International Technological Diffusion Following Accession to the WTO

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There is growing interest in understanding the effects that different influences have on the level of innovation undertaken by private sector firms. One category of such influences is government policy – both direct (such as R&D subsidies) and indirect (such as trade policies). In this paper, we analyze how innovation in the U.S. economy has been impacted by membership of U.S. trading partners in the World Trade Organization (WTO). We use various pieces of data from U.S. patents to measure the impact that accession to the WTO has on technological diffusion from 20 emerging economies to the U.S. Using four different model specifications, we find that WTO membership results in an increase in knowledge spillovers from emerging economies to the U.S., suggesting that the economic reforms which generally accompany WTO accession help to stimulate innovation.

INTRODUCTION

It is common knowledge that technological innovation is a key element of long term economic growth. Because it is an integral part of economic development, there is an extensive literature on the process of technological accumulation. One subset of this literature deals with technological or knowledge spillovers between countries, whereby producers and/or inventors in one country are able to learn from their counterparts in another country.

In this paper we analyze the impact of WTO membership on technological spillovers from certain emerging markets to the U.S. economy, using information obtained from U.S. patents. We look at the role that WTO membership might play in a country's technological accumulation because joining the WTO is generally accompanied by trade liberalization and the passage of intellectual property rights agreements. Both of these factors are likely to influence innovative behavior within the country and might then affect spillovers to others.

In contrast to much of the existing literature, which emphasizes North-South spillovers, our focus is on South-North knowledge spillovers (*from* emerging economies *to* the U.S.). It would come as little surprise if an emerging economy were to obtain significant spillovers from its

relationship with a technologically advanced country like the U.S. But are these spillovers one-way? Is a technologically advanced country able to enjoy knowledge spillovers from its relationships with emerging economies?

We find that, for emerging countries with a range of economic, geographic and demographic characteristics, membership in the WTO yields a small but significant increase in the flow of knowledge to the U.S. economy.

LITERATURE REVIEW

Within the extensive literature on technological diffusion, the subsection of research that is relevant for this paper deals with international influences on spillovers. This is generally divided into two areas of focus: (1) spillovers acquired via imports or foreign direct investment (FDI) and (2) spillovers acquired more directly from the research and inventions undertaken in other countries (such as via patents).

With regard to the former focus, there is widespread agreement that trade and FDI have a positive impact on technological accumulation. International trade has been found to play a significant role in knowledge spillovers for developed countries (Coe and Helpman, 1995, Keller, 2000), as well as developing countries (Coe, Helpman, and Hoffmaister, 1997, Bayoumi, Coe and Helpman, 1999, Schiff and Wang, 2004a), while FDI has been found to yield spillovers for the U.S. (Keller and Yeaple, 2007), less developed countries (Schiff and Wang, 2008) and transition economies (Smarzynska, 2004).

With regard to the latter focus, there is also widespread agreement that R&D has a positive impact on international knowledge spillovers. This research is built upon the extensive literature using patent citations as a measure of spillovers (For example, Jaffe, 1986, Pavitt and Soete, 1997, and Jaffe, Trajtenberg, and Fogarty, 2000).

Patent citations have been used as an indication of international spillovers from the U.S. and Japan to South Korea and Taiwan (Hu and Jaffe, 2003), and in the U.S., German and Japanese auto industries (Isely and Simons, 2002). Jaffe and Trajtenberg (1999) also find that international spillovers are larger for countries that have language/cultural similarities (for example, the U.S. and the U.K.).

There are also a few empirical studies of technological spillovers following the implementation of NAFTA. Lopez-Cordova (2003), Schiff and Wang (2004b) and Iacovone and De Hoyos (2006) find positive impacts on trade/FDI-related technology spillovers in Mexico, while Isely and Simons (2007) find positive impacts on patenting related spillovers in the U.S. auto industry.

The finding of knowledge spillover effects generated by NAFTA indicates that a change in trade policies can have an effect on international technical diffusion. This leads to our supposition that joining the WTO might influence knowledge spillovers, and that the direction of these spillovers could be South-North in addition to the usual North-South. We investigate this possibility using patent data as a measure of knowledge spillovers.

METHODOLOGY

Data

Our data period is 1985-2002. Using a later ending date would not be appropriate as it takes several years for a U.S. patent application to be granted and to become accessible to the public.

We use a variety of different countries for this study, representing different geographical regions, different levels of development, and different demographic characteristics. These countries have a range of WTO accession dates including years outside of our data period. We also restrict our sample to countries which consistently patent over the data period. The countries are summarized in Table 1.

TABLE 1
COUNTRY SUMMARY

Country	Observations	WTO Accession Year
Armenia	11	2003
Brazil	18	1995
Bulgaria	11	1996
China	20	2001
Croatia	11	2000
Ecuador	18	1996
Estonia	11	1999
Georgia	11	2000
India	20	1995
Jordan	11	2000
Latvia	11	1999
Lithuania	11	2001
Malaysia	18	1995
Oman	11	2000
Panama	18	1997
Saudi Arabia	18	2005
South Africa	18	1995
South Korea	18	1995
UAE	18	1996
Vietnam	11	2007

The U.S. patent process involves a search of existing patents. Relevant "prior art" is listed on approved 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 use the U.S. Patent and Trademark Office (USPTO) patent database to obtain the following:

i. the number of U.S. patents applied for (and eventually granted) with a U.S. assignee per year;
ii. the number of U.S. patents applied for (and eventually granted) with a U.S. assignee per year, which either cite a patent from the emerging economy in question or which have an inventor/co-inventor from that emerging economy.

In addition to the patent data, economy-wide data is necessary. We obtain bilateral trade data from the U.S. Census Bureau, and U.S. R&D data from the National Science Foundation.

Model

We start with the following basic model:

$CITES_{kt} = f(R\&D_t, TRADE_{kt}, PATENTS_t, YEAR_{kt}, WTO*YEAR_{kt})$
Where:

- $CITES_{kt}$ is the sum of U.S. patents applied for (and eventually granted) in year t with a U.S. assignee, which cite a patent from country k or which have an inventor from country k
- $R\&D_t$ is total U.S. spending on R&D in year t (deflated by $PATENTS_t$)
- $TRADE_{kt}$ is the sum of bilateral imports and exports between the U.S. and country k in year t (deflated by $PATENTS_t$)
- $PATENTS_t$ is the total number of U.S. patents applied for (and eventually granted) in year t with a U.S. assignee.
- $YEAR_{kt}$ is year t in country k.
- $WTO*YEAR_{kt}$ is year t in country k multiplied by 1 if the country was in the WTO and 0 otherwise.

All monetary units are in millions of 2002 dollars using the implicit price deflator and all explanatory variables have been converted to natural logs except for the time trend. Summary statistics are provided in Table 2.

TABLE 2
SUMMARY STATISTICS

Variable	Obs.	Mean	Std. Dev.
CITES	364	27.60714	72.10011
R&D	364	3.054331	0.40761
TRADE	294	0.181446	0.391687
PATENTS	364	62959.43	21728.82
YEAR	366	1993.656	5.293217
WTO	366	0.259563	0.438995

Several issues need to be addressed in estimating this model. First, CITES is a non-negative count variable. We use a Poisson model to allow for this distribution. Second, there are unique characteristics within each country. We use a fixed effect model with panels consisting of a time series of countries to take this into account. Third, the variance for each panel is not equal to the mean. We estimate a Negative Binomial model in addition to the Poisson model as a result of the suggested overdispersion. Fourth, 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.

We estimate four models: Models 1 and 2 are the basic model described above using Fixed Effect Poisson and Fixed Effect Negative Binomial regressions, respectively. Models 3 and 4 expand the basic model by re-estimating Models 1 and 2 but now fully interacting every variable with the WTO dummy. This allows us to use an F-test to examine if a WTO member country behaves in a different manner than one that has not joined the WTO.

Results

Table 3 gives the regression results for the four model specifications.

TABLE 3
REGRESSION RESULTS

	Fixed effect Poisson (Model 1)	Fixed effect Negative Binomial (Model 2)	Fixed effect Poisson (Model 3)	Fixed effect Negative Binomial (Model 4)
R&D	-0.619* (-2.00)	-0.586 (-0.73)	-1.511 (-2.65)***	-2.129 (-1.75)*
TRADE	0.925*** (15.71)	0.436*** (6.46)	.744 (11.14)***	0.624 (4.90)***
PATENTS	0.965** (3.19)	0.382 (0.50)	1.805 (2.55)**	2.269 (1.48)
YEAR	0.075*** (4.35)	0.119** (2.78)	-0.016 (-0.38)	-0.065 (1.53)
WTO*YEAR	0.000096*** (4.52)	0.0001* (2.95)	0.262 (5.21)***	0.163 (1.11)
WTO			-493.22 (-5.41)***	-319.412 (-1.20)
WTO*R&D			-1.690 (-2.28)**	2.136 (0.91)
WTO*TRADE			0.225 (10.28)***	0.0601 (1.53)
WTO*PATENTS			-2.564 (-3.13)	-0.732 (-0.32)
CONSTANT		-237.534** (-3.12)		110.597 (0.68)
N	294	294	294	294
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.				

Models 1 and 2

Looking for evidence of the influence of WTO membership on information flows to the United States, we start by comparing the time trend before and after a country enters the WTO. 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 YEAR and WTO*YEAR. Therefore, there is evidence that after a country enters the WTO there is faster growth in the number of U.S.-filed patents that either cite patents from that country or were invented by someone in that country.

Models 3 and 4

Although the results for Models 3 and 4 show differences in the significance of the individual variables, an F-test of the terms interacted with WTO is significant at the 1% level. This shows that countries do behave differently after joining the WTO with respect to patenting in the U.S.

The coefficients on the R&D, TRADE, PATENTS and WTO*YEAR variables have the same signs under all four model specifications. However, when moving from Models 1 and 2 to Models 3 and 4, the YEAR variable changes sign, although it is no longer significant at the 10% level under Models 3 and 4.

General Discussion of Results

Since the countries chosen for this study have different accession years, the increase in the patent growth rate after joining the WTO is unlikely to be just a proxy for increased rates in general patenting after the launch of the WTO in 1995. However, Models 3 and 4 suggest that there may still be collinearity between YEAR and a country's behavior after joining the WTO. We require a longer time series of data and further testing to rule out this scenario. Nevertheless this adds evidence that inclusion in the WTO can lead even an emerging economy to be more productive in terms of patenting.

Using the coefficients from Model 3, we predict the number of patents in 2002 for an average country under two hypothetical scenarios: (i) if it were a member of the WTO and (ii) if it were not a member of the WTO. These predictions are shown in Table 4. Membership in the WTO yields a 35% greater quantity of patents-related knowledge spillovers to the U.S. for that year. The increase in patents calculated using the results from Model 4 is even larger.

TABLE 4
PREDICTED PATENTS BEFORE AND AFTER WTO ACCESSION

	Average Country Prediction	**Lower Error 95%**	**Higher Error 95%**
WTO	9.9	9.6	10.2
NOT WTO	7.3	6.9	7.7

CONCLUSIONS

In this paper we use four different model specifications to investigate the impact of WTO membership on patenting in the U.S. All four of these models indicate that joining the WTO has a positive impact on the flow of knowledge from emerging economies to the U.S. This enhanced South-North knowledge spillover may be a result of the liberalization measures which generally accompany WTO accession helping to stimulate innovation.

The flow of information from industrialized to emerging economies is well known. But in today's global economy, where companies have facilities all over the world, there are more opportunities for research in emerging economies to influence industrialized countries. For example, the U.S. is currently adapting technologies created in Brazil for the extraction of ethanol; China is now a space-faring nation; and India's Tata Industries Ltd. has become a parts supplier for Boeing. As emerging countries continue to open their markets and liberalize their economies, we can expect the flow of knowledge from them to the U.S. to increase.

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