVERS_{kt} = f(R\&D_{kt}, PATENTS_{kt}, SALES_{kt}, SALES_{G1t} - SALES_{kt}, SALES_{G2t})$

Where

- Subscript k designates individual Group 1 firms, and t is years.
- $SPILLOVERS_{kt}$ is the number of granted semiconductor patents that were applied for in the U.S. in year t, which cite a patent from a Group 2 country or which have an inventor from a Group 2 country, where firm k is the assignee
- $R\&D_{kt}$ is the natural log of firm k's spending on research and development in year t.
- $PATENTS_{kt}$ is the number of granted semiconductor patents that were applied for in the U.S. in year t, where firm k is the assignee.
- $SALES_{kt}$ is the natural log of semiconductor sales by firm k in year t.
- $SALES_{G1t}$ is the natural log of semiconductor sales by all of Group 1 in year t.
- $SALES_{G2t}$ is the natural log of semiconductor sales by all of Group 2 in year t.

Because SPILLOVERS is a non-negative count variable, we use a Poisson fixed-effects regression.

3. Results

Tables I and II give the summary statistics and regression results.

Table I. Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
$Spillovers_{kt}$	256	31	45	0	289
$R\&D_{kt}$	256	6.7	1.3	0.34	9.2
$Patents_{kt}$	256	326	323	1	1466
$Sales_{kt}$	256	8.4	1.3	1.6	11
$Sales_{G1t}$ - $Sales_{kt}$	256	120226	22241	61463	186901
$Sales_{G2t}$	256	11	0.66	9.4	12

Table II. Regression Results

Dependent Variable: $SPILLOVERS_{kt}$	
$R\&D_{kt}$	0.5798* (0.2454)
$PATENTS_{kt}$	0.0005* (0.0002)
$SALES_{kt}$	-0.0778 (0.2634)
$SALES_{G1t}$ - $SALES_{kt}$	- 1.11e-05** (1.87e-06)
$SALES_{G2t}$	1.3307** (0.4436)
Robust standard errors in parentheses. *, ** indicate statistical significance at 5%, and 1% level, respectively	

The coefficients indicate that, with statistical significance, there are more knowledge spillovers to individual Group 1 firms as they spend more on R&D, as they patent more (even with R&D constant), as sales by other Group 1 firms decreases, and as sales by Group 2 firms increases. The coefficient for their own sales is negative but not significant.

4. Summary and Conclusions

The positive and significant coefficients on R&D spending and patenting indicate that a North firm learns more from the South when the former spends more on R&D or simply patents more without any corresponding increase in R&D spending. This result is what we would expect – a firm learns more from others when the firm tries to innovate more. The negative sign and lack of statistical significance for the coefficient on a North firm's own sales may seem surprising – after all, we might expect that a larger firm would be in a better position to learn more from foreign inventors. However, we should interpret that coefficient holding the level of patenting and R&D spending constant, so the lack of significance means that the size of the firm does not matter for spillovers, if that firm is not undertaking more innovation in the first place. In addition, the negative sign might be a result of the larger number of personnel involved with innovation in a larger firm larger firms might have less need to be "reliant" on learning from outside inventors as they have a sufficient number of in-house innovators.

The negative and significant coefficient on the sales by other North firms indicates that an individual North firm learns less from South firms when it faces greater competition from the North. This seems surprising as, holding the other variables constant, we might expect that any increase in the level of competition from the North would encourage a firm to learn more from any source. We hypothesize that this result might be due to a substitution effect – greater competition from the North might encourage a firm to "look towards the North" to learn more from those northern competitors, and it thereby focuses less and learns less from the South. The positive and significant coefficient on the sales by South firms indicates direct South-North knowledge flows. All else constant, an increase in the sales of firms in the South leads individual North firms to learn more from southern inventors. This is in contrast to the standard North-South innovation models, which conclude that knowledge flows from North to South. Our result is consistent with the view that countries such as China have moved away from merely duplicating existing products to engaging more in their own innovative activities.

5. References

Branstetter, L. (2006). Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the United States. Journal of International Economics, 68, 325-344.

The Economist. (2016). Innovation in China: Out of the Master's Shadow, July 7, London, U.K.Grossman, G., &Helpman, E. (1991a). Quality ladders in the theory of growth. The Review of Economic Studies, 58, 43–61.

Grossman, G., &Helpman, E. (1991b). Quality ladders and product cycles. Quarterly Journal of Economics, 106, 557–586.

Hu, A., & Jaffe, A. (2003). Patent citations and international knowledge flow: the cases of Korea and Taiwan. International Journal of Industrial Organization, 21, 849-880.

ICInsights. (2015). Top Semiconductor R&D Leaders for 2014. [Online] Available: http://www.icinsights.com/news/bulletins/Top-Semiconductor-RD-Leaders-Ranked-For-2014 (October 1, 2017).

Isely, P., & Simons, G. (2002). Global influences on U.S. auto innovation. Economics of Innovation and New Technology, 11, 25-34.

Jaffe, A. (1986). Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value. American Economic Review, 76, 984-1001.

Jaffe, A., Fogarty, M., & Banks, B. (1998). Evidence from patents and patent citations on the impact of NASA and other federal labs on commercial innovation. Journal of Industrial Economics, 46, 193-205.

Jaffe, A., Trajtenberg, M., & Fogarty, M. (2000). Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors. American Economic Review Papers and Proceedings, 90, 215-218.

Pavitt, K., &Soete, L. (1982). International differences in economic growth and the international location of innovation. In H. Giersch (Ed.), Emerging Technologies: The consequences for economic growth, structural change and employment (pp. 105-133). Tübigen: JCB Mohr.

PwC (2014). A Decade of Unprecedented Growth: China's Impact on the Semiconductor Industry – 2014 Update.

World Bank. (1992). Global Economic Prospects and the Developing Countries – 1992, Washington, D.C.

WSTS. (2015). Historical Billings Report,[Online] Available: http://www.wsts.org/67/Historical-Billings-eport (October 12, 2017).