The Effect of Offshoring on Patenting in the U.S. Automobile Industry

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ABSTRACT

In the growing literature on offshoring, little attention has been given to the impact on product innovation. In this paper we empirically investigate the connection between industry innovation and offshoring in manufacturing. Specifically, our focus is on how information flows to the U.S. economy have been affected by the increase in manufacturing offshoring in the U.S. automobile industry. We measure these knowledge spillovers using different aspects of patent data, namely foreign citations and inventor country of origin. Our results indicate that offshoring has resulted in increased knowledge spillovers to the U.S., and that the size of such spillovers from emerging economy recipients of offshoring work are greater than those from developed country recipients.

Key Words: Offshoring, innovation, patents, automobile, spillovers.

JEL codes: L6, F2

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INTRODUCTION

An extensive amount of research has been conducted on technological innovation, due to its importance in influencing an economy's long run growth. Researchers have looked at the roles that both domestic and international factors may have on such innovation rates. Our research contributes to the existing literature by analyzing the role that the offshoring of manufacturing work plays in the process of technical accumulation.

We investigate the impact that manufacturing offshoring in the U.S. automobile industry has on knowledge spillovers from the "host" or recipient country back to the "home" country (the U.S. in this case). We look at how this type of offshoring affects a country's technological accumulation because as it increases the amount of manufacturing work undertaken in the host country such offshoring creates a more open, direct channel by which ideas can flow between innovators in the host country and those in the home country. Both the increase in host country manufacturing output and the creation or enhancement of this knowledge channel are likely to influence innovative behavior within the host country itself. This in turn might affect technological spillovers back to the home country.

We choose to analyze the effects of one industry by itself because existing research (for example, Giedeman, Isely, and Simons, 2006) shows that using economy-wide data can conceal significant differences in innovation rates between industries. Our decision to study the U.S. automobile industry is based on a number of factors: (1) the substantial changes that the industry has undergone in recent decades (in terms of output, productivity etc.); (2) the extensive R&D investments and the sizeable amount of patenting conducted by the industry; (3) the increasing offshoring of manufacturing work in the industry; and (4) the variety of offshoring recipient countries. This last point also allows us to investigate possible differences in knowledge spillovers resulting from offshoring to developed versus developing economies.

LITERATURE REVIEW

The marked increase in the volume of offshoring[1] over the last decade, and the heightened media and public awareness of it, has given rise to numerous studies attempting to discern the various impacts and welfare effects involved. Some, such as with the heated debate between Samuelson (2004) and Bhagwati, Panagariya and Srinivasan (2004), have focused on the theoretical underpinnings of offshoring; but there is also a growing literature of empirical analyses of offshoring's effects.

A number of researchers have looked at the impacts that offshoring in manufacturing has on employment and productivity. However, a consensus on these effects has yet to emerge. For example, Burke, Epstein and Choi (2004) look at offshoring in U.S. industry and find a strong relationship between the intensity of offshoring and job losses in manufacturing. In contrast, Harrison and McMillan (2007) find that offshoring has contributed to only a minor decline in manufacturing employment in the U.S, and Hijzen and Swaim (2007) find that offshoring has either no effect or a small positive effect on industry-wide employment levels in 17 high-income OECD countries.

Within the literature on the diffusion of technology, the subsection dealing with international knowledge spillovers falls into two categories: (1) those obtained through foreign

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[1] Despite frequent use as synonyms, the terms "offshoring", "outsourcing", and "foreign outsourcing" have quite different meanings. We use offshoring to refer to any transfer of production or services from a facility in the home country to an affiliated or non-affiliated facility in a foreign (host) country. See OECD (2007) for a thorough explanation of the related terminology.

direct investment (FDI) or international trade and (2) those obtained directly from the R&D performed in foreign countries.

There is much agreement that trade and FDI have a positive impact on technical diffusion. Coe and Helpman (1995) and Keller (2000) find that international trade plays a significant role in technological spillovers in developed countries, while Coe, Helpman, and Hoffmaister (1997) and Bayoumi, Coe and Helpman (1999) get similar results for developing countries. Positive spillover effects have also been found for FDI flows (see for example, Keller and Yeaple, 2007 and Schiff and Wang, 2008).

There is also general agreement that R&D has a positive impact on the international diffusion of technology, with patent citations frequently used to measure spillovers. For example, patent citations are used by Hu and Jaffe (2003) to measure spillovers from the U.S. and Japan to South Korea and Taiwan, and by Isely and Simons (2002) to measure spillovers in the U.S., German and Japanese automobile industries.

Although there is an extensive literature using patent data as a proxy for innovation, it is by no means a perfect measure. One problem is that the propensity to patent varies across firms. Brouwer and Kleinknecht (1999), for example, find that when controlling for the level of innovation output, smaller firms are less likely to apply for a patent. Despite such valid criticisms, patent data remains favored by many researchers, in large part due to the lack of consistent, alternative measures of innovative output across industries.

To date, much of the research on innovation and offshoring has focused on the offshoring of R&D activity itself. For example, Calantone and Stanko (2007) and Lewin, Massini and Peeters (2008) look at the major determinants of R&D offshoring in U.S. firms. Bardhan (2006) looks at the implications that R&D offshoring might have for the home firm's performance, while Qu et al. (2007) look at the impacts on host country firms.

However, there has been little research dealing with the effects that offshoring of manufacturing work by itself has on innovation. Fifarek, Veloso and Davidson (forthcoming) use patent data to analyze changes in innovation rates in the U.S. rare earth industry. They find that the innovation rate has decreased since the beginning of offshoring in the industry. Unfortunately, data limitations prevent them from measuring the degree or intensity of offshoring during that time period. Our study differs in that we use measurements of offshoring intensity to analyze the impact on knowledge spillovers from the offshoring recipient countries to the domestic industry, using specific measurements of the degree of offshoring.

METHODOLOGY

Measuring Offshoring

One area of agreement amongst researchers in this field is that there is currently no perfect measure of offshoring. Offshoring is frequently taken to imply a movement away from domestic providers of inputs to foreign providers. Following Feenstra and Hanson (1996, 1999), a commonly used approach in the literature is to measure offshoring as the amount of imported intermediate inputs relative to total non-energy inputs. That is, offshoring intensity for industry *i* is measured[2] as

$$(1) \qquad \textit{Offshoring Intensity}_i = \sum_j \left(\frac{\textit{imported inputs}_{ij}}{\textit{total non-energy inputs}_i} \right)$$

Because data on the amount of imported inputs used by a particular industry is often difficult to

[2] Several other measures have been used in the literature. For example, Hijzen and Swaim (2007) use imported intermediate goods as a proportion of value added; Yeats (2001) uses intermediate imports as a proportion of total imports; and Egger and Egger (2003) use intermediate inputs as a proportion of gross production.

obtain for a sufficient time series, much of the existing research has relied on proxy measures for imported inputs used by an industry. To this end, equation (1) is adapted by estimating the amount of imported inputs as follows:

$$\text{(2)} \qquad \textit{Imported Inputs}_{ij} = \sum_{j} \left(\textit{inputs}_{ij} \times \frac{\textit{imports of good } j}{\textit{domestic consumption of good } j} \right)$$

where the last term refers to the economy's total imports and consumption of inputs *i*, rather than that of the specific industry itself. Thus, implicit in the use of equation (2) is the assumption that the relative use of imported inputs in industry *i* is identical to its relative use in the economy as a whole.

Because our interest lies in the impact that offshoring has on knowledge spillovers that show up in patents, we focus on the offshoring of automotive parts production rather than, for example, the offshoring of service work or the offshoring of raw material supplies used by the auto industry. We also want to consider the intensity of offshoring by recipient country. We then modify equation (1) and measure the intensity of auto parts offshoring in automobile production, from the U.S. to country *k* in year *t* as follows:

$$\text{(3)} \qquad \textit{Auto Parts Offshoring Intensity}_{kt} = \frac{\textit{auto parts imported from country } k \textit{ in year } t}{\textit{total consumption of auto parts in year } t}$$

Data

Because of limitations in the availability of data, we use two different data sets to perform separate analyses.

For our first dataset, we measure the offshoring intensity for the U.S. automobile industry using data on the Original Equipment (OE) parts market, including the volume of OE inputs sourced from U.S. suppliers, the volume of OE inputs imported from Canada, China, Japan and

Mexico, and the overall volume of OE inputs. By focusing on the OE parts market (as opposed to "aftermarket" parts sold mostly by retailers directly to consumers), this data specifically measures the volume of auto parts used as inputs in the production of automobiles in the U.S. We obtain this data from DesRosiers Automotive Consultants Inc., a Canadian market research company which specializes in the automotive industry. As this data is available only from 1997 on, we use the time period 1997-2005[3]. Therefore, for this data set our offshoring measurement of equation (3) becomes

$$\text{(4)} \qquad \textit{Auto Parts Offshoring Intensity}_{kt} = \frac{\textit{OE inputs imported from country k in year t}}{\textit{total OE inputs in year t}}$$

We will refer to this measurement as Offshoring Measure 1.

For our second dataset, we measure offshoring intensity for the U.S. automobile industry with equation (3), but now modifying it in a similar way to how equation (2) is used in the literature to modify equation (1). That is, we proxy imported auto parts inputs with the country's overall level of imported auto parts. Such national import data measures auto parts imports for any end-use; that is, it counts imports for OE parts together with aftermarket parts and does not separate the two. The obvious drawback with this data is that it is a cruder measure of the degree of offshoring in auto parts production. The benefit of using this data is that it is available for a longer time period and for a larger number of trade partners than the data used for Offshoring Measure 1.

We use the U.S. Department of Commerce's online national trade databank "TradeStats Express" (available at http://tse.export.gov) to measure U.S. imports of auto parts (using the NAICS category 3363 "Motor Vehicle Parts") from the following countries: Mexico, Canada, Japan, Germany, China, South Korea, Taiwan, France, and the United Kingdom. These

[3] See the section on patent data for the rationale of our 2005 end date.

countries, make up nine of the ten largest exporters of auto parts to the U.S. in 2005. (We drop Brazil, the ninth largest exporter of auto parts to the U.S., from our study because of inconsistencies in the measurement of R&D spending needed for our regressions shown below). We use data from DesRosiers Automotive Consultants to measure the overall size of the U.S. auto parts market (both OE and after market parts) – the denominator in equation (3). The DesRosiers data is available from 1991 on, so we use the time period 1991-2005 for this dataset. We will refer to this measurement as Offshoring Measure 2.

The application and approval process for U.S. patents involves a search of existing domestic and international patents, which are known as "prior art." Patents must list the relevant prior art as citations or references, along with their country of origin. Included in the patent's information is the country of origin of the inventor or co-inventor, as well as the country of origin of the patent's owner (assignee). Thus, for example, a patent listing Ford Motor Co. as its assignee might have an individual in India as its inventor, and include references to U.S. and British patents as prior art. We obtain all our patent data from the U.S. Patent and Trademark Office's online patent database (http://www.uspto.gov).

We measure the knowledge spillovers from the offshoring recipient countries to the U.S. auto industry by the counting the number of U.S. patents from the U.S. patent classes 180 (Motor Vehicles) and 123 (Internal-Combustion Engines) which

a. have an inventor from the recipient country *or*

b. cite a patent from the recipient country

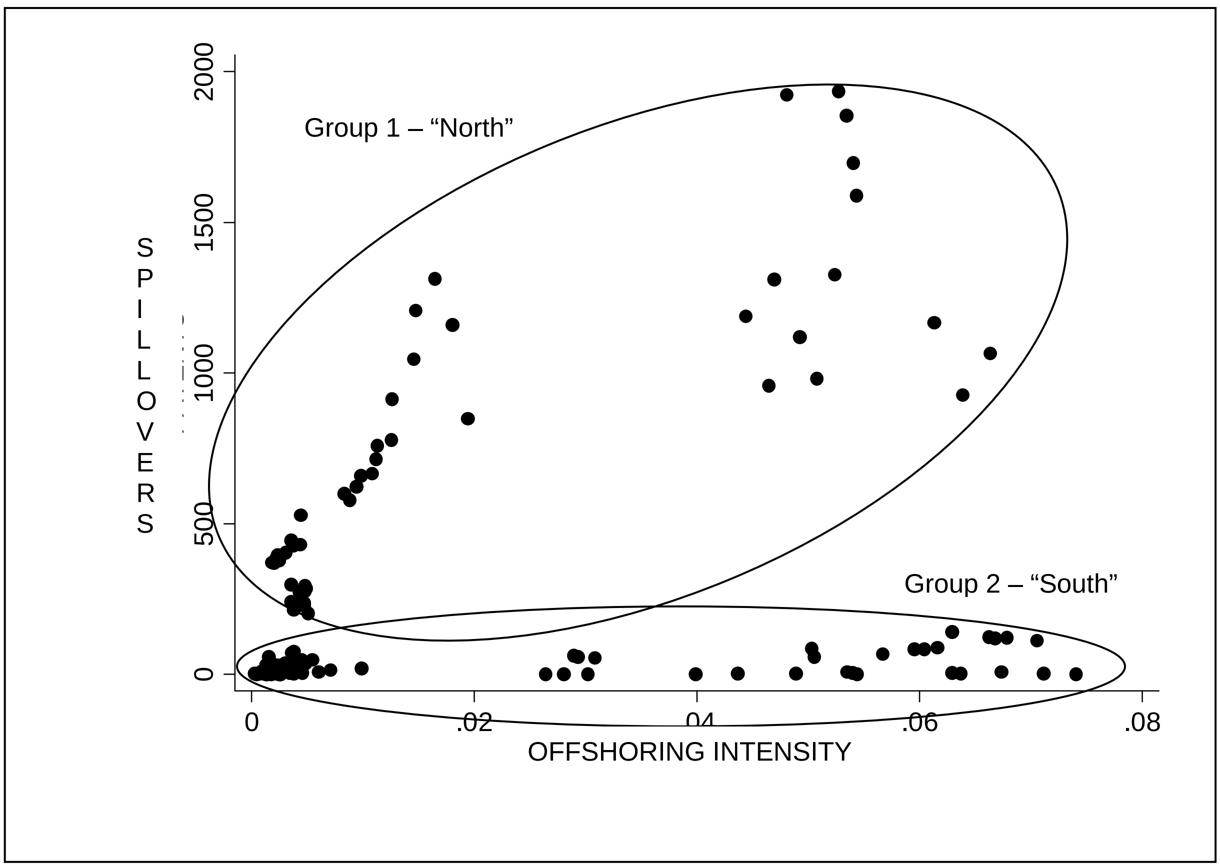
Because it takes about three years, on average, for the USPTO to either grant or deny a patent application, we use 2005 as the cutoff date for our two time periods.

We obtain data on Motor Vehicle R&D spending in the different countries from OECD

(2006) and from the OECD's "Research and Development Statistics" database. We convert this data from current U.S. dollars to Purchasing Power Parity values using the OECD's (2006) conversion tables, and into real 2000 values using the U.S. GDP Deflator (available at www.bea.gov).

Figure 1 shows how knowledge spillovers by country vary with offshoring intensity. Here, "spillovers" refers to the total number of successful patents during the data period which cite a patent from country *k* or which have an inventor from country *k*; "offshoring intensity" is the Offshoring Measure 2 as described by equation 2.

FIGURE 1: <u>How Spillovers Vary With Offshoring Intensity</u>



When looking at Figure 1 we can see that there appear to be two different populations.

Group 1, which we designate here as "North", is comprised of Canada, Japan, Germany, France, and the United Kingdom – all countries with well established, highly developed automobile industries and an extensive domestic patenting system. Group 2, which we designate as "South", is comprised of Mexico, China, South Korea, and Taiwan – countries with younger or relatively less developed automobile industries and with relatively smaller domestic patenting systems (for at least some of our data period). The number of successful patents which cite a particular South country or which have an inventor from that South country averages less than 75 per year. The same measure for each of the North countries averages more than 75 per year. We use this cut-off point to distinguish between the two groups in our regressions below.

Model

We begin by modeling knowledge spillovers from the foreign host country to the U.S. as a Cobb–Douglas style production function, where the foreign patents/citations are a function of R&D spending in the foreign country, R&D spending in the U.S. and the amount of offshoring. We deflate all of these terms by the overall level of automobile patenting in the U.S. and so we also include that term in the production function. The initial result is a log–log country fixed-effects estimation of:

(5) $$SPILLOVERS_{kt} = \alpha + \beta_1 (OFFSHORING_{kt}) + \beta_2 (OFFSHORING_{kt} * BIG) + \beta_3 (FOREIGN\ R\&D_{kt}) + \beta_4 (US\ R\&D_t) + \beta_5 (TOTAL_t)$$

where:

- $SPILLOVERS_{kt}$ is the natural log of the total number of patents applied for (and eventually granted) in the U.S. in year *t*, which cite a patent from country *k* or which have an inventor from country *k*, divided by $TOTAL_t$.

- *OFFSHORING*$_{kt}$ is the natural log of auto parts offshoring intensity to country *k* in year *t*, divided by *TOTAL*$_t$.
- *BIG* is a dummy variable that equals zero if the total number of patents applied for (and eventually granted) in the U.S., which cite a patent from country *k* or have an inventor from country *k*, has an average of less than 75 per year and equals one otherwise.
- *FOREIGN R&D*$_{kt}$ is the natural log of country *k*'s spending on motor vehicle research and development in year *t*, divided by *TOTAL*$_t$.
- *US R&D*$_t$ is the natural log of U.S. spending on motor vehicle research and development in year *t*, divided by *TOTAL*$_t$.
- *TOTAL*$_t$ is the natural log of the number of auto patents applied for (and eventually granted) in the U.S. in year *t*.

In Table 1 we provide the summary statistics for the data used to calculate the above variables. Thus, the measurements in Table 1 are actual, not log values, and are not deflated by *TOTAL*$_t$.

TABLE 1: Summary Statistics

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Spillovers	140	301.46	457.43	0	1934
Offshoring (Measure 1)	32	0.10	0.06	0.003	0.18
Offshoring (Measure 2)	150	0.02	0.02	0.0003	0.08
Foreign Auto R&D ($ millions)	124	305335.5	396507.3	1909.11	1886682
U.S. Auto R&D ($ millions)	140	1376026	350288.5	836754.4	1858140
TOTAL	140	2860.36	716.91	1935	4084

A log-log estimation of equation (5) has limitations though, because there are zeros for some data points and *SPILLOVERS* is a count variable. Following Hausman, Hall, and Griliches [1984], Hall and Ziedonis [2001] and Bessen and Hunt [2007], the expected number of patents obtained by a firm in any given year can be hypothesized as an exponential function:

(6) $E[PATENTS_{kt}|X_{kt}] = \lambda_{kt} = exp(X_{kt}\beta)$

where X_{kt} consists of the independent variables listed above. This estimation can be handled by a Poisson fixed-effects regression since *SPILLOVERS* is a non-negative integer. However, there is overdispersion in the data suggesting that a negative binomial regression would be a more appropriate procedure. For a comprehensive analysis of the data we run all three types of regressions.

Results

Table 2 shows the results from the log-log, Poisson, and negative binomial regressions for our two measures of offshoring intensity. For the South countries, the impact of offshoring on knowledge spillovers is given by the coefficient on *OFFSHORING* alone. For the North countries, the impact on knowledge spillovers is given by the sum of the coefficients on *OFFSHORING* and *OFFSHORING*BIG*.

Models 1–3 use the Offshoring Measure 1 as described by equation 4. This is the more accurate of our two measures of offshoring in the U.S. auto industry, but has the limitation of only 28 observations. There is an unambiguous positive effect of offshoring to the South countries on their knowledge spillovers to the U.S. in all three models. For the North countries, there is a negative coefficient for *OFFSHORING*BIG* in all three cases, indicating a smaller spillover effect than for the South countries. However, an F-test for Model 1 and chi-squared tests for Models 2 and 3 show that in each case the sum of the coefficients on *OFFSHORING* and *OFFSHORING*BIG* is not statistically different from zero. This indicates that offshoring to the North countries does not have any statistically significant effect on knowledge spillovers to the U.S. This outcome is intuitive given the already large domestic patent base of these countries.

TABLE 2: Regression Results

	Model 1 Log–Log	**Model 2** Poisson	**Model 3** Neg-Binomial	**Model 4** Log-Log	**Model 5** Poisson	**Model 6** Neg-Binomial
OFFSHORING (Measure 1)	0.973 (2.19)*	0.814 (1.91)+	0.480 (1.95)+			
*OFFSHORING*BIG* (Measure 1)	-1.685 (1.00)	-0.700 (1.42)	-0.379 (2.35)*			
OFFSHORING (Measure 2)				0.318 (2.12)*	0.909 (4.54)**	0.225 (3.51)**
*OFFSHORING*BIG* (Measure 2)				-0.240 (0.80)	-1.012 (4.95)**	-0.208 (5.70)**
FOREIGN R&D	0.270 (1.12)	0.275 (4.34)**	0.265 (3.21)**	0.256 (2.96)**	0.370 (10.70)**	0.335 (5.00)**
US R&D	-1.154 (1.11)	-0.269 (2.16)*	-0.259 (1.70)+	-0.393 (1.61)	-0.248 (6.39)**	-0.251 (2.99)**
TOTAL	-0.622 (0.48)	1.010 (7.04)**	1.003 (6.00)**	0.670 (3.68)**	0.663 (21.90)**	0.678 (9.93)**
Constant	16.977 (1.10)		0.905 (0.28)	2.827 (0.94)		-0.037 (0.04)
Observations	28	28	28	102	105	105
Number of Panels	4	4	4	9	9	9
R-squared	0.43			0.48		
Absolute value of t statistics in parentheses + significant at 10%; * significant at 5%; ** significant at 1%						

The coefficients on *FOREIGN R&D* show that an increase in R&D spending per patent in the offshoring recipient countries results in greater knowledge spillovers to the U.S. (though this coefficient is not significant in Model 1). This positive coefficient follows, since the more R&D spending the more intense the research in that country, which should result in more patents. However, as *U.S. R&D* increases, knowledge spillovers to the U.S. decrease (again, this coefficient is not significant in Model 1). Recall that *U.S. R&D* measures R&D spending in the U.S. *per patent*. As U.S. R&D spending per patent increases, there is a greater probability that any patent filed in the U.S. has a U.S. assignee rather than a foreign assignee. This would give the observed negative sign on the coefficient. Finally, for Models 2 and 3, as the total number of auto patents applied for (and granted) in the U.S. increases so do knowledge spillovers. This again is intuitive because more patents in the U.S. results in more opportunities to cite a foreign patent, or the greater likelihood that one of the patents is invented in a foreign country. This coefficient is negative but not significant in Model 1.

Models 4-6 use the Offshoring Measure 2. This allows for a larger data set to be explored which includes more countries and more years. For the South countries, there is again an unambiguous positive effect of offshoring on their spillovers to the U.S. in all three models. For the North countries, there is again a negative coefficient for *OFFSHORING*BIG* in all three models, indicating a smaller spillover effect than for the South as a result of offshoring. An F-test for Model 4 and a chi-squared test for Model 6 show that the sum of the coefficients on *OFFSHORING* and *OFFSHORING*BIG* is not statistically different from zero, once more indicating that offshoring to North countries does not give a statistically significant effect on knowledge spillovers to the U.S. For Model 5, a chi-squared test indicates that the sum of these coefficients is statistically different from zero, but the resulting coefficient is relatively small. Recall also that overdispersion suggests that Model 6 is a superior approach to Model 5.

The results for the remaining variables for Models 4-6 are qualitatively the same as with Models 1-3.

CONCLUSION

The results of our regressions shown above indicate that there is a statistically significant knowledge spillover effect from offshoring to South countries, but little or no spillover effect from offshoring to North countries. These results are robust across the different model specifications and the different measures of offshoring intensity.

The effects of offshoring to South countries on knowledge spillovers are statistically significant, but do they represent a significant quantity impact? We can estimate the knowledge spillovers using the results from Model 4. The predicted number of patents/citations (our measure of knowledge spillovers) arising from China in 2003 is 7.198. Increasing the measure of offshoring intensity from 0.007116 in 2003 to the 2004 level of 0.009881 and leaving all the other information unchanged, results in the predicted patenting level increasing to 8.444. This means that, ceteris paribus, the increase in U.S. auto industry offshoring to China between 2003 and 2004 has resulted in a 17.3% increase in knowledge spillovers from China to the U.S.

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