NAFTA and U.S. Innovation*

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Abstract

Changes in technology have played a central role in international trade theory at least since the work of Ricardo (1817). In this study, we consider the effects of the North American Free Trade Agreement on the levels of innovation by U.S. publicly traded firms. Despite strong evidence that the agreement affected the level of trade between the U.S. and Mexico, we do not find evidence of an effects for public firms as a whole as well as for firms headquartered in border states in particular.

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1 Introduction

The North American Free Trade Agreement (NAFTA) has been controversial since before initial passage in 1994, culminating recently with the passage of its renegotiation in the United States-Mexico-Canada Agreement (USMCA) in 2020. In essence, it added Mexico to the 1988 Canada–United States Free Trade Agreement. Despite the large amount of public debate on the topic, we still do not have comprehensive evidence on how the initial agreement affected innovation in the U.S. A large literature in recent years has addressed the topic and in a wide range of countries. In this study, we consider how the tariff cuts for U.S. imports into Mexico that were a part of NAFTA affected patenting by publicly traded U.S. firms. Unlike prior results, who tend to find positive effects of trade liberalization on innovation, we do not find any evidence of an effect.

We begin by exploring a number of facts about NAFTA. The trade agreement was one of the first major regional trade agreements that precipitated a wave of further trade agreements worldwide. There is strong evidence not only that it significantly affected the volume of trade between the U.S. but also that it had significant effects on the extensive margin of trade in terms of the number of firms that exported to Mexico. Looking at the institutional detail of the agreement, it is clear that there was significant variation in the tariff changes across very narrow product categories, suggesting that a firm level approach is better suited to understanding the effects of the trade agreement than more aggregate industry level analyses. Looking at real gross domestic product (GDP) growth in the years before and after NAFTA went into effect, we also find a significant increase in the synchronization of the business cycles of the three countries after. This was despite a secular trend of structural change towards services that is likely to have mitigated the impact of the increase in trade on business syncronization due to NAFTA.

We then combine data from Compustat on the firm operations of publicly traded firms, patent data from the U.S. Patent and Trademark Office (USPTO), and tariff data from the United Nations Conference on Trade and Development's (UNCTAD's) Trade Analysis Information System (TRAINS). This utilizes two bridges between data sets. The first is described in Pierce and Schott (2014) that allows us to match tariff data in HS industry classifications to the Compustat firm Standard Industrial Classification (SIC) industry codes. The second is a bridge between the patent data from the USPTO and Compustat that was constructed by the Duke Innovation and SCientific Enterprises Research Network (DISCERN). After documenting a number of descriptive statistics about our firm panel, we perform a number of fixed effects estimations on the relationship between changes in Mexican tariffs and patenting by U.S. firms. In studying the effects of NAFTA, Mexican tariffs are the most relevant because NAFTA added Mexico to the existing Canada-U.S. agreement that went into effect 6 years earlier. This is done for our full sample as well as across different forms of firm heterogeneity. We first consider the effects on firms headquartered in border states relative to other firms. We then break this out across firms headquartered in states that border Mexico and firms headquartered in states that border Canada. Across all of these estimations, we do not find any effect of changes in Mexican tariffs on firm patenting.

Despite ample evidence that NAFTA affected the economy of the United States, the results about innovation are perhaps surprising. The firms in our sample account for a very large percentage of business cycle fluctuations (see Gabaix 2011) and are some of the most innovative in the economy (see Arora et al. 2024). Despite significant increases in business cycle syncronization over time after NAFTA was signed, we do not find any effects of the trade agreement on patenting by these firms. This is in stark contrast to a burgeoning literature on the topic of trade liberalization and innovation that has found positive effects on innovation in the economies. Since it is a technological leader, however, the effects in the United States may be different than what we may expect in Chile or Indonesia. Indeed, our findings are more in line with broader earlier studies (e.g. Bernard, Jensen, and Schott 2006 and de Loecker 2011) a well as more recent studies particularly on the effects of China joining the World trade Organization such as Chakravorty et al. (2017) and Autor et al.(2017).

In what follows, Section 2 provides a thorough description of the literature to date. In Section 3 we describe the data at the heart of our estimations and establish a number of new stylized facts. Section 4 considers our main estimations. In Section 5 we conclude and discuss future directions for research.

2 Literature Review

2.1 The Effects of Trade on Innovation

The literature on trade and innovation has grown substantially as worldwide trade grows and shifts in trade liberalization alter the global market and barriers to trade. Providing insight into a number of academic works on innovation and trade, Shu and Steinwender (2019) survey the literature categorize the impacts of trade in 4 different ways: import competition, export opportunities, foreign inputs competition, and access to imported intermediates. Using the above delineations between trade effects, Shu and Steinwender (2019) assess the literature evaluating the relationship between trade on innovation both through various that can be directly observed like research and development, patents, and product mix and measures that have to be estimated such as TFP levels. In their assessment, the authors find consensus across literature that firms facing import competition alter innovation efforts. This depends on if the respective importer is a threat to the firm's business and the firm's placement within the industry corresponds to being a follower or a leader. The authors note that these results are more strongly represented in Europe than the United States and are highly dependent on the level of development in the respective country and location of imports.

Shifting their focus to the effects of exporting on trade, the authors divide academic work based on the ways exporting affects market size and learning by exporting. In terms of market size, exporting has largely positive effects on innovation depending on the firm's market size and increases in market competition following exporting. As for knowledge acquisition, there is a positive relationship between exportation, firm learning, and innovation. With regards to the influence of importing intermediate goods, the literature reflects a positive relationship specifically between R&D, patenting, product innovation, and technology adoption. Shu and Steinwender (2019) note, however, that the majority of the literature reflects experiences of firms in developing nations. The positive relationships between innovation and importing intermediates is largely a result of decreased costs, allowing firms to reallocate funds to enhance production or shift their focus to innovation. Lastly, considering the role of foreign input competition on firms, the authors note a lack of research, with one study finding positive outcomes on innovation, although Shu and Steinwender (2019) theorize that the reverse effect could be true.

Similar to Shu and Steinwender (2019), Akcigit and Melitz (2022) survey the literature to analyze the influence trade liberalization has on innovation and complement this with the development of a new theoretical framework. Measuring innovation through changes in quality and variety of firm output, the authors differentiate between incumbents and entrants. Further, they consider the role of knowledge spillover and how international trading increases innovation itself rather than innovation incentives. By building up a closed economy model, the authors are able to consider intermediate goods, quality and labor, and elasticities determining market equilibrium and profits in relation to quality metrics. Measuring innovation in the next period, the authors create a profit maximization equation that defines equilibrium innovation levels. Following the basic model of innovation introduced above, the authors continue to add specifications to the model such as the role of competition between different types of firms, finding that only industry leaders will innovate as opposed to industry followers. The authors expand this model further to consider the impact on innovation efforts when firms are entrants or two industry leaders. Shifting to consider how changes in trade impact the model, the authors include both firm differences in exporting and how "market size and competition" influence innovation efforts. The results indicate exporters have stronger incentives to innovate to increase quality levels, as the nature of exporting expands competition. Further, extending the model beyond two period cycles, the authors find similar results with the added influence of interest rates on innovation incentives and the role of competitions overtime between incumbent firms. With the inclusion of competition, industry followers now have a stronger incentive to innovate as they have the potential to overtake the leaders.

Both Shu and Steinwender (2019) and Akcigit and Melitz (2022) refer back to the seminal work of Atkeson and Burstein (2010) that provides insight into the ways firms respond to increases in trading costs overtime with respect to productivity metrics like innovation and decisions to trade. Atkeson and Burstein (2010) measure firm shifts within productivity following an increase in trade costs. Using a market equilibrium model in conjunction with a steady-state model to analyze the relationships between trade, firms, and consumers, the authors consider three different trading scenarios: 1. Exporting by all firms 2. Exporting by most productive firms 3. Exporting by some firms independent of size. Atkeson and Burstein (2010) note in the second scenario firms have no productivity dynamics after their decision to export. In the third scenario firms have endogenous productivity dynamics. Applying the model of steady state to data the authors measure how market conditions such as interest and elasticity of innovation change the ways firms react to increase trade costs. In an economy when interest is 0 and innovation is elastic, innovation shifts from non-exporters to exporters increasing overall productivity but leaving "marginal trade costs" constant. Conversely, with a model including a 5 percent interest rate and inelastic innovation, the authors find although productivity increases, innovation decreases at a higher rate and marginal trade costs are negative. Lastly, when innovation is elastic and interest is 5 percent firms shift innovation from process to product. Connecting these results to welfare measured through consumption, Atkenson and Burstein (2010) find that although costs of trade influences firm decisions to innovation and exit/enter affect steady state overtime, the effect is gradual so benefits to welfare are limited.

While Atkeson and Burstein (2010) find welfare effects to be limited following a change in trade costs, Impullitti and Licandro (2018) expand on this model to consider the effects of firm competition as a result of trade on product variation, finding a positive impact of limited trade costs on welfare. Building a two-country economic model, when the number of firms is fixed, trade increases induce competition, narrowing the market to the more productive firms resulting in "cost-reducing innovation" and subsequently higher productivity. Deriving welfare out of the variety of products offered to consumers, the authors note more competition negatively affects welfare as there are less firms producing differing goods. In alternate conditions to the initial model, Impullitti and Licandro (2018) consider the impacts of free entry for firms into the economy, and the influence varying trade costs has on the number of firms exporting, the results of markups on increasing competition, and welfare. The resulting effects indicate when trade costs decrease, the number of firms exporting increases, resulting in welfare benefits largely due to pro-competitive effect. Shifting away from comparative statics, Impullitti and Licandro (2018) apply the model to US census data indicating similar results to the base model analysis: A decrease in trade costs prompts pro-competitive resulting in consumption growth by 50 percent attributed to dynamic gains. Lastly, the authors connect the results to innovation, finding a decrease in trade costs increases innovation for exporters but has the opposite effect on non-exporters.

Authors Aghion et al. (2018) expand on the role of exports on innovation that Impullitti and Licandro (2018) highlight, while reinforcing similar conclusions through an analysis of data from French manufacturing firms on "patent, customs, and production data." Beginning with a theoretical explanation, Aghion et al. (2018) model the economic interaction between consumers and French firms with an included innovation function. Combining these relationships and performing comparative statics the authors conclude firms with lower production costs have larger incentives to innovate as opposed to firms with higher costs. Further, higher levels of market competition disincentivizes all firms to limit innovation but particularly firms with higher costs. Applying the above theoretical explanation to data Aghion et al. finds 95 percent of firms that innovate also export and that firms with high export outputs have the largest amount of innovation, "[accounting] for 41 percent of aggregate share of French patents." Despite this correlation, the authors note the direction of the relationship and nature of causality between innovation and exports remains unclear. To provide further clarity, the authors create an "exogenous export demand" model controlling for possible changes within the firm, isolating the effects of exports on innovation. Using patent amount and type to measure innovation, the authors confirm when exports increase, firms with higher productivity innovate more, even when considering changes with the firm, firm placement within the market, and sector differences.

Shifting away from firm specific study to measuring global trends Cai, Li, and Santacreu (2022) and Coelli, Moxnes, and Ulltveit-Moe (2022) both seek to understand how trade impacts productivity via innovation and knowledge spillover across various industries and countries. Coelli, Moxnes, and Ulltveit-Moe (2022) provide the broadest global scope of the impact of trade liberalization by considering 65 different countries. The authors compile a data set from the European Patent Office and refine it to represent firm level measures of market exposure, weighing the number of patents filed prior to liberalization and following the tariff decrease. The economic model used reveals increases in trade bolsters overall productivity via knowledge stock and changes to tariffs affect innovation in larger markets more than smaller. The authors note the economic model does not include, but could be extended to encompass firm entry, competition, and entry of exporting firms to expand on the impacts on innovation.

Coelli, Moxnes, and Ulltveit-Moe (2022) apply the economic model to data including firm specific patent data and tariff information, accounting for differences in the ways tariffs affect industries and firms. The subsequent results suggest that over 8 years 1 percentage point reduction in tariffs causes a 2.6 percent increase in the knowledge stock of a firm and that 13 percent of growth of total knowledge stock is accounted for by considering tariff increases. The authors include an analysis of patents as being an adequate measure of innovation by introducing other signs of innovation such as, citation amount and research capabilities.

Building off Coelli, Moxnes, and Ulltveit-Moe (2022), Cai, Li, and Santacreu (2022) provide a refined equilibrium model including a "trade block" measuring a countries resting state and a "growth block," indicating a countries productivity levels are shifting. Including patents and patent citation data from 19 different countries and sectors, the authors measure the pace of "knowledge spillover" in both the trade and growth blocks while considering the differing effects of domestic versus international firms. Using comparative statics in the initial equilibrium model to measure the influence of increases of trade, the authors find productivity as a result of R&D allocation shifts to firms with the highest "increase in production" and subsequent profits. The role of knowledge spillovers aiding in the process of R&D allocation depends on a country's previous innovation tendencies. Applying the model to empirical data, within the US the authors find the speed at which knowledge is defused is fastest in the technology subsectors and slowest within the wood products sector.

With regards to measuring the influence R&D on productivity the authors also use patent data, to compare the share of domestic versus international R&D within nations, indicating that in the US, 14 percent of productivity is a result of domestic R&D. Cross country, the US, Japan, Germany, and UK have the fastest knowledge diffusion speeds in part due to the ability to effective information transference. Further, across all 19 countries, the authors conclude productivity differences between sectors is explained 27 percent by the amount of domestic innovation and 73 percent by knowledge spillover with the US, Germany, and Japan producing the most global knowledge. The authors differentiate between heterogeneous and homogeneous knowledge, noting heterogeneous knowledge as having a substantial effect. Cai, Li, and Santacreu (2022) expand their model to include changes to trade costs and an analysis of Brexit, as well.

2.2 The Effects of NAFTA

Following the implementation of the North American Free Trade Agreement between the US, Mexico and Canada in January of 1994, academic research began to predict and evaluate the agreement's outcomes both in terms of GDP and welfare. The vast majority of early academic studies find consensus on the projected and actual benefits of NAFTA on GDP and welfare measures to be positive for Mexico but with limited effects on the US and Canada in part due to developmental differences and prior agreements between the two later countries. Mexico, in contrast to the US and Canada had far more room to benefit from FTAs and hence attained the highest relative benefit.

Kehoe and Kehoe (1994) produce the seminal literature illustrating the predicted effects of NAFTA on the three nations by assessing on the four studies presented to both the US International Trade Commision and the FED. All four studies use an Applied General Equilibrium model, universally finding NAFTA will have a positive effect on GDP for Mexico, limited positive effects on the US, and with Canada experiencing the most limited changes in GDP as it was already engaged in FTA's with the US. Burfisher, Robinson, and Thierfelder (2001) provide a responding analysis to Kehoe and Kehoe (1994) but in 2001 to assess the accuracy of predictive NAFTA studies. The authors reiterate the difficulty in differentiating the effects of NAFTA isolated from broader economic trends and shocks early on, particularly the financial crisis of 1994-1995, but confirm Kehoe and Kehoe's (1994) assessment of the benefits Mexico receives via NAFTA and the limited effects on both the US and Canada. Further, the authors highlight the impacts on specific sectors of interest such as agriculture, automobiles, and Textiles. Ultimately, Burfisher, Robinson, and Thierfelder (2001) note studies estimating the future effects of NAFTA prior and directly following its implementation represent the truth.

Beyond predictive studies, Gould (1998) and Krueger (1999) both provide an initial analysis of the ways in which NAFTA affected movement of trade between the three member nations. Both authors acknowledge the influence of exogenous events, specifically the 1995 Mexican financial crisis and general GDP growth as a result of an increase in international trade outside of NAFTA countries strongly influenced trade patterns. By controlling these external influences on trade, Gould isolates the effect of NAFTA on trade using a Gravity Model, finding trade between US and Mexico was the only statistically significant relationship positively affected by NAFTA. As for US trade with Canada, Gould notes trade as a result of previous FTAs and general trade openness between the nations limits the effect of NAFTA itself. Lastly, the effect on trade between Canada and Mexico remains mixed. In terms of exports and imports, with respect to the US, Gould finds an overall increase of around 16 percent with the change in exports having higher statistical significance than imports.

Kruger (1999) provides further specification to the discussion of US exports and imports, noting an increase in exports to Mexico from 6.9 percent in 1980 to 11.6 percent in 1998 whereas exports to Canada increased from 16 percent to 22.7 percent during the same period. As for imports from Mexico and Canada to the US, there was an increase from 5 percent-10.2 percent and 16.3 percent-18.8 percent. Similar to Gould, Krueger uses gravity models while incorporating an "shift and share analysis" in an attempt to isolate the effects of NAFTA. Krueger (1999) notes trade increases across the three nations within the commodity goods sector. Ultimately, both Krueger (1999) and Gould (1998) agree although trade increased following NAFTA implementation, defining a casual relationship between the agreement and trade remains challenging due to external economic factors and the role of past FTAs between the US and Canada. Both Krueger (1999) and Gould (1998) conclude these changes to trade were, for the large part, a result of trade creating and not diverting, highly influenced by external trading patterns and economic events rather than NAFTA in isolation.

The previous studies encompass the predictive time frame prior to the implementation of NAFTA and directly following to measure the outcome. The following studies expand on this analysis and provide further information regarding more recent studies assessing the longer term effects on GDP. Villareal and Fergusson (2017) offer an influential contemporary assessment of NAFTA, particularly within the context of political uncertainty over the Trump Administration's attempt to withdraw from the agreement. Compiling trade data via the census bureau, Villareal and Fergusson (2017) conclude that trade and service exchanges between the US and Canada have substantially increased. Further, US-Mexico trade had increased by 455 percent since NAFTA was enacted with the US exporting more than importing. The authors provide updated information regarding exports and imports as well, with exports to Mexico and Canada from the US making up 34 percent of total exports and 26 percent of total imports. Evidently, trade and GDP for all NAFTA nations has increased over time, but the authors note the challenges of isolating NAFTA within these changes. More substantially than minimal increases to US GDP, the authors note increases in manufacturing and supply chain efficiencies between both the US and Mexico. Similar to the US, the direct results of NAFTA on the Mexican economy has been "positive but modest" with redistributional failures limiting the lived benefit broadly speaking. In regards to economic integration between the US and Mexico, FDI in terms of US stock in the Mexican economy has increased by 77.6 billion in 2015 with spikes in the stock in years of economic upturn. Similarly, Canada has experienced increases in FDI, although this is largely attributed to previous FTAs with the US rather than NAFTA itself.

Outside of GDP and trade analysis, Caliendo and Parro (2014) assess the influences of NAFTA and resulting tariff changes on welfare more generally in the US, Mexico, and Canada. Using a Ricardian and quantitative general equilibrium models to control for differences between sectors, the authors consider the interaction between decreased tariffs and both micro level factors, such as household preferences and wage changes, and macro trade level factors, such as quantity of intermediate goods, the value of trade, and total expenditure and trade balance. As a result of decreased tariffs following NAFTA implementation, Caliendo and Parro (2014) affirm past research showing trade increases, finding imports across all number countries grew with the largest effects being Mexican imports from both Canada and the US increasing by 116.60 percent and 118.31 percent. Specifically in terms of welfare, using changes in terms of trade, trade volume, and wages to measure welfare outcomes, Caliendo and Parro (2014) find US and Mexico received .08 percent and 1.13 percent increases in welfare respectively, whereas Canada experienced a .06 percent decline. In terms of real wages, all three countries experienced positive growth, although both welfare and wage results are highly varied across sectors.

Hakobyan and McLaren (2016) build off Caliendo and Parro's (2014) consideration of NAFTA's influence on welfare in their study regarding how the agreement altered US wages controlling for sector specifications and geography. The regression model the authors provide uses US census data from 1990-2000 to test for wage effects with key controls being level of education, industry level tariffs, and geography. The authors find that Footwear and Apparel and Accessories" were the least impacted by NAFTA through tariffs limitations while Carpets and Rugs and Gain and Mill Products were the least protected by tariffs. These less protected sectors following NAFTA implementation had limited wage growth in comparison to locations that had little NAFTA exposure. Further, Hakobyan and McLaren (2016) find that for unprotected industries, wages for blue-collar and highschool educated workers declined in large part due to the inability of these workers to adapt to labor market changes. Beyond specific industry, even workers that are not employed by a traditionally tradable sector but are in a location where NAFTA affected an unprotected sector wage affects hold true.

2.3 NAFTA and Innovation

A number of studies link increased trade and liberalization to further innovation and productivity (Shu and Steinwender 2019). This connection has led to further academic work seeking to define the influence of FTAs like NAFTA on measures of development, such as TFP, including both innovation and productivity. In general, there is limited research regarding innovation as a result of NAFTA within both the US and Canada, with the majority of studies emphasizing the influences on TFP in the Mexican economy as it is still developing. Within studies on innovation and overall effects of NAFTA, similar to the above works, authors struggle to isolate the direct influences of NAFTA, highlighting the complexity of defining causality between FTAs and TFP. Rather than seeking to measure direct causal links between NAFTA and innovation, authors like Rodriguez and Gomez (2011) instead focus on how broader policy changes within NAFTA countries impact factors of innovation, like patent applications. Utilizing data from the World Intellectual Property Organization and the Network for Science and Technology, the authors test for structural breaks in patent data to identify how shifting IP and technology exchange policies with the US may influence innovation both within the US and Canada and Mexico via NAFTA and Trade Related Aspects of Intellectual Property Rights (TRIPS) agreements. The results indicate a number of structural breaks that correspond to changes in patent policy, specifically via the Bayh-Dole Act, revealing the influence regulatory changes may have on fostering innovation. Rodriguez and Gomez (2011) further note the interaction between policy and patent applications reach beyond the US, holding true in both Canada and Mexico as well. Despite indicating the results of policy changes on patents more generally, the authors fail to specify the influence of NAFTA on factors of innovation.

In contrast to the US and Canada, Mexico receives strong academic attention in regards to defining the influence of NAFTA on TFP levels, largely analyzed via changes in Foreign Direct Investment and tariffs. In a comparative analysis between Chile and Mexico, authors Alvarez and Robertson (2017) provide a broad level analysis of the relationship between free trade policies and innovation within Mexico. Due to the nation's involvement in NAFTA, the authors note Mexico experienced further trade liberalization impacting both FDI increases and volume of trade. Taking into account previously defined influence of exports, foreign investment, and trade in intermediate goods on innovation, Alvarez and Robertson measure the relative influence of each factor. They also consider the role of productivity measures including ideas and products, implementation of technology, and increasing competition on innovation levels. Using data from firms within Mexico from 1993-1995 and innovation information regarding R&D capabilities and foreign technical licences, the authors run a probit model regression. Out of 7 different variables used to measure innovation, the authors conclude that exports having the largest impact with FDI and importing intermediate inputs having a positive effect as well. It should be noted Alvarez and Robertson's (2017) study focuses on defining factors that influence innovation as a result of trade liberalization, not the direct influence of NAFTA specifically.

Authors López-Córdova (2003) and Lederman et al. (2005) provide an initial analysis of how NAFTA's regulatory limitations expanded trade opportunities and increased FDI shaping innovation. Using OLS estimation techniques and firm specific data, López-Córdova (2003) find, following the implementation of NAFTA, Mexican manufacturing experienced an increase in TFP by 1.2 percent between the years of 1993-2000, although this result is highly dependent on sector specifications within manufacturing. In an attempt to isolate the effect of NAFTA on TFP growth, through controlling for FDI, trade, and sectorial and firm differences, López-Córdova (2003) find competitiveness due to liberalization, preferential access to US markets for Mexican goods, and, although indirectly, increasing exports are statistically significant in increasing productivity. Further, the author analyzes the effects of FDI on productivity, both within the same sectors as the investment and sectors external to the investment, finding that within the same sector there is a negative relationship, while the opposite is true in sectors outside of the FDI. Ultimately, the author concludes NAFTA has had a strong influence on increasing Mexican productivity despite economic shocks of the 1990s with the most significant impact being through import penetration raising TFP by an estimated 45 percent.

Leaderman et al. (2005) finds concurrence with López-Córdova (2003) regarding positive TFP growth following the implementation of NAFTA specifically within the manufacturing sector. Further Leaderman et al. (2005) notes the positive relationship between TFP growth in importing capital or intermediate goods, both of which increases as a result of NAFTA. Providing specificity on innovation within TFP itself, Lederman et al. (2005) notes there is minimal statistical evidence to indicate that increases in trade through FDI and growth in productivity increases technological innovation in Mexico. Beyond technological expansion Lederman et al. (2005) notes direct knowledge spillovers as a result of trade did not increase innovation to a large extent. Rather, Leaderman et al. (2005) argues human capital technical skills and learning capacity are more conducive avenues for innovation growth measured through R&D. With respect to R&D and NAFTA, despite initial increases in R&D following the enactment of the agreement there has been minimal positive influences on innovation. Ultimately, Lederman et al. (2005) concludes while increasing TFP, NAFTA has had a limited influence on innovation and that FTAs, like NAFTA, need to be coupled with domestic policy initiatives to be effective at stimulating innovation.

Waldkirch (2010) in his study on the influences of FDI on the Mexican economy provides further quantitative information into the relationships between FDI and TFP differentiating between sectors. Using industrial census data the author seeks to define the impact of FDI on both labor shifts and TFP levels and to provide a broader international analysis by using Industrial Census Data. Amounting to 170 billion dollars in 2005, Waldkrich (2010) finds 60 percent of FDI in the Mexican economy comes from the US particularly within the sectors of manufacturing and services. Through regression analysis, Waldkirch (2010) tests for the influence on FDI on TFP, controlling for FDI between maquiladora and non-maquila sectors and by US given FDI vs alternate FDI. Beyond FDI, Waldkirch (2010) considers the following explanatory variables: quantity of labor, scale, and concentration of industry. The key significant result, Waldkrich (2010) highlights is the positive relationship between US FDI to non-maquiladora sectors on TFP.

Recent studies reinforce Leaderman et al.'s (2005) early assertion that NAFTA has positive but limited influence on innovation and TFP within the Mexican economy. Both Hernandez-Trillo (2017) and Durán (2019) perform similar studies to one another assessing innovation capacities within Mexico following NAFTA noting ineffective policy support continues to limit the realization of trade liberalization. In his study on NAFTA's effects on Mexican economy, Hernandez-Trillo (2017) notes while trade and welfare increased with the enactment of NAFTA, treaty stipulations, specifically, modernization of rules of origin and intellectual property regulations in combination with government initiatives need to be reformed to maximize the treaty's positive effects. In noting the positive outcomes of NAFTA, the authors highlight how the agreement strengthens property rights assurances within Mexico for Canadian and American investors enabling higher rates of FDI with US to Mexico FDI resting at around 27 percent between 1999 and 2015. Despite this increase in FDI, Hernandez-Trillo (2017) conclude that while NAFTA has the potential to increase innovation within Mexico through trade openness and treaty stipulations, domestic economic limitations and a failure to promote development limits the country's innovation on a mass scale.

Durán (2019) provides further nuance to Hernandez-Trillo's (2017) work through considering the influence of wage differences on development and innovation. Using manufacturing and trade data Durán (2019) analyzes the role NAFTA, GATT and domestic policy plays in bolstering Mexican economic capacities. Similar to Hernandez-Trillo (2017), Durán (2019) affirms the positive relationship between NAFTA and FDI, but he notes this correlation is largely due to the attractive wage differential for foreign firms coupled with strong domestic policies positively influencing the level of FDI. The author argues further FDI in the Mexican economy enforces a cycle of investment and innovation particularly in central Mexico, Mexico City, and in US-Mexico border cities. Ultimately Hernandez-Trillo (2017), Durán (2019) converge on the same conclusion: despite increase in FDI following NAFTA, innovation and prolonged economic growth, is not directly guaranteed through FTAs, rather a combination of government incentives and promotion of domestic innovation capabilities need to be implemented to ensure long term economic development.

3 Data and Stylized Facts

3.1 Data

Our data combines three primary sources of information: Compustat, USPTO patent data, and tariff data from TRAINS. The primary source of firm-level data is Compustat, originally compiled by Standard & Poor's. This data provides comprehensive annual financial and operational characteristics of publicly traded firms. For this analysis, we focus on firms headquartered in the United States from 1985 to 2000. This data set offers key attributes such as firm identifiers (gvkey), industry classification (NAICS codes), and metrics like sales, profitability, employee counts, R&D expenditure, and capital expenditures. To maintain consistency and avoid redundancy, we limit the sample to firms with primary securities ***** and ensure unique identifiers for each observation by retaining only one Employee Identification Number (EIN) per firm per year.

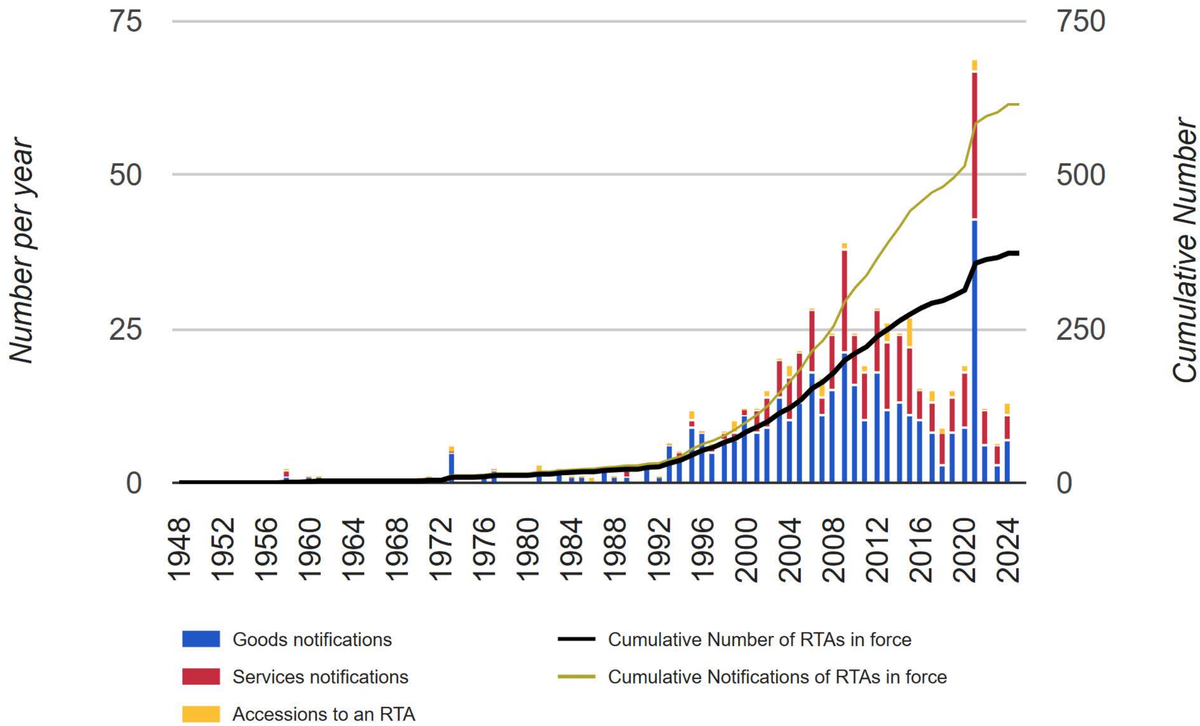
The data preparation involved several filtering and cleaning steps. First, we drop observations with missing or negative sales, which indicate firms that are likely inactive or idling. Missing R&D expenditures are set to zero and firms reporting negative employment are removed. Firms have strong financial incentives to report R&D expenditures due to the R&D Tax Credit and is a common assumption in the literature. Next, we ensure that each observation links to a unique firm identifier per year. These steps provide a dataset that focuses on financially active, US-headquartered firms, improving the validity of our subsequent analyses.

Our second primary data source is the United States Patent and Trademark Office (USPTO) patent data, which we use to evaluate each firm's innovation output. This dataset includes patent IDs, application and grant dates, and patent assignee details, allowing us to gauge the scope of each firm's innovative efforts. To link Compustat's firm-level financial data to USPTO patent filings, we use DISCERN 2, a bridge dataset bridge from Duke University's Innovation & Scientific Enterprises Research Network (DISCERN). This matches Compustat firm identifiers with patent identifiers, adjusting for firm ownership changes, mergers, and acquisitions. This linkage allows us to accurately track patent activity across firms despite changes in name, reassignment of firm identifiers, and ownership structure over time. This enables robust linking between financial data while dynamically tracking each firm's patenting efforts. Details are found in Arora et al. (2024). After using the HS to SIC concordance in Pierce and Schott (2012), we can then match the UNCTAD TRAINS data to Compustat using the common SIC industry identifier for each firm. Tariff data is initially at the 6 digit level and is interpolated for missing values using steps following Lincoln and McCallum (2018).

3.2 Stylized Facts

Figure 1 is sourced from data from the World Trade Organization and plots the number of regional trade agreements (RTAs) worldwide. A number of conclusions come out of this figure. The first is that regional trade agreements have expanded dramatically in the wake of a lack of progress in policy changes at the

Figure 1: Worldwide Regional Trade Agreements Over Time



Notes: Data is sourced from the World Trade Organization.

World Trade Organization. the Doha round of trade negotiations has been ongoing since 2001 and has produced very little policy changes in the world trade system to date. It is the longest such round of trade negotiations in world trade history. The second conclusion from this graph is that NAFTA was one of the most important of these agreements that was signed at the beginning of this process. At the time there were very few regional trade agreements and indeed the World Trade Organization (WTO) had not yet been formally founded; at the time the NAFTA countries were operating under the General Agreement on Tariffs and Trade, the forerunner to the WTO.

In Figure 2 we plot the distribution of the United States' most favored nation (MFN) tariffs rates in the year 2000, 6 years after NAFTA was signed. This is sourced from Romalis (2007). A simple average across different products yields an average of 5.2 percent, with a substantial standard deviation of 12 percent. Much of this variation happens within very narrow product classifications, emphasizing the benefits of a firm level perspective and suggesting that broad industry level studies may be missing the most important variation in the policy changes due to the free trade agreement.

In Figure 3, we reproduce data from the Longitudinal Firm Trade Transactions database maintained by the U.S. Census Bureau and was sourced from Lincoln and McCallum (2018). In 1994 the Mexican government suddenly devalued the peso against the U.S. dollar, eroding Mexican consumers' purchasing power for goods from the U.S. The number of firms begins rising dramatically to over 200 percent by the early 2002, however. This suggests that NAFTA may have had significant effects on U.S. firms' incentives to export to Mexico and that the change was felt at the extensive margin of the level of the firm.

In Figure 4, we similarly depict data from the Federal Reserve Bank of St. Louis on the real exports of goods from the U.S. to Mexico. Data is at the quarterly level and is seasonally adjusted. It is clear that the

Figure 2: Tariffs on Mexican Imports

FIGURE 4A.—U.S. IMPORT TARIFFS IN 2000

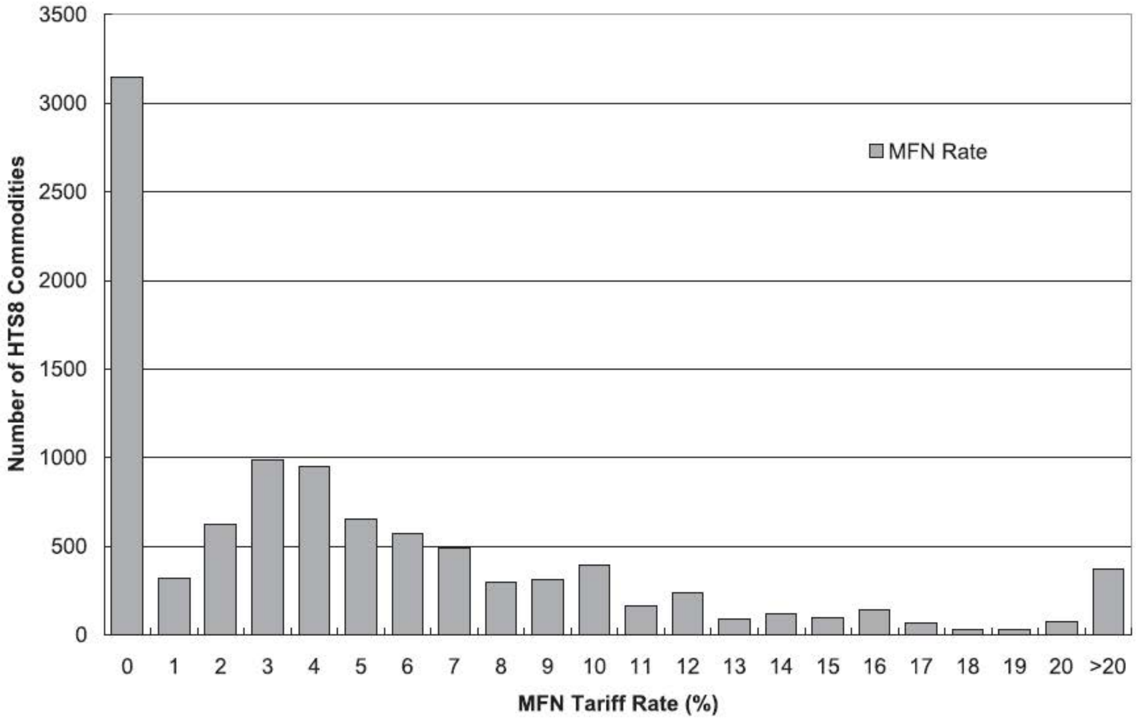
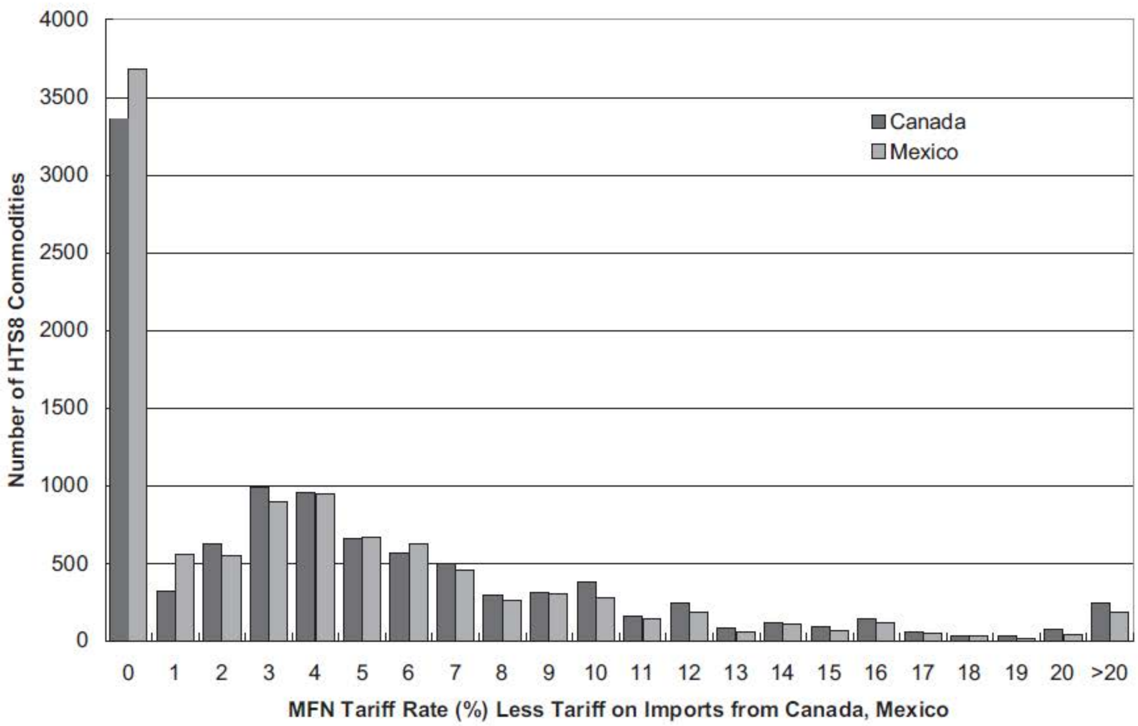
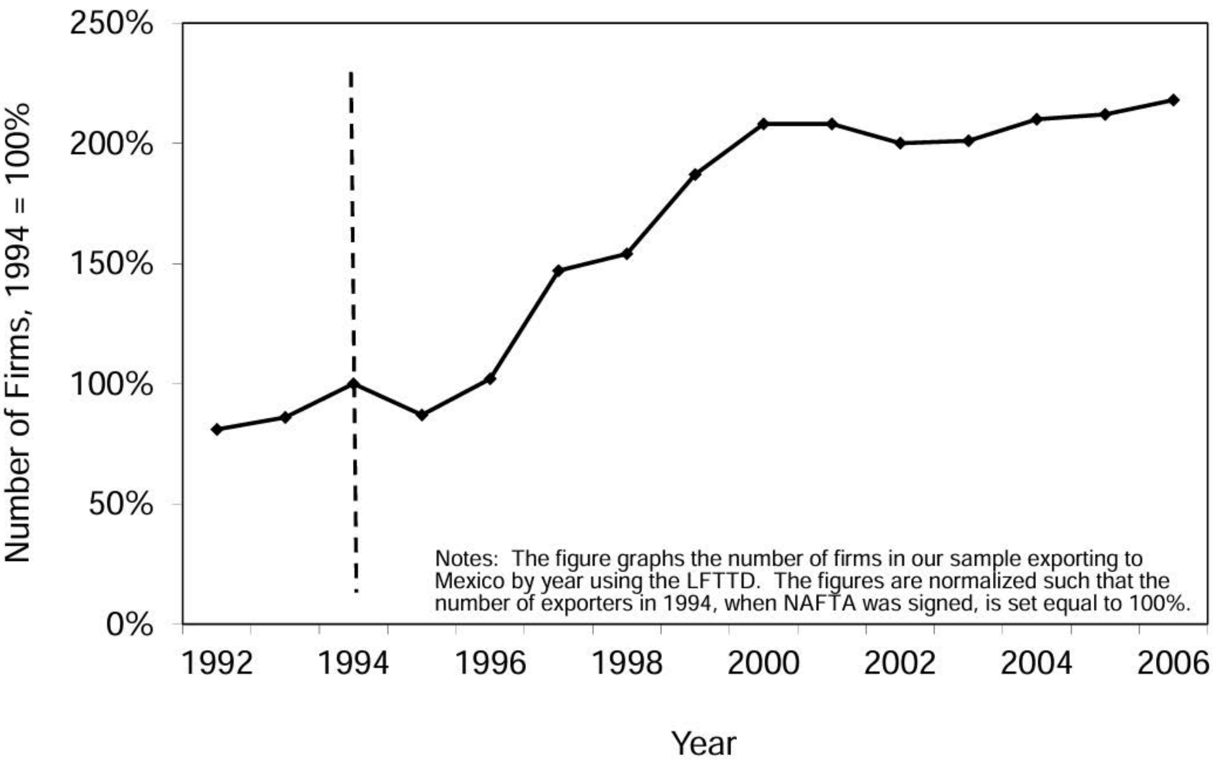


FIGURE 4B.—U.S. TARIFF PREFERENCES FOR CANADIAN AND MEXICAN GOODS IN 2000



Notes: The graph considers the distribution of tariffs import tariffs in the U.S. in the year 2000, 6 years after NAFTA went into effect. Panel A considers the most favored nation (MFN) rate and Panel B considers the MFN tariff rate in percentage terms less the tariff on imports from Canada and Mexico.

Figure 3: Number of U.S. Firms Exporting to Mexico



Notes: The graph depicts the number of U.S. firms exporting to Mexico. The number is normalized to 100 percent in 1994, when NAFTA was signed.

Figure 4: Value of U.S. Goods Exports to Mexico

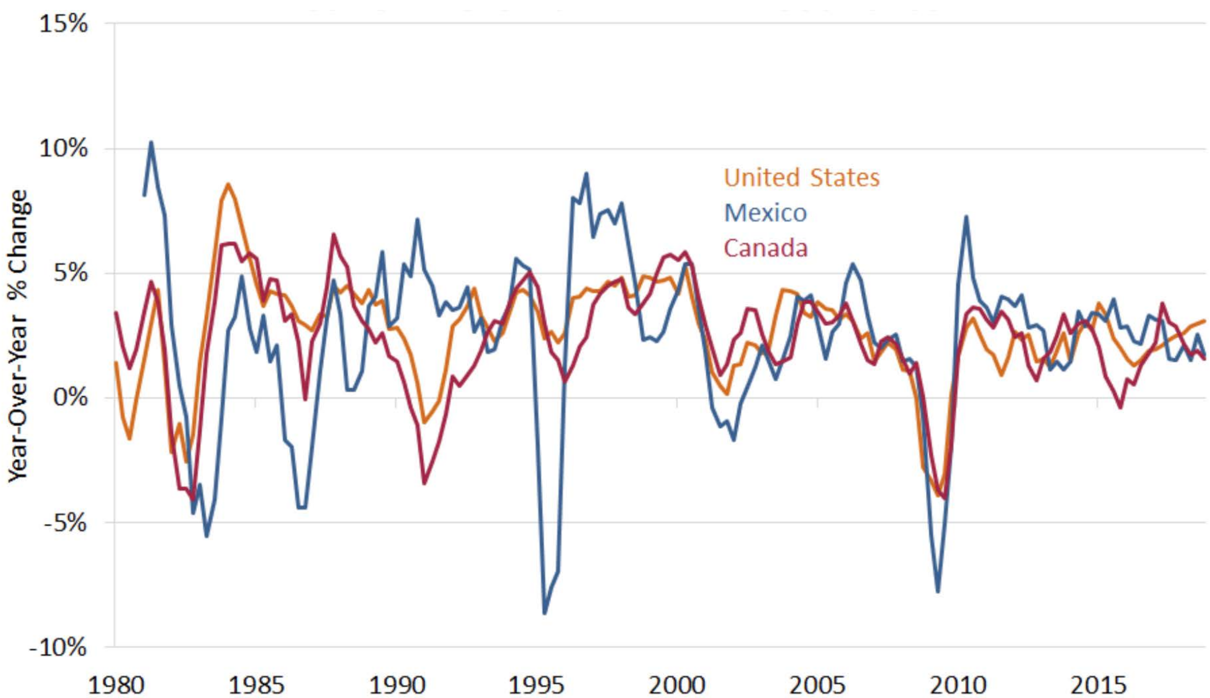
Notes: The graph plots data on the real value of exports of goods from the U.S. to Mexico over time. Data are sourced from the website of the Federal Reserve Bank of St. Louis.

increase along the extensive margin for U.S. exports was matched by an increase in overall trade over time, further suggesting that NAFTA had the capacity to have significant effects on U.S. innovation. This is true even in the wake of the peso crisis of 1994. Indeed, we see an immediate increase of exports to Mexico, even despite the decline in purchasing power of consumers that was occurring at the same time.

In considering whether NAFTA had an effect on the U.S. economy broadly, in Figure 5 we plot GDP growth in the 3 NAFTA countries over time. Prior to the agreement going into effect, economic growth in the three different countries was correlated but more widely dispersed. After the agreement, however, real GDP growth was much more highly synchronized and displays a much tighter correlation. This suggests that the trade agreement could have had an effect on making the U.S. economy significantly more interconnected. This is in the face of the long trend of structural change towards services in the U.S. that is likely to have reduced the interconnectedness of the three economies that has been explored in recent work by Bonadio, et al. (2025).

In Table 1 we report a number of descriptive statistics for our main estimation panel. We have firms headquartered in a number of different parts of the country, including 5 percent of the sample that is headquartered in a state that borders Mexico and 7 percent of the sample that is headquartered in a state that borders Canada. Like most studies of publicly traded firms, there is wide variation in the size of the businesses in the sample in terms of sales, employment, and research and development expenditures. Firms headquartered in border states broadly look similar to other firms, facing an average tariff rate between 8 and 10 percent and similar levels of patenting. They are on average smaller than other firms in terms of sales, employment, and R&D expenditures. There is also somewhat less variation in the distribution of these characteristics for these firms relative to others.

Figure 5: Economic Growth in NAFTA Countries



Notes: The graph plots data on real GDP growth in NAFTA countries over time. Data are sourced from the website of the Federal Reserve Bank of St. Louis.

Table 1: Descriptive Statistics for Firm Panel

Variable	Median	Mean	Stand. Dev.	Minimum	Maximum
A. All Firms in Sample					
Annual Patent Count	0	0.08	3.82	0	954
New England	0	0.03	1.34	0	144
Middle Atlantic	0	0.20	8.46	0	825
East North Central	0	0.83	2.27	0	166
West North Central	0	0.02	0.57	0	42
South Atlantic	0	0.11	4.21	0	954
East South Central	0	0.02	0.63	0	25
West South Central	0	0.01	0.18	0	12
Mountain	0	0.01	0.27	0	22
Pacific	0	0.03	0.62	0	31
Tariff Rate (%)	9%	9%	7%	0%	161%
Border State (%)	0	12%	33%	0	1
Bordering Mexico (%)	0	5%	21%	0	1
Bordering Canada (%)	0	7%	26%	0	1
Firm Level Compustat Activity					
Annual Sales ($m)	64	1,125	6,640	0	458,361
Annual Employment (k)	0.60	6	28	0	2,545
Annual R&D ($m)	1.07	44	311	0	12,183
B. Firms Headquartered in Border States					
Annual Patent Count	0	0.09	5.88	0.00	825
Tariff Rate (%)	12%	10%	7%	0%	50%
Firm Level Compustat Activity					
Annual Sales ($m)	38	775	4,645	0	180,929
Annual Employment (k)	0.32	4.68	28	0	854
Annual R&D ($m)	0.57	31	289	0	9,010
C. Firms Not Headquartered in Border States					
Annual Patent Count	0	0.08	3.44	0	954
Tariff Rate (%)	9%	8%	8%	0%	161%
Firm Level Compustat Activity					
Annual Sales ($m)	70	1,223	6,872	0	458,361
Annual Employment	0.66	7	29	0	2,545
Annual R&D ($m)	1.2	46	314	0	12,183

Notes: This table summarizes descriptive statistics for key variables in the firm panel dataset. Panels B and C divide firms by whether they are headquartered in border states.

4 Estimations

To conduct our regression analysis, we first sorted the data by firm identifier (`gvkey`) and grant year. To ensure data quality and avoid duplicate entries, we removed duplicate firm-year observations. Observations with missing sales values were dropped to maintain consistency in our key financial metric. The merged dataset is further restricted to patents granted between 1985 and 2000, aligning the dataset with the time-frame of financial data in Compustat. We then conducted a heterogeneity analysis segmented by industry and geographic location. To do this, firms were classified into Manufacturing, Services, or Other categories based on SIC codes. Separate regressions were run for each group to investigate potential differences in the sales-profit relationship across industries. We further segmented firms by headquarters location, distinguishing firms in states bordering Mexico or Canada from non-border states. Within this categorization, separate regressions were performed to examine if proximity to international borders influenced firm performance, particularly for states bordering Mexico or Canada. This allowed us to explore whether geographic location and access to cross-border trade networks influenced the financial impact of firm-level innovation.

$$Patents_{it} = \beta_0 + \beta_1 \cdot MexTariff_{it} + \mu_i + \mu_t + \varepsilon_{it} \tag{1}$$

where β_0 is a constant, $MexTariff_{it}$ refers to the tariff faced by the firm in the primary industry that is reported for the firm in Compustat. μ_i and μ_t are firm and year fixed effects, respectively.

In Table 2 we present the results from running this regression on the sample described in Section 3. We first begin by running the regression on all firms in the sample in column (1), failing to find any significant effects. In columns (2)-(3) we split the sample based on whether the firm has its headquarters in a border state or not. This includes firms that are headquartered in both Canada and Mexico together. While the point estimates are positive for firms headquartered in border states and negative for other firms, neither of the estimates are statistically significant. To get a better sense of the estimates and focus on the firms most likely to feel the effects of the trade agreement, we then break down the sample based on which country the firm has a headquarters bordering in columns (4)-(5). We again find point estimates for firms headquartered near the most recent liberalizing country, Mexico, but they are also not statistically significant.

Table 2: Mexican Tariffs and U.S. Firm Innovation

Variable	Baseline	Border State	Non-Border State	Border Mexico	Border Canada
Tariff	0.0045	0.0028	-0.0048	0.0114	-0.0048
	(0.0051)	(0.0055)	(0.0057)	(0.0079)	(0.0078)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes
R^2	0.30	0.16	0.30	0.16	0.16

Notes: This table presents results from baseline and geographic-specific specifications using fixed effects. Results with ** denote significance at the 5 percent level. Results with * denote significance at the 10 percent level.

5 Conclusion and Future Directions

In this study we have considered the impacts of the North American Free Trade Agreement on innovation in the United States. A burgeoning literature in recent years has found a positive relationship between trade agreements and innovation in the liberalizing economy. Considering the experience of U.S. publicly trade firms, we do not find any evidence that NAFTA had an effect on patenting by these businesses. This is despite ample evidence that NAFTA affected U.S. exports to Mexico and the functioning of the U.S. economy more broadly. Going forward, we plan to expand this analysis using data from the U.S. Census Bureau. This will allow us to expand the analysis to all firms, including those that are not publicly traded. It will also likely increase the power associated with our estimations. A more rigorous estimation approach, such as that of Lileeva and Trefler (2010) will further be considered, which may allow us to better identify the causal effects of NAFTA, since fixed effects estimations are still subject to concerns about omitted variable bias. We look forward to extending the analysis beyond this initial set of exploratory estimations.

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