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Regional Integration and Technology Diffusion

The Case of the North America Free Trade Agreement

Maurice Schiff
Yanling Wang

Abstract

The literature on regional integration agreements (RIAs) is vast and deals with political, economic, and political economy issues. The literature on the economics of RIAs deals mostly with static effects and concludes that these effects are, in general, ambiguous.

So far there has been no empirical analysis of the dynamic effects of RIAs based on their impact on technology diffusion from partner and nonpartner countries. Schiff and Wang's paper is a first attempt in this direction. The authors examine the impact of the North America Free Trade Agreement (NAFTA) on total factor productivity in Mexico through its impact on trade-related technology transfers from OECD countries. They estimate trade-related technology diffusion by using a measure of trade-related foreign research and development (R&D). Foreign R&D is constructed based on industry-specific R&D in the OECD, OECD-Mexico trade patterns, and input-output relations in Mexico.

The authors find that:

• Mexico's trade with its NAFTA partners had a large and significant impact on Mexico's total factor productivity, while trade with the rest of the OECD did not.

• Simulating the impact of NAFTA has led to a permanent increase in total factor productivity in Mexico's manufacturing sector of between 5.5 percent and 7.5 percent and to some convergence with the economies of Canada and the United States.

REGIONAL INTEGRATION AND TECHNOLOGY DIFFUSION: THE CASE OF NAFTA

Maurice Schiff[a] and Yanling Wang[b]

World Bank

a. Corresponding author. Mailstop No. MC3-303, International Trade Unit, The World Bank, 1818 H. St. NW Washington DC 20433. Tel. (202) 473-7963; Fax (202) 522-1159.. E-mail: Mschiff@worldbank.org.

b. Department of Economics, Georgetown University, 580 ICC, 37th & O Streets, NW Washington, DC 20057. Email: wangy6@georgetown.edu.

REGIONAL INTEGRATION AND TECHNOLOGY DIFFUSION:
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1.   Introduction

The literature on regional integration agreements (RIAs) is vast and deals with political, economic and political economy issues. A recent overview of that literature is World Bank (2000) and Schiff and Winters (2003). The literature on the economics of RIAs deals mostly with static effects, and concludes that these effects are in general ambiguous. This has led a large number of economists to be skeptical about the benefits of RIAs, particularly for South-South ones. Bhagwati and Panagariya (1996), World Bank (2000) and Schiff and Winters (2003) show that, under homogeneous goods, a South-South RIA is likely to lower bloc welfare. The latter two studies also show that the less developed member country is likely to lose relative to the more developed one.

As for North-South RIAs, the Southern member is likely to lose in the case of homogeneous goods because it typically has higher trade barriers than the Northern member, so that it provides larger transfers to the North than it obtains through its improved access to it.[1] For instance, Panagariya (1999) finds that NAFTA resulted in a static loss for Mexico in 1996 of US\$ 3.26 billion, or 0.98% of GDP.

On the other hand, CGE models using the Armington assumption of products differentiated by country of origin typically generate gains for Mexico from NAFTA. These gains are small under the assumptions of constant returns to scale and perfect

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[1] A sufficient (though not necessary) condition for this result is an internal solution where the Southern member continues to import from excluded countries after formation of the RIA.

competition (Bachrach and Mizrahi, 1992) and are larger under increasing returns to scale and imperfect competition (e.g., Brown, Deardorff and Stern, 1991; Roland-Holst et al., 1992; Sobarzo, 1992). Brown et al. (1991) obtain a gain of US$ 1.98 billion, or 0.63% of GDP, due to the removal of tariffs and NTBs under NAFTA. The effects obtained with CGE models are based on simulations, not ex-post evaluations. And the NAFTA simulations typically include the trade liberalization that took place under the Canada-US FTA as well as some of the unilateral liberalization that occurred in Mexico after 1985. Thus, the results should be interpreted with care.

There has been little analysis of the dynamic effects of RIAs. Ben-David (1993) examined the issue of convergence among member countries in the EU and found that the variance of (the log of) country per capita incomes fell as integration proceeded, though the factors underlying the convergence were not explicitly modeled. Other studies have used CGE models to examine the potential impact of NAFTA on industry location and productivity (Hunter et al., 1992; Krugman and Hanson, 1993). Hunter et al. conclude that NAFTA would result in relocation of production of the auto industry to Mexico, with fewer but larger firms in Mexico producing more output with a lower price-cost margin.

So far, there has been no empirical analysis of the dynamic effects of RIAs based on their impact on technology diffusion from partner and non-partner countries. This paper is a first attempt in this direction. It examines the impact of NAFTA on total factor productivity (TFP) in Mexico through its impact on trade-related technology transfers from OECD countries. Our main findings are:

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- Trade with Mexico's NAFTA neighbors has a large and significant impact on TFP in Mexico's manufacturing sector. This is not the case for trade with the rest of the OECD.

- NAFTA has led to a permanent increase in TFP in Mexico's manufacturing sector of between 5.5% and 7.5% and to some convergence to the economies of the US and Canada.

The paper is organized as follows. Section 2 provides a brief analytical framework. Section 3 describes the empirical implementation. Data sources and variable definitions are given in Section 4. Section 5 presents the empirical results, Section 6 simulates the impact of NAFTA and Section 7 concludes.

2.   Analytical Framework

The theoretical basis for the approach used here is endogenous growth theory. The development of that theory originated with the papers of Romer (1986, 1990) and Lucas (1988). These papers posit that the returns to. the accumulation of knowledge capital (Romer) and human capital (Lucas) do not diminish at the aggregate level because of positive spillover effects, and that policies can have a permanent impact on the rate of economic growth.[2]

Grossman and Helpman (1991) extended the Lucas and Romer analysis by exploring endogenous growth theory in an open economy setting. The basic idea is that goods embody technological know-how and therefore countries can acquire foreign

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[2] An excellent review of the origins of endogenous growth is Romer (1994).

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knowledge through imports. Coe and Helpman (1995) provide an empirical implementation of the open economy endogenous growth model. They construct an index of the foreign R&D to which a country has access as the trade-weighted sum of that country's trading partners' stocks of R&D. They find for a sample of developed countries that both domestic and foreign R&D have a significant impact on TFP, and that TFP increases with the general degree of openness of the economy and with openness towards the larger R&D producing countries.[3]

Coe, Helpman and Hoffmaister (1997) examine the same issue for developing countries. They find that developing countries benefit more from foreign R&D spillovers, the more open they are and the more skilled is their labor force. These findings provide support for the hypothesis that trade is an important mechanism through which knowledge and technological progress is transmitted across countries.

This paper builds on Schiff, Wang and Olarreaga (2002). That paper expanded on Coe and Helpman (1995) and Coe et al. (1997) by examining these issues at the industry level in developing countries.[4] The idea is that importing countries learn from the knowledge embedded in the *inputs* that they import. As is shown in Section 3 below, our measure of the stock of foreign R&D obtained by an importing country at the industry level explicitly incorporates the production structure of the economy as reflected in the input-output relationships.

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[3] Keller (1998) argues that Coe and Helpman's finding on trade as a channel for R&D spillovers is not entirely conclusive. Lumenga-Neso et al. (2001) show that Coe and Helpman's results do seem to hold once "indirect" trade-related R&D spillovers are taken into account.

[4] Keller (2002a) did examine trade-related R&D spillovers at the industry level for the G-7 countries and Sweden.

3. Empirical Implementation

Coe and Helpman (1995) estimate the following equation based on Grossman and Helpman's (1991) theoretical work on endogenous growth in the open economy:

$$\ln TFP_{ct} = \alpha_{ct} + \beta_d \ln RD_{ct}^d + \beta_f \ln RD_{ct}^f + \varepsilon_{ct}; \beta_d, \beta_f > 0, \qquad (1)$$

where RD_{ct}^d (RD_{ct}^f) is the domestic (foreign) R&D stock, ε is an error term, and c (t) denotes country (year). Due to lack of data for Mexico (and for developing countries in general)--and as in Coe et al. (1997) and Schiff et al. (2002)--the estimation in this paper does not include domestic R&D. This is unlikely to be a problem because most of the world's R&D is performed in developed countries.[5]

We estimate TFP equations with pooled data for a panel of industries. We define the stock of foreign R&D available in industry i, NRD_i, as:

$$NRD_i \equiv \sum_j a_{ij} \overline{RD}_j = \sum_j a_{ij} \left[\sum_k \left(\frac{M_{jk}}{VA_j} \right) RD_{jk} \right] \qquad (2)$$

where k indexes OECD countries, j indexes industries, M (VA) (RD) denotes imports (value added) (R&D stock), and a_{ij} is the import input-output coefficient (which measures the share of imports of industry j that is sold to industry i).

The first part of equation (2) says that foreign R&D in industry i, NRD_i, is the sum, over all industries j, of $\overline{RD}_j$, the industry-j R&D obtained through imports from

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[5] In 1990 (1995), 96% (94.5%) of the world's R&D expenditures took place in industrial countries. Moreover, recent empirical work has shown that much of the technical change in OECD countries is based on the international diffusion of technology among OECD countries (Eaton and Kortum, 1999; Keller 2002a). For instance, Eaton and Kortum (1999) estimate that 87% of French growth is based on foreign R&D. Since developing countries invest much fewer resources in R&D than OECD countries, foreign R&D must be even more important for developing countries as a source of growth.

OECD countries, multiplied by a_{ij}, the share of imports of industry j that is sold to industry i. The second part of equation (2) says that $\overline{RD}_j$ is the sum, over OECD countries k, of M_{jk}/VA_j, the imports of industry-j products from OECD country k per unit of industry-j value added (i.e., the bilateral openness share), multiplied by RD_{jk}, the stock of industry-j R&D in OECD country k.

In fact, we split NRD (foreign R&D) into two parts, the NRD obtained through imports from the US and Canada (NRD^N), and NRD obtained through imports from the other 13 OECD countries in our sample (NRD^{OT}).

Education was included as an explanatory variable in regressions covering several countries in previous work (Schiff et al., 2002). However, we do not include education in single-country regressions because education is constant in a given year, i.e., it is the same across all industries, and is thus perfectly collinear with the industry dummies. The estimated equation is:

$$\ln TFP_{it} = \beta_0 + \beta_N \ln NRD_{it}^N + \beta_{OT} \ln NRD_{it}^{OT} + \sum_t \beta_t D_t + \sum_i \beta_i D_i + \varepsilon_{cit}; \beta_N, \beta_{OT} > 0, \quad (3)$$

where D_t (D_i) represents time (industry) dummies.

4.   Definition of Variables and Data Sources

Our sample consists of 6 R&D-intensive and 10 low R&D-intensive manufacturing industries over the period 1981-98. The TFP index is calculated as the

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[6] The 6 R&D-intensitive industries are: (1) 351/2-Chemicals, Drugs & Medicines; (2) 353/4-Petroleum Refineries & Products; (3) 382-Non-Electrical Machinery, Office & Computing Machinery; (4) 383-Electrical Machinery and Communication Equipment; (5) 384-Transportation Equipment; (6) 385-

difference between the logs of output and factor income, with inputs (labor and capital) weighted by their income shares, i.e., $\log TFP = \log Y - \alpha \log L - (1-\alpha)\log K$, with α equal to labor's share. The capital stocks are derived from investment series using the perpetual inventory model with a 5% depreciation rate.

The R&D flow data are taken from the ANBERD 2000 (OECD) database (DSTI/EAS Division). The database covers 15 OECD countries from 1973 to 1998 at either the two-, three- or four-digit level.[7] From this, we construct R&D flow data for the 16 manufacturing industries at the two- or three-digit level (according to the United Nations International Standard Industrial Classification (ISIC) Revision 2). R&D flows cover all intramural business enterprise expenditures. Cumulative R&D stocks are derived using the perpetual inventory method with a 10% depreciation rate.

The import input-output matrix is not available, and instead, the national input-output matrix is used as a proxy, which is derived from GTAP (1998). Bilateral openness shares are derived from the World Bank database "Trade and Production 1976-1998" (Nicita and Olarreaga, 2001). For each industry and year, the shares are measured as the ratio of industry imports over value added. Trade data were collected at the 4-digit level and input-output data at the 3-digit level for the period 1981-98 (the available years for

Professional Goods. The 10 low R&D-intensive industries are: (1) 31-Food, Beverage & Tobacco; (2) 32-Textiles, Apparel & Leather; (3) 33-Wood Products & Furniture; (4) 34-Paper, Paper Products & Printing; (5) 355/6-Rubber & Plastic Products; (6) 36-Non-Metallic Mineral Products; (7) 371-Iron & Steel; (8) 372-Non-Ferrous Metals; (9) 381-Metal Products; and (10) 39-Other Manufacturing. Industry R&D intensity is defined as the ratio of R&D spending over its value added. The R&D intensity of U.S industries was used to group them into low and high R&D-intensity industries.

[7] The 15 OECD countries are: Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States.

Mexico), and both were aggregated to 2- and 3-digit levels for consistency with the R&D data (16 industries).

5. Estimation Results

5.1 Panel Unit Root Test

Before turning to the econometric analysis, we need to consider the issue that two or more variables may be trended and contain unit roots, making the regression results spurious (unless the variables are co-integrated). Levin and Lin(1992, 1993) developed a specific procedure to test for panel data unit roots. This paper adapts the method in Levin and Lin (1993) to conduct unit root tests for each of the variables of interest: total factor productivity (TFP), trade-related foreign R&D from the US and Canada (NRD^N), and trade-related foreign R&D from the rest of the OECD (NRD^{OT}). The model under

consideration is $\Delta y_{i,t} = \alpha_{0,i} + \alpha_{1,i}t + \delta_i y_{i,t-1} + \sum_{L=1}^{P_i} \theta_{iL} \Delta y_{i,t-L} + \varepsilon_{i,t}$, where L=1,..., P_i; t=1,...,

T; i=1,..., N; and P_i is the number of lags included in each panel. The null hypothesis (variables contain unit roots) is that $\delta_i = 0$ for all i and the alternative hypothesis is that $\delta_i < 0$.

As shown in Table 1, whether P = 1 or P = 2, we reject the hypothesis that there is a panel unit root for all three variables: TFP, NRD^N and NRD^{OT}. Therefore, any panel regression results in the paper are unlikely to be spurious.

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5.2 Regression Results·

Column (i) of Table 2 presents the estimation results of equation (3). Coefficients of time and industry dummies are not shown. The elasticity of TFP with respect to foreign R&D from the US and Canada (NRD^N) is equal to .361 and is significant at the 1% level (t = 3.01). The elasticity of TFP with respect to foreign R&D from the other 13 OECD countries in our sample (NRD^{OT}) is equal to .041 and is not significantly different from zero (t = .21).

In other words, Mexico obtains large and statistically significant productivity gains from its trade with its NAFTA partners, and obtains very small and statistically non-significant productivity gains from its trade with the other OECD countries. The difference in elasticities suggests that NAFTA has had a positive impact on TFP. This is shown in Section 6.

Why is the impact of NRD^N so much bigger than that of NRD^{OT} ? One possibility is that trade between Mexico and its Northern neighbors involves more than just an exchange of goods. It may entail personal interaction, including sub-contracting relationships where Mexican firms import intermediate goods from US firms and export finished products back to the same firms. In that case, learning is associated not only with the knowledge-content of the imported goods but also with the close contacts associated with trade. This is more likely to hold inside NAFTA than with the more distant countries of Europe, Japan and Australia.

A relevant paper in this regard is Keller (2002b) who shows that knowledge is geographically localized in the sense that its impact on TFP declines with distance. He

defines ERD, the effective R&D, as ERD $\equiv$ RD*$e^{-\delta D}$, where D is the bilateral distance between the importing and exporting countries, normalized to 1 for the shortest distance. He obtains a value for δ = 1.005. Replacing the solution for ERD in equation (2), we obtain that ENRD, the effective NRD, is ENRD = NRD* $e^{-\delta D}$. The weighted average distance between Mexico and non-NAFTA OECD countries is 3.31 times the distance between Mexico and its NAFTA neighbors (10,052 versus 3041 km).[8] Thus, ENRD from the US and Canada is $ENRD^N$ = .366NRD^N ($e^{-1.005}NRD^N$) and ENRD from the rest of the OECD is $ENRD^{OT}$ = .036NRD^{OT} ($e^{-1.005*3.31}NRD^{OT}$). In other words, the effectiveness of the former is 10 times larger than the latter (.366 versus .036).

Thus, according to Keller's results, one might expect the elasticity of TFP with respect to NRD^N to be about ten times as large as that with respect to NRD^{OT}. This is supported by our results in column (i) of Table 2 which indicate that the former is about nine times larger than the latter (.361 versus .041).

We also tried alternative estimations to that given in column (i) of Table 2. The two measures of foreign R&D, NRD^N and NRD^{OT}, happen to be highly correlated, with a correlation coefficient of .92. This might affect the regression results. We therefore also examined the effect of each measure of foreign R&D separately. This is shown in columns (ii) and (iii) of Table 2. The results for NRD^N are very similar to those when both measures are used. This is not surprising, given that NRD^{OT} was highly non-significant in the first regression. The elasticity of TFP with respect to NRD^{OT} is larger,

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[8] Aggregate import shares within each group are used as weights.

though still not significant. The larger coefficient is probably due to the fact that NRD^{OT} is capturing some of the effect of NRD^N.

We also examined whether the elasticities differed in the post-NAFTA period (post-1994) and found no significant difference. Moreover, we ran regressions with interaction effects of the foreign R&D variables and a dummy variable (DR) for the R&D-intensive industries, in order to examine whether the elasticities are different in those industries. As shown in column (iv) of Table 2, the interaction effects are not significantly different from zero. Thus, the elasticity of TFP with respect to foreign R&D appears invariant with respect to the industry's R&D intensity.

6.   Simulation

We need to assess the extent of trade creation and trade diversion associated with NAFTA. Mexico's total imports for the 16 industries are shown in Table 3. Comparing 1994 and 1995, we see that imports remained approximately unchanged, falling by $.85 billion. Imports from NAFTA countries increased by $1.1 billion and those from other OECD countries fell by $1.95 billion. Under trade diversion, total imports remain unchanged. Assume that total imports remain at $59.1 billion in 1995 and that the change in imports due to trade diversion is equal to the average of $1.1 billion and $1.95 billion, or a $1.5 billion increase in imports from NAFTA neighbors and the same decrease from the other OECD countries. In that case, imports from NAFTA neighbors in 1995 would have been $49.4 billion and those from the rest of the OECD $9.7 billion.

How about trade creation? We assume that the increase in imports from the rest of the OECD to $10.5 billion in 1996 is due to factors unrelated to NAFTA, including unrelated changes in the world and Mexican economies. In percent, that change is equal to (10.5 -9.7)/9.7 = 8.25%. Second, we assume that the non-NAFTA forces that led to the increase in imports from the rest of the OECD had the same proportional impact on Mexico's imports from NAFTA countries. Imports from NAFTA are $63.8 billion in 1996. If we correct these for the 8.25% increase, we obtain that imports from NAFTA countries would have been $58.9 billion in 1998 in the absence of unrelated shocks in the Mexican or world economies. Finally, we attribute the remaining increase to trade creation. Thus, trade creation is estimated to have led to an increase in imports from NAFTA countries from $49.4 billion to $58.9 billion, or of 19.3%.

Note that if we do the same calculations but use 1997 as a base year, we obtain an estimate of trade creation of 14.1%, and if we use 1998 as a base year, we obtain an estimate of 17.9%. In what follows, we use the range of estimates for trade creation (14.1% to 19.3%) to calculate the impact of NAFTA on Mexico's TFP.

We calculate the effect on TFP based on the estimation in column (i) of Table 1. With an elasticity of .361, and assuming that trade creation has the same proportional effect on imports for all industries, a 14.1% increase in imports from NAFTA countries results in a 14.1% increase in NRD^N and in a 5.1% increase in TFP. And a 19.3% increase in imports results in a 7.0% increase in TFP. Thus, we conclude that trade creation resulted in an increase in the level of productivity of the manufacturing sector of between 5.1% and 7%.

As for trade diversion, the $1.5 billion increase in imports from NAFTA countries is about a 3% increase in imports and in NRD^N, which—with the elasticity of .361--raises TFP by 1.1%. The reduction in imports from the rest of the OECD of $1.5 billion amounts to a 15.4% reduction in imports and in NRD^{OT} and—with the elasticity of .041--in a reduction of .63% in TFP. Thus, the net impact of trade diversion on TFP is (1.1% - .63%) = .47%.

The total effect of NAFTA on TFP in Mexico's manufacturing sector ranges from about 5.6% (5.1% from trade creation plus .47% from trade diversion) to 7.5% (7% from trade creation plus .47% from trade diversion). The share of manufacturing in Mexico's GDP averaged 21.5% in 1996-98. Consequently, NAFTA's impact on manufacturing TFP amounted to an increase in GDP ranging from 1.2% to 1.6%. Panagariya (1999) obtained a loss from NAFTA of close to 1% of GDP while Brown et al. (1991) obtained a gain of 0.63% of GDP. Thus, our results based on the impact of NAFTA on technology diffusion seem to dominate the static losses or gains from NAFTA based on the standard approaches found in the literature.

Mexico's economy is about one twentieth of that of the rest of NAFTA (US + Canada). It thus seems reasonable to assume that NAFTA has only had a minor impact on the economies of the US + Canada (who already had a FTA between them, CUSFTA). Thus, NAFTA has resulted in some convergence of Mexico's economy to those of the US and Canada.

Note that, due to a lack of data, we have abstracted from the service sector where benefits from technology flows are likely to be important, including in the area of

transport, communications and financial services. The share of the service sector averaged 22% in 1996-98 (and growing fast). Assuming the same productivity gains from NAFTA in services as in manufacturing, the impact on GDP would have been twice as large as that reported above.

7.   Conclusion

Recent theoretical models of economic growth have highlighted the importance of trade as a channel of technology diffusion. Empirical studies of the impact of North-South trade-related technology diffusion on total factor productivity (TFP) have been undertaken at the aggregate level. This paper examines this issue at the industry level.

The paper focuses on Mexico. It examines the separate effects on Mexico's TFP of foreign R&D from the US and Canada, on the one hand, and from the rest of the OECD, on the other. We find that the impact of foreign R&D on the TFP of Mexico's manufacturing sector is large for imports from Mexico's NAFTA neighbors but not for imports from the rest of the OECD.

Based on the estimated TFP equation, we show that NAFTA has led to an increase in TFP in Mexico's manufacturing sector of 5.5% to 7.5%. Given the plausible assumption that it has had negligible effects on the joint economies of the US and Canada, NAFTA has resulted in some convergence of Mexico's economy to those of the US and Canada.

Table 1: Panel Unit Root Test Results

Variables	Levin and Lin (1993) Test Statistics	
	P=1	P=2
TFP	-9.42	-6.72
NRD^N	-25.95	-7.49
NRD^{OT}	-37.66	-5.88

Note: Model under test is specified as:

$$\Delta y_{i,t} = \alpha_{0,i} + \alpha_{1,i}t + \delta_i y_{i,t-1} + \sum_{L=1}^{P_i} \theta_{iL} \Delta y_{i,t-L} + \varepsilon_{i,t}$$. The

critical values at 1%, 5% and 10% confidence levels are
–2.94, -2.23 and –1.84 respectively.

Table 2. Regression Results
(Dependent variable: lnTFP)

Variable	(i)	(ii)	(iii)	(iv)
$ln(NRD^N)$	0.361	0.37		0.403
	(3.01)***	(3.27)*		(2.52)**
$ln(NRD^{OT})$	0.041		0.233	0.062
	(0.21)		(1.26)	(0.27)
$ln(NRD^N)*DR$				-0.070
				(-0.37)
$ln(NRD^{OT})*DR$				0.058
				(0.27)
Adjust R^2	0.80	0.80	0.79	0.80
No. of Observations	282	282	282	282

Note: Figures in parenthesis are t-statistics. The *** (**) (*) means that the coefficient is significant at the 1% (5%) (10%) significance level. NRD^N is the trade-related R&D from NAFTA countries (USA and Canada), and NRD^{OT} is the trade-related R&D from other OECD countries. DR = 1 for high R&D-intensity industries, and DR = 0 for low R&D- intensity industries.

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Table 3. Mexico's Imports, 1981-1998
(US$ billion)

| Year | All R&D Intensity Industries | | | NAFTA / Total (%) |
| | Imports | | | |
	NAFTA	Other OECD[1]	Total	
1981	13	5.309	18.309	71
1982	6.961	3.321	10.282	68
1983	3.588	1.661	5.249	68
1984	5.117	2.265	7.382	69
1985	7.248	2.117	9.365	77
1986	9.723	2.728	12.451	78
1987	7.404	2.933	10.337	72
1988	11	3.762	14.762	75
1989	13.7	3.653	17.353	79
1990	18.2	5.949	24.149	75
1991	20.3	5.949	26.249	77
1992	43.7	9.604	53.304	82
1993	46.7	10	56.7	82
1994	47.9	11.2	59.1	81
1995	49	9.257	58.257	84
1996	63.8	10.5	74.3	86
1997	79	13.6	92.6	85
1998	89.5	14.9	104.4	86

1. Other OECD does not include the USA and Canada.

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