The Effect of NAFTA on Information Flows in the Automobile Industry

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There is a substantial amount of research on product innovation and a growing interest in the role that patents play in this process. This paper contributes to the existing literature by empirically investigating the connection between innovation in the U.S. automobile industry and NAFTA, and by looking at knowledge spillovers from Canada and Mexico to the U.S. Findings indicate that NAFTA has not resulted in any significant change in knowledge spillovers from Canada, but has resulted in a significant increase in knowledge spillovers arising from Mexico.

INTRODUCTION

In this paper we investigate the impact of NAFTA on knowledge spillovers from Canada and Mexico to the U.S. automobile industry. We measure these spillovers using different pieces of information from U.S. patents, including foreign citations and inventor/assignee country of origin. This is in contrast to the existing literature on NAFTA's effect on technological diffusion, which focuses on trade- and FDI-related spillovers.

Our decision to analyze a specific industry follows from previous research (for example, Giedeman, Isely and Simons, 2006) that shows that substantial differences in patenting behavior across industries can be masked when using aggregate data. We use the U.S. automobile industry because of the significant changes that the industry has experienced in recent years (e.g. in terms of production location, profitability, employment, etc.), the large volume of patents obtained by the industry both before and after NAFTA, and the widely held belief that NAFTA has had a uniformly negative impact on the industry.

Our emphasis on knowledge spillovers *from* Canada and Mexico *to* the U.S. is also in contrast to the existing literature, which focuses on spillovers from the U.S. to Mexico. It is reasonable to expect that a country like Mexico would enjoy knowledge spillovers from a more technologically advanced partner like the U.S. What is less obvious is if the more technologically advanced nation "learns" from the other (a South-North flow of knowledge rather than the more common North-South flow).

We find that the effect of NAFTA on knowledge spillovers to the U.S. automobile industry does indeed differ by country of origin. NAFTA has not resulted in any significant change in knowledge spillovers from Canada, but has resulted in a significant increase in knowledge spillovers arising from Mexico. In this sense, we can say that the U.S. automobile industry is learning from its Mexican counterpart.

LITERATURE REVIEW

There is a large body of literature on technological diffusion, looking at both domestic and international influences. The research on international influences has mostly focused on two mechanisms in the diffusion process: (1) the acquisition of technology embodied in imported goods or via FDI and (2) knowledge spillovers from R&D programs and inventors in different countries (for example, through patents and research publications).

Although there is disagreement on the magnitude of the impact of trade on the transfer of technology, there is general agreement that imports do play a role in this process. Coe and Helpman (1995) and Keller (2000, 2002) find that trade is an important mechanism for the international transfer of technology in developed countries, while Coe, Helpman, and Hoffmaister (1997), Bayoumi, Coe and Helpman (1999), Schiff, Wang and Olarreaga (2002) Schiff and Wang (2004a) and Wang (2007) also find benefits from trade-related spillovers for developing countries.

Other studies find that indirect trade-related spillovers also play a major role in international technology diffusion in both developed countries (Lumenga-Neso, Olarreaga and Schiff, 2005) and developing countries (Schiff and Wang, 2006).

In addition to the role that imports play in the acquisition of technology, there is some research on the role of FDI. Keller and Yeaple (2007), Schiff and Wang (forthcoming) and Smarzynska (2002, 2003) find spillover benefits arising from FDI in the U.S., developing, and transition economies, respectively.

There is also a large body of research on the use of patents to measure innovation and patent citations to measure knowledge spillovers, including work by Jaffe (1986), Pavitt and Soete (1997), Jaffe, Fogarty and Banks (1998), and Jaffe and Trajtenberg (2002). Jaffe, Trajtenberg, and Fogarty (2000) find that “aggregate citation flows can be used as proxies for knowledge-spillover intensity…between countries” (p. 218).

Jaffe and Trajtenberg (1999) explore patent citations for U.S. patents obtained by inventors in the U.S., the U.K., France, Germany and Japan. They find substantial spatial aspects to knowledge flows (inventors being more likely to cite patents from the same country) as well as likely language/culture connections (the greatest bilateral spillover in their study being between the U.S. and the U.K.).

Hu and Jaffe (2003) use patent citations to measure the diffusion of knowledge from the U.S. and Japan to South Korea and Taiwan. They find a substantial knowledge flow from Japan to Korea and significant but less intense knowledge flows from the U.S. to Korea and from Japan and the U.S. to Taiwan.

Isely and Simons (2002) investigate the impact that information flows (measured by trade and patent citations) have on patenting in the U.S. auto industry. They find that knowledge spillovers from Germany have a positive impact on patenting in the U.S., while spillovers from Japan have a negative impact on U.S. patenting.

There are relatively few statistical studies of technological spillovers specifically under NAFTA. These have focused on trade/FDI-related technology diffusion in Mexico and uniformly find a positive impact from NAFTA, with estimates of the resulting increase in productivity in Mexico ranging from 5.6% (Schiff and Wang 2003, 2004b) to 10% (Lopez-Cordova 2003a, 2003b, Iacovone and De Hoyos, 2006)

The contribution of this paper is in a combination of characteristics which differs from previous research: statistical analysis of NAFTA and international technology diffusion in a specific industry in the U.S., using patent data as a measure of knowledge spillovers.

METHODOLOGY

NAFTA and the Automobile Sector

NAFTA's implementation date of January 1, 1994 is seen as a pivotal point in trade liberalization between Canada, Mexico and the U.S. However, as Hufbauer and Schott (2005) point out, several other developments need to be taken into consideration when looking at automotive trade.

Canada and the U.S. have essentially enjoyed free trade in automobiles and parts since the 1965 Canada-United States Automotive Products Trade Agreement (a.k.a. the 1965 Auto Pact), which eliminated tariffs on auto trade between the two countries, subject to specified local content. In 1989, the Canada-U.S. Free Trade Agreement (CUSFTA) increased the rule-of-origin threshold for a final product to be considered "made in Canada/U.S." and changed some of the regulations concerning Canada's automotive trade with third party countries. The only policy changes for Canada-U.S. automotive trade brought about by NAFTA were increases in the rule-of-origin threshold.

In contrast, Mexico's automotive sector was highly protected in the 1960s and 1970s following a ban on imports of fully assembled vehicles in 1962. The 1989 Mexican Automotive Decree introduced some liberalization measures (aimed at improving the performance of the Mexican auto parts industry), but did little to increase automobile trade between Mexico and the rest of North America. It was not until NAFTA that Mexico's protection of its automotive sector, with respect to trade with Canada and the U.S., was eliminated (albeit over a ten-year phase-out period).

For our purposes then, the following is relevant: (1) U.S-Canada automotive trade was highly liberalized prior to NAFTA and (2) NAFTA involved a dramatic reduction in automotive trade barriers in Mexico.

Data

The companies we use in this study are General Motors Corp. and Ford Motor Co. We chose not to use Chrylser Corp. because of the complications created by the Daimler-Chrysler merger of 1998. We add Delphi Corp.'s numbers to GM and Visteon Corp.'s numbers to Ford to account for parts companies that were spun off by them in the late 1990's. Our data period is 1985-2002. Using a later ending date would not be appropriate as most patents take three to four years to be granted.

The U.S. patent process involves a search of existing patents. Relevant "prior art" is listed on granted patents in the form of citations along with its country of origin. The assignee's country and the inventor's country are also given. We obtain data on the number of U.S. patents assigned to these companies, and the other patent information indicated below, from the USPTO database.

We measure the impact of NAFTA on innovation for Ford and GM by the sum of the following:

1. the number of U.S. patents assigned to the company which cite a patent from Mexico/Canada
2. the number of U.S. patents assigned to the company for which the assignee country or inventor country is Mexico/Canada
3. the number of U.S. patents assigned to the company which reference any other U.S. patent which is
    a. from the U.S. patent class 180 (Motor Vehicles) or 123 (Internal-Combustion Engines) *and*
    b. has an assignee/inventor from Mexico/Canada

In addition to the patent data, company level data is necessary. We use Ward's Automotive Yearbook (1981-2003) to get vehicle production numbers for Ford and GM in Canada and Mexico. We use Compustat to get data on research and development (R&D) spending.

Model

To model the relationship between citations of patents originating in Mexico/Canada and Ford and GM, we estimate the following basic model:

$$Cites_{ikt} = f(R\&D_{it}, Production_{ikt}, Patents_{it}, Year_{ikt}, Mexico_{it} * Naftadummy_t, Naftadummy_t)$$

Where:

- $Cites_{ikt}$ is the sum of U.S. patents cited or created by company i in country k in year t
- $R\&D_{it}$ is firm i's spending on R&D in year t (deflated by $\mathrm{PATENTS}_{\mathrm{ikt}}$)
- $Production_{ikt}$ is the number of vehicle units produced by company i in country k in year t (deflated by $Patents_{it}$)
- $Patents_{it}$ is the total number of U.S. patents applied for (and eventually granted) by firm i in year t.
- $Year_{ikt}$ is year t for company i in country k.
- $Mexico_{it}$ is a dummy variable set to 1 if the country is Mexico.
- $Naftadummy_t$ is a dummy variable if year t is greater than 1994.

Subscript i designates companies; k countries; and t years. All monetary units are in millions of 2002 dollars using the implicit price deflator, and all non-dummy explanatory variables have been converted to natural logs. Summary statistics are provided in Table 1.

Several issues need to be addressed in estimating this model. First, the number of citations granted to a firm in year t is a non-negative count variable. We use a Poisson model to allow for this distribution. Second, there are unique characteristics within each company and each country. We use a fixed effect model with panels consisting of a time series of companies in a country to take this into account. Third, as can be seen in Table 1, the variance for each panel is much larger than the mean. We estimate a Negative Binomial model in addition to the Poisson model as a result of the suggested overdispersion. Finally, the panels have more time periods than there are individual panels. A Fisher test suggests that the variables as listed have non-zero drift which is corrected by the trend variable *Year*.

TABLE 1
SUMMARY STATISTICS

		Ford and Mexico		GM and Mexico	
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Cites	18	1.22	2.10	3.44	7.25
R&D	18	2.83	0.28	2.83	0.45
Production	18	6.27	0.37	6.07	0.55
Patents	18	5.78	0.59	6.07	0.42
Year	22	1995.50	6.49	1995.50	6.49
*Mexico*Naftadummy*	22	0.55	0.51	0.55	0.51
		Ford and Canada		**GM and Canada**	
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Cites	18	18.72	15.06	10.83	15.12
R&D	18	2.83	0.28	2.83	0.45
Production	18	7.47	0.64	7.49	0.39
Patents	18	5.78	0.59	6.07	0.42
Year	27	1993.00	7.94	1993.00	7.94

RESULTS

Looking for evidence of the influence of NAFTA on information flows from Mexico to the United States, we start by comparing Canada and Mexico. Although both countries are part of NAFTA, recall that Canada had a trade agreement on automobiles already in place for many years. Comparing simple averages before and after NAFTA, the percent increase in Mexico is larger (see Table 2). This is an uncontrolled difference, so the next step is to control the parts of the patent production function suggested in the Model section.

TABLE 2
PATENTS THAT ORIGINATE IN OR CITE CANADA AND MEXICO, YEARLY AVERAGES

Country	Company	1985 – 1994	1995- 2002	Percent Change
Mexico	Ford	0.3	2.375	6.9%
Mexico	GM	0.0	7.75	Undefined
Canada	Ford	9.1	30.75	2.4%
Canada	GM	4.1	19.25	3.7%

The model results are presented in Table 3. There is no qualitative difference between the Poisson model and the Negative Binomial model (columns 1 and 2), so we will discuss the results of the Negative Binomial model. There is a significant ($p<0.05$) difference between *Naftadummy* and *Mexico*Naftadummy*. Therefore, the effect of NAFTA on Mexico is different than the effect of NAFTA on Canada as seen in the simple averages.

TABLE 3
REGRESSION RESULTS

	Simple Poisson Model	**Simple Negative Binomial Model**	**Chow Test Negative Binomial Model**	**Adjusted Negative Binomial Model**	**Fully Interacted Negative Binomial Model**
R&D	-0.593 (-1.612)	-0.948 (-1.614)	-1.315* (-2.297)	-1.229* (-2.272)	-1.081 (-1.907)
Production	1.503*** (4.104)	1.861*** (4.189)	0.479 (0.629)	0.936 (1.680)	1.680* (2.517)
Patents	1.224 (1.825)	0.981 (1.071)	-0.735 (-0.637)	-0.206 (-0.212)	0.495 (0.474)
Year	0.236*** (6.373)	0.284*** (4.699)	0.266*** (4.705)	0.281*** (5.258)	0.332*** (5.171)
Naftadummy	-0.920*** (-3.639)	-1.062* (-2.223)	-0.607 (-1.193)	-0.834* (-1.962)	-1.299* (-2.573)
Mexico Naftadummy*	1.417* (2.320)	0.269 (0.503)	0.675 (0.463)	1.210 (1.554)	1393.364*** (3.548)
*R&D*Mexico *Naftadummy*					5.325* (2.284)
*Production*Mexico *Naftadummy*					0.674 (0.438)
*Patents*Mexico *Naftadummy*					9.822** (2.892)
*Year*Mexico *Naftadummy*					-0.737*** (-3.686)
*R&D*Mexico*			0.603 (0.209)		
Production Mexico*			1.080 (0.739)		
*Patents*Mexico*			1.833 (0.444)		
*Year*Mexico*			-0.011 (-0.576)	-0.002** (-2.740)	
Constant		-581.114*** (-4.857)	-523.319*** (-4.552)	-560.785*** (-5.280)	-672.756*** (-5.224)
N	72.000	72.000	72.000	72.000	72.000
* p<0.05, ** p<0.01, *** p<0.001 t statistics are given in parentheses					

Since Canada and Mexico appear different we can use a fully interacted model to determine if it is appropriate to pool the results. The only variable that is significantly different at the 5% level is *Year* vs. *Year*Mexico*. The initial regression is redone with *Year*Mexico* to account for this difference. The difference between *Naftadummy* and *Mexico*Naftadummy* increases in size and significance with the inclusion of *Year*Mexico*.

Finally, Mexico after NAFTA might have more than just a different intercept. As a result, we run a model interacting the coefficients with *Mexico*Naftadummy*. Overall R&D spending by Ford and GM shows decreasing returns for Canadian and pre-NAFTA Mexican citations, however, in post-NAFTA Mexico we see increasing returns to R&D spending. In addition, the base level of citations for post-NAFTA Mexico is significantly larger than the Canadian and pre-Mexican model. Finally, the trend variable is negative in post-NAFTA Mexico showing that the size of these gains is decaying over time.

CONCLUSION

Our results show that there is a significant increase in the flow of information, measured by patent citations/creations, from Mexico to the United States since the start of NAFTA. We do not see the same results for Canada where the changes as a result of NAFTA are much smaller.

Given the relatively minor changes that NAFTA made to U.S.-Canada automotive trade, the lack of a significant impact on knowledge flows between them arising from the trade agreement is perhaps not surprising. However, the increased South-North knowledge flow from Mexico to the U.S. is of greater interest. This suggests an increase in the engineering capabilities resident in Mexico as its exposure to the United States market increased. In addition, the model suggests that the gains have somewhat decayed over time. The reason for this decay is the subject of future research.

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