

Investment Responses to Trade Liberalization: Evidence from U.S. Industries and Establishments*

Justin R. Pierce[†]

Board of Governors of the Federal Reserve System

Peter K. Schott[‡]

Yale School of Management & NBER

First Draft: October 2017

This Draft: November 2017

Abstract

This paper examines the effect of a change in U.S. trade policy on the domestic investment of U.S. manufacturers. Using a difference-in-differences identification strategy, we find that industries more exposed to reductions in import tariff uncertainty exhibit relative declines in investment after the change in trade policy. Within industries, we find that this relationship is concentrated among establishments with low initial levels of labor productivity, capital intensity and skill intensity. Plants with high initial levels of skill intensity, by contrast, exhibit relative increases in investment with exposure. We also find evidence that establishments' investment activity is smoother following the policy change. *Keywords: Investment; Trade Policy; Manufacturing; China; Normal Trade Relations; MFN*

*Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau, the Board of Governors or its research staff. All results have been reviewed to ensure that no confidential information has been disclosed. We thank Dave Donaldson, Gordon Hanson, Colin Hottman, Stephen Redding and seminar audiences at the NBER and Georgetown for suggestions and Travis Adams and Emily Wisniewski for helpful research assistance.

[†]20th & C Streets NW, Washington, DC 20551, tel: (202) 452-2980, email: justin.r.pierce@frb.gov.

[‡]165 Whitney Avenue, New Haven, CT 06511, tel: (203) 436-4260, email: peter.schott@yale.edu.

1 Introduction

The U.S. manufacturing sector has undergone profound changes since the turn of the century, when a shift in U.S. trade policy increased import competition from China. While a range of studies link this trade liberalization to employment loss and establishment exit, less is known about the extent to which survivors adapt by investing in new production processes or product upgrades.¹ Greater understanding of such reactions is particularly relevant in the current policy environment, where the 2016 U.S. Presidential election and the U.K.’s vote to exit the European Union have created considerable uncertainty among producers in some of the world’s largest markets.

In this paper, we examine how the domestic investment and capital stocks of U.S. manufacturing establishments respond to the October, 2000 U.S. granting of Permanent Normal Trade Relations to China (PNTR), a trade liberalization that removed the threat of substantial U.S. import tariff increases on Chinese goods. By eliminating this cost uncertainty, PNTR provided U.S. producers with greater incentives to invest in finding Chinese suppliers, moving production from the United States to China, or otherwise increasing their competitiveness in the face of rising Chinese import competition. We use industry- and establishment-level data on domestic investment by U.S. manufacturers to examine the latter channel.²

Our empirical analysis takes place in three steps. First, we examine the relationship between exposure to PNTR and both investment and capital stocks at the industry-level. Second, we use confidential U.S. Census Bureau microdata to examine how individual establishments adjust investment in response to PNTR, with a particular focus on heterogeneous responses along a broad range of establishment-level attributes. The industry analysis serves as an important benchmark for our subsequent analysis of establishments because the expected impact of trade liberalization at the establishment-level is ambiguous: some plants may shrink or exit, lowering investment, while others may alter their production processes in ways that increase investment.³

¹Consider, for example, this anecdote from a recent article in the Wall Street Journal ([Michaels \(2017\)](#)), quoted in [Fort, Pierce, and Schott \(2017\)](#): “When Drew Greenblatt bought Marlin Steel Wire Products LLC, a small Baltimore maker of wire baskets for bagel shops, he knew nothing about robotics. That was 1998, and workers made products manually using 1950s equipment....Pushed near insolvency by Chinese competition in 2001, he started investing in automation. Since then, Marlin has spent \$5.5 million on modern equipment. Its revenue, staff and wages have surged and it now exports to China and Mexico.”

²In prior research ([Pierce and Schott \(2016\)](#)), we show that goods more exposed to PNTR exhibit substantial relative increases in U.S. imports from China as well as the number of U.S. firms that import from China, the number of Chinese firms that export to the United States, and the number of U.S.-Chinese firm pairs engaged in a trading relationship. One interpretation of these outcomes is that they reflect investment in trading relationships that was unleashed by the elimination of cost uncertainty.

³[Pierce and Schott \(2012\)](#) show that industries with greater exposure to PNTR exhibit relatively higher job destruction due to plant and firm exit and relatively lower job creation due to suppressed plant and firm entry.

Finally, motivated by models of investment under uncertainty, we investigate the timing, frequency, and lumpiness of establishments' investment before and after the change in trade policy.

We employ a generalized differences-in-differences (DID) identification strategy that estimates how investment and capital stocks change after the granting of PNTR for industries and establishments with varying levels of exposure. The baseline specification includes controls for other factors that may affect investment in manufacturing during our sample period, including changes in Chinese trade policy that occur as part of China's accession to the WTO (e.g. liberalization of export licensing), the phasing out of the global Multi-Fiber Arrangement governing quotas on developing-country textile and clothing exports, and changes in the relationship between investment and industry characteristics – such as capital and skill intensity – that may be correlated spuriously with the trade liberalization.

At the industry-level, we find that greater exposure to PNTR is associated with a relative decline in investment, and that the timing of the decline corresponds closely to PNTR's implementation. We find little evidence of such a response with respect to the capital stock, however, an outcome that may be due to the relatively slow response of capital stocks to changes in investment flows.

Our establishment-level analysis focuses on the investment activity of continuing plants observed in the quinquennial U.S. Census of Manufactures (CM). We find that plant-level responses to PNTR vary according to their pre-PNTR characteristics. Specifically, while PNTR is associated with a relative decline in investment for the average plant, establishments with higher initial levels of labor productivity and capital intensity exhibit little to no relative decline, and plants with the highest levels of initial skill intensity exhibit a *positive* relationship between exposure to the trade liberalization and relative investment. The relatively high investment associated with skill- and capital intensive plants is consistent with U.S. comparative advantage.

To assess the potential effects of PNTR's reduction of uncertainty on the frequency and smoothness of plants' investment, we use data from the Annual Survey of Manufactures (ASM) to compute the average, standard deviation and share of years with positive investment across years leading up to and after the change in policy. Here, too, accounting for heterogeneity in establishment responses is important. In specifications that control for plants' initial characteristics, we find that, for the average plant, larger reductions in tariff rate uncertainty are associated with relative reductions in the standard deviation of investment, though these reductions are not present for plants with initially high levels of productivity.

Our findings make three contributions to the literature. First, they provide a broader view of the impact of trade liberalization on firms. While negative relationships between import competition and employment are well-known, especially for the period we are considering (Autor, Dorn, and Hanson (2013); Pierce and Schott (2016)), our finding that higher exposure to PNTR is associated with lower industry-level in-

vestment helps explain the reduction in overall manufacturing investment and the flattening of the capital stock that has been noted elsewhere (Kurz and Morin (2016)). Furthermore, to the extent that depressed investment has dynamic effects on employment, our findings provide insight into the potential persistence of weak employment and earnings growth in the years following a liberalization.

Second, our results highlight the potential heterogeneity of responses to trade liberalization across plants within similarly exposed industries, and identifies the characteristics of establishments – including low labor productivity and high labor intensity – that are associated with relatively greater declines in investment in the face of increased import competition. These results relate to the large literature studying the impact of competition on innovation and investment (e.g., Aghion, Bloom, Blundell, Griffith, and Howitt (2005)). In this respect our research is most closely related to Gutierrez and Philippon (2017), which uses publicly available data from Compustat to show that increased exposure to PNTR induces relative increases in investment among “leader” firms, defined as firms with high market to book value. Compared to that paper, our contribution is twofold. First, we consider the full population of manufacturing establishments, as opposed to the publicly traded firms present in Compustat. Second, we examine a wider range of firm attributes – such as capital and skill intensity and productivity – that capture other dimensions of “leadership,” i.e., consistency with U.S. comparative advantage. Furthermore, our findings also add additional context to recent research finding evidence in favor of trade-induced technical change (Bloom, Draca, and Reenen (2016)) and a negative relationship between import competition and innovation (Autor, Dorn, Hanson, Pisano, and Shu (2016)) among firms in the UK and United States, respectively, facing import competition from China.

Finally, we contribute to the relatively small number of empirical studies associated with the large theoretical literature on investment under uncertainty (Pindyck (1993); Rob and Vettas (2003)). Finding plausibly exogenous shocks to uncertainty is an important challenge in in these studies and several papers, including Guiso and Parigi (1999), Schwartz and Zozaya-Gorostiza (2003), and Bloom, Bond, and Van Reenen (2007), have estimated such shocks using surveys, cost data for specific information technology investments, or detailed information from firms’ annual reports. Here, PNTR provides a large and plausibly exogenous shock to establishments’ cost uncertainty, and we identify effects on investment that are consistent with Bloom, Bond, and Van Reenen (2007).⁴

The paper proceeds as follows: Section 2 describes the data, Section 3 describes our empirical strategy and presents industry-level results. Section 4 presents the establishment-level analysis and and Section 5 concludes.

⁴For other studies on uncertainty in trade, see Handley (2014) and Handley and Limao (2017).

2 Data

2.1 Establishment- and Industry-Level Investment Data

Establishment-level investment and capital stock data are drawn from the U.S. Census Bureau’s confidential Census of Manufactures (CM) and Annual Survey of Manufactures (ASM). In both cases, the Census Bureau asks manufacturing establishments to break down their capital expenditures into two categories – structures and equipment – as well as to report their total capital expenditures. The CM collects this information, as well as data on other establishment attributes, including employment, shipments and value added, on every U.S. manufacturing establishment (i.e., plant) quinquennially in years ending in two and seven. In all of our analyses using the CM, we follow standard practice in excluding all administrative records, i.e., observations for which most of the key variables of interest are imputed.

Table 1 summarizes real investment (i.e., real capital expenditures) among U.S. manufacturing establishments appearing in our regression sample below.⁵ Each row of the table reports results for a different Census year, while each panel focuses on a different measure of investment: average investment per plant, average investment as a share of establishments’ capital stock, and average share of establishments with positive investment. In each case, we report figures for total investment and its components, investment in structures and investment in equipment.

	Average Investment Per Plant ('000 USD)			Average Investment as a Percent of Capital (K) Stock			Share of Establishments with Positive Investment		
	Total	Structures	Equipment	Total	Structures	Equipment	Total	Structures	Equipment
1992	905	138	767	11%	2%	10%	87%	44%	86%
1997	970	132	838	15%	2%	13%	89%	55%	89%
2002	790	113	676	13%	1%	12%	93%	38%	92%
2007	954	146	808	16%	2%	14%	90%	54%	90%

Notes: Table reports summary statistics related to manufacturing establishments' investment in Census of Manufactures years. All investment and capital stock data are deflated using the price indexes in the NBER-CES Manufacturing Industry Database. Sample excludes administrative records. Source: U.S. Census Bureau's Census of Manufactures.

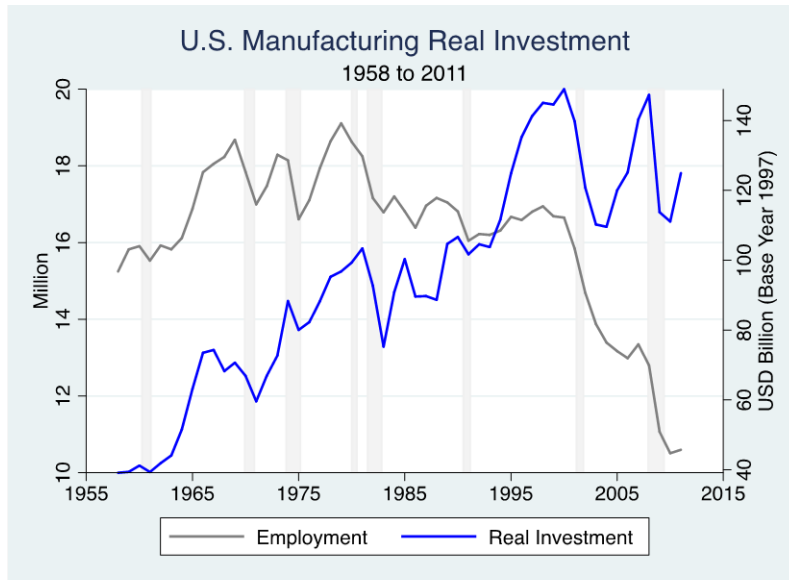
Table 1: PNTR and Industry-Level Capital Stock

As indicated in the table, total investment averages 905 thousand dollars across establishments in 1992, versus 954 thousand dollars in 2007. As a share of the capital stock, these levels of investment range from 11 percent in 1992 to 16 percent in 2007. Furthermore, the table reveals that investment in equipment accounts for roughly 85 percent of total capital expenditures, with the remaining 15 percent accounted for by investment in structures. Finally, the table indicates that most plants invest in each Census year, with 87 percent of establishments reporting positive capital expenditures

⁵We discuss the deflators used in the computation of real investment below.

in 1992 and 90 percent reporting investment in 2007. Investments in equipment are much more common than investment in structures, with the latter occurring at 44 percent of establishments in 1992 and 54 percent of establishments in 2007.

For the portion of our analysis where we investigate attributes of investment that must be estimated across time – e.g., the standard deviation of investment or average investment per year – we require higher-frequency data than is available in the CM. We therefore augment the CM data with annual data from the ASM. However, because the ASM collects information from only a subset of plants, we must restrict our analysis to the establishments that are surveyed in every year across our 1992 to 2007 sample period.⁶ While this sample is restricted, these long-lived plants typically account for a disproportionately large share of activity in the manufacturing sector.



Source: NBER-CES Manufacturing Industry Database.

Figure 1: Manufacturing Employment versus Real Investment

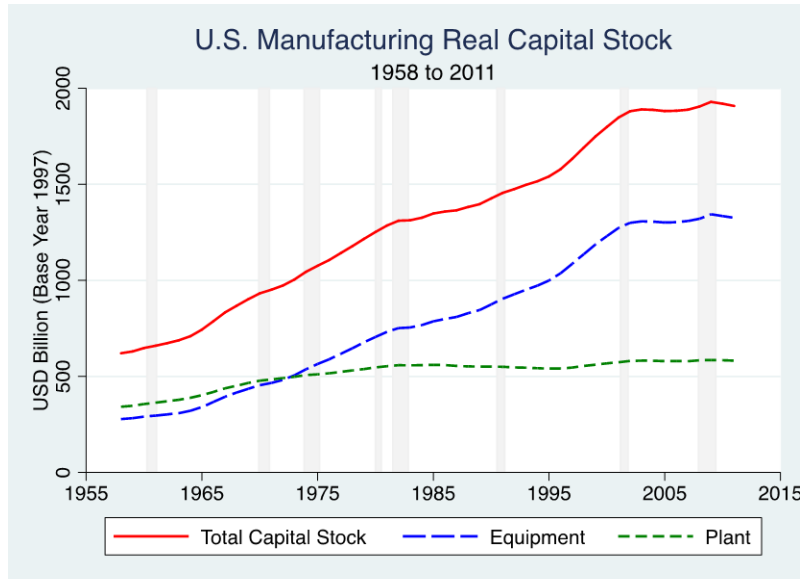
Our industry-level analysis makes use of the publicly available NBER-CES Manufacturing Industry Database assembled by [Becker, Gray, and Marvakov \(2013\)](#), which can be downloaded from the NBER website. This dataset tracks many of the same outcomes contained in the CM and ASM across six-digit North American Industry Classification (NAICS) categories, including employment, nominal investment and the real capital stock, including separate data for real stocks of equipment and structures. We deflate the nominal investment in both these data and the CM and ASM using industry-specific investment deflators contained in the database.⁷ Because investment

⁶This restriction arises from changes in the sampling frame for the ASM that occur every five years, which prevent tracking some plants consistently over time. Furthermore, while some plants are sampled with certainty in the ASM, the threshold used for selecting these “certainty cases” changed several times over the period we consider.

⁷[Becker, Gray, and Marvakov \(2013\)](#) convert the nominal information on total capital expenditures

is not broken out by equipment versus structures in the NBER-CES database, we construct this breakdown ourselves using publicly available versions of the Census of Manufactures (CM) and Annual Survey of Manufactures (ASM) available on the Census Bureau’s website.⁸

Figure 1 shows that total real investment by U.S. manufacturing firms in equipment and structures rises faster than trend in the late 1990s before falling substantially in the early 2000s. Indeed, the decline in manufacturing investment from 1999 to 2003 is roughly equal to the decline experienced during the much-deeper Great Recession. As a result, the manufacturing real capital stock fell from 2003 to 2004, the first time it had registered a decline since the data have been tracked (Kurz and Morin (2016)). This decline can be seen in Figure 2, which also reveals that most of the increase in manufacturing capital stock since the 1970s is in equipment versus structures.



Source: NBER-CES Manufacturing Industry Database.

Figure 2: Manufacturing Capital Stock

2.2 Industry and Firm Exposure to PNTR

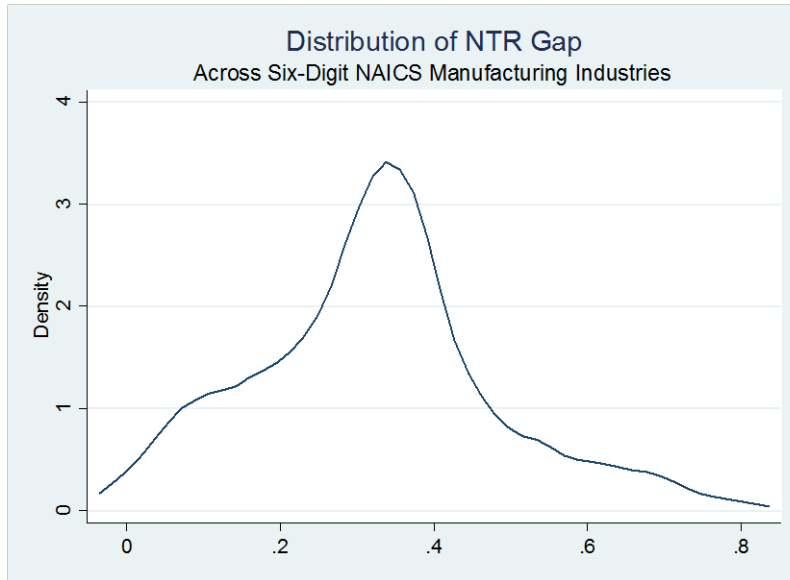
Our analysis makes use of a plausibly exogenous change in U.S. trade policy – the U.S. granting of PNTR to China in October 2000 – that effectively liberalized U.S.

for each industry collected in the CM and ASM into real expenditure data using investment deflators produced by the Federal Reserve Board. They then construct industry-level real capital stocks using a perpetual inventory equation in conjunction with depreciation rates for each industry also developed by the Federal Reserve Board.

⁸For instances in which data from the CM and ASM are available only at levels of aggregation higher than the six-digit NAICS industries used in our analysis, we employ industry shares developed by the Federal Reserve Board to allocate investment to six-digit NAICS industries. Further detail is available from the authors upon request.

imports from China. This impact can be understood by considering the two sets of tariff rates that comprise the U.S. tariff schedule. The first set of tariffs, known as NTR tariffs, are generally low and are applied to goods imported from other members of the World Trade Organization (WTO). The second, known as non-NTR tariffs, were set by the Smoot-Hawley Tariff Act of 1930 and are often substantially higher than the corresponding NTR rates. Imports from non-market economies such as China generally are subject to the higher non-NTR rates, but U.S. law allows the President to grant these countries access to NTR rates on a year-by-year basis, with the President’s decision subject to potential overruling by Congress.

U.S. Presidents granted China such a waiver every year starting in 1980, but Congressional votes over annual renewal became politically contentious and less certain of passage following the Chinese government’s crackdown on Tiananmen Square protests in 1989 and other flashpoints in U.S.-China relations during the 1990s such as China’s transfer of missile technology to Pakistan in 1993 and the Taiwan Straits Missile Crisis in 1996. Uncertainty over China’s access to NTR tariff rates ended with Congress passing a bill granting PNTR status to China in October, 2000, which formally took effect upon China’s entry into the WTO in December 2001.



Source: Feenstra et al. (2002) and authors’ calculations.

Figure 3: Distribution of Industry-Level NTR Gaps

We follow [Pierce and Schott \(2016\)](#) in measuring the impact of PNTR as the rise in U.S. tariffs on Chinese goods that would have occurred in the event of a failed annual renewal of China’s NTR status prior to PNTR,

$$NTR\ Gap_j = Non\ NTR\ Rate_j - NTR\ Rate_j. \tag{1}$$

We refer to this difference as the NTR gap, and compute it for each SIC industry j using *ad valorem equivalent* tariff rates provided by [Feenstra, Romalis, and Schott \(2002\)](#) for 1999, the year before passage of PNTR. As indicated in Figure 3, which reports the distribution of NTR gaps across six-digit NAICS industries, NTR gaps vary widely, with a mean and standard deviation of 30 and 14 percentage points, with an interquartile range of 0.21 to 0.40. Analysis of the underlying NTR and non-NTR rates in [Pierce and Schott \(2016\)](#) reveals that seventy-nine percent of the variation in the NTR gap across industries is due to variation in non-NTR rates, set 70 years prior to passage of PNTR. This feature of non-NTR rates effectively rules out reverse causality that would arise if *non-NTR rates* were set to protect industries with declining employment or surging imports. Furthermore, to the extent that NTR rates were set to protect industries with declining employment prior to PNTR, these higher NTR rates would result in lower NTR gaps, biasing our results away from finding an effect of PNTR.

2.3 Other Policy Variables

Our empirical analysis includes controls for a wide range of additional factors that may affect U.S. manufacturing investment. First, we allow for the possibility that the relationship between certain industry-level characteristics and investment may have changed around the time of PNTR’s passage. For example, a decline in the competitiveness of labor intensive industries in the United States or the decline of unions may have disproportionately affected certain industries. We control for these explanations by including interactions of a post-PNTR indicator with initial values of industry capital and skill intensity and the industry-level share of union membership in 1990 ([Hirsch and Macpherson \(2003\)](#)).

We also control for changes in Chinese domestic and trade policies related to its accession to the WTO. These changes include reductions in export licensing requirements, production subsidies and import tariff rates. Our controls draw on data from work on export licensing requirements by [Bai, Krishna, and Ma \(2015\)](#), on production subsidies from [Khandelwal, Schott, and Wei \(2013\)](#), and on Chinese import tariff rates from [Brandt, Van Biesebroeck, Wang, and Zhang \(2017\)](#). To account for the fact that reductions in barriers to foreign investment in China also declined at this time, we control for the share of industry inputs requiring relationship-specificity from [Nunn \(2007\)](#).

Finally, we control for other policy and macroeconomic shifts occurring in the U.S. around 2000. The first of these changes is the bursting of the 1990s tech bubble, which we control for with the interaction of the post-PNTR indicator with an indicator for whether the industry is engaged in the production of advanced technology products, as defined by the International Trade Commission. In addition, we control for the elimination of quotas associated with the phasing out of the global Multi-Fiber Arrangement

(Khandelwal, Schott, and Wei (2013)).

3 PNTR and Industry-Level Investment

As indicated in the large literature on the impact of competition on innovation and investment (e.g., Aghion, Bloom, Blundell, Griffith, and Howitt (2005)), the relationship between PNTR and investment is theoretically ambiguous. Some establishments might step up investment in their U.S. operations in an effort to increase competitiveness *vis a vis* rising imports, while others might choose to exit the market, or cease domestic production in favor of production abroad. In this section we set the stage for our establishment-level analysis below by examining the aggregate impact of these decisions on investment at the industry level.

Our baseline difference-in-differences (DID) specification examines whether industries with higher NTR gaps (first difference) experience differential changes in investment after the change in U.S. trade policy (second difference) versus before,

$$\begin{aligned} y_{jt} = & \theta Post PNTR_t \times NTR Gap_j + \\ & \beta \mathbf{X}_{jt} + \gamma Post PNTR_t \times \mathbf{X}_j + \\ & \delta_j + \delta_t + \varepsilon_{jt}. \end{aligned} \tag{2}$$

The sample period for the industry analysis is 1990 to 2007. The dependent variable, y_{jt} , represents an outcome in industry j , for example log investment. The first term on the right hand side is the DID term of interest, an interaction of the NTR gap and an indicator for the post-PNTR period, i.e., years from 2001 forward. The second term on the right-hand side of equation 2 captures the impact of time-varying industry characteristics, such as exposure to MFA quota reductions and the NTR tariff rate. The third term on the right hand side is an interaction of the post-PNTR dummy variable and time-invariant industry characteristics, such as initial industry capital and skill intensity, the degree to which industries encompass high-technology products and the extent of initial union membership in the industry. These interactions allow for the possibility that the relationship between employment and these characteristics changes in the post-PNTR period in ways that might spuriously be related to the trade liberalization. δ_j , δ_t and α represent industry and year fixed effects and the constant.

An attractive feature of this DID identification strategy is its ability to isolate the role of the change in U.S. trade policy. While industries with high and low NTR gaps are not identical, comparing outcomes within industries over time isolates the differential impact of China's change in NTR status.

The first three columns of Table 2 report results for our main variable of interest,

total investment, with standard errors clustered at the industry level. The first column reports a specification with only the DID term, the second column adds interactions of the post-PNTR indicator with industry capital intensity and skill intensity, and the third column includes the full set of controls described in Section 2.3. As indicated in the table, we find negative and statistically significant coefficients on the DID term in all three cases. We assess the economic significance of the estimated DID coefficients in terms of the effect on the dependent variable of an interquartile shift in an industry's NTR gap (from 0.214 to 0.402). These coefficients indicate that an interquartile shift in industry exposure to PNTR is associated with relative declines in investment of -0.131 to -0.168 log points (e.g., -0.696×0.188 to -1.017×0.188). The next six columns report analogous results for investment in structures and equipment. We find a negative and significant relationship between exposure to PNTR and each of these types of investment in all three specifications.

	Investment								
	ln(Total _{it})	ln(Total _{it})	ln(Total _{it})	ln(Struct _{it})	ln(Struct _{it})	ln(Struct _{it})	ln(Equip _{it})	ln(Equip _{it})	ln(Equip _{it})
Post x NTR Gap _j	-0.744	-1.121	-0.566	-1.412	-1.436	-0.811	-0.871	-1.255	-0.705
	0.301	0.240	0.180	0.401	0.300	0.267	0.286	0.253	0.179
Post x ln(K/Emp _j)		-0.117	-0.195		-0.002	-0.108		-0.121	-0.191
		0.052	0.034		0.057	0.048		0.051	0.036
Post x ln(NP/Emp _j)		0.300	0.377		0.267	0.384		0.190	0.291
		0.079	0.068		0.096	0.090		0.085	0.065
Post x Contract Intensity _j			0.037			0.012			0.039
			0.167			0.238			0.159
Post x ΔChina Import Tariffs _j			-0.006			-0.006			-0.007
			0.001			0.003			0.002
Post x ΔChina Subsidies _j			0.685			0.746			0.648
			0.105			0.147			0.101
Post x ΔChina Licensing _j			-0.525			-0.442			-0.387
			0.249			0.372			0.253
Post x 1{Advanced Technology _j }			-0.002			0.005			-0.048
			0.084			0.092			0.088
Post x U.S. Union Membership _j			0.002			0.006			0.002
			0.002			0.004			0.002
MFA Exposure _{it}			-0.029			-0.027			-0.027
			0.005			0.007			0.006
NTR _{jt}			-0.084			-0.492			0.153
			0.485			0.626			0.488
Observations	8,280	8,280	8,280	8,280	8,280	8,280	8,280	8,280	8,280
R-Squared	0.94	0.95	0.95	0.88	0.88	0.88	0.95	0.95	0.95
Fixed Effects	i,t	i,t	i,t	i,t	i,t	i,t	i,t	i,t	i,t
Implied Impact of PNTR	-0.140	-0.211	-0.106	-0.265	-0.270	-0.152	-0.164	-0.236	-0.133

Notes: Table reports results of unweighted OLS generalized difference-in-differences regressions. The dependent variable is the log of industry-year investment (total, structures, or equipment) or employment and the independent variable representing the effect of PNTR is the interaction of the NTR gap and a post-PNTR indicator. Additional controls include time-varying variables -- MFA exposure, NTR tariff rates, union membership rates -- as well as interactions of the post-PNTR indicator with time-invariant controls including the log of 1990 capital and skill intensity, contract intensity (Nunn 2007), changes in Chinese import tariffs, changes in Chinese production subsidies, changes in Chinese export licensing requirements and an indicator for whether the industry produces advanced technology products. Data span 1990 to 2007. Robust standard errors adjusted for clustering at the industry (j) level are displayed below each coefficient. Estimates for the year (t) and industry fixed effects as well as the constant are suppressed. Final row reports implied impact on dependent variable of an interquartile shift in industry exposure to PNTR.

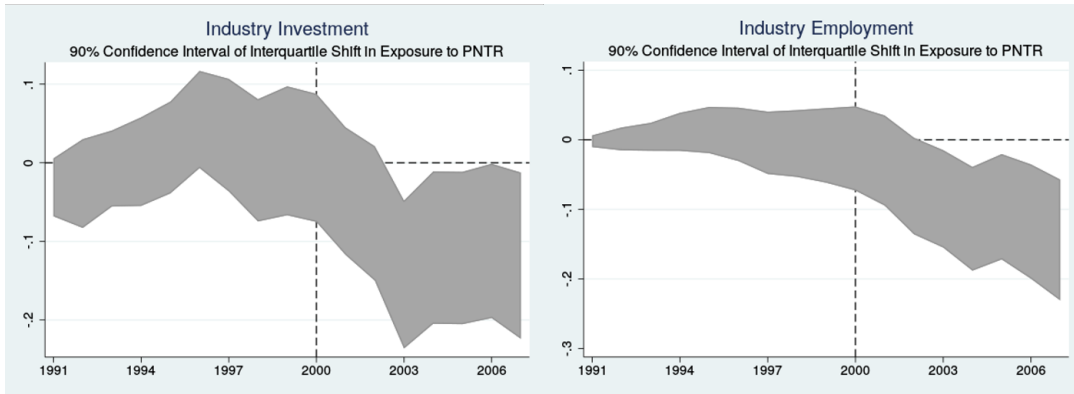
Table 2: PNTR and Industry-Level Investment

For the decline in investment to be attributable to PNTR, the NTR gap should be correlated with investment after PNTR, but not before. To determine whether

there is a relationship between these variables in the years before 2001, we replace the *PostPNTR* indicator used in equation 2 with interactions of the NTR Gap and the full set of year dummies,

$$y_{jt} = \sum_{y=1991}^{2007} (\theta_y 1\{y = t\} \times NTR\ Gap_j) + \sum_{y=1991}^{2007} (\lambda_y 1\{y = t\} \times \mathbf{X}_j) + \beta \mathbf{X}_{jt} + \delta_j + \delta_t + \alpha + \varepsilon_{it}. \quad (3)$$

Here, we estimate equation 3 with the full set of controls noted above. Results are reported visually in Figure 4. The left panel of this figure traces out the impact on investment of an interquartile shift in industry exposure to PNTR implied by the estimated difference-in-differences coefficients θ_y . For comparison, a similar figure for employment is provided in the right panel. As indicated in the left panel of the figure, point estimates are statistically insignificant at conventional levels until after 2001, at which time they generally become negative and statistically significant. This pattern is consistent with the parallel trends assumption inherent in our difference-in-differences analysis, lending further support for our empirical strategy.⁹



Notes: Figure display the 90 percent confidence intervals associated with an interquartile shift in industry exposure to PNTR on industry-level investment (left panel) and employment (right panel). Source: Authors' calculations based on data from the NBER-CES Manufacturing Productivity database.

Figure 4: Implied Industry-Level Impact of PNTR

Next, we examine whether the decline in investment associated with PNTR in Table 2 is also apparent in capital stocks. As indicated in Table 3, we find that higher

⁹To further evaluate the role of the policy change versus other factors, [Pierce and Schott \(2016\)](#) compares the relationship between the NTR gap and manufacturing employment in the U.S. with that in the EU, which was not subject to a similar policy change. They find that the negative relationship between exposure to PNTR and manufacturing employment is only present in the United States.

exposure to PNTR is associated with positive but statistically insignificant changes in the capital stock for total capital (column 1) and equipment capital (column 2) and negative and statistically insignificant changes in structures capital (column 3). One potential reason for the lack of a relationship between PNTR and the capital stock, unlike for investment, is that the capital stock adjusts slowly to changes in investment flows.

	Capital Stocks		
	ln(Total _{it})	ln(Equipment _{it})	ln(Structures _{it})
Post x NTR Gap _{it}	0.083	0.038	-0.033
	0.087	0.095	0.081
Post x ln(K/Emp _{it,1990})	-0.093	-0.118	-0.070
	0.016	0.017	0.016
Post x ln(NP/Emp _{it,1990})	0.161	0.130	0.076
	0.036	0.036	0.026
Post x Contract Intensity _{it}	0.105	0.048	-0.007
	0.078	0.080	0.054
Post x ΔChina Import Tariffs _{it}	-0.002	-0.002	-0.003
	0.001	0.001	0.001
Post x ΔChina Subsidies _{it}	0.276	0.395	0.135
	0.048	0.044	0.036
Post x ΔChina Licensing _{it}	-0.050	-0.140	0.071
	0.119	0.125	0.121
Post x 1{Advanced Technology _{it} }	0.138	0.140	0.111
	0.047	0.055	0.065
U.S. Union Membership _{it}	-0.003	-0.001	-0.002
	0.001	0.001	0.001
MFA Exposure _{it}	-0.009	-0.011	-0.004
	0.001	0.001	0.001
NTR _{it}	0.139	0.244	0.166
	0.314	0.382	0.373
Observations	8,280	8,280	8,280
R-Squared	0.99	0.99	0.99
Fixed Effects	j,t	j,t	j,t
Weighting	K	K	K
Implied Impact of PNTR	0.016	0.007	-0.006

Notes: Table reports results of OLS generalized difference-in-differences regressions. The dependent variables are the log of industry-year capital stock and its constituents, the log of the stock of equipment and structures. The independent variable representing the effect of PNTR is the interaction of the NTR gap and a post-PNTR indicator. Additional controls include time-varying variables -- MFA exposure, NTR tariff rates, union membership rates -- as well as interactions of the post-PNTR indicator with time-invariant controls including the log of 1990 capital and skill intensity, contract intensity (Nunn 2007), changes in Chinese import tariffs, changes in Chinese production subsidies, changes in Chinese export licensing requirements and an indicator for whether the industry produces advanced technology products. Data span 1990 to 2007. Robust standard errors adjusted for clustering at the industry (j) level are displayed below each coefficient. Estimates for the year (t) and industry fixed effects as well as the constant are suppressed. Observations are weighted by 1990 industry capital stock. Final row reports implied impact on dependent variable of an interquartile shift in industry exposure to PNTR.

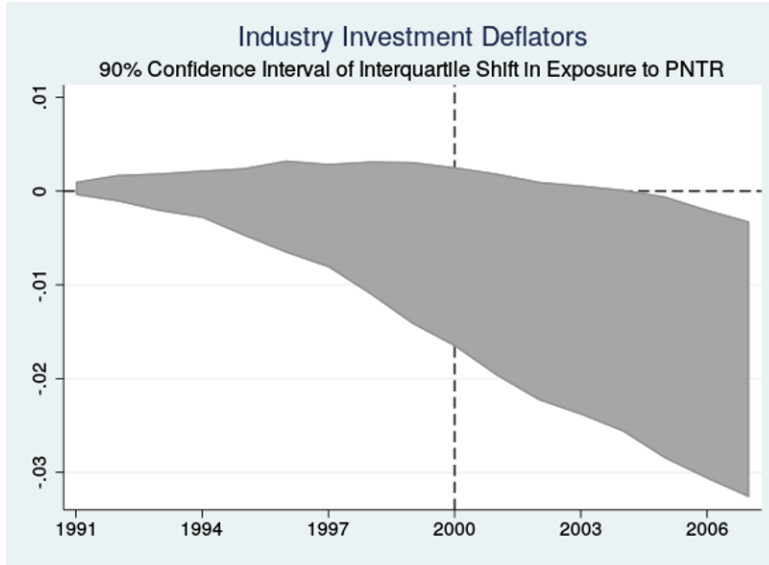
Table 3: PNTR and Industry-Level Capital Stock

An interesting question for further study is whether the relative weakening in investment may help explain the persistence of the reduction in manufacturing employment associated with PNTR (Pierce and Schott (2016)). That is, while increases in investment may lead to subsequent rebounds in employment, declines in investment driven by establishment exit may have a long-run dampening effect on job creation.¹⁰

Finally, we examine the relationship between the change in U.S. trade policy and investment deflators using equation 3. To conserve space, we summarize the results of

¹⁰Fort, Pierce, and Schott (2017) show that more than eighty percent of the decline in manufacturing employment between 1977 and 2012 is due to net establishment death.

this regression in Figure 5, which plots the 90 percent confidence interval associated with an interquartile shift in industry exposure to PNTR. As indicated in the figure, we find that industries with greater exposure to PNTR exhibit greater declines in their investment deflators. One potential explanation for this relationship relates to plant closures. [Pierce and Schott \(2016\)](#), for example, find that plants with greater exposure to the change in policy are relatively more likely to shut down. If these closures increase the supply (on the secondary market) of the capital goods used to produce in that industry, their price might fall.



Notes: Figure display the 90 percent confidence intervals associated with an interquartile shift in industry exposure to PNTR on industry-level investment deflators. Source: Authors' calculations based on data from the NBER-CES Manufacturing Productivity database.

Figure 5: PNTR and Industry Investment Deflators

4 PNTR and Establishment-Level Investment

In this section, we exploit the plant-level data available in the CM and ASM to determine the extent to which different plants in the same industry might vary in their response to PNTR. Plant-level analysis also permits examination of the extent to which changes in investment are driven by adjustments in average investment per year versus changes in the “lumpiness” of investment. We find that in both cases, larger, more productive and more skill- and capital-intensive plants are less likely to adjust their investment activity in response to the change in U.S. trade policy.

4.1 Baseline Plant-level Estimates

We begin by examining the average investment responses of plants to PNTR without including terms that might account for within-industry heterogeneity. We use data from the CM, which covers the population of manufacturing establishments and is available every five years. Our sample is composed of observations from the 1992, 1997, 2002 and 2007 CMs and this baseline specification is as follows,

$$\begin{aligned}
 y_{pt} = & \theta Post PNTR_t \times NTRGap_j + \\
 & \gamma Post PNTR_t \times \mathbf{X}_j + \beta \mathbf{X}_{jt} + \\
 & + \delta_p + \delta_t + \alpha + \varepsilon_{pt}.
 \end{aligned}
 \tag{4}$$

where p indexes establishments, j indexes industries and t indexes years. The dependent variable is one of three real investment shares – total investment (i.e., total capital expenditures), investment in equipment, or investment in structures, where each is divided by the establishment’s capital stock – or the log value of the capital stock. The first term on the right-hand side is the DID term representing the effect of PNTR, and it consists of the interaction of a $Post PNTR_t$ indicator and the time-invariant $NTRGap_j$. The next two terms represent the additional control variables used in Equation 2. The remaining terms represent plant and year fixed effects. Note that this specification yields within-plant estimates of the relationship between exposure to PNTR and capital expenditures, but does not account for changes in investment driven by establishment entry and exit.

The first two columns of Table 4 report the results of estimating equation 4, first with only the DID term of interest and the fixed effects required for its identification (column 1), and then with the full set of covariates (column 2). We find that while the relationship between exposure to PNTR and total investment is negative, as in the industry-level estimates discussed above, it is not statistically significant at conventional levels. The next six columns indicate similar negative but statistically insignificant relationships for the two broad categories of investment shares – equipment and structures – as well as for the log real book value of capital. The overall message of Table 4 is that the relationship between exposure to PNTR and investment within continuing plants is negative but not precisely estimated.

We note that establishment-level results in Table 4 differ from the industry-level estimates in Table 2 for two reasons. First, the samples are different.¹¹ Second, the

¹¹The samples are different in three ways. First, inclusion of plant fixed effects in the establishment-level analysis means that identification is restricted to within-establishment variation, thereby excluding the impact of establishment exit, which is substantial during this period (Fort, Pierce, and Schott (2017); Pierce and Schott (2012)). Second, these fixed effects also exclude plants that are not present in both the pre- and post-PNTR periods. Finally, the establishment-level regressions are restricted to Census years – 1992, 1997, 2002 and 2007 – while the industry-level sample includes data for every

	Investment as a Share of Capital Stock						Capital Stock	
	Total _{itp}	Total _{ip}	Struct _{itp}	Struct _{ip}	Equip _{itp}	Equip _{ip}	Total _{itp}	Total _{ip}
Post x NTR Gap _j	-0.044	-0.017	-0.014	-0.003	-0.030	-0.014	-0.116	0.070
	0.028		0.015	0.008	0.004	0.021	0.172	0.171
Post x ln(K/Emp _{j,1990})		-0.010		0.001		-0.010		-0.012
		0.003		0.001		0.002		0.036
Post x ln(NP/Emp _{j,1990})		0.024		0.003		0.021		0.070
		0.005		0.002		0.005		0.070
Post x Contract Intensity _j		-0.012		-0.002		-0.010		0.098
		0.013		0.004		0.010		0.152
Post x ΔChina Import Tariffs _j		-0.021		-0.001		-0.021		-0.475
		0.013		0.005		0.010		0.176
Post x ΔChina Subsidies _j		0.045		0.010		0.036		0.239
		0.008		0.002		0.007		0.098
Post x ΔChina Licensing _j		0.049		0.008		0.041		0.863
		0.028		0.006		0.024		0.351
Post x 1{Advanced Technology _j }		-0.0003		0.0005		-0.0008		-0.1017
		0.008		0.002		0.007		0.103
Post x Union Membership _j		0.0003		0.0000		0.0003		-0.0059
		0.0002		0.0000		0.0001		0.0021
MFA Exposure _{it}		-0.001		0.000		-0.001		-0.019
		0.0002		0.0001		0.0002		0.0029
NTR _{it}		0.018		-0.017		0.035		0.547
		0.057		0.019		0.048		0.978
Observations	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000
R-Squared	0.46	0.46	0.38	0.39	0.46	0.46	0.46	0.90
Fixed Effects	p,t	p,t	p,t	p,t	p,t	p,t	p,t	p,t
K Stock Weighted	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table reports results of plant-level OLS generalized difference-in-differences regressions. The dependent variables are total investment as a share of the capital stock (book value), investment in structures as a share of the capital stock, investment in equipment as a share of the capital stock, and the natural log of the capital stock. The independent variable representing the effect of PNTR is the interaction of the NTR gap and a post-PNTR indicator. Additional controls include time-varying variables -- MFA exposure, NTR tariff rates -- as well as interactions of the post-PNTR indicator with time-invariant controls including the log of 1990 capital and skill intensity, contract intensity (Nunn 2007), changes in Chinese tariffs, changes in Chinese production subsidies, changes in Chinese export licensing requirements, an indicator for whether the industry produces advanced technology products, and the 1990 percentage of union membership. Data span 1990 to 2007. Robust standard errors adjusted for clustering at the industry (j) level are displayed below each coefficient. Estimates for the year (t) and plant (p) fixed effects as well as the constant are suppressed. Observations are weighted by capital stock (book value).

Table 4: PNTR and Establishment-Level Investment

dependent variables are not the same: the industry-level analysis examines variation in log investment, while the plant-level regressions investigate investment shares because establishment-level investment can be zero in some years.¹²

4.2 Plant-level Results Allowing for Heterogeneous Responses

To assess the importance of plant heterogeneity within industries, we augment Equation 4 with an additional covariate that interacts the DID term with one of several normalized initial plant attributes: plant size, as measured by employment or value added; plant productivity, as measured by TFP, value added (VA) per worker or shipments per worker; and plant capital and skill intensity,

year from 1990 to 2007.

¹²Further discussion of the differences between the industry- and plant-level results in appendix section B.

$$\begin{aligned}
y_{pt} = & \theta_1 Post PNTR_t \times NTRGap_j + \\
& \theta_2 Post PNTR_t \times NTRGap_j \times EstabChar_p + \\
& \varphi_1 Post PNTR_t \times EstabChar_p + \beta \mathbf{X}_{jt} + \gamma Post PNTR_t \times \mathbf{X}_j + \\
& \delta_p + \delta_t + \alpha + \varepsilon_{pt}
\end{aligned} \tag{5}$$

These terms, which we refer to as “plant heterogeneity terms” and which we include one-at-a-time in separate regressions, appear as the triple interaction in the second line of equation 5. The normalization divides the 1992 plant attribute by the average of that attribute across all plants in the same industry in 1992, therefore explicitly accounting for heterogeneity within industries, rather than differences across industries.¹³ The third term in equation 5 represents the interaction of the plant heterogeneity term with the *Post PNTR_t* indicator required to identify the triple interaction. We do not simultaneously include all plant heterogeneity terms in a single regression given their high correlation.¹⁴

Estimates are reported in Table 5. To conserve space we restrict our reporting to the equipment investment share, as that form of investment accounts for the majority of total investment, and suppress the estimates for the non-DID terms. As indicated in the table, a key difference between these results and those reported in Table 4 is the statistical significance of the main PNTR DID term in all columns of the first row except the second (value added). The plant heterogeneity terms themselves, reported in the remaining rows of the table, are positive in all columns and statistically significant in the final four, i.e., for both measures of labor productivity and for capital and skill intensity. These positive coefficients indicate that, for a given level of exposure to PNTR, plants with higher values of these attributes exhibit relatively higher levels of equipment investment after the change in trade policy, relative to those with lower values of the attributes.

As noted in the bottom panel of the table, an interquartile shift in industry exposure to PNTR implies relative reductions in the equipment investment share of -0.004 (-0.0229*0.188+0.0022*0.188*1.1176) in the first column of the table (where employment is the plant heterogeneity attribute), to -0.0014 in the last column (skill intensity). In each case, these impacts are evaluated at the mean level of the noted attribute across

¹³Given the fixed effects, plants are included in the regression only if they span 1997 and 2002. For plants that are not present in 1992, we divide their 1997 attribute by the relevant industry attribute in 1992.

¹⁴One potential concern with our regression specification is that plants with different values of initial characteristics may have been on different trends prior to the PNTR, and that these trends may drive the relationship between the policy change and the plant heterogeneity terms. In unreported but available results, we control for this possibility by augmenting equation 5 with interactions of year dummies and the plant characteristic being examined. Results are virtually identical to those described below.

plants in 1992. These changes represent -1.1 to -3.2 percent of the mean equipment investment share in 1997, the prior year closest to the change in trade policy.

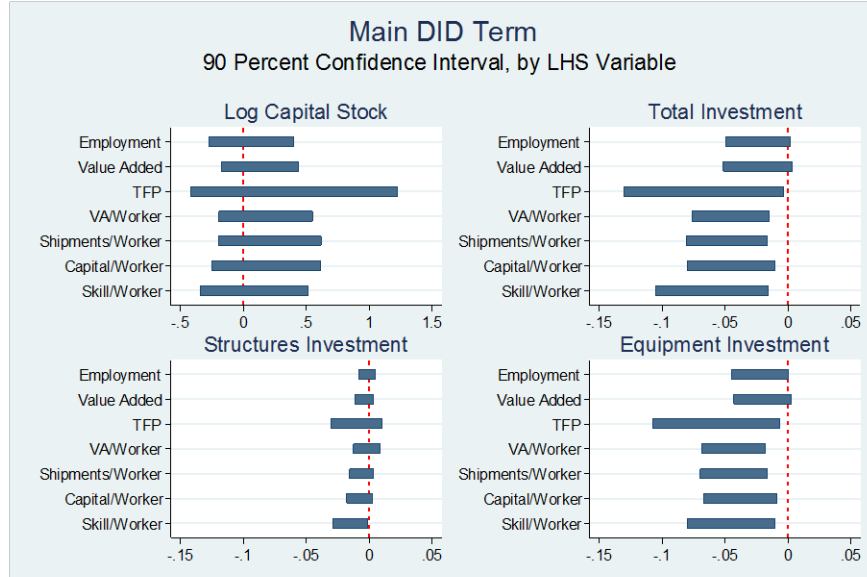
	Investment as a Share of Capital Stock						
	Equip _{pt}	Equip _{pt}	Equip _{pt}	Equip _{pt}	Equip _{pt}	Equip _{pt}	Equip _{pt}
Post x NTR Gap _j	-0.0220	-0.0432	-0.0570	-0.0432	-0.0429	-0.0378	-0.0450
	0.0135	0.0154	0.0305	0.0154	0.0161	0.0176	0.0214
x Employment _p ¹⁹⁹²	0.0020						
	0.0016						
x VA _p ¹⁹⁹²		0.0243					
		0.0089					
x TFP _p ¹⁹⁹²			0.0410				
			0.0283				
x VA Per Worker _p ¹⁹⁹²				0.0243			
				0.0089			
x Shipments Per Worker _p ¹⁹⁹²					0.0252		
					0.0095		
x Capital Per Worker _p ¹⁹⁹²						0.0149	
						0.0081	
x Skill Per Worker _p ¹⁹⁹²							0.0380
							0.0213
Observations	396,000	396,000	396,000	396,000	396,000	396,000	396,000
R-Squared	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Fixed Effects	p,t	p,t	p,t	p,t	p,t	p,t	p,t
K Stock Weighted	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Attribute Mean (1992)	1.176	1.202	1.017	1.033	1.029	1.066	0.993
Mean Equip Inv Share (1997)	0.129	0.129	0.129	0.129	0.129	0.129	0.129
Implied Impact of PNTR	-0.004	-0.003	-0.003	-0.003	-0.003	-0.004	-0.0014
Implied Impact (% Mean Inv Share)	-2.9	-2.0	-2.2	-2.6	-2.5	-3.2	-1.1

Notes: Table reports results of establishment-level OLS generalized difference-in-differences regressions. The dependent variable is investment in equipment as a share of the capital stock. The independent variables representing the effect of PNTR are the interaction of the NTR gap and a post-PNTR indicator (first covariate), and a triple interaction of that term with one of seven initial (1992) plant attributes, which are normalized by the average of that attribute across all plants in the same industry in 1992. Additional controls included in the regression but whose results are suppressed include time-varying variables – MFA exposure, NTR tariff rates – as well as interactions of the post-PNTR indicator with time-invariant controls including the log of 1990 capital and skill intensity, contract intensity (Nunn 2007), changes in Chinese tariffs, changes in Chinese production subsidies, changes in Chinese export licensing requirements, an indicator for whether the industry produces advanced technology products, and the 1990 percentage of union membership. Bottom panel of table notes the mean of the plant attribute used in the triple interaction across plants in 1992, the mean equipment investment share in 1997 and the impact of PNTR implied by the difference-in-difference terms evaluated for a plant with the mean attribute in 1992. Data span 1990 to 2007. Robust standard errors adjusted for clustering at the industry (j) level are displayed below each coefficient. Estimates for the year (t) and plant (p) fixed effects as well as the constant are suppressed. Observations are weighted by capital stock (book value).

Table 5: PNTR and Heterogeneity in Establishment-Level Equipment Investment

The DID coefficients from these and analogous regressions for total and structures investment are summarized visually in Figures 6 and 7. The first of these figures plots the main DID coefficient across specifications, with each panel of the figure reporting the ninety percent confidence interval for the seven separate regressions that correspond to the inclusion of the seven plant heterogeneity attributes we examine. The bottom right panel of this figure corresponds to the first row of Table 5. As noted in the figure, the main DID terms are negative for log capital (upper left panel) and for the total (upper right panel) and equipment investment (lower right panel) shares, but generally statistically significant only for the latter two. Results for the structures investment share (lower left panel) are typically statistically insignificant, with the exception of the skill intensity attribute regression, where the relationship is negative and significant.

Figure 7 provides a similar plot for the plant heterogeneity DID terms. In this case, the bottom right panel reports the results from the second row of Table 5. As with the



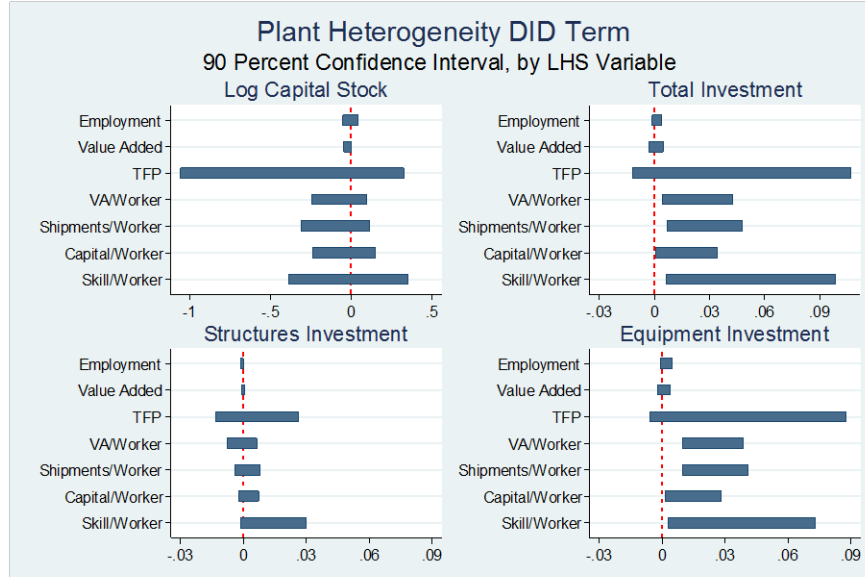
Notes: Figure reports the 90 percent confidence intervals of the main difference-in-differences term that interacts an indicator variable for the post-PNTR period with the NTR gap. Each bar is computed from a separate regression (equation 6) that contains a different plant heterogeneity term constructed with the noted plant attribute (e.g., employment). The results in the bottom right panel correspond to the estimates in the first row of Table 5. Source: authors calculations based on data from the CM.

Figure 6: Main DID Coefficients for CM Regressions

main DID terms, relationships between the change in trade policy and outcomes are stronger for the equipment and total investment shares than they are for structures investment and the capital stock.

Finally, Figure 8 uses the coefficients reported in Figures 6 and 7, as well as information about the distribution of plants' attributes in 1992, to quantify how the economic impact of PNTR varies across establishments with different levels of a particular attribute. In the figure, each pair of bars is computed using coefficient estimates from the separate regressions described above (e.g., one of the columns of Table 5). Each bar is an evaluation of the impact of an interquartile shift in exposure to PNTR for a plant with a “low” versus “high” level of the noted attribute. We define the low level of an attribute as the mean less one standard deviation and the high level as the mean plus one standard deviation. We report results for total, structures and equipment investment shares. Economic impacts are expressed as the implied change in the investment share as a percentage of the mean investment share across plants in 1997, the prior year closest to the change in trade policy.

As indicated in the figure, we find that the impact of greater exposure on low- versus high-attribute establishments varies by attribute but that it is similar across the three types of investment. Our discussion here focuses on total and equipment investment shares given the stronger relationship between exposure to PNTR and these outcomes found above.



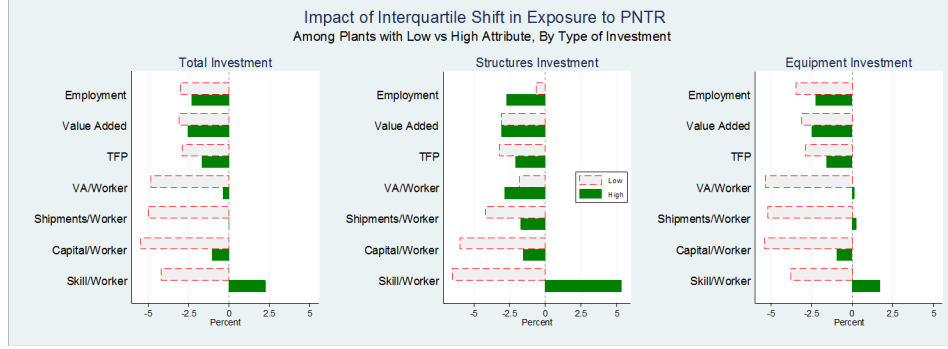
Notes: Figure reports the 90 percent confidence intervals of the plant heterogeneity difference-in-differences term that interacts an indicator variable for the post-PNTR period with the NTR gap and the noted plant attribute (e.g., employment). Each bar is computed from a separate regression (equation 6) that contains a different plant heterogeneity term. The results in the bottom right panel correspond to the estimates in the second row of Table 5. Source: authors calculations based on data from the CM.

Figure 7: Plant Heterogeneity DID Coefficients for CM Regressions

Overall, we find that plants with high values of the attributes we examine experience smaller relative reductions in equipment investment following PNTR. This difference is most noticeable for labor productivity, capital intensity, and skill intensity. For plant size and TFP, the differences between low- and high-attribute plants are relatively small. A second notable feature of Figure 8 is that plants with the highest skill intensity actually experience a relative increase equipment investment after the change in trade policy versus before.

Combined, the results in this section suggest that the average continuing establishment reduces equipment (and total) investment in response to PNTR relative to the period before the change in trade policy. However, for the subset of plants with relatively high skill intensity, greater exposure to the change in trade policy is associated with relatively higher equipment (and total) investment. This increased investment could represent trade-induced technological change of the type discussed in [Bloom, Draca, and Reenen \(2016\)](#). Alternatively, it could reflect capital expenditures used to upgrade product quality ([Schott \(2003, 2004\)](#)) or switch production ([Bernard, Jensen, and Schott \(2006\)](#); [Bernard, Jensen, Redding, and Schott \(2011\)](#); [Khandelwal \(2010\)](#)) towards goods more in line with U.S. comparative advantage.

Our results in this section are consistent with those reported in [Gutierrez and Philippon \(2017\)](#), who find that while investment in property, plant and equipment is relatively lower for publicly traded firms after PNTR versus before, the relative decline



Notes: Panels display the impacts of an interquartile shift in exposure to PNTR on noted investment outcomes for establishments with “low” versus “high” values of the noted attributes. Impact is expressed as the change in the noted investment share relative to its respective 1997 average across establishments. “Low” is defined as the mean less one standard deviation, while “high” is defined as the mean plus one standard deviation. Each pair of bars is computed using estimated coefficients from a separate difference-in-differences (DID) regression (equation 6) that contains a plant heterogeneity DID term corresponding to the noted attribute. Third panel above, for example, uses the estimates from Table 5. Source: Census of Manufacturers and authors’ calculations.

Figure 8: Implied Impact of PNTR With Plant Heterogeneity From CM Regressions

is less substantial for “leader” firms, defined as firms whose market-to-book value of capital is above the median.

4.3 Responses in the Timing and Frequency of Investment

PNTR’s elimination of the risk of potential tariff increases offers a unique setting for examining how uncertainty affects establishments’ investment behavior in ways beyond those explored above, in particular its timing and frequency. [Bloom, Bond, and Van Reenen \(2007\)](#), for example, show theoretically that greater uncertainty lowers the responsiveness of firms’ investment to demand shocks, provided that investments are at least partially irreversible. In particular, because uncertainty drives a wedge between the marginal products of capital required for investment and disinvestment, it increases the “zone of inaction,” rendering it lumpier. In this section, we use the ASM to examine how the timing and frequency of investment respond to PNTR.¹⁵

As noted above, the ASM has two drawbacks relative to the CM: it is a survey rather than a census; and the survey sample is re-drawn every five years, complicating one’s ability to track individual plants for a long period of time. Given these limitations, our analysis is limited to the balanced panel of plants present in every ASM from 1990 to 2007. This selected sample clearly differs from the general population, as the plants included are larger, older and more likely to be exporters.

We relate the patterns of establishments’ investment to the change in trade policy by collapsing the balanced panel into two periods: a pre-PNTR period encompassing the years 1990 to 2000; and a post-PNTR period comprising 2001 to 2007. A virtue of this sample interval, in addition to its spanning the passage of PNTR, is that each

¹⁵Empirically, [Bloom, Bond, and Van Reenen \(2007\)](#) show that publicly traded UK firms’ investment is negatively associated to the standard deviation of their stock returns, a potential manifestation of demand uncertainty.

sub-period roughly coincides with a full business cycle, beginning around the time of a recession peak and continuing through the start of the next recession.

For each period, we calculate three plant-level measures of investment activity. The first measure is the average size of establishments' investments, defined as the sum of plant p 's investment for period c , divided by the number of years in the period. This measure provides a useful comparison to our results above. The second measure is the standard deviation of the level of investment, within plants, across the years in each period. This measure captures changes in the lumpiness of plants' investment behavior. The third measure is the share of years in each period with positive investment, a measure that captures the frequency with which establishments invest. In practice, as noted in Table 1, a high share of establishments invest each year, though the share is lower for structures investment. With these measures, we estimate the following equation:

$$\begin{aligned} \ln(y_{pc}) = & \theta \text{Post PNTR}_c \times \text{NTRGap}_j + \\ & \beta \mathbf{X}_{jc} + \gamma \text{Post PNTR}_c \times \mathbf{X}_j + \\ & \delta_p + \delta_c + \alpha + \varepsilon_{pc}, \end{aligned} \tag{6}$$

where p indexes establishments and j indexes industries, as before, and c indexes the two time periods. The dependent variable $\ln(y_{pc})$ is the log of one of the three measures of investment behavior for plant p in period c noted above, and the DID term and control variables are identical to those in Equation 2, with the exception that in equation 6, time-varying control variables are averaged over each period.

As in Section 4.1, Table 6 sets a baseline by reporting coefficient estimates and standard errors from estimating equation 6 without controls for plant heterogeneity. The first three columns of the table display results for total investment, the next three columns for investment in structures, and the final three columns for investment in equipment.

The results indicate that higher industry-level exposure to PNTR – and therefore a larger reduction in tariff rate uncertainty – is associated with smaller average investment sizes, a smaller standard deviation of investment across years, and a higher share of years with positive investment. Though the signs for the latter two variables generally are in line with the predictions from Bloom, Bond, and Van Reenen (2007), in that larger reductions in uncertainty lead to investments that are less lumpy (standard deviation) and more frequent (share positive), only one of these relationships – the standard deviation of equipment investment – is statistically significant at conventional levels. One potential explanation for the lack of significance may be that our data are at a relatively infrequent annual frequency, thereby masking variation in the timing of investments within calendar years.

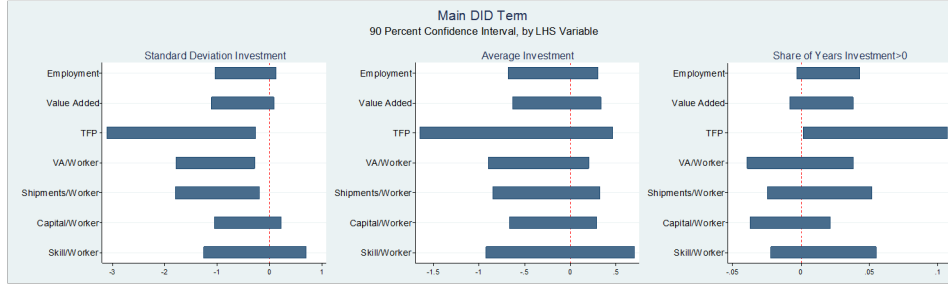
	Standard Deviation (SD), Average (Avg) and Years with Positive (Pos) Investment								
	$\ln(SD_{pc}^{Total})$	$\ln(Avg_{pc}^{Total})$	$\ln(Pos_{pc}^{Total})$	$\ln(SD_{pc}^{Struct})$	$\ln(Avg_{pc}^{Struct})$	$\ln(Pos_{pc}^{Struct})$	$\ln(SD_{pc}^{Equip})$	$\ln(Avg_{pc}^{Equip})$	$\ln(Pos_{pc}^{Equip})$
Post x NTR Gap _j	-0.372	-0.279	0.004	-0.947	-0.915	-0.195	-0.366	-0.205	0.005
	0.334	0.264	0.010	0.523	0.561	0.197	0.323	0.260	0.013
Post x $\ln(K/Emp_{j,1990})$	-0.151	-0.139	0.001	-0.007	-0.053	-0.019	-0.203	-0.171	0.003
	0.081	0.071	0.002	0.109	0.098	0.024	0.076	0.069	0.002
Post x $\ln(NP/Emp_{j,1990})$	0.379	0.412	-0.001	0.281	0.245	0.067	0.384	0.435	0.007
	0.096	0.091	0.005	0.136	0.131	0.055	0.101	0.095	0.008
Post x Contract Intensity _j	0.255	-0.055	0.011	0.783	0.554	-0.057	0.077	-0.151	0.020
	0.335	0.346	0.011	0.522	0.468	0.090	0.314	0.332	0.012
Post x Δ China Import Tariffs _j	-0.260	-0.370	-0.011	-0.294	-0.593	-0.424	-0.293	-0.367	0.008
	0.318	0.295	0.010	0.465	0.483	0.144	0.324	0.295	0.015
Post x Δ China Subsidies _j	0.572	0.531	-0.010	0.063	0.082	0.028	0.600	0.557	-0.014
	0.156	0.117	0.006	0.238	0.246	0.097	0.148	0.116	0.007
Post x Δ China Licensing _j	0.904	0.789	0.024	1.170	1.016	0.125	0.829	0.850	0.017
	0.530	0.532	0.020	0.771	0.737	0.173	0.506	0.504	0.019
Post x 1{Advanced Technology _j }	0.104	0.190	0.001	0.137	0.172	0.041	0.130	0.195	-0.009
	0.089	0.100	0.006	0.147	0.149	0.052	0.099	0.097	0.011
Post x Union Membership _j	-0.0026	0.0020	0.0000	-0.0064	-0.0080	-0.0019	-0.0014	0.0028	-0.0002
	0.0037	0.0024	0.0001	0.0047	0.0047	0.0025	0.0036	0.0024	0.0001
MFA Exposure _{j,c}	-0.011	-0.014	0.001	-0.010	-0.027	-0.018	-0.016	-0.016	0.002
	0.011	0.012	0.001	0.015	0.014	0.006	0.012	0.012	0.002
NTR _{j,c}	-1.588	0.488	0.080	-1.426	-0.067	1.504	-1.044	0.723	0.098
	1.699	0.844	0.060	2.272	1.708	0.873	1.450	0.769	0.082
Observations	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000
R-Squared	0.90	0.95	0.54	0.81	0.84	0.67	0.91	0.95	0.54
Fixed Effects	p,t	p,t	p,t	p,t	p,t	p,t	p,t	p,t	p,t
K Stock Weighted	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table reports results of OLS generalized difference-in-differences regressions. The dependent variables are the natural logs of the standard deviation, average, and share of years with positive investment for total investment (columns 1-3), investment in structures (columns 4-6), and investment in equipment (columns 7-9). The independent variable representing the effect of PNTR is the interaction of the NTR gap and a post-PNTR indicator. Additional controls include time-varying variables -- MFA exposure, NTR tariff rates -- as well as interactions of the post-PNTR indicator with time-invariant controls including the log of 1990 capital and skill intensity, contract intensity (Nunn 2007), changes in Chinese tariffs, changes in Chinese production subsidies, changes in Chinese export licensing requirements, an indicator for whether the industry produces advanced technology products, and the 1990 percentage of union membership. Sample includes present in every year from 1990 to 2007, and data are collapsed to two periods, 1990-2000 and 2001-2007. Robust standard errors adjusted for clustering at the industry (j) level are displayed below each coefficient. Estimates for the year (t) and plant fixed effects as well as the constant are suppressed. Observations are weighted by capital stock (book value).

Table 6: PNTR and the Lumpiness of Plant Investment

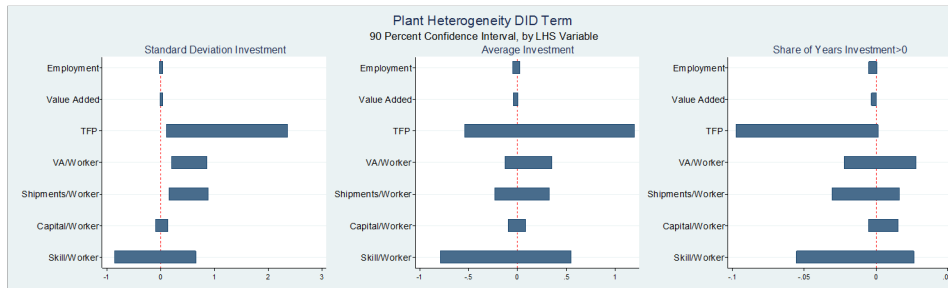
As above, when we augment equation 6 with plant heterogeneity terms, these relationships become clearer. Results from this augmented specification are displayed in Figures 9 and 10, which take the same format as Figures 66 and 7. The figures display results only for equipment investment, as this is the category of investment that displays the strongest relationship with PNTR, as in Section 4.1. Analogous figures for total investment and investment in structures are unreported, but available.

Figure 9 displays 90 percent confidence intervals for the coefficient estimates on the main DID term. The left panel of this figure reveals that, for the average establishment, higher exposure to PNTR is associated with a relative reduction in the standard deviation of equipment investment, but that these relationships are statistically significant at conventional levels only for the specifications that examine heterogeneity in productivity. A relative decline in lumpiness is also manifest in the share of years with positive investment (right panel), but only for the specification that uses TFP to capture heterogeneity. The main DID terms for average investment (middle panel) are statistically insignificant at conventional levels. This difference compared to the results



Notes: Figure reports the 90 percent confidence intervals of the main difference-in-differences term that interacts an indicator variable for the post-PNTR period with the NTR gap. Each bar is computed from a separate regression (equation 8) that contains a different plant heterogeneity term constructed with the noted plant attribute (e.g., employment). The three panels here display the results for three different characteristics of establishment investment in the pre- (1990 to 2000) versus post- (2001-2007) PNTR periods: the average size of investment, the standard deviation of investment, and the share of years during the period in which investment is positive. Source: authors calculations based on data from the ASM.

Figure 9: Main DID Coefficients for ASM Regressions



Notes: Figure reports the 90 percent confidence intervals of the plant heterogeneity difference-in-differences term that interacts an indicator variable for the post-PNTR period with the NTR gap and the noted plant attribute (e.g., employment). Each bar is computed from a separate regression (equation 8) that contains a different plant heterogeneity term constructed with the noted plant attribute (e.g., employment). The three panels here display the results for three different characteristics of establishment investment in the pre- (1990 to 2000) versus post- (2001-2007) PNTR periods: the average size of investment, the standard deviation of investment, and the share of years during the period in which investment is positive. Source: authors calculations based on data from the ASM.

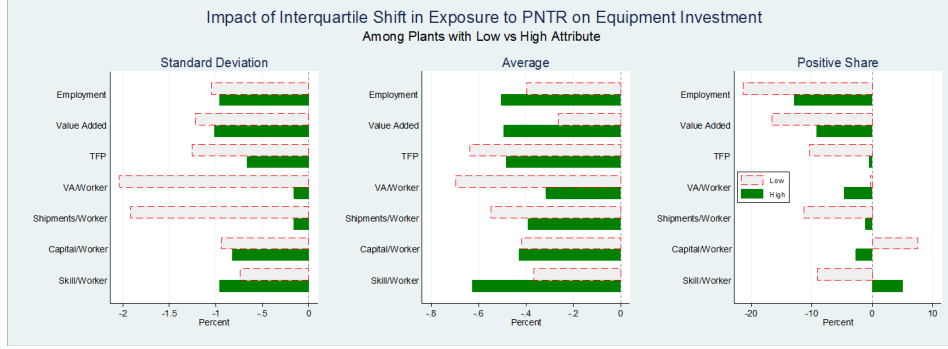
Figure 10: Plant Heterogeneity DID Coefficients for ASM Regressions

for the CM, above, may reflect the select group of firms present in the balanced ASM sample.

Figure 10 displays 90 percent confidence intervals for the plant heterogeneity DID terms. As shown in the figure, plant heterogeneity DID terms are positive and statistically significant for the standard deviation of equipment investment (left panel) for the three productivity terms. Likewise, among the plant heterogeneity DID terms for the share of years with positive investment (right panel), the estimate is positive and statistically significant at conventional levels for TFP.

As in the previous section, we combine the estimates plotted in in Figures 9 and 10 with information on the distribution of plants' initial attributes to compare the impact of an interquartile shift in exposure to PNTR among plants with low and high values of each attribute. These results are reported in Figure 11. As indicated in the left panel of the figure, plants with low initial values of labor productivity exhibit a decline in the standard deviation of equipment investment of approximately 2 percent relative to their 1997 levels. Plants with high labor productivity, by contrast, exhibit hardly any change relative to the period before the change in U.S. trade policy.

One potential explanation of the results in this section can be found by considering



Notes: Panels display the impacts of an interquartile shift in exposure to PNTR on noted pattern of investment outcomes in the pre- (1990 to 2000) versus post- (2001 to 2007) periods for establishments with "low" versus "high" values of the noted attributes (e.g., employment). Impact is expressed as the change in the noted investment characteristic relative to its respective 1997 average across establishments. "Low" is defined as the mean less one standard deviation, while "high" is defined as the mean plus one standard deviation. Each pair of bars is computed using estimated coefficients from a separate difference-in-differences (DID) regression (equation 8) that contains a plant heterogeneity DID term corresponding to the noted attribute (e.g., employment). Source: ASM and authors' calculations.

Figure 11: Implied Impact of PNTR With Plant Heterogeneity from ASM Regressions

the expectations of high-productivity establishments prior to passage of PNTR. If these establishments viewed their productivity level as being sufficiently high to continue operating even if tariffs increased substantially, their investment activity may not have been suppressed by uncertainty in the pre-PNTR period. As a result, less of a response to the timing of these establishments' investment following passage of PNTR might be expected.

5 Conclusion

This paper estimates the investment responses of U.S. manufacturing industries and establishments to the elimination of tariff rate uncertainty associated with the U.S. granting of PNTR to China in October 2000. We use a differences-in-differences approach to examine how variation in exposure to PNTR is associated with changes in manufacturing investment and capital stock after the policy change, relative to before.

At the industry-level, we find that industries more exposed to PNTR experience relative declines in manufacturing investment, both for equipment and structures, and that more-exposed industries experience statistically insignificant declines in the capital stock. Examining a flexible specification that makes no assumptions about the timing of the effects of PNTR, we find that the decline in investment lines up closely with the timing of the granting of PNTR.

At the establishment-level, we find that there is heterogeneity within industries in terms of how establishments respond to PNTR's trade liberalization. While the average effect of PNTR is to lower investment, for establishments with higher initial levels of labor productivity and of capital and skilled labor intensity, higher exposure to PNTR's trade liberalization is associated with increases in investment. These within-plant increases in investment are consistent with trade-induced technical change, product-

upgrading, or other activities that differentiate U.S. production from import-competing products.

Examining the timing, frequency, and lumpiness of establishments' investment behavior, we find that larger reductions in uncertainty associated with PNTR are associated declines in the lumpiness of investment, though there is less of a change in behavior for establishments with high initial productivity levels.

In sum, the findings in this paper provide new information on the effect of trade liberalization on investment, while highlighting the heterogeneous responses of individual plants.

References

- AGHION, P., N. BLOOM, R. BLUNDELL, R. GRIFFITH, AND P. HOWITT (2005): “Competition and Innovation: An Inverted-U Relationship,” *The Quarterly Journal of Economics*, 120(2), 701–728.
- AUTOR, D., D. DORN, G. H. HANSON, G. PISANO, AND P. SHU (2016): “Foreign Competition and Domestic Innovation: Evidence from U.S. Patents,” Working Paper 22879, National Bureau of Economic Research.
- AUTOR, D. H., D. DORN, AND G. H. HANSON (2013): “The China Syndrome: Local Labor Market Effects of Import Competition in the United States,” *American Economic Review*, 103(6), 2121–68.
- BAI, X., K. KRISHNA, AND H. MA (2015): “How You Export Matters: Export Mode, Learning and Productivity in China,” Working Paper 21164, National Bureau of Economic Research.
- BECKER, R., W. GRAY, AND J. MARVAKOV (2013): “NBER-CES Manufacturing Industry Database: Technical Notes,” Working Paper 5809, National Bureau of Economic Research.
- BERNARD, A. B., J. B. JENSEN, S. REDDING, AND P. SCHOTT (2011): “Multi-Product Firms and Trade Liberalization,” *Quarterly Journal of Economics*, 126(3), 1271–1318.
- BERNARD, A. B., J. B. JENSEN, AND P. K. SCHOTT (2006): “Survival of the Best Fit: Exposure to Low-Wage Countries and the (Uneven) Growth of US Manufacturing Plants,” *Journal of International Economics*.
- BLOOM, N., S. BOND, AND J. VAN REENEN (2007): “Uncertainty and Investment Dynamics,” *The Review of Economic Studies*, 74(2), 391–415.
- BLOOM, N., M. DRACA, AND J. V. REENEN (2016): “Trade Induced Technical Change: The Impact of Chinese Imports on Innovation, Diffusion, and Productivity,” *Review of Economic Studies*, 83, 87–117.
- BRANDT, L., J. VAN BIESEBROECK, L. WANG, AND Y. ZHANG (2017): “WTO Accession and Performance of Chinese Manufacturing Firms,” *American Economic Review*, 107(9), 2784–2820.
- FEENSTRA, R. C., J. ROMALIS, AND P. K. SCHOTT (2002): “US Imports, Exports, and Tariff Data, 1989-2001,” Working Paper 9387, National Bureau of Economic Research.

- FORT, T. C., J. R. PIERCE, AND P. K. SCHOTT (2017): “New Perspectives on the Decline of US Manufacturing Employment,” .
- GUIISO, L., AND G. PARIGI (1999): “Investment and Demand Uncertainty,” *The Quarterly Journal of Economics*, 114(1), 185–227.
- GUTIERREZ, G., AND T. PHILIPPON (2017): “Declining Competition and Investment in the U.S.,” Working Paper 23583, National Bureau of Economic Research.
- HANDLEY, K. (2014): “Exporting Under Trade Policy Uncertainty: Theory and Evidence,” *Journal of International Economics*, 94(1), 50–66.
- HANDLEY, K., AND N. LIMA (2017): “Policy Uncertainty, Trade, and Welfare: Theory and Evidence for China and the United States,” *American Economic Review*, 107(9), 2731–83.
- HIRSCH, B. T., AND D. A. MACPHERSON (2003): “Union Membership and Coverage Database from the Current Population Survey: Note,” *Industrial and Labor Relations Review*, 56, 349–54.
- KHANDELWAL, A. (2010): “The Long and Short (of) Quality Ladders,” *Review of Economic Studies*, 77, 1450–1476.
- KHANDELWAL, A. K., P. K. SCHOTT, AND S.-J. WEI (2013): “Trade Liberalization and Embedded Institutional Reform: Evidence from Chinese Exporters,” *American Economic Review*, 103(6), 2169–95.
- KURZ, C. J., AND N. J. MORIN (2016): “Annual Data on Investment and Capital Stocks,” Feds notes, Board of Governors of the Federal Reserve System (US).
- MICHAELS, D. (2017): “Foreign Robots Invade American Factory Floors,” *Wall Street Journal*.
- NUNN, N. (2007): “Relationship-Specificity, Incomplete Contracts, and the Pattern of Trade,” *The Quarterly Journal of Economics*, 122(2), 569–600.
- PIERCE, J. R., AND P. K. SCHOTT (2012): “The Surprisingly Swift Decline of U.S. Manufacturing Employment,” Working Paper 18655, National Bureau of Economic Research.
- (2016): “The Surprisingly Swift Decline of U.S. Manufacturing Employment,” *American Economic Review*, 106(7), 1632–1662.
- PINDYCK, R. S. (1993): “Investments of uncertain cost,” *Journal of financial Economics*, 34(1), 53–76.

- ROB, R., AND N. VETTAS (2003): "Foreign direct investment and exports with growing demand," *The Review of Economic Studies*, 70(3), 629–648.
- SCHOTT, P. K. (2003): "One Size Fits All? Heckscher-Ohlin Specialization in Global Production," *American Economic Review*, 93(3), 686–708.
- (2004): "Across-Product versus Within-Product Specialization in International Trade," *The Quarterly Journal of Economics*, 119(2), 647–678.
- SCHWARTZ, E. S., AND C. ZOZAYA-GOROSTIZA (2003): "Investment Under Uncertainty in Information Technology: Acquisition and Development Projects," *Management Science*, 49(1), 57–70.

Online Appendix

A Industry Results Through 2011

The regression sample in the main text extends through 2007 in order to avoid the Great Recession. For comparison, Figure 12 reports results for industry-level investment and for the industry-level investment deflators using equation 3 for 1990 to 2011, the limit of the NBER-CES Manufacturing Productivity Database.

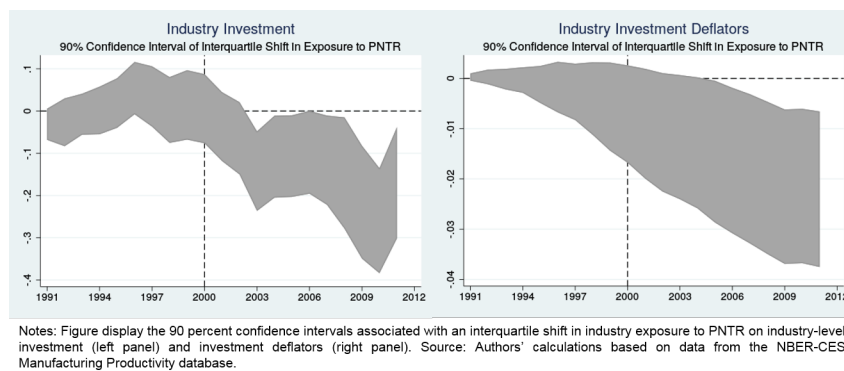


Figure 12: Implied Industry-Level Impact of PNTR, 1991-2011

B Reconciling Industry and Plant Results

	Investment	Investment Share
	$\ln(\text{Total}_i)$	$\text{TotInv}/K_{i,t}$
Post x NTR Gap _i	-0.382	-0.030
	0.229	0.013
Post x $\ln(K/\text{Emp}_i)$	-0.160	-0.003
	0.039	0.002
Post x $\ln(\text{NP}/\text{Emp}_i)$	0.271	0.005
	0.087	0.005
Post x Contract Intensity _i	0.078	-0.003
	0.200	0.013
Post x $\Delta\text{China Import Tariffs}_i$	-0.396	0.013
	0.267	0.017
Post x $\Delta\text{China Subsidies}_i$	0.539	0.005
	0.114	0.007
Post x $\Delta\text{China Licensing}_i$	0.649	0.002
	0.400	0.026
Post x 1{Advanced Technology _i }	0.001	-0.005
	0.087	0.006
MFA Exposure _{i,t}	-0.038	0.000
	0.004	0.000
NTR _{i,t}	0.946	0.048
	0.764	0.053
Post x U.S. Union Membership _i	0.002	0.000
	0.002	0.000
Observations	2,000	2,000
R-Squared	0.96	0.68
Weighting	K_i	K_i
Fixed Effects	i,t	i,t
Implied Impact of PNTR	-0.072	-0.006

Notes: Table reports results of unweighted OLS generalized difference-in-differences regressions. The dependent variable in the first two columns is the log of industry-year total investment and the independent variable representing the effect of PNTR is the interaction of the NTR gap and a post-PNTR indicator. The dependent variable in the last two columns is total investment divided by capital stock. Columns one and three are unweighted while columns two and four are weighted by the initial value of the capital stock. Additional controls include time-varying variables -- MFA exposure, NTR tariff rates, union membership rates -- as well as interactions of the post-PNTR indicator with time-invariant controls including the log of 1990 capital and skill intensity, contract intensity (Nunn 2007), changes in Chinese tariffs, changes in Chinese production subsidies, changes in Chinese export licensing requirements and an indicator for whether the industry produces advanced technology products. The sample is constructed by aggregating the establishment-level sample employed in Table 4 to the industry-year level. Sample includes census years 1992, 1997, 2002 and 2007. Robust standard errors adjusted for clustering at the industry (i) level are displayed below each coefficient. Estimates for the year (t) and industry fixed effects as well as the constant are suppressed. Final row reports implied impact on dependent variable of an interquartile shift in industry exposure to PNTR.

Table 7: Aggregating Plant Results to Industry Results

Table 7 illustrates that the differences between industry- and establishment-level results largely disappear when they are aggregated to the same level and consider the same same dependent variable. Specifically, the first column of the table reports results of estimating equation 2 after starting with the establishment-level sample, aggregating to the industry-level, and using the natural log of total investment as the dependent variable. Comparing the coefficient estimate for the DID term in column 1 of Table 7 to the analogous estimate in column 3 of Table 2 indicates that both are negative and statistically significant, and of similar magnitudes. The implied effect in Table 2 is somewhat larger than that in Table 7, as the latter excludes the effect of plant exit that occurs between 1997 and 2002. Alternatively, when we estimate equation 2 with the same sample as column one of Table 7, but use the dependent variable from the establishment-level regressions—investment divided by capital stock—we again find that the magnitude of the DID coefficient estimate is similar to the analogous establishment-

level results from column 2 of Table 4. The coefficient in this *industry*-level analysis is statistically significant, likely because it captures changes in investment associated with net plant exit, which the establishment-level regressions do not.